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Aims and Scope:

The International Journal of Environmental and Rural Development, IJERD, is an interdisciplinary journal concerning environmental and rural development research in the education for sustainable development, ESD. The IJERD is devoted to publishing peer-reviewed research article, review article and technical report in the fields of environmental and rural development, such as education for sustainable rural development, rural development, environmental management or agricultural systems. Every article or report in IJERD must be accepted by at least 2 reviewers and an editorial member.

The aims of IJERD are to publish the latest research development and achievements, to strengthen education systems, to promote cooperation in environmental and rural development and to contribute to the progress in sustainable development. The editorial board of this journal covers a variety of scientific disciplines.

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The following areas are envisioned in IJERD.

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Environmental Education, Food and Agricultural Education, Participatory Approach, Capacity Building, Community Empowerment, Agricultural Extension, etc.

Rural Development:

Marketing, Partnership, Value Added Product, Community Development, Access to Technology, Cultural Preservation, etc.

Environmental Management:

Bio-Diversity, Soil Degradation and Land Conservation, Water Quality Conservation, Deforestation and Sustainable Forest Management, Environmental Management, etc.

Agricultural Systems:

Organic Farming, Conservation Tillage, Mechanization, Irrigation and Drainage, Nutrient and Pest Management, Cattle Breeding, Agro-Forestry, Indigenous Technology, etc.

Infrastructural Systems:

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

Contents

Invited article

Bridging Sustainable Agriculture and Education for Sustainable Development

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Abstract When multi-stakeholders in local communities come together to tackle sustainable development problems, they not only offer solutions to local constituents, but also create impact to the broader policymaking process at local, regional and national levels. A United Nations University flagship project, namely a network of Regional Centres of Expertise (RCE) on Education for Sustainable Development (ESD) indicates that local networking for sustainable development, and in particular for sustainable agriculture, can be an effective approach for local communities to employ learning tools in ESD to improve the situation and render positive influence in policymaking. RCEs on ESD, as an innovative platform for multi-stakeholder networking at the local and regional level, has proven to be an effective vehicle for promoting sustainable agriculture, linking sustainable livelihood and ESD, involving farmers, school teachers, students, non-governmental organizations, and other stakeholders in the community.

Keywords sustainable agriculture, Education for Sustainable Development, ESD, Regional Centre of Expertise, sustainability, UNU, RCE

UNSUSTAINABLE AGRICULTURE PRACTICES – A CASE IN CAMBODIA

Kampong Cham is a rural province of Cambodia with an area of nearly 10,000 square kilometers. Due to the rapid increase in population, the province faces food security concerns. Farmers have resorted to the use of chemical fertilizers and pesticides, and other unsustainable practices, to increase farm productivity. These practices have not only affected the health of farmers and their families, but have contaminated the soil, jeopardizing the environment and degrading the area as a whole. Specifically in the investigated target areas, located in the Samroung commune of the Kampong Cham province, the use of agricultural fertilizers and pesticides has rapidly increased over the past decade, contributing to a higher agricultural productivity in the short term. Local farmers that suffered from several ailments such as throat pain or dermatitis have been eager to shift to a more sustainable farming system, based on natural resource circulation. However, the lack of knowledge and resources has hampered the shift towards practicing sustainable agriculture. Government policy to rectify unsustainable agricultural practices was deemed imperative.

MULTI-STAKEHOLDER NETWORKING

The RCE network[1] in Cambodia known as RCE Greater Phnom Penh (GPP) initiated a project on

[1] A Regional Centre of Expertise (RCE) is a network of existing formal and non-formal education organizations mobilized to deliver ESD in the region or locality where it is situated. It creates a platform for dialogue among regional and local ESD stakeholders and for exchanging information, experience and good practices on ESD. It develops a regional and local knowledge base and assists in

'Promoting Sustainable Agriculture at Kampong Cham Province in Cambodia', funded by the Japan International Cooperation Agency (JICA) and executed by the stakeholders of RCE GPP led by ERECON[2] and the Royal University of Agriculture (RUA) of Cambodia, with the cooperation of the local government. The aim of the project, which ran from April 2011 to March 2016, was to promote sustainable agriculture, based on natural resource circulation in 11 villages in the Samroung commune. The project's goals were to switch to sustainable farming practices and to increase public awareness on how a region can achieve acceptable economic benefits together with high and sustained production levels, while concurrently conserving the environment. The project gave evidence of successful transformative learning through sustainable agriculture, by teaching farmers about sustainable practices without or the use of low chemicals, and integrating sustainable agriculture and ESD in school curricula in the region. Lessons learned from reformed farmers' practices together with ESD general knowledge and practices were used by the community schools in the area. The school students were themselves mostly children of farmers, and so learning conversations and practices continued at home. Knowledge on sustainable agriculture was also passed on from pupils to their non-farming parents. A number of farmers and farmers' families as well as schools were identified as models, where other members of the community could learn from on sustainable agriculture and ESD.

This project made a case of addressing national policy towards improving agricultural production, both in terms of quantity and quality of produce in line with the principles of a Green Economy, resulting in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.[3] At the same time, the project addressed several Sustainable Development Goals such as SDG-2 on Hunger, SDG-4 on Education, and SDG-12 on Sustainable Consumption and Production and was implemented in line with the goals of the Stockholm Convention on Persistent Organic Pollutants.[4] According to the Rector of the Royal University of Agriculture of Cambodia, the project "*supports the vision of the Cambodian Ministry of Agriculture, Forestry and Fisheries towards sustainable natural resource management and conservation, and in particular the Ministry's policy on agricultural extension. The project has influenced policymaking in the Ministry and created a good model case for promoting the policy of the Cambodian Government on organic agriculture and ESD transformative learning*".

CAPACITY BUILDING OF FARMERS

In order to effectively change agricultural production practices, farmers' groups were formed and a series of workshops conducted, explaining the concept and benefits of sustainable agriculture, including technical aspects as well as how to manage farms and distribute their products. The principal project proponents – RCE GPP stakeholders such as RUA, ERECON, and local government authorities – worked together to train farmers how to make organic fertilizer, organic pesticides, and utilize techniques that render the use of chemicals unnecessary, including the use of nets to protect plants and vegetables from various insects. Farmers were also trained how to build and manage composts using model composts. Learning by using real examples and demonstration models inside the farms proved effective. In order to widen the participation of farmers across the region, sharing of experiences among the farming community was encouraged and 'workshops-on-the-field' together with farmers already practicing agriculture sustainably were organised. A farmers' committee was set up and a common pellet compost center built. Training for pellet compost production was conducted for village

promoting vertical alignment of curricula from primary through university education and in linking formal and non-formal sectors of the education community.

[2] Institute of Environmental Rehabilitation and Conservation, headquartered in Tokyo, Japan, with branch office in Phnom Penh, Cambodia.

[3] UNEP, 2011

[4] Stockholm Convention, http://chm.pops.int/TheConvention/ThePOPs/TheNewPOPs/tabid/2511/Default.aspx

leaders and members of farmers' groups. Transformative learning and real change hinged on capacity building and in turn influenced the local government to adopt and promote sustainable practices.

PROMOTING EDUCATION FOR SUSTAINABLE DEVELOPMENT

Food, agriculture and environmental education that focuses on sustainable agriculture based on natural resource circulation was promoted in form of experiential learning using local schools as living laboratories. With the support of the farmers' groups, school teachers managed organic school gardens and compost boxes to teach students on the different practices of sustainable agriculture. Together with farmers, workshops were conducted at selected schools and students demonstrated learning outcomes using poems and songs pertaining to ESD. In addition, training activities on mixed cropping were introduced in schools where students shared their experience from a field visit to Thailand as part of the project ESD learning activities. The stakeholders of RCE GPP, mainly RUA, ERECON Cambodia, school teachers and project advisers, developed teaching materials for the schools. The project transformed the schools in the region to adopt ESD in their curricula. It is important to underscore the fact that a majority of these elementary school students do not pursue secondary let alone tertiary education, and a vast majority of them become farmers themselves. Thus there is a real need to ingrain the moral imperative of ESD amongst the Youth, so that they create sustainable lifestyles and livelihoods and carry these on into adult life.

PROMOTING DISTRIBUTION OF GREEN NO/LOW-CHEMICAL INPUT PRODUCTS

By improving the distribution of products with no or low chemical input, the number of farmers who sold their products on the green market increased. Market surveys were conducted by RCE GPP stakeholders and the results were shared with the farmers' respective communities. Farmers were encouraged to join the Cambodian Organic Agriculture Association (COrAA) to market chemical-free and organic products with COrAA certification. Market research was carried out to develop a plan for sustainable agriculture product fairs. The Samroung Safe Agricultural Products (SSAP) Shop was established to serve as the main outlet for green agricultural products. During regular meetings, the farmers shared information on trends of sales of different types of vegetables sold at the SSAP Shop. The shop has great potential to expand as more farmers come on board and consumers become more aware of the benefits of healthy organic products. Local governments were advised to promote these activities considering the benefit of healthy communities, by drafting policies that encourage the population to consume chemical-free and organic agricultural products.

POLICY RELEVANCE, IMPACT AND SUSTAINABILITY

Leading by example is an effective approach to policymaking. Stakeholders of the policy-relevant initiative were not simply beneficiaries, but were also directly involved in project activities on the ground. This project is a good example of a local-based network on ESD, RCE GPP assuming leadership and demonstrating the important role of communities in shaping national and local policies on sustainable development, specifically in the area of sustainable agriculture. Lessons learned from this project can be used to shape government policies that can be implemented in other regions across the country and elsewhere. Farmers have become increasingly committed to sustainable agriculture and now sell products through the SSAP outlet and other third party buyers. They have also pledged to continue the scheme, even beyond the official end of the project, believing wholeheartedly that organic farming is a pathway to creating sustainable agriculture communities.

RECOMMENDATIONS

Based on experiences and lessons learned from this project, the following policy recommendations to implement sustainable agriculture may be considered:

- The use of agricultural chemicals is damaging the soil and water environment of farmlands and has direct impact on the health of not only of farmers and their families but also the consumers. Effective policies to reduce and eventually eliminate the use of these chemicals need to be formulated. This would not only address the relevant goals of the 2030 Sustainable Development Agenda and Sustainable Development Goals, but also of the purpose of the Stockholm Convention on Persistent Organic Pollutants.
- Regional challenges need to be addressed in a broader context. This can be achieved by addressing the issues in a triangular manner – sustainable farming, ESD and the social use of sustainable lifestyle and livelihood.
- To increase the adaptability of local farmers and the understanding of students to sustainable agriculture, the policy should reflect the need for a multi-stakeholder networking approach that leads to a series of activities through awareness-raising and learning among farmers, curriculum transformation in schools, and implementing the notion of sustainable livelihood.
- For promoting sustainable agriculture practices through organic farming at primary schools, field practices such as vegetable gardening are effective to supplement classroom teaching as life-skill education. Training for primary school teachers are to be promoted.
- To move towards ascertaining the quality of education with increasing teachers' and students' understanding, offering ESD knowledge and practices conjunctively and providing materials and equipment in an organized and coordinated fashion enhances motivation and learning.
- On the local community level, workshops on sustainable agriculture, demonstrating how to make a compost box, the use of compost and pellet compost, liquid bio-fertilizer and liquid bio-pesticide, establishing a model garden, organizing leadership training and study tours will increase the awareness and understanding of sustainable agriculture.

Overall, it is recommended that to aspire for sustainability at the local and regional (subnational) level, national policy must embrace a type of multi-stakeholder approach, and have a strong evidenced-based, science-society-policy interface. Regional Centres of Expertise on ESD, a global network on ESD at the local and regional level, can play an important role by bringing all concerned stakeholders together and join community efforts to make transformative changes.

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Research article

Studies on Reducing Cadmium Uptake of Paddy Rice (*Oryza sativa* L.) by both Soil Dressing and Mixing Tillage

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Abstract Though soil dressing is one of the most effective methods for reducing cadmium (Cd) uptake in rice plants of Cd contaminated paddy fields, it needs large amount of soil and thus often requires a high cost and heavy environmental loads. In this study, we investigated any possibility of minimizing the thickness of soil dressing by utilizing mixing tillage before the soil dressing. 15 cm-thick mixed contaminated soil and overlying 12.5 cm-thick soil dressing (the conventional thickness of soil dressing being 20-30 cm in Japan) were used to form the usual stratified paddy field of the three layers (plow layer, plowsole, and subsoil). Cd concentration of the contaminated soil was adjusted to approximately 2.0, 1.0 and 0.5 mg/kg by mixing tillage. Then rice plants were grown under ponding condition during the cultivation and the experiments of each treatment were conducted under two different water flow systems, open and closed systems. As a result, Cd concentration in brown rice with water flow in an open system was 0.07 mg/kg, 0.05 mg/kg, and 0.17 mg/kg when Cd concentration of soil was 0.5, 1.0 and 2.0 mg/kg, respectively. Cd concentration in brown rice of 2.0 mg/kg soil was 5% significantly higher by 5% than those of other treatments. These results indicated that it was effective to dilute soil Cd concentration to 1.0 mg/kg for reducing Cd uptake of rice plants. There was no significant difference in growth and yield a way these treatments. However, we conclude that mixing tillage may have potential to minimize the thickness of soil dressing to half of the conventional thickness, 20 -30 cm, under ponding condition during the cultivation.

Keywords Cadmium, rice, water flow system, mixing tillage, soil dressing

INTRODUCTION

Heavy metal contamination of agricultural lands resulting from human activities has been causing serious health damages all over the world. Alarmed by this situation, Codex Alimentarius Commission has decided upon the limits of the cadmium (Cd) contents in food, e.g. 0.4 mg/kg in rice (MAFF, 2015a). Separately from the international standard, some countries have employed stricter standards and thus with a view to international trading, it is necessary for any country to reduce Cd contamination level of agricultural products as much as possible.

Cd health damages in Japan have mainly resulted from the intake of rice, Japanese staple food. Cd from mine waste water had accumulated in the paddy field soil, and the intake of the high-Cd rice caused the famous Itai-itai Disease (Kobayashi, 1978). In Japan, soil dressing of 20-30 cm-thick has been employed as the usual countermeasures for Cd contaminated agricultural fields. Though soil dressing is effective to reduce the Cd uptake of rice, it needs such a large amount of soil and therefore it costs much and causes heavy environmental loads.

The Ministry of Agriculture, Forestry and Fishery in Japan recommends that rice should be cultivated under ponding condition as a treatment for reducing the Cd uptake of rice (MAFF, 2015b) since solubility of Cd is low under reduction condition. However, Pongpattanasiri et al. (2005), Sasaki et al. (2010, 2012) and Paul et al. (2011) pointed out that even under ponding condition, the plowsole and subsoil layers showed oxidation condition when water flow in these layers was the open-system percolation and thus Cd might be dissolved in the soil water and absorbed by roots. Sasaki et al. (2010) and Paul et al. (2011) conducted rice growing experiments using paddy field models with 12.5 cm-thick soil dressing and reported that the percolation pattern in the plowsole and subsoil affected the degree of the Cd uptake of rice. In these cases, however, the Cd concentration of the subsoil was 3.39 mg/kg, which was twice as high as that of the average contaminated soils in Japan (Shibuya et al., 1980). Other than those mentioned above, there are few studies which considered the percolation patterns (Adachi and Sasaki, 1999; Sasaki et al., 2001).

In this study, aiming at the reduction of Cd uptake in rice plants, we investigated any possibility to minimizing the thickness of soil dressing by both utilizing soil dressing and mixing tillage and cultivation under ponding condition regulating the percolation systems in the subsoil.

METHODOLOGY

Soil Properties

In this study, the soil from plow layer of the Cd contaminated paddy field, where the mine waste water had been used as the irrigation water, was sampled for the experiments. Non-contaminated soil for soil dressing and gravel were obtained from the plow layer of a paddy field and a mountainous district in Tohoku region, or the north-eastern part of Japan.

Table 1 Physical and chemical properties of soil samples and gravel

	Density (g/cm^3)	Soil Texture	MgO *	Na_2O *	CaO *	K_2O *	Cd *	T-C (%)	T-N (%)	C/N	OM (%)
Non Polluted Soil	2.62	LiC	120	64	400	120	0.14	2.07	0.16	13.27	3.6
Polluted Soil	2.44	CL	640	128	2280	288	1.81	5.30	0.39	13.57	9.1
Gravel	2.68	-	147	18	539	600	0.13	-	0.00	-	0.1

*Note: * mg/kg*

Table 1 shows the physical and chemical properties of the soil samples and gravel. The soil textures of contaminated and non-contaminated soils were CL and LiC, respectively, and their contents of soil organic matter were 9.2% and 3.6%, respectively. The Cd concentration of the contaminated, non-contaminated and gravel were, 1.81, 0.14, and 0.13 mg/kg, respectively. By mixing these two kinds of soils, the Cd concentration of the experimented soils was adjusted to the aforementioned three levels. The experimental apparatus was designed after the fashion of paddy fields near a river and thus gravel was also used for the lower layer.

Experimental Design

Two kinds of stratified paddy field models were used for the experiments (Fig.1). The air entry values were determined by the method of Sasaki (1992). These models consisted of an iron box (30 cm × 50 cm × 70 cm) filled with soils and gravel in three layers. Plow layer (1st layer) was from 0 cm to 10 cm deep (dry density was 1.02 Mg/m^3): plowsole (2nd layer) was from 10.0 cm to 20.0 cm deep (dry density at the depth from 10.0 cm to 12.5 cm and from 12.5 cm to 20.0 cm were 1.23 Mg/m^3 and 0.75 Mg/m^3, respectively) : subsoil (3rd layer) was from 20.0 cm to 62.5 cm deep (dry density from 20.0 cm to 27.5 cm was 0.75 Mg/m^3 and that from 27.5 cm to 62.5 cm was 1.4 Mg/m^3, those layers were formed by compaction). The thickness of non-polluted soil dressing was 12.5 cm deep, and beneath the soil dressing there lay the polluted soil of 15.0 cm depth, the gravel layer was placed beneath the polluted soil layer.

In order to make three different levels of contaminated concentration of the plowsole and subsoil in the stratified paddy field models, polluted and non-polluted soils were mixed. The authors defined O-1 and C-1 as the setting value of 0.5 mg/kg of the stratified paddy field model (the actual Cd concentration after mixture became 0.57 mg/kg). Similarly, O-2 and C-2 were defined as the setting value of 1 mg/kg of Cd concentration (the actual Cd concentration after mixture became 1.21 mg/kg). Moreover, we defined O-3 and C-3 (the actual Cd concentration 1.81 mg/kg) as the polluted soil without dilution. Note that 'O' and 'C' mean the open-system and the closed-system percolation, respectively. The ground water levels of the open-system and the closed-system percolation models were controlled at 57.5 cm and 20.0 cm depths, respectively. In the closed-system percolation models, the holes in the side walls of iron box were blocked in order to prevent the penetration of the atmosphere. On the other hand, in the open-system percolation models the holes in the side walls of the iron box were open in the lower part of the 2nd layer and the upper part of the 3rd layer in order to aerate those layers.

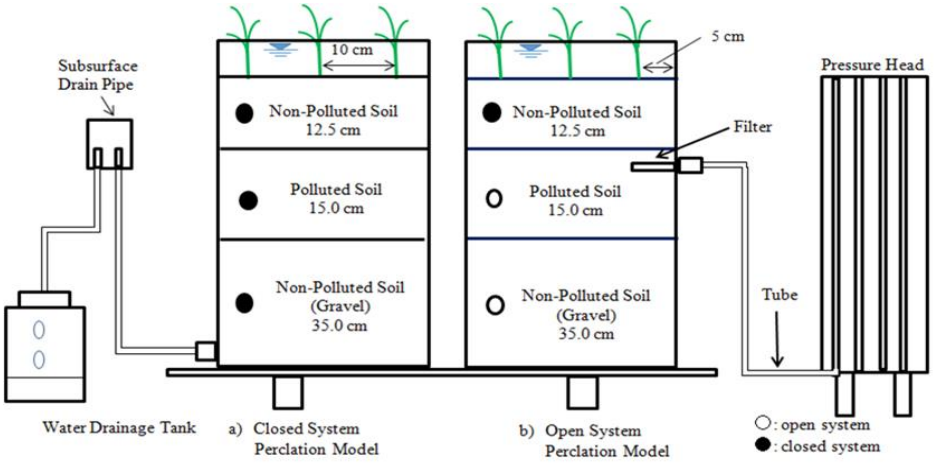

Fig. 1 Layout of the experimental design

After the two types of models were prepared, fifteen paddy seedlings (plant length and leaf stage were from 14.0 to 18.0 cm and from 5.4 to 6.8 leaves, respectively) named '*Oryza sativa* L. Tsugaru Roman' were transplanted. The paddy seedlings were transplanted by 10.0 cm intervals. As for fertilizer, 2.0 g of N, 2.0 g of P_2O_5 and 2.0 g of K_2O was put per model and mixed with the whole plowed layer before transplanting. While the cultivation period, the water ponding condition was constantly adopted, and the mid-summer drainage was not done. Transplanting of the paddy seedlings and harvesting were conducted at the end of May and at the end of September, respectively. This experiment was conducted without repetition, and Tukey-Kramer methods were used to test the statistical significance of the data of growth and yields of rice plants.

Measuring Method

The ORP meter (Central Kagaku co Ltd, model UC-203) was used for measuring oxidation -reduction potential (Eh), and it was set at each soil layer. We measured plant length, leaf number, the number of stems and panicles, the weight of straws, the number and weight of brown rice. Before the quantitative analyses of Cd concentrations in the stems and leaves, roots, brown rice and soils, the samples were treated with HNO_3 and HCl to extract Cd as sample preparation, and then absorbance of extracted solution was measured with atomic absorption spectroscopy (MAFF, 1979). Other measurements i.e., (density of soil particle, soil texture, grain size analysis, C/N ratio) were also conducted in standard methods in Japan.

RESULTS AND DISCUSSION

Oxidation-reduction Potential (Eh)

The oxidation-reduction state in the soil is an important factor for Cd mobility. In the oxidized layer, the solubility of Cd increases in soil solution (the main form of Cd component is $CdSO_4$) and so the uptake of Cd from plant roots is promoted. On the other hand, in the reduced layer, the solubility of Cd decreases (the main form of Cd component is CdS) and so the uptake of Cd from plant roots is limited (Iimura, 1981). From these, the measurement of oxidation-reduction potential (Eh) is very important for judging the mobility of Cd. The oxidized layer in paddy fields is defined as the layer whose Eh value is higher than +300 mV (Yamane, 1982).

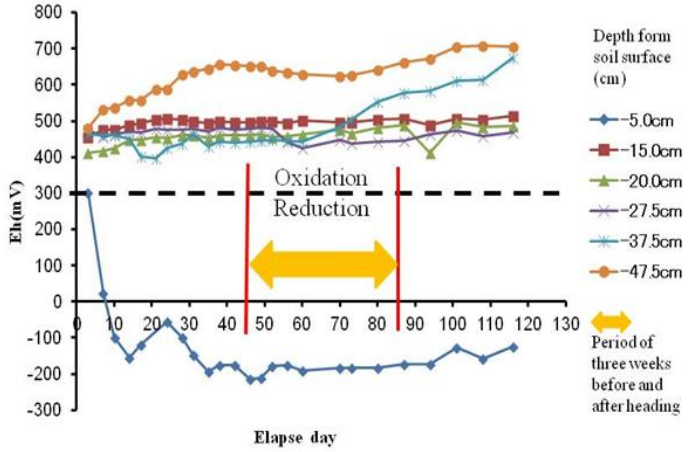

Fig. 2 Oxidation-reduction values in soil layers of the open system percolation model

The trends of Eh in each soil layer of O-1, O-2 and O-3, and of C-1, C-2 and C-3 were similar change from the transplanting to the harvest. Therefore, we have used below the Eh of open-system percolation model (O-3) in Fig. 2 and the Eh of closed-system percolation model (C-3) in Fig. 3. In the open-system percolation model, the Eh of the first layer (5.0 cm depth) had been about -100 mV during cultivation of paddy rice and so the first layer was a reduced layer. The Eh of the second layer (15 cm and 20 cm depth) and the third layer (27.5 cm, 37.5 cm and 47.5 cm depth) had been higher than +400 mV and those layers were oxidized layers. On the other hand, in the closed system percolation model, the Eh of all layers had been lower than -100 mV since 20 days after transplanting to harvest and so those layers were reduced layers.

It is said that Cd uptake of paddy rice is relatively high during three weeks before and after heading (MAFF, 2015b). In the open-system percolation model (Fig. 2), the second layer and the third layer were oxidized layers during three weeks before and after heading. On the other hand, all layers of the closed-system percolation model (Fig. 3) were reduced layers during the period. From these results, it is estimated that soluble Cd affects to paddy rice in the open-system percolation model.

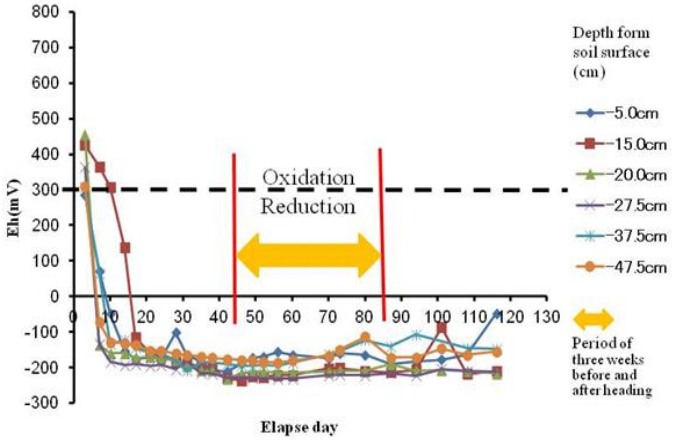

Fig. 3 Oxidation-reduction values in soil layers of the closed system percolation model

Table 2 Parameters of rice plant growth

Model	Plant length (cm)	No. of stems (Stems/hill)	Dry weight of straw (g)
O-1	94.8±4.0^{ab}	15.2±2.3^{a}	16.1±3.9^{a}
O-2	97.5±3.2^{b}	14.8±3.2^{a}	16.4±3.9^{a}
O-3	98.1±3.6^{b}	17.1±2.5^{a}	17.3±3.8^{a}
C-1	92.5±2.5^{a}	17.5±2.5^{a}	18.1±4.6^{a}
C-2	94.9±2.9^{ab}	13.8±3.9^{a}	20.9±4.7^{a}
C-3	98.3±3.5^{b}	17.1±3.2^{a}	20.7±6.3^{a}

Note: Tukey-Kramer test was performed at 5% level; letter indicates significant difference (n=10). The numerical value of ± shows standard deviation.

Growth of Paddy Rice

Table 2 shows the growth of paddy rice in the open-system percolation model and the closed-system percolation model. The average plant length ranged from 92.5c m to 98.3 cm in the two types of

models. The average number of stem ranged from 13.8 to the 17.5 in the two types. The average dry weight of straw ranged from 16.1 g to 20.9 g in two types. There were no significant differences in the growth parameters between the open-system percolation model and the closed-system percolation model. Paul et al. (2011) reported that the growth parameters of the closed-system percolation model were significantly higher than those of the open-system percolation model in the case of 3.39 mg/kg in plowsole. Furthermore, Ito and Iimura (1976) and Asami et al. (1995) reported that the increase of Cd concentration in the soil caused the decrease of plant length, number of stems and dry weight of straw. Those previous researches had different results from ours and that in probably because in our experiments the root system mainly existed in the non-polluted soil dressing and the Cd concentration in the soil was relatively low (less than 2 mg/kg).

Yield Components of Paddy Rice

Table 3 shows the yield components of paddy rice both in the open-system percolation model and the closed-system percolation model. The average number of panicles ranged from 9.9 to 13.2 in the two types of models. The average weight of brown rice ranged from 15.0 g to 21.7 g in the two types. The average number of brown rice grain ranged from 634 to 938 in the two types. The average 1000 grain weight of brown rice ranged from 18.7 g to 19.6 g in the two types. There were no significant differences in the yield components between the open-system percolation model and the closed-system percolation model. However, Paul et al. (2011) reported that the yield components of the closed-system percolation model were significantly higher than those of the open-system percolation model. Sasaki et al. (2010) and Pongpattanasiri et al. (2005) also reported that the average number of panicles in the closed-system percolation model was significantly higher than that of the open-system percolation model. Furthermore, Ito and Iimura (1976) and Asami et al. (1995) reported that the increase of Cd concentration in the soil caused the decrease of the weight of brown rice. The reasons why there were no significant differences in our experiments in the yield components between the two types of models was thought to be the effects of soil dressing and the relatively low Cd concentration of less than 2 mg/kg in the plowsole and subsoil.

Table 3 Parameters of rice plant yield

Model	No. of Panicles (Panicles/ hill)	Weight of brown rice per unit hill (g)	Number of brown rice grain per unit hill	1000 grain weight of brown rice (g)
O-1	10.1±2.2^{a}	15.0±4.2^{a}	634±173^{b}	19.6±1.4^{a}
O-2	10.0±1.9^{a}	16.6±4.4^{ab}	720±189^{ab}	19.3±0.4^{a}
O-3	12.9±2.5^{ab}	17.4±4.2^{ab}	790±189^{ab}	18.9±0.4^{a}
C-1	10.1±2.2^{a}	17.5±3.7^{ab}	740±173^{ab}	18.7±2.1^{a}
C-2	9.9±2.9^{ab}	15.9±2.9^{ab}	701±110^{ab}	18.7±0.9^{a}
C-3	13.2±2.7^{b}	21.7±6.3^{b}	938±260^{a}	19.4±1.1^{a}

Note: Tukey-Kramer test was performed at 5% level; letter indicates significant difference (n=10). The numerical value of ± shows standard deviation.

Cadmium Concentration in Rice Plants

Root: Table 4 shows the Cd concentration in roots in each soil layer: a range of 1.8-3.7 mg/kg was observed in the plow layer, though these values were not appreciably different among the experimental models; in the plowsole, a range of 1.70-17.00 mg/kg was observed. The result of larger amount of Cd

concentration in O-3 than other could be explained by the experimental condition of open-system percolation. In the subsoil, a range of 1.2-4.5 mg/kg was observed, which was 10 times higher than that of 0.13 mg/kg in the gravel layer. This result proved the occurrence of Cd movement from contaminated soil layer in the direction of downward or upward. The similar tendency was reported by Sasaki (2010, 2012) and Paul et al. (2011). This fact may provide a new perspective regarding the phytoremediation. The concentration factor, which is defined as the ratio of Cd concentration in roots in each soil layer, showed the ranges of 12.9-26.4, 2.0-9.4, and 9.2-34.6 from the plow layer to subsoil, respectively. The concentration factor in the plowsole was lower than both the plow layer and subsoil.

Table 4 Cd concentration in roots of different soil layers in the open and closed system percolation models

Model	Plow layer Non-polluted soil (mg/kg)	Plowsole polluted soil (mg/kg)	Subsoil Gravel (mg/kg)
O-1	2.90	4.20	1.20
O-2	3.20	2.70	1.60
O-3	3.00	17.00	4.50
C-1	3.00	1.70	1.80
C-2	1.80	6.00	1.70
C-3	3.70	3.60	2.20

Stem and Leaves: Table 5 shows the Cd concentration of stem and leaves. Except for O-3 (0.86 mg/kg), the range of Cd concentration was 0.18-0.33 mg/kg in the rest of five kinds of models. Thus, there was a significant difference between O-3 and the other models. It was inferred that the obvious Cd increment in stems and leaves became remarkable at a Cd concentration above 2 mg/kg in the contaminated soil layer. The similar tendency of a Cd increment had been recognized in open-system percolation (Sasaki et al., 2010; Paul et al., 2011). They reported similar values of Cd concentrations of stem and leaves under almost the same formation of soil layers except for the Cd concentration of 3.39 mg/kg in the contaminated soil layer. As Shibuya et al. (1980) pointed out that, the Cd concentration in contaminated soils higher than 1.5-2.0 mg/kg provides an appropriate lower limit and may be valid for our results in the stratified paddy field models.

Table 5 Cd concentration in the stem and rice grain

Model	Rice grains (mg/kg)	Stem and leaves (mg/kg)
O-1	0.07 ± 0.04^{b}	0.33 ± 0.13^{b}
O-2	0.05 ± 0.01^{ab}	0.28 ± 0.14^{b}
O-3	0.17 ± 0.05^{c}	0.86 ± 0.45^{a}
C-1	0.05 ± 0.01^{ab}	0.21 ± 0.10^{b}
C-2	0.04 ± 0.01^{ab}	0.18 ± 0.03^{b}
C-3	0.03 ± 0.01^{a}	0.24 ± 0.13^{b}

Note: Tukey-Kramer test was performed at 5% level;letter indicates significant difference (n=10). The numerical value of ± shows standard deviation.

Rice Grains: Table 5 shows the Cd concentration of rice grain. Except for O-3 (0.17 mg/kg), the Cd concentrations of rice grains were less than 0.07 mg/kg in the rest of five models. However, Cd concentrations in rice grains harvested from the contaminated soil with Cd concentration of below 1.0 mg/kg were similar regardless of percolation types. These values were consistent with the value of 0.06

mg/kg produced in non-contaminant paddy fields in Japan (MAFF, 2015b). There was a statistically significant difference between O-3 and the other five models.

Itou and Iimura (1976) reported that the value dividing Cd concentration of rice grains by that of straw was ranged between 0.1 and 0.2. Our experimental data brought about the same result, 0.1-0.2. This suggested that the ratio range of 0.1-0.2 may be common under widely variable cultivation conditions, such as pot experiments, field experiments (Tokunaga et al., 1977) and model experiments for stratified paddy fields (Sasaki et al., 2012).

CONCLUSION

As the countermeasures against Cd-polluted paddy fields, we experimented with six models of stratified paddy fields that had ponding during cultivation and soil dressing (12.5 cm), thickness being half of the conventional soil dressing in Japan, and also two different percolation patterns, closed-system percolation and open-system percolation of the plowsole and the subsoil. Those models had Cd concentration of 0.57 mg/kg, 1.21 mg/kg and 1.81 mg/kg in the plowsole and the subsoil.

As a result, the open-system percolation layers became an oxidation condition and the closed-system percolation layers became a reduction condition. But we could not recognize statistically significant difference in growth and yield in rice plants with those models. Cd concentration in rice grains, stems and leaves in the open-system percolation models with 2.0 mg/kg Cd-polluted soil was statistically significant and higher than those models of the others. Consequently, we found that with Cd-polluted soil models of less than 1.0 mg/kg made by mixing tillage we just needed almost half of the usual amount of soil dressing to significantly reduce the Cd concentration in the rice grains, stems and leaves. Thus, we found that the countermeasures which combined soil dressing and mixing tillage were an effective method with economic and safety merits.

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Research article

Development of an Emergency Discharging Device and an Early Warning System for Floods at Irrigation Ponds

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Abstract The spillways of irrigation ponds in Japan should be repaired to safely pass the 200-year flood event, which is the design criteria set by the government. However, extensive time is required to repair the spillways owing to the large number of ponds and the high repair costs. Therefore, we developed a low-cost early warning system (EWS) to reduce the risk to households in case of floods, as well as a low-cost emergency discharging device (EDD) to prevent or mitigate these floods. The Yutani irrigation pond in Tottori, Japan was selected for this study. The pond stores runoff from the catchment area and has no inflow from other basins. A siphon tube with a diameter of 20 cm was employed as the EDD for the pond and the discharge performance was evaluated. First, 60-min rainfalls at return periods of different years were estimated. Then, the peak runoff and subsequent arrival time of each year's 60-min rainfall and the discharges from the spillway and siphon were estimated. The water balance of the pond was calculated using the peak runoff as an inflow element, and the discharges from the spillway and the siphon were used as the outflow elements. The results showed that the pond will overflow if a 50-year rainfall event occurs under current conditions; however, it will not overflow when the siphon is employed even if a 60-year rainfall event occurs. Since the siphon discharge was not large enough to pass a flood event greater than 60 years, we developed an EWS that informs villagers living near the pond when the water level of the pond reaches these levels through an alarm lamp and an e-mail. Based on the results of the water balance analysis, the EWS provided information to judge whether villagers should be evacuated or not and the timing of the evacuation in the case of heavy rainfall events if necessary.

Keywords siphon, probability of rainfall, peak runoff, arrival time, water balance

INTRODUCTION

There are 1,094 irrigation ponds in the Tottori Prefecture, Japan as of September 2014. Heavy rainfall increases the risk of floods, which could cause damage to the villages located downstream of the ponds. Two of the possible countermeasures against floods include facility improvements and management of flood preparation plans. The purpose of facility improvements is to construct spillways that will safely pass the flood events, and proper flood management includes the preparation of hazard maps to show evacuation routes as well as the water levels at different places and roads when the flood occurs. The spillways of most irrigation ponds in Japan require repairs to safely pass the 200 year flood event that means the probability of flood occurrence, once per 200 year, which is the design criteria set by the Japanese government (MAFF, 2015). However, due to the large number of ponds and the high repair

costs, extensive time will be required to repair the spillways of every irrigation ponds. Therefore, we developed a low-cost early warning system (EWS) to reduce the potential risks in the case of floods, as well as a low-cost emergency discharging device (EDD) to help to prevent the floods and mitigate any damages that may be caused. The results of our research will assist with flood management plans in areas that still require spillway repairs.

OBJECTIVE

This study aimed to develop a low-cost EWS to reduce risks in the case of floods as well as a low-cost EDD to help prevent or mitigate the floods. Forecasting or real-time monitoring systems are employed in many EWSs installed at rivers and reservoirs, though they are not often applied to irrigation ponds that typically rely on water level monitoring and warning systems that can send alerts by sirens, lamps, and/or e-mails when the water reaches certain levels. However, these systems do not relay information related to the timing of evacuation to villagers living in the affected areas. Therefore, we developed an EWS that informs villagers living near the pond, through an alarm lamp and e-mail when the water level of the pond reaches certain levels, and on the basis of the results of a water balance analysis, the EWS also provides information during heavy rainfall events to judge whether villagers should be evacuated as well as the timing of evacuation if necessary. The function of an EDD was also quantified in this study to assess the capabilities of the device to prevent or mitigate floods during different rainfall events.

METHODOLOGY

Study Area

The study area selected was the Yutani irrigation pond in Tottori City, Japan. The storage capacity and the catchment area of the pond are 3,800 m^3 and 0.082 km^2, respectively. The pond receives and stores runoff from the catchment area and does not have inflow from other basins. The residential area of the village is located only 200 m downstream from the pond.

Water Balance Analysis

To simulate the water balance and water level of the pond under heavy rainfall, 60-min rainfall events at return periods of 10, 20, 30, 40, 50, 60, 100, and 200 years were estimated using the Iwai method. The hourly rainfall record over a 71-year range (1943–2013) was downloaded from the Japan Meteorological Agency (JMO), and the top 30 rainfall events were used for analysis.

The peak runoff and associated arrival times of the 60-min rainfall event during each year were estimated using the Rational equation and the values were used to simultaneously solve both the Talbot (Eq.1) and Kadoya–Fukushima formulas (Eqs.2 and 3), respectively:

$$I = \frac{a}{t+b} \quad \text{Eq. 1}$$

$$t_p = C \cdot A^{0.22} \cdot r_e^{-0.35} \quad \text{Eq. 2}$$

$$r_e = f_p \cdot I \quad \text{Eq. 3}$$

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

The Rational equation for determining the peak discharge from the catchment area and average effective rainfall intensity is expressed as follows:

$$Q = \frac{1}{3.6} \cdot r_e \cdot A \qquad \text{Eq. 4}$$

where Q is the peak runoff (m^3/s). The discharges from the spillway and the emergency discharging device (siphon) were estimated using the hydraulic formula as expressed in Eqs. 4 and 5. The siphon tube was assumed to be 20 cm in inner diameter.

The discharge from the spillway was calculated using rectangular weir or orifice formulas according to the water level. The EDD comprises a siphon tube that was 20 cm in diameter. Therefore, the average velocity of the siphon tube was estimated in consideration of all head losses owing to parameters such as friction and the curve of the tube. The formulas used in the calculation are expressed in Eqs. 5 and 6:

$$Q_s = C_s \cdot b \cdot H^{\frac{3}{2}} \qquad \text{(if the water level is below 0.54 m)} \qquad \text{Eq. 5}$$

$$\mathrm{Qs} = C_0 \cdot b \cdot \sqrt{2g(H_2^{1.5} - (H_2 - H_1)^{1.5})} \qquad \text{(if the water level is over 0.54 m)} \qquad \text{Eq. 6}$$

where Q_s is the discharge from the spillway, C_s and C_o are the discharge coefficients for the rectangular weir or orifice condition, respectively, g is the gravity acceleration (m/s^2), b is the width of the spillway (m), H is the water level of the spillway (m), H_1 is the height from the water surface to the top of the spillway (m), and H_2 is the height from the water surface to the bottom of the spillway (m).

The water balance and rate of increase of the water level of the pond were calculated using the peak runoff as the inflow element and the discharges from the spillway and the siphon as the outflow elements on a secondary basis. Due to the assumption of short and heavy rainfall, evaporation and infiltration from the pond were ignored. The necessary information to create the height–volume curve of the pond was surveyed. The function of EDD was evaluated and the alert and warning water level of the EWS was set on the basis of the results of the simulation.

RESULTS AND DISCUSSION

Estimated Rainfall and the Peak Discharge

The 60-min rainfalls at different return periods; the arrival time; the effective rainfall intensity; and the peak runoff discharge, are shown in Table 1. To meet the design criteria set by the government, the 200-year rainfall intensity was estimated to be 85.4 mm/h, and the arrival time of the peak runoff was estimated to be 34.5 min. The pond was assumed to have a spillway capable of passing discharges at rates >2.10 m^3/s.

Table 1 Estimated rainfall intensity and the peak runoff

Return period (y)	Rainfall intensity (mm/h)	Arrival time (min)	Effective rainfall intensity (mm/h)	Peak runoff (m^3/s)
10	56.3	41.5	53.9	1.24
20	62.5	39.6	61.5	1.42
30	66.2	38.6	66.2	1.53
50	71.1	37.4	72.4	1.67
100	78.0	35.9	81.4	1.88
200	85.4	34.5	91.1	2.10

Function of the Emergency Discharging Device

The water levels of the pond according to the different years of rainfall were simulated based on the water balance discharge calculated on a secondary basis. Figure 1 shows the peak water level at different years of rainfall with and without the EDD. As shown in the figure, the pond was not predicted to overflow when the 30-year rainfall event occurred, regardless of the presence or absence of the EDD. However, the pond was predicted to overflow during the 50-year rainfall event without the presence of the EDD, while it was not predicted to overflow until a greater-than- 60-year rainfall event occurred when the EDD was present.

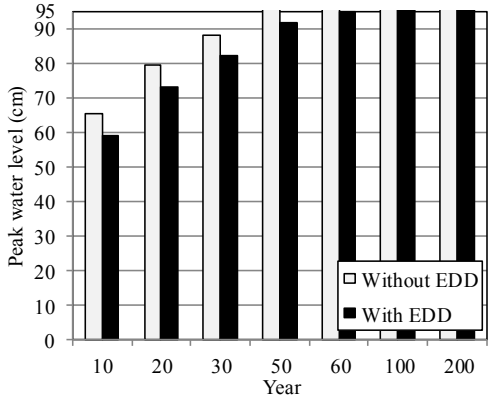

Fig. 1 Peak water levels for different years of rainfall events, where 95 cm refers to the top of the dike

Figure 2 shows a comparison of the discharges from the spillway and EDD. The EDD was observed to discharge more than the spillway during peak runoff, and when the water level reached the top of the spillway at 54 cm, the discharge from the spillway exceeded the EDD. When the maximum discharge occurred, the EDD contributed to approximately 20% of the total discharge. The result of the water balance simulation indicated the requirement for an EWS to alert the villagers to be evacuated when a greater-than-60-year rainfall event occurs.

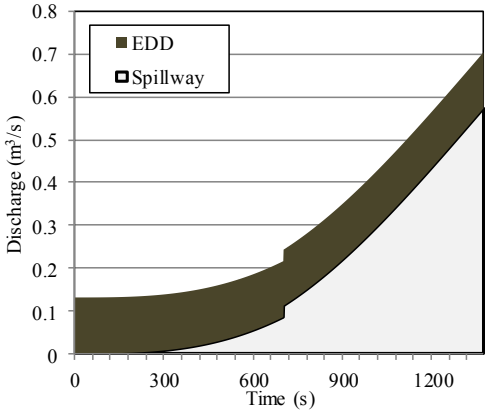

Fig. 2 Comparison of the discharges simulated for the spillway and the EDD

Setting Alert and Warning Water Level of the EWS

The EWS has two water sensors at different water levels. The sensor set at the lower water level is considered as the alert water level to indicate the villagers to start preparing for evacuation, while the other sensor set to a higher water level is considered as the warning water level to indicate the timing of the evacuation. Based on the evacuation route found on the hazard map made by the villagers and the Tottori Prefectural Federation of Land Improvement Association (2014), the time to evacuate from the houses to the designated safe places is estimated to be 10 min, with an additional 5 min assumed to be necessary to prepare for the evacuation. Therefore, the warning water level can be defined as the water level that is measured 10 min before the flood occurs (95 cm), and the alert water level can be defined as the water level that is measured 5 min before the water level reaches the warning level. As explained above, the pond will overflow when a greater- than-60-year rainfall event occurs. If the time for the water level to rise from alert to warning is less than 5 min during a greater-than-60-year rainfall event, then it should take longer than 5 min for the water level to rise from alert to warning during a less-than-60-year rainfall event. This means that the villagers can judge whether they need to be evacuated by the time it takes the water level to rise from the alert to the warning levels. The concept of setting the warning and alert water levels is illustrated in Fig. 3.

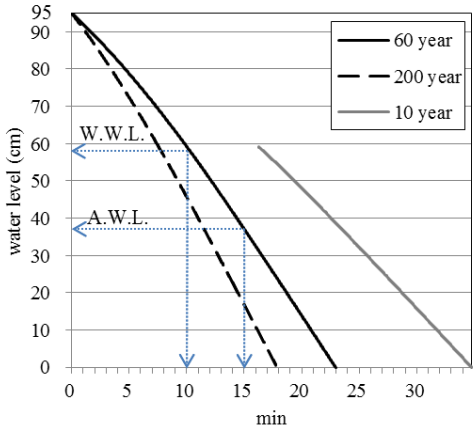

Fig. 3 Concept of setting the warning and alert water levels, where A.W.L. indicates the alert water level, and W.W.L indicates the warning water level

Table 2 Time required for the water to reach between two different levels

Water level	30 cm	40 cm	54 cm	60 cm	95 cm
20 cm	2 min 8 s	4 min 19 s	7 min 27 s	8 min 52 s	18 min 40 s
30 cm	-	2 min 11 s	5 min 19 s	6 min 44 s	16 min 32 s
40 cm	-	-	3 min 8 s	4 min 33 s	14 min 21 s
54 cm	-	-	-	1 min 25 s	11 min 13 s
60 cm	-	-	-	-	9 min 48 s

Table 2 shows the time for the water level to reach 20, 30, 40, 54, 60, and 95 cm under a 60-year rainfall event. The distance of 54 cm was selected instead of 50 cm because the top of the spillway is 54 cm, and this distance makes it easier for people to gauge the water level immediately. From the table, the alert water level should be set lower than 54 cm to obtain more than 10 min for evacuation. Supposing the warning water level is set to 54 cm, the starting water level will be 40 cm to result in a rise to 54 cm in less than 5 min. However, the preparation time for evacuation is only 3 min and is too less for people to prepare for evacuation. Therefore, we set the alert water level to 30 cm. Following

that, if the time of the water level rise from 30 to 54 cm is less than 6 min, we can judge if evacuation needs to occur.

Installation of the EDD and the EWS

The EWS and EDD were installed at the studied irrigation pond (see Fig. 4). The opening and closing of the 20-cm diameter siphon tube (KanaLine N. S., Kanaflex Co., ltd.) is controlled by an electric bulb (Butterfly Valve Electric Actuated Type T-57, Asahi Organic Chemicals Industry Co., ltd.). The EWS was settled at the dike and sends e-mails to registered people such as villagers, local government officers, and university officials when the water level rises up to the alert and warning water levels and also informs the villagers via an alarm lamp.

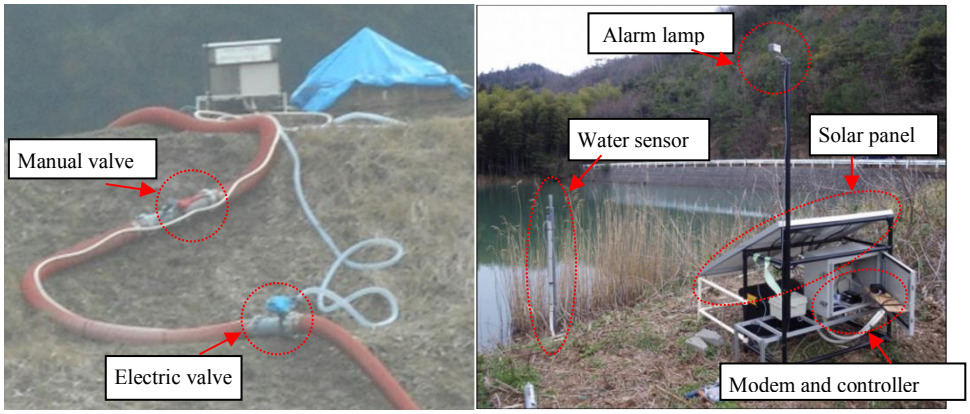

Fig. 4 Photographs of the EDD (left) and the EWS (right)

CONCLUSION

An EWS and EDD were developed to reduce the risk in case of floods and to prevent or mitigate the floods at an irrigation pond that did not have a sufficiently large spillway to safely pass a discharge caused by heavy rainfall. The developed EDD could not satisfy the criteria designed by the government but could prevent against floods caused by less-than-60-year rainfall events. The EDD enhanced the drainage function by at least 20% during flood conditions. The previous EWS had just informed the relevant people and agencies when the water level reached a certain level, but the newly developed EWS presented in this work is a type of epoch-making device in terms of informing the timing of potential evacuations. Our results also suggested that multiple countermeasures such as a combination of EDD, EWS, and hazard maps are required to prevent floods and mitigate flood damage to people.

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Research article

Influence of Pig Breeds on Growth Performance and Immunity During Pre-weaning Period

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Abstract This study was conducted to find out the influence of pig breeds on growth performance and immunity during the pre-weaning period. The experimental designed consisted of a completely randomized design and was performed with a total of 892 piglets acquired from 105 Thai native (TN), Meishan (MS), and Large white x Landrace (LWxLR) sows. After farrowing, the piglets were weighted daily until weaning at 21 days of age and the average daily gain (ADG) was calculated. Serum samples were collected from piglets at 12 and 24 h and IgG concentrations were determined by the ELISA technique. The growth performance of LWxLR piglets measured at birth and at seven days (1.43±0.20 and 2.67±0.20, respectively) was higher ($p<0.01$) than TN (0.65±0.15 and 1.12±0.15, respectively) and MS (1.07±0.02 and 1.97±0.37, respectively). The growth performance of MS piglets was similar ($p>0.01$) to LWxLR piglets at fourteen and twenty-one days of ages. The ADG of MS and LWxLR were significantly ($p<0.01$) higher than TN during all lactation periods. However, the piglets of MS showed the highest ADG at fourteen days. The IgG concentrations in all breeds at 12 h were less than 24 h but the values were not considered significant ($p>0.01$) among the breeds. The present results indicate that different pig breeds did have an effect on growth performance and ADG. Moreover, this study showed that low birth weight of piglets resulted in low growth performance, but IgG concentrations were not found to be different among the breeds.

Keywords piglet, breed, immunity, body weight

INTRODUCTION

The growth potential of pigs is influenced by many factors (breed, sex, and stage of growth), including housing conditions (floor type, space allowance and group size) and climatic factors (temperature, relative humidity, air speed). Breed is an important factor that can affect the growth potential of pigs (Renaudeau et al., 2006). Indigenous breeds of pigs have lower rates of feed conversion efficiency, growth rates, and growth potential than exotic breeds (Nwakpu, 2013). The breeds of pigs display different characteristics. Certain cross breeds (Landrace, Large white, Duroc, Pietrain) have high levels of growth performance, carcass quality and meat quality (McClann et al., 2008), but cross breed has been known to be least adaptable in hot humid climates (De et al., 2013), while certain local breeds (Thai native, Meishan, Korean native black pigs, Mongcai) possess higher fat content than cross breeds and adapt well to hot and humid climates, can tolerate low quality feed, and are resistant to disease (Rattanaronchart, 1994). For example, Thai native pigs display significant genetic differences with certain cross breeds (Large White, Spotted Large White, and Pietrain) (Chaiwatanasin et al., 2002).

Meishan is the local pig breed of central China (Bazer et al., 1988). The Meishan breed displays low growth performance, low muscle content, and low quality of ham, but their fat percentage was higher than that of the Large White and Pietrain breeds, and Meishan also adapted well with trough feeding (McLaren, 1990; Van Milgen et al., 1998). Breed is not the only factor that can be related to growth potential (Gerbens et al., 1999) and disease resistance of pigs (Lamont, 1998). It has been determined that immunity is also related to growth potential and disease resistance in pigs (Porter and Hill, 1970). Colostrum provides nutrition (Farmer and Quesnel, 2009), energy and maternal antibodies to piglets (Dividich et al., 2005). New-born piglets acquired immunoglobulin from colostrum after parturition on the fifth day after ingesting colostrum and milk for passive immune protection (Xu et al., 2000). Immunoglobulin concentrations in the plasma of piglets depend on the amount of colostrum ingested by the piglet. Immunoglobulin concentrations in the colostrum and the timing of the gut closure (when intact IgG can no longer be absorbed by the gastrointestinal tract of the piglet) are related. However, the capacity of the piglets is revealed when they have absorbed adequate amounts of IgG for disease protection (Rooke and Bland, 2002).

OBJECTIVE

The objective of this study was to find out the influence of pig breeds on growth performance and immunity during the pre-weaning period.

METHODOLOGY

Experimental Flow

This experiment was conducted at a designated demonstrative and training swine farm at the Department of Animal and Aquatic Sciences, Faculty of Agriculture, Chiang Mai University. The experimental design was a completely randomized design involving 3 treatments, and the total piglets in each breed were used as a replication. One hundred and five sows belonging to Thai native (n=35), Meishan (n=28), Large white x Landrace (n=42) breeds and their litters (251 piglets from Thai native, 299 piglets from Meishan, and 342 piglets from Large white x Landrace) were observed from birth to weaning at 21 days of age. The day of birth was defined as day 0 of age. During the suckling phase, piglets were housed in farrowing pens where they were individually penned until weaning. Pens were equipped with nipples, feeders, creep boxes containing a heat lamp and an opening to permit free access to the piglets. From day 10 of lactation, piglets were offered creep feed but intake values could not be measured.

During the first 12 weeks of gestation, sows were fed 2 kg/day, and during the last 4 weeks, 3 kg/day (formulated to contain 12% CP, 0.53 lysine, 3,190 kcal ME/kg). After farrowing, sows were fed the same feed formula, but feed intake was distributed according to litter size. Sows had free access to fresh water.

The farrowing process was induced on day 114 of gestation with 1 ml of prostaglandins (Cloprostenol Sodium). Piglets received 2 ml of oxytocin (2 ml of a 10 IU/ml solution; General Drugs House Co., Ltd) by intramuscular route. Parturitions were watched but observers interfered as little as possible in the farrowing process and manual birth assistance was only performed when the birth interval exceeded 1h immediately after birth, piglets were dried with the use of powder, their umbilical cords were clamped, and they were weighed using a general balance. Piglets were weighed again at 7, 14, and 21 days of age. All the piglets were weaned at 21 days. At three days after birth, all piglets received iron (Ferric oxide dextran solution with phenol) 2 ml/piglet by intramuscular injection.

IgG concentration was determined in the serum. Blood samples were collected from piglets via jugular venipuncture at 12 and 24 h after farrowing. The blood samples were centrifuged for 10 min at

1,500 rpm and serum samples were stored at -20 ^{o}C until analysis. IgG concentration was evaluated by Enzyme linked immunosorbent assay (ELISA). A modified method of Devillers et al. (2004) was employed. The plates were coated with 100 µl of rabbit anti-pig IgG (whole molecule) in 1% in 0.05 M sodium bicarbonate solution (pH 9.6) and incubated overnight at 4 ^{o}C. After that, the plates were washed 3 times with a washing buffer. Then, TBS containing 1% BSA was added and the specimens were incubated for 1 h at 20 ^{o}C. Thereafter, the plates were washed 3 times using a washing buffer. Then, the serum sample was added to the plates and the standard (pig IgG) was placed into duplicate wells and incubated for 2 h at 20 ^{o}C. The plates were then washed 3 times with a washing buffer. Rabbit anti-pig labeled peroxidase 10 µl was added to each well and the specimens were incubated for 1 h at 20 ^{o}C. After that, the plates were washed again 3 times with a washing buffer. Then, the substrate OPD was added and the colored reaction was stopped by 100 µl 4 M H_2SO_4 and the absorbance was read at 492 nm. Ultimately, the standard curve was calculated for the sample.

Data Analysis

In terms of the statistical method, data were analyzed by using the procedure of SPSS Windows. All statistical tests were performed with SPSS Statistics 17.0 (SPSS Inc., Chicago, IL). For the analysis of growth performance, piglets were weighed daily from birth to weaning and the average daily gain (ADG) and IgG were calculated. The observed mean in multiple comparisons was based on the Duncan Post Hoc test. Using the SPSS for Windows, Pearson's correlation coefficients were estimated for the treatments.

RESULTS AND DISCUSSION

The influence of pig breed on growth performance and average daily gain during the pre-weaning period is presented in Table 1. The body weights of all treatments increased over time. However, the body weights of TN piglets were the lowest. The average daily gain (ADG) of TN piglets was lower than those of the MS and LWxLR breeds at 14 and 21 days. The LWxLR breed was significantly higher at birth and at seven days (1.43±0.20 and 2.66±0.20, respectively) compared to piglets of TN (0.65±0.15 and 1.12±0.15, respectively) and MS (1.07±0.02 and 1.97±0.37, respectively) breeds ($p<0.01$). However, in this regard, MS piglets were not found to be significantly different ($p<0.01$) from the LWxLR breed at fourteen and twenty-one days of age. For the ADG of the MS and LWxLR breeds, it was found to be significantly higher than the that of the TN breed during the pre-weaning period ($p<0.01$), but ADG of the MS and LWxLR breeds were not found to be significantly different during all lactation periods and the piglets of the MS breed (0.20±0.05) had the highest ADG at fourteen days.

The results of our study indicated that there is a significant effect of breed on performance traits. The body weights of piglets from each breed for all treatments during the pre-weaning period were both negatively and significantly correlated with birth weight in accordance with previous results obtained in our study (Skorjanc et al., 2007). In our study, birth weights of TN pigs were lower than those of the cross-bred piglets, and TN pigs were also lower in growth potential and ADG than the cross-bred piglets, which were similar to the findings of the report of Skok et al. (2008) who studied the growth performance of piglets during the lactation period. Their results showed that heavy piglets at birth were still heavier at the end of lactation in comparison to light piglets. Vaclavkova et al. (2012) reported that low birth weight piglets grew at lower rates than pigs with higher birth weights and that low birth weight piglets gained less weight during all periods of production, and they also had less longissimus muscle (Fix et al., 2010). The results reported herein are also in agreement with the study conducted by Kaensombath and Lindberg (2012) that studied the growth performance of exotic and native breeds and found that cross-bred piglets displayed higher growth performance than native breeds.

The native breed piglets had lower performance and production inputs, but displayed excellent adaptation traits when compared with exotic breeds (Keonouchanh et al., 2011). Nwakpu (2013) studied the characteristics of inbred and cross-bred native piglets with regard to pre-weaning and weaning growth performance levels in pigs. They found that the effects of growth potential among native pigs were more affected inbred than exotic breeds, and that pre-weaning and weaning performance values of the cross-bred piglets were better than those of the native pig breeds because of the dominant genes that were acquired from the exotic parent. The significant differences observed among the genetic delivery of four pig breeds in Thailand suggested that Thai native pigs displayed the highest genetic diversity between Large White (LW), Spotted Large White (SLW), and Pietrain breeds (there was a great genetic differentiation observed between Thai native breeds and the other three breeds) (Chaiwatanasin et al., 2002). Leenhouwers et al. (2002) reported that high genetic merit of piglets could improve the ability to cope with hazards during birth and the first days of life. Renaudeau et al. (2006) showed that the performance and the feeding records of pigs raised in tropical climates were affected significantly by their breeds. The native breeds better tolerated hot conditions than the cross breeds. The best heat tolerance was observed in indigenous breeds and this was associated with a greater ability to lose heat.

Table 1 Body weight and Average daily gain (ADG) of each breed during lactation period

Variable	Age, day	TN	MS	LWxLR	SEM	*P*-value
BW, kg						
	Birth weight	0.65±0.15c(d)	1.07±0.02b(d)	1.43±0.20a(d)	0.065	0.000
	7	1.12±0.15c(c)	1.97±0.37b(c)	2.66±0.20a(c)	0.068	0.000
	14	1.61±0.15b(b)	3.74±0.48a(b)	3.84±0.18a(b)	0.106	0.000
	21	2.20±0.15b(a)	4.55±1.18a(a)	5.05±0.42a(a)	0.134	0.000
ADG, kg						
	7	0.07±0.00b	0.13±0.05ab	0.18±0.24a	0.016	0.05
	14	0.07±0.01b	0.20±0.05a	0.17±0.01a	0.018	0.00
	21	0.07±0.01b	0.17±0.06a	0.17±0.21a	0.016	0.05

a,b,c Means with different superscripts within a row differ, p<0.01
(a),(b),(c), (d) Means with different superscripts within a column differ, p<0.01
Breeds: TN=Thai Native, MS=Meishan, LWxLR=Large whitexLandrace

Table 2 IgG concentrations of piglet serum at different times in each breed

Stage of lactation(h)	Immunoglobulin G, mg/ml			SEM	*P*-value
	TN	MS	LWxLR		
12	16.98±2.98	17.90±2.43	15.28±3.33	0.759	0.388
24	21.32±3.29	20.90±2.29	20.06±3.73	0.768	0.817

Breeds: TN=Thai native, MS=Meishan, LWxLR=Large whitexLandrace

The concentrations of IgG in each breed at 12 h were less than 24 h of all breeds (Table 2). The IgG concentration in the serum of piglets increased over time. However, IgG concentration was not significantly different for different breeds (p>0.01). The immunoglobulin is secreted from the mammary tissue in the mammary gland (Foisnet et al., 2010). The transport of maternal immunoglobulin to the neonate occurs by two routes: the blood stream and colostrum, and immunoglobulin transfer in quantity in the blood stream or via the colostrum is mainly of the IgG class and has lower concentrations of IgA and IgM (Bourne and Curtis, 1973). Markowska-Daniel and Pomorska-Mol (2010) reported the average concentrations of IgA, IgM, and IgG in sow serum 10 days before parturition were 1.58, 6.12 and 39.56 mg/ml, respectively. After farrowing 7 days, the average of IgG concentrations level was lower (34.94 mg/ml), but concentrations of IgA and IgM level increased to 2.25 and 7.25 mg/ml. For the colostrum of sows at farrowing, the IgG concentration was 118.5 mg/ml, the IgA concentration was 23.8 mg/ml and decreased to 7.85 mg/ml at 6 h and to 4.59 mg/ml at 24 h, and concentration of IgM was 12.1 mg/ml and decreased to 4.23 mg/ml at 24 h postpartum. Cabrera et al. (2012) studied the influence of colostrum and serum immunoglobulin G on

neonatal piglet survival. It was confirmed that the concentration of IgG in the serum was 1,000 mg/dl and displayed a 67% piglet survival rate at weaning. Serum IgG concentrations were recorded at between 2,250 to 2,500 mg/dl and displayed a 91% survival rate at weaning. Farmer et al. (2007) studied the influence of genotype on colostrum and the milk composition of primiparous sows (Belgian Landrace, Duroc, Landrace and Yorkshire). They found that colostrum and day-2 milk from Duroc sows contained more protein and less amounts of lactose than sows of other genotypes. The first-born piglet had low energy stores and was devoid of serum immunoglobulin (Dividich et al., 2005). Colostrum samples contained nutrition and immunoglobulin. Both of them are comprised of important energy and maternal antibodies that are provided for the survival and development of neo-natal piglets (Devillers et al., 2011). Csapo et al. (1995) researched the composition of colostrum in porcines. The results showed that the first colostrum samples contained 16.65% of total protein. The high protein content in colostrum was largely produced by the immunoglobulin. During the first 6 h after farrowing, IgG accounted for nearly all the protein in the colostrum (Klobasa et al., 1987). Kielland et al. (2015) investigated the association between IgG in sow colostrum and piglet plasma. They found that the colostrum IgG and piglet IgG had a strong association and that when the IgG level in the colostrum was increased, the levels of IgG in the piglets would improve and this would potentially increase the survival rates of the piglets. Quesnel et al. (2012) and Devillers et al. (2007) reported that the consumption of 200 g of colostrum per piglet during the first day after birth significantly reduced the risk of mortality before weaning, while the consumption of 250 g of colostrum was an indicator of good health and pre-weaning and post-weaning growth among piglets.

CONCLUSION

In conclusion, the presented data has demonstrated the breeds of pigs influenced body weight and ADG during pre-weaning period. The MS and LWxLR showed better growth performance than TN. However, the pig breeds did not affect the IgG concentration in serum of piglets at 12 and 24 h.

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Research article

Predicting Soil Temperature Condition in Agricultural Land under Climate Change in Japan

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Abstract Decomposition of soil organic carbon as well as growth of crops are affected by soil physical condition such as soil moisture and soil temperature. Thus predicting soil moisture and temperature condition of arable lands under future climate change is important for both mitigation and adaptation of climate change in agriculture. In this study, we attempted to predict soil temperature condition in arbitrary arable lands in Japan. Soybean fields of Toyama city, middle part of Japan facing Japan Sea were chosen as the experimental site. There, monitoring of soil temperature and measurement of soil thermal properties which is a function of soil moisture, was conducted. For the future application to arbitrary locations, the thermal properties were also predicted with a mathematical model, by using soil physical properties such as the ratio of sand: silt :clay, soil particle density and dry bulk density in soil physical database. Then, numerical simulation of soil moisture and temperature was conducted with predicted soil hydraulic and thermal properties. The model with estimated thermal properties described the measured soil temperature fairly well especially when the soil condition was wet.

Keywords climate change, thermal conductivity, soil temperature, soil database, numerical simulation

INTRODUCTION

Soil is a foundation of agriculture and ecosystem. Growth of crops and vegetables, and/or incidence of insect and pest as well as decomposition of soil organic matter are affected by soil physical condition such as soil moisture and soil temperature (e.g. Allmaras et al., 1964; Singh and Dhaliwal, 1972; Simunek and Suarez, 1993). Climate change including temperature rise and change in rainfall patterns will alter soil physical conditions. For example, Bai et al. (2014) showed that soil temperature at depth of 50 cm has increased at an average rate of 0.79 ℃ per decade from 1982 to 2000 in Mojav Desert region in USA and mentioned that the temporal changes of soil temperature was correlated with those of air temperature. The available observed data of soil temperature and soil moisture has been limited spatially and temporarily compared to the meteorological data.

Numerical simulation of soil water and heat movement with GCM (General Circulation Model) projections as boundary condition is one of the effective way to predict future soil physical condition. Kato and Nishimura (2015) proposed the methods of temporal downscaling of GCM prediction, especially the rainfall data, for producing boundary conditions for numerical simulations of soil moisture, and applied the downscaled projections to prediction of future soil moisture of an agricultural land in Japan. Kato and Nishimura (2016) attempted to estimate soil hydraulic parameters for numerical simulation of soil moisture in arbitrary agricultural lands by using soil physical properties database Solphy J (Eguchi et al., 2011). As for the soil temperature, Kato et al. (2011), for example,

conducted the numerical simulation of soil temperature of agricultural field to reproduce the past temperature records with measured soil thermal conductivity. For the further application, it is beneficial to predict soil temperature in arbitrary locations without measurement of soil thermal properties. Since soil thermal properties are generally affected by soil physical properties such as soil texture, soil bulk density, etc., soil physical properties databases are probably useful for estimation of soil thermal properties and subsequent simulation of soil temperature.

Based on the above, in this study, we investigated the possibility of estimation of soil thermal properties by using available soil physical properties databases and prediction of soil temperature under climate change in arbitrary agricultural lands.

METHODOLOGY

Study Site

One of the plain agricultural field in Toyama city, the middle part of Japan facing Japan Sea, was chosen as the study site (Fig. 1). Hokuriku District, including Toyama city is the representative grain growing area in Japan and has often been chosen as research sites for effects of climate change on agriculture (MEXT, 2015). Recently, a multiple cropping system of paddy rice-barley-soybean in two years has often been employing in the region around our study site. Barley and soy beans were grown from November 2010 to May 2011, and from June to October 2011, respectively, at Agricultural Research Institute of Toyama Prefectural Agricultural, Forestry and Fisheries Research Center in Toyama City. There, soil moisture and temperature at depths of 5, 10, 20, 30 and 40cm was monitored continuously with ECH2O 5TE sensors (Decagon Devices, Inc., USA) from April to October, 2011. Undisturbed 100 cm^3 core samples and disturbed soil were sampled from a pit in the field and then soil samples were brought back and their physical properties (soil texture, particle density, water retention, saturated hydraulic conductivity) were measured in the laboratory (Kato and Nishimura, 2016). Soil thermal conductivity λ_{meas} was also measured with KD2 heat probe (Decagon Devices Inc. USA).

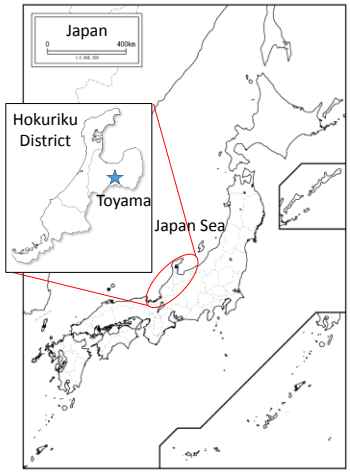

Fig. 1 The location of Toyama City (Kato and Nishimura, 2016, modified)

Numerical Model

HYDRUS-1D model has widely been used for calculation of soil moisture and temperature, and in this study, the ver. 4.xx (Šimůnek et al., 2013) was used. Since heat is also transported with water, and soil

thermal properties often changes with soil moisture condition, both soil moisture and soil temperature were simulated simultaneously. The governing equation of liquid and vapor water movement in soils was an extended Richrads' equation with root water uptake $S(h)$ (Eq. (1)).

$$\frac{\partial \theta_T(h)}{\partial t} = \frac{\partial}{\partial x}\left[(K + K_{vh})(\frac{\partial h}{\partial x} + 1) + (K_{LT} + K_{vT})\frac{\partial T}{\partial x} \right] - S(h) \tag{1}$$

where h is the pressure head [L], θ_T is the total volumetric water content, or the sum of the volumetric water content of liquid (θ) and vapor (θv) water [L^3L^{-3}], respectively. T is temperature [K], K and K_{LT} are the isothermal and thermal hydraulic conductivity of the liquid phase [LT^{-1}], K_{vh} and K_{vT} are the isothermal and thermal vapor hydraulic conductivity, respectively[LT^{-1}].

Heat transfer with vapor transport was described with heat flow equation (Eq. (2)).

$$C_p(\theta)\frac{\partial T}{\partial t} + L_0 \frac{\partial \theta_v}{\partial t} = \frac{\partial}{\partial x}\left[\lambda(\theta)\frac{\partial T}{\partial x} \right] - C_w \frac{\partial T}{\partial x} - C_v \frac{\partial q_v T}{\partial x} - L_0 \frac{\partial q_v}{\partial x} \tag{2}$$

where C is the volumetric heat capacity and subscript p, w, and v mean porous medium, liquid water and vapor, respectively, L_0 is the volumetric latent heat of vaporization of liquid water [$ML^{-1}T^{-2}$] and q_v is the vapor flux density [LT^{-1}]. λ is the apparent thermal conductivity of the soil [$M\ LT^{-3}K^{-1}$] which is the sum of the thermal conductivity of the porous medium under no flow condition λ_0 (θ) and the macrodispersivity. The details can be found in Šimůnek et al. (2013).

Soil Hydraulic Parameters

In this study, van Genuchten-Mualem (VG-M) model (van Genuchten, 1980) Eq. (3) and (4) was employed for predicting water retention curves and unsaturated hydraulic conductivity.

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} = \left(1 + |\alpha h|^n\right)^{-m} \tag{3}$$

$$K(h) = K_s S_e^l \left[1 - (1 - S_e^{1/m})^m\right]^2 \tag{4}$$

where θ_r and θ_s are the residual and saturated volumetric water content [L^3L^{-3}], K_s is the saturated hydraulic conductivity [LT^{-1}], S_e is the effective saturation [dimensionless], α [L^{-1}], l, m=1-1/n, and n [dimensionless] are empirical parameters.

Hydraulic parameters of VG-M model for soils of each layer were determined based on the digital soil map (Takata et al., 2009) and the agricultural soil-profile physical properties database, Japan "SolphyJ" (Eguchi et al., 2011). Here, calculation area was divided into three layers according to SolphyJ database and dataset of water retention, i.e., volumetric water contents at suctions of 32, 500, 16000 and 320000 cmH_2O of each soil layer were prepared. Then "RETC program" (Yates et al., 1992), which can predict parameters of soil hydraulic functions such as VG-M model by fitting observed water retention by nonlinear least-squares method, was used for determining the VG-M parameters. The saturated hydraulic conductivity "K_s" value was predicted with a neural network based model "Rosetta" (Schaap et al., 1998). The recommended value 0.5 was employed as l. The details can be found in Kato and Nishimura (2016).

Soil Thermal Parameters

Volumetric heat capacity C (θ) and thermal conductivity λ_0 (θ) vary among soils. Considering the application to arbitrary locations, both C and λ_0 were determined with the soil properties database.

Volumetric heat capacity of soil can be described as the sum of heat capacities of the constituents as follows (Šimůnek et al., 2013),

$$C_{soil} = C_n\theta_n + C_o\theta_o + C_w\theta + C_a a_v \approx (1.92\theta_n + 2.51\theta_o + 4.18\theta)10^6 \quad (\mathrm{J\ m^{-3}K^{-1}}) \tag{5}$$

where C means heat capacity and subscription of n, o, w and a are solid, organic matter, water and air, respectively and a_v is the volumetric fraction of air. θ_n can be found in SolphyJ database and θ_o can also be obtained assuming that particle density of organic matter is 1.63 (g $\mathrm{cm^{-3}}$).

Models have been proposed to estimate soil thermal conductivity. In this study, Chung and Horton (1980) (C-H) model and Campbell (1985) model were employed.

Chung and Horton (1980) described soil thermal conductivity as follows (Eq.(6)).

$$\lambda_{CH} = b_1 + b_2\theta + b_3\theta^{1/2} \tag{6}$$

where b_1, b_2 and b_3 are empirical parameters. Chung and Horton (1980) proposed the sample set of b_1~b_3 corresponding with "sand", "loam", and "clay" and hereafter we call those λ_{CH} as λ_{sand}, λ_{loam} and λ_{clay}, respectively.

According to Campbell (1985), soil thermal conductivity is describes as follows (Eq. (7)).

$$\lambda_{camp} = A + B\theta - (A - D)\exp\left\{-(C\theta)^E\right\}$$
$$A = \frac{0.57 + 1.73\theta_q + 0.93\theta_m}{1 - 0.74\theta_q - 0.49\theta_m} - 2.8\theta_n(1 - \theta_n), \quad B = 2.8\theta_n$$
$$C = 1 + 2.6\theta_c^{-1/2}, \quad D = 0.03 + 0.7\theta_n^2, \quad E = 4 \tag{7}$$

where subscription q, m and c represent quartz, minerals other than quartz, and clay, respectively, and ρ_d and ρ_s are soil dry bulk density and soil particle density, respectively. θ_q, θ_m, and θ_c can be calculated as equations (8) assuming that the entire sand fraction is originated from quartz, while silt and clay are from other minerals

$$\theta_n = \rho_d/\rho\ ,\ \theta_q = \theta_n \times \theta_{Sand}\ (\%)\ ,\ \theta_m = \theta_n - \theta_q\ ,\ \theta_c = \theta_n \times \theta_{Clay}\ (\%) \tag{8}$$

where θ_{sand} and θ_{clay} are the volumetric fraction of sand and clay, respectively. Here, mass ratio of sand and clay in SolphyJ database were substitute for θ_{sand} and θ_{clay}, respectively. Though both ρ_d and ρ_s can be found in Solphy J database, here, three different ρ_d (ρ_{d1}, ρ_{d2}, and ρ_{d3}) were employed for Eq. (8) as follows since soil bulk density easily changes with cultivation.

$$\rho_{d2} = \rho_{d1} - 0.10, \rho_{d3} = \rho_{d2} - 0.10 \tag{9}$$

where dry bulk density value in Solphy J database were employed for ρ_{d1}. In this study, ρ_{d1}=1.02, ρ_{d2}=0.92, and ρ_{d3}= 0.82 were used for the simulation. Hereafter we call λ_{camp} which were predicted with ρ_{d1}, ρ_{d2}, ρ_{d3} as $\lambda_{1.02}$, $\lambda_{0.92}$, $\lambda_{0.82}$, respectively.

Scenario Study

Using determined parameters, scenario study was conducted to predict soil moisture and temperature of arable lands in Toyama under climate change. ELPIS-JP (Iizumi et al., 2012) is approximately 20 km scale daily GCM projection dataset of "50 time series" of 110 years. The "50 time series" represents variability of meteorological phenomena incident to temporal downscaling of GCM projections (Iizumi et al., 2012). Corresponding to Toyama weather station, MIROC 3.2 hires and A1B of Toyama weather station data were employed for GCM and IPCC SRES Scenario, respectively. Since temporal scale of soil water and heat movement in agricultural lands are usually shorter than a

day, daily ELPIS-JP dataset was temporally downscaled into hourly or shorter scale by using weather generator CLIGEN (Nick et al., 1995). Details of temporal downscaling methods can be found in Kato and Nishimura (2015). According to the climate scenario of the possible monthly rainfall depth of the soybean growing period (June, July, August and September), expected maximum values in present (1981-2000) are 291, 405, 346 and 363 mm, respectively, and those values in future (2071 to 2090) tend to increase to 1.3 ~ 1.6 times of those of present, except August. Average monthly air temperature of four months from June in present are projected to be 24.4, 28.6, 30.4 and 25.9 ℃, respectively and are likely to rise 3~5 ℃ through a year in late 21st century. Here, we attempted to predict soil moisture and temperature with an assumption of maximum monthly rainfall in June both in "present" and "future" (Kato and Nishimura, 2015).

RESULTS AND DISCUSSION

Determined hydraulic parameters are shown in Table 1 and Kato and Nishimura (2016) reported that the model described soil moisture well with RMSE (root mean square error) of 0.01 $cm^3\ cm^{-3}$.

Table 1 Determined soil hydraulic parameters of each layer

Location	Level	θ_r ($cm^3\ cm^{-3}$)	θ_s ($cm^3\ cm^{-3}$)	α	n	K_s (10^1 cm d^{-1})	l
Toyama	1	0.027	0.470	0.043	1.11	18.9	0.5
	2	0.029	0.361	0.032	1.11	11.6	0.5
	3	0.009	0.468	0.046	1.12	72.0	0.5

Soil thermal diffusivity K_a, which is calculated by the ratio of thermal conductivity λ_a to volumetric heat capacity C_a, is an indicator of the ability of soil to have temperature change with heat inflow. Hereafter we call the thermal diffusivities calculated with λ_{sand}, λ_{loam}, λ_{clay}, $\lambda_{1.02}$, $\lambda_{0.92}$, and $\lambda_{0.82}$ as K_{sand}, K_{loam}, K_{clay}, $K_{1.02}$, $K_{0.92}$, and $K_{0.82}$, respectively. Figure 2 shows the comparison of soil thermal diffusivities among those determined with (a) C-H model (K_{sand}, K_{loam} and K_{clay}) and (b) Campbell model ($K_{1.02}$, $K_{0.92}$, and $K_{0.82}$). Both figures also show K_{meas}, which were calculated with measured soil thermal conductivity λ_{meas} fitted with C-H model. Compared with the measured values, C-H model overestimated thermal conductivities and thus thermal diffusivities (Fig. 2 (a)). Especially, K_{sand} is four times larger than K_{meas}. This discrepancy is probably due to the difference in soil bulk density and type of minerals which constitute the soil. Campbell model, which can partly consider some of physical properties, tended to describe the thermal diffusivities better than C-H model and the predicted values were improved by assuming the lower dry bulk density, especially when soil moisture is high (Jury and Horton, 2004) (Fig. 2(b)).

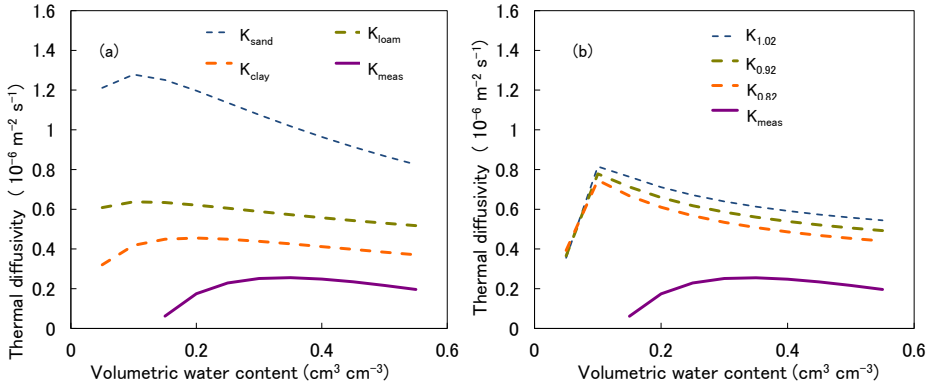

Fig. 2 Estimated thermal diffusivities with (a) Chung and Horton and (b) Campbell models

Figure 3 shows the comparison of measured and simulated soil temperature at depth of 10cm in the study field. Simulated values were calculated by using measured thermal conductivity λ_{meas}. The model described the measured soil temperature well with RMSE = 1.7 ℃.

Figure 4 shows the comparison of the simulated vertical distribution of soil temperature among those calculated with five different thermal conductivity, or λ_{sand}, $\lambda_{1.02}$, $\lambda_{0.92}$, $\lambda_{0.82}$ and λ_{meas} on a (a) dry day (the sunny day after a few sunny days in succession) and (b) wet day (the day after a rainy day), and Fig.4(c) shows the simulated vertical distribution of volumetric water content of the dry day (a) and the wet day (b) of Fig. 4. Simulated soil temperature with λ_{sand} was larger than other simulated results regardless of the soil moisture condition. On the other hand, simulated results with Campbell model ($\lambda_{1.02}$, $\lambda_{0.92}$, and $\lambda_{0.82}$) agreed well with that with λ_{meas} under wet soil condition. It might be reflected that the thermal diffusivities $K_{1.02}$, $K_{0.92}$, and $K_{0.82}$ at high water content are more similar to K_{meas} than those at low water content (Fig. 2). Campbell model gives smaller thermal diffusivity at low water content due to the exponential function with water content as a variable (Eq.7). Probably this made it quite difficult to evaluate thermal conductivity of soil under dry condition. Changes in dry bulk density in the estimation of soil thermal conductivity did not affect predicted soil temperature so much (<1 ℃) compared to changes in soil moisture condition (Jury and Horton, 2004).Those results indicated that in wetted seasons or humid regions such as Japan, soil temperature can be predicted with acceptable preciseness by using soil thermal conductivity which estimated with Campbell model by using SolphyJ database.

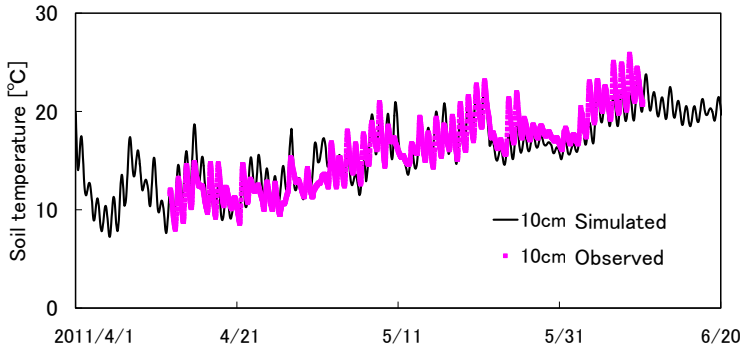

Fig. 3 Comparison of the simulated and observed soil temperature at depth of 10 cm

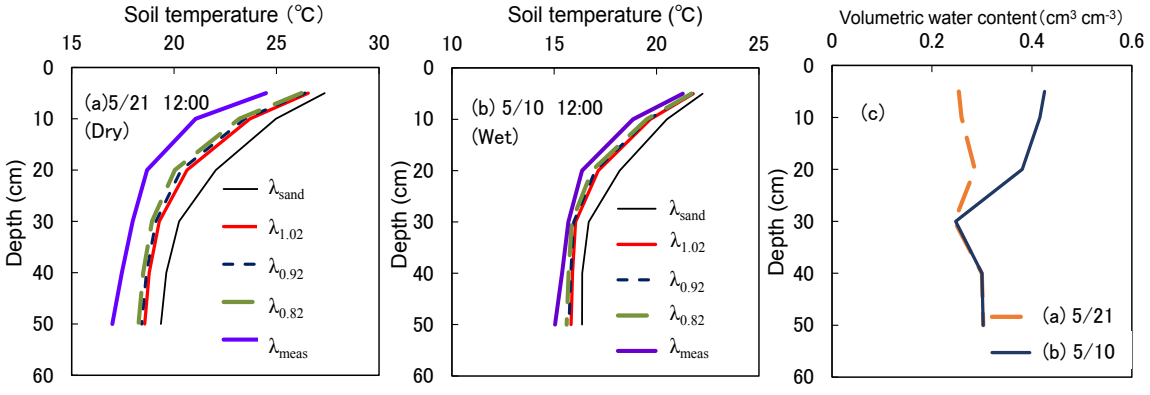

Fig. 4 Comparison of the simulated vertical distribution of the soil temperature predicted with estimated thermal conductivities on a dry day (a) and a wet day (b), and the simulated vertical distribution of soil moisture of both days (c)

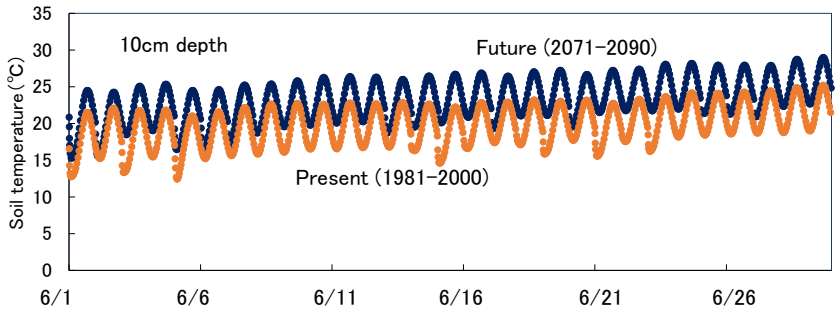

Fig. 5 Comparison of the simulated and observed soil temperature at depth of 10cm between "future" and "present"

Figure 5 shows the comparison of simulated soil temperature at depth of 10cm between "present" and "future". $\lambda_{1.02}$ was employed in this scenario study. In the future, soil temperature may rise three to five degrees accompanies with rising air temperature. In this way, the quantitative discussion about soil temperature in the future in arbitrary agricultural lands maybe possible with estimated thermal conductivity.

CONCLUSION

In this study, we investigated the proper method of estimating soil thermal properties by using digital soil map and the soil physical database in order to predict soil temperature in arbitrary agricultural lands. Soil thermal conductivity could be estimated with mathematical model by using soil physical properties such as the ratio of sand: silt :clay, soil particle density and dry bulk density in the soil physical database. Soil temperature was well described the past soil temperature records with numerical simulation by using estimated parameters especially when the soil is wet. This result indicated that it may be possible to predict soil moisture and soil temperature quantatively with the combination of soil physical properties database and downscaled climate model projections especially for the high humid regions such as Asian countries.

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Research article

Prevalence and Determinants of Household Food Security in Resettled Areas in Sekong Province, Lao PDR

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Abstract Relocating isolated villagers from upland to lowland areas is an important rural development strategy to eradicate poverty and food insecurity in Laos. However, previous research found several social and livelihood problems after resettlement, including poverty and food insecurity. This study investigated the level of food insecurity after resettlement and identified factors influencing household food security. We surveyed 60 households through a structured questionnaire in Tok Ong Keo village of Lamam district, Sekong province. The U.S. Food Security/Hunger Survey Module was employed to measure the severity of food insecurity. In addition, we applied a logistic regression model to examine the factors influencing food security. The results show that about 55% of the sample households experienced rice shortages for about 1–3 months and 61.7% were food insecure with moderate hunger. The education level of household heads, household size, and livestock ownership all had statistically significant influences on food security.

Keywords food security, determinants, resettlement, upland areas, Sekong province, Laos

INTRODUCTION

Food security is defined as "a situation that exists when all people, at all time, have physical and economic access to sufficient, safe and nutritious food for an active and health life." Food security remains one of the critical challenges for developing countries owing to multifaceted factors, such as persistent poverty, rapid population growth, and natural disasters (Smith et al., 2000). More than 868 million people (or 12.5% of the global population) are estimated to suffer from chronic undernourishment in terms of dietary energy supply. Approximately 64.8% of undernourished people (563 million people) live in rural areas in Asia, including Lao PDR (FAO, 2012). Lao PDR is a poor country in Southeast Asia with an estimated per capita gross domestic product (GDP) of USD 1,320 in 2012, and with roughly 68% of the population residing in rural areas. According to the Lao Expenditure and Consumption Survey 2007/08, about 27.6% of Lao people live below the national poverty line and 24.6% are classified as food insecure (Government of Laos, 2010). The highest food insecurity levels are found mostly in mountainous areas, in particular, in Sekong province, where food insecurity affects 50.3% of people, about 60% of children less than 5 years of age are stunted, and nearly half are underweight. The mountainous terrain is a major constraint in eradicating food insecurity; most upland villagers live in scattered small villages where they are unable to access roads, markets, and social services, such as education and health care.

In order to improve the livelihood of villagers, the government has combined households from various ethnic groups and scattered villages in the remote highlands to lowland areas and along roads. Through implementation of the policy, there have been several positive changes in villagers' lives,

including improvement of roads, electricity, education, health services, water, and sanitation. Nevertheless, it is expected that the level of food insecurity will remain high at the start of relocation for various reasons. For example, based on a literature review, a number of land-use conflicts and social and livelihood problems have occurred in the resettled areas (Douangsila, 2012). High mortality rates and the prevalence of water-borne diseases and malaria have arisen (Romagny, 2006). Some newcomers in resettled villages have had access to less land and a shorter fallow period of shifting cultivation, resulting in rice deficiency (Evrard, 2004). In addition, there has been inadequate availability of natural resources and social services (World Food Programme, 2007). Even so, there is limited literature on household-level food security among resettled households. In addition, understanding the cause of food insecurity at the household level is essential to provide information to local, national, and international organizations in order to eradicate food insecurity and improve the livelihoods of rural people.

Our research sought to address the following two questions. First, what is the food insecurity situation after resettlement? Second, what are the socioeconomic factors and individual resource factors that influence food security among resettled households? Therefore, the aims of this study were to 1) investigate the incidence of food insecurity in resettled villages, and 2) identify the factors affecting household food security.

METHODOLOGY

Background Information of the Study Village

This study was conducted in Sekong province, which is located in the southern region of Laos and has an area of 8,742 km^2, comprising 229 villages, 17,158 households, and a total population of 104,499 in 2012. In this province, people from several small mountainous villages were moved to villages in the lowland areas, which have more opportunities to access social services. For our study area, we selected Tok Ong Keo village of the Lamam district in Sekong province.

In 1978, the villagers were relocated from the original highland areas to a plains area near roads (about 2 km away from the original highland place). For the first year of resettlement, the local government provided households with zinc roofing sheets and, in some cases, goats and pigs. All villagers continued to cultivate upland rice through shifting cultivation methods in their original upland fields; the total land available for cultivation was about 336 ha with an average fallow period of 6–10 years. Thereafter, in 2010, all villagers were moved again to a larger permanent location, which was about 1 km away from the previously settled place. This was because the government had selected the village for implementing the Focal Site Development (FSD) project, and the previous location of the houses was reclaimed for lowland paddy fields. Of the total village area of 2,100 ha, about 48 ha are used to grow rice in the lowland paddy field, but only 36 households are able to use the areas owing to insufficient land for development. Consequently, all villagers continue to rely on upland rice cultivation for their primary livelihood activities. However, the land available for upland rice has reduced from 336 ha during 1978–2010 to 220 ha after resettlement in 2010 as a result of the government policy to promote resettlement, which has led to the reduction of shifting cultivation. Accordingly, the average fallow period has been shortened to 3–5 years. Above all, we consider the data of our study, which was collected in 2013, as the initial stage of resettlement because more than 30 years has passed between the first and second resettlement stage.

Measurement of Food Insecurity at Household Level

To measure the severity of food insecurity, a subjective method, namely the U.S. Household Food Security/Hunger Survey Module (U.S. FSSM) was used. The U.S. FSSM is one of the most reliable

indicators and has widely used to access food security. It was first developed in the early 1990s by the federal interagency Food Security Measurement Project (Bickel et al., 2000). The reliability and validity of this indicator has been proven by previous research, and a mean score of the U.S. FSSM has a statistically significant correlation with calorie and nutrient intake, income poverty and weekly food expenditure (Tarasuk, 1999; Edward et al., 2007).

The concept of the U.S. FSSM is essentially used for 18 items related to experience of food deficit among adults and children due to lack of resources (money and food) over a specific period of 30 days or 12 months. Household food security is categorized by ranging a scale score of the affirmative responses from 0 to 10, with 0 representing no evidence of food insecurity and scores close to 10 indicating cumulative evidence of the severest degree of hunger. The answer from 18 items provides a continuous measure scale score that can be used to classify households into four categories, as follows:

1. Food secure (0–2.32): Households show no or least evidence of food insecurity.
2. Food insecure without hunger (2.33–4.56): Household members are concerned about the adequacy of household food supply and have adjusted to household food management, including reduced quality of food and increased unusual coping patterns.
3. Food insecure with moderate hunger (4.57–6.53): Adults have decreased food intake, meaning they have repeatedly experienced the physical sensation of hunger.
4. Food insecure with severe hunger (6.54–10): All households with children have reduced the children's food intake to an extent indicating that children have experienced hunger.

Data Collection and Analysis

The primary data were gathered through a field survey conducted in January 2013. Of the total 82 households living in the village, 22 households were excluded from the survey because they were not available during the survey; thus, only 60 were interviewed using a structured questionnaire. The questionnaire consists of information on household composition, upland/lowland rice areas, rice production, household income, and experience of food insecurity over 12 months.

We employed a logistic regression model to identify the determinants of household food security. To set up a dependent variable, the food security status was reorganized from four categories into two. Households that were food insecure with moderate and severe hunger were combined into a single broader category and classified as a food insecure or households with hunger (Y = 0). In contrast, households that were both food secure and insecure without hunger were classified as food secure or households without hunger (Y = 1). With regard to the independent variables, education, household size, number of relatives and friends, cultivated upland areas, upland rice yield, cultivated rain-fed lowland rice, and livestock ownership were selected.

RESULTS AND DISCUSSION

The results show that about 55% of households experienced at least 1–3 months of rice shortages, and 38.3% reported longer rice shortage periods of more than 3 months, from July to October (Table 1). Having said that, only 6.7% households were able to produce sufficient rice to meet the requirements of their households all year round. The results of the U.S. FSSM reveal that about 61.7% of households were categorized as "food insecure with moderate hunger." This means that most adults in the study area frequently experienced the physical sensation of hunger. They employed rationing as a coping strategy, which includes limiting the amount of food given to each household member at mealtimes and reducing the number of meals eaten in a day. Moreover, about 11.7% of households surveyed were "food insecure with severe hunger," indicating that the amount for food intake for children living in these households was reduced owing to lack of food and money to purchase food. Conversely, about

21.6% and 5% of households surveyed were categorized as "food insecure without hunger" and "food secure," respectively.

Table 1 Rice shortage and food insecurity

Month of rice shortage (month)	N = 60	%
No experience	4	6.7
1-3 months	33	55.0
More than 3 months	23	38.3
Food security status (scale score)		
Food secure	3	5.0
Food insecure without hunger	13	21.6
Food insecure with moderate hunger	37	61.7
Food insecure with severe hunger	7	11.7

Source: Author's calculation based on 2013 household survey

The anxiety, experiences, perceptions, and adjustment regarding food insecurity and hunger reported by respondents are illustrated in Table 2. Of the sample households, 96.7% reported that they could not afford balanced meals for both adults and children and they relied on a few kinds of low-cost food for children. In addition, the majority of respondents (93.3%) had worried that food would run out, about 83.3% stated that the food they bought did not last owing to lack of money to purchase more, 75% had cut or skipped meals for adults, and 43.3% had felt hungry but did not eat. Moreover, approximately 66% of households with hunger acknowledged that they had cut the size of children's meals and skipped meals for children (50%). This implies that half of households in the resettled areas relied on non-nutritious food for their children and children did not have enough to eat. Declining food consumption among children can lead to poor health and malnutrition in the future. It was observed that rice was often eaten together with chili paste, vegetables, bamboo shoots, and sometimes, fish and chicken. However, meat was eaten only occasionally, mainly at such events as traditional spirit sacrifices, wedding parties, and village festivals.

Table 2 Affirmative response from the U.S. FSSM questionnaires

Question No. (Q) [a]	List of 18 questions from the FSSM	N = 60 (%)	Household without hunger [c] N =16 (26.7%)	Household with hunger [d] N = 44 (73.4%)	t-test
2	Worried food would run out	56 (93.3)	12 (75.0)	44 (100)	0.00***
3	Food bought did not last	50 (83.3)	12 (75.0)	38 (86.4)	0.30
4	Could not afford to eat balanced meals [b]	58 (96.7)	15 (93.7)	43 (97.7)	0.45
5	Few kinds of low-cost food for children	58 (96.7)	14 (97.5)	44 (100)	0.02**
6	Could not feed children a balanced meal	58 (96.7)	14 (87.5)	44 (100)	0.02**
7	Children were not eating enough	33 (55.0)	4 (25.0)	29 (65.9)	0.00***
8	Adult(s) cut or skipped meals	45 (75.0)	6 (37.5)	39 (88.6)	0.00***
8a	Adult(s) cut or skipped meals, 3+ months	0 (0)	0 (0)	0 (0)	N/S
9	You ate less than felt you should	44 (73.3)	5 (31.5)	39 (88.6)	0.00***
10	You were hungry but did not eat	26 (43.3)	2 (12.5)	24 (54.5)	0.00***
11	You lost weight because not enough food	N/S	N/S	N/S	N/S
12	Adult(s) not eat for whole day	18 (30.0)	1 (6.3)	17 (38.6)	0.02**
12a	Adult(s) not eat for whole day, 3+months	0 (0)	0 (0)	0 (0)	N/S
13	Cut size of children's meals	29 (48.3)	0 (0)	29 (65.9)	0.00***
14	Children skip meals	22 (36.7)	0 (0)	22 (50.0)	0.00***
14a	Children skip meals, 3+months	0 (0)	0 (0)	0 (0)	N/S
15	Children ever hungry	21 (35.0)	0 (0)	21 (47.7)	0.00***
16	Children not eat for whole day	1 (1.7)	0 (0)	1 (2.7)	0.55

Source : Author's calculation based on 2013 household survey.

*Note : *** and ** denotes significance at 1% and 5%; [a] The first question (Q1), which is asked whether do you have enough food to eat or not, is a screening question. This question is not part of the actual scale in the U.S. FSSM so it is excluded from Table 2; [b] Balanced meal is defined as "at least three types of food group, such as rice, meat, fish, egg, green leafy vegetables"; [c] "Household without hunger" refers to those households that are food secure and insecure without hunger; [d] "Household with hunger" refers to those households that are food insecure with moderate and severe hunger.*

The results of the logistic regression model show that the education level of the household head is a positively significant influence on household food security. From Table 3, the marginal effect shows that a unit increase in education level of the household head, holding all other variables at their mean, leads to a 6% increase in the probability of the household being food secure. This implies that higher education levels make household heads more likely to have the capacity to use the resources that he or she owns more rationally, and to learn more idea about how to increase agricultural productivity. Moreover, those who are educated seem to have the ability to escape from food insecurity through participating in non-farm income generating activities, such as construction work, petty trade, and other services. It was reported that there were only five people in the village who go to work in towns or big cities. Language barriers are a possible explanation as about 60% of the respondents, especially those among food insecure households, were unable to read and write the official Lao language. As a result, their access to non-farm work was limited and their average non-farm income was only USD 190 per household per year, whereas that of literate households was USD 370 per year. In addition, the impact of education on food security can be viewed as a key factor in accessing public information, such as agricultural information, concerning health, nutrition, and hygiene because most information is often written in Lao language. It was observed that the majority of villagers lived in unhealthy environments and lacked health knowledge, such as information about how to avoid and treat illnesses. Some households did not even boil their drinking water. As a result, about 69% and 62% of households that were food insecure with moderate hunger had experienced malaria and diarrhea, respectively, over the previous 12 months.

Table 3 Determinants and "Marginal" effect of household food security

Variables	Mean	S.D	Coeff.	t-value	dy/dx	t-value
Constant			-1.15	- 0.95		
Education (year)	2.35	2.32	0.43	2.19 **	0.06	2.48 **
Household size (person)	9.95	5.41	-0.35	-2.88 ***	0.05	-2.96 ***
Number of relatives and friends (household)	18.35	16.30	-0.04	-1.29	0.01	-1.42 *
Cultivated upland size (ha)	1.06	0.44	0.68	0.52	0.11	0.75
Upland rice yield (kg/ha)	747	0.45	0.38	0.85	0.06	0.46
Cultivated rain-fed lowland rice(ha)	0.33	0.35	0.57	0.92	0.09	0.53
Livestock ownership (tropical livestock unit, TLU[a])	0.63	0.46	2.42	2.62 ***	0.51	2.45 **
Log-Likelihood: -23.854 Pseudo R^2 = 0.314 (Prob.chi : 0.000)						

Source : Author's calculation based on 2013 household survey.

*Note : ***, **, and * represent significance at the 0.01, 0.05, and 0.10 levels, respectively*; [a] *TLU is calculated based on the number of livestock and the exchange ratio for livestock (e.g., cattle = 0.7, pig = 0.2, and poultry = 0.01)*

As expected, household size was statistically significant at the 1%. A one-unit increase in the number of household members, computed at sample means, resulted in a 5% decrease in the probability of the household being food secure. This indicates that larger household size may not provide more labor for food production but represents more mouths to feed and higher consumption demand. In the case of the study area, about 51.6% of sample households comprised at least two families who lived in the same dwelling and shared food. Of these, about 90.3% were among the food insecure households. Most were young married couples living with parents and were likely to depend on their parents because of resource constraints to construct a new house. Moreover, the majority did not generate any income owing to limited non-farm income activities around the village and lack of micro credit to start livestock farms.

With regard to livestock ownership, the marginal effect reveals that a one-unit increase in the livestock ownership (TLU), calculated at sample means, resulted in a 51% increase in the possibility of food security. Livestock production, especially pigs and poultry, contributed to about 88% of farm cash income (USD 66 per household per year), which was used mainly for buying rice and other food to

meet the basic nutritional needs of all household members, resulting in increasing self-consumption. Another key point to remember is that about 7% of the households surveyed obtained cash income from selling cattle and buffalo, which was used to cover expenses for building houses. The result shows that the average number of livestock (cattle=1.7, pigs=3, and poultry=25) reared by food secure households were higher than those of food insecure household (cattle=0.4, pigs=1.8, and poultry=8.3). The major problems in livestock rearing were insufficient technical knowledge to prevent livestock disease, lack of funding to purchase young animals, such as calves and piglets, and lack of feed. About 75% of households indicated that their poultry had died from disease, while 50% of households that kept larger livestock, such as buffaloes and cattle, indicated that there was a lack of feed near the village during the dry season. Insufficient number of female laborers was a constraint to keeping more pigs and poultry. In the study area, women played a vital role in not only domestic works, such as food preparation and gathering wild food, but also in productive tasks. According to the survey results, women had 95% of responsibility for poultry and local pig rearing. However, they seem to be overlooked from agricultural programs because the majority of women did not speak or understand the Lao language.

It is essential to note that both the cultivated upland farm size and the upland rice yield were not statistically significant, but positively influenced food security. The marginal effect shows that a one-unit increase in cultivated upland rice areas and rice yields would lead to the probability of food security increasing by 11% and 6%, respectively. This implies that households that have larger cultivated upland rice areas and gain higher yields are likely to have higher production levels to support their home consumption. However, villagers were not allowed to expand upland rice areas owing to a ban on shifting cultivation, resulting in a shorter fallow period (3–5 years). The decline in fallow period was accelerated by land use restriction and resulted in poor soil fertility, a cause of low rice productivity (747 kg/ha). In addition, weeds, rodents, wild pigs, ants, and birds were another important cause of low productivity.

With regard to lowland rice cultivation, the results show that rain-fed lowland areas have no statistically significant correlation with household food security. This is because many resettled villagers lacked knowledge on farm management practices, such as methods of land preparation, fertilizer application, and use of improved rice varieties. They were likely to receive less support from agricultural officers, especially on how to increase lowland rice productivity. Accordingly, the average rain-fed lowland yield cultivated by resettled villagers was very low (904 kg/ha). In addition, most of the resettled villagers from mountainous areas were new rain-fed lowland cultivators, so they could not suddenly adapt to the new technologies of lowland paddy fields (Douangsila, 2012). The number of relatives and friends had a negative influence on household food security. A possible explanation is the tradition and culture of the Alak ethnic group, whose people depend highly on relatives and friends when they face food shortages. It was reported that although the total rice production in resettled households did not cover their annual needs, they shared their own rice or other food with relatives and friends who experienced food shortage.

CONCLUSION AND RECOMMENDATION

The main aims of this study were to investigate household-level food security in a resettled area in Laos, and to identify the factors influencing whether households were food secure. We concluded that the prevalence of food insecurity in the resettled villages was enormously high; approximately 61.7% were “food insecure with moderate hunger” and 11.7% were “food insecure with severe hunger.” However, our findings did not indicate that the resettlement program had a negative impact on the food security of the resettled households. Further studies are needed to monitor whether the prevalence of household food insecurity persists and the living condition improves.

Other important findings of this study were that the education level of household heads, household size, and livestock ownership had a statistically significant influence on household food security in the resettled area. Hence, in order to improve food security in new resettled villages, the education sector should focus on non-formal education for uneducated and unskilled household heads to improve their ability to access information, deal with the markets, and find alternative income source. These efforts should also target women who are unable to read and write in the Lao Language in order to give them access to healthcare information and nutritional knowledge. Agricultural extension officers should provide information, in particular, new techniques to increase pig and poultry production and prevent livestock disease. Another key point is that microcredit to start livestock farming is a vital task that should be considered in the study area.

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Research article

Potential of a New Slow-release Urea Fertilizer under On-farm Conditions in a Semi-arid Environment

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Abstract Nitrogen (N) fertilizers play an important role to increase grain yield and grain quality in crop production systems. In Western Siberia, predominantly used N-fertilizers for cereal production are urea and ammonium-nitrate ('Selitra'). Due to semi-arid climate, only one fertilizer application is common, simultaneously with sowing and directly into the seed furrow. A new kind of slow-release fertilizer is a modified urea with silicate coating and urease inhibitor and was developed at the State Agrarian University of the Northern Transurals (Russian Federation). In a field trial, the comparative performance of the novel fertilizer type was tested with spring wheat near the city of Ishim in Tyumen region (Western Siberia) on 3.4 ha under on-farm conditions. 4 levels of the slow-release urea (25/50/75/100%) were compared to 100% of conventional urea, 100% of Selitra and an unfertilized control in randomized complete block design with 4 replications. Results showed significant differences in soil nitrate availability but no differences in ammonium release. Differences between N-levels dispersed during heading, afterwards only plots with Selitra fertilization showed significant higher nitrate values. Leaf chlorophyll content as indicator for plant Nitrogen supply showed significant differences from beginning stem elongation on. The harvested grain yield showed no significant differences between the compared fertilizer types at the 100% N-level. Even if the grain yield with reduced dose of slow-release fertilizer was on the same level, it was not significantly higher than the unfertilized control. From the results of this field trial there seems to be no beneficial advantage of the tested slow-release fertilizer so far.

Keywords slow-release fertilizer, silicate coating, urease inhibitor, Nitrogen use efficiency, spring wheat, Western Siberia

INTRODUCTION

Nitrogen (N) fertilizers play an important role to increase wheat productivity and grain protein content. In Western Siberia predominantly ammonium-nitrate ('Selitra') and urea are used for N-fertilization.

Due to the dry sub-humid climate (Selezneva, 1973), only one N-application is common, simultaneously during sowing.

Also from an economic point of view, N-fertilizers play a key role in grain production processes and due to high inputs of energy, they mainly affect the total economic balance (Lubkowski, 2014). Urea is the most used Nitrogen fertilizer around the world agriculture, because of the high Nitrogen content by 46.6% (Trenkel, 1997; Zheng et al., 2009). When urea is applied to a soil, it is almost immediately hydrolysed into ammonium carbonate, which breaks down to carbon dioxide (CO_2) and ammonia (NH_3), producing high soil pH and ammonia loss (Eriksen and Kjeldby, 1987; Fenn and Kissel, 1973). The remainder of the ammonium in the soil can be converted to nitrates by the soil bacteria. Therefore, reducing water solubility of urea granules by physical or chemical inhibitors is very important and can improve the Nitrogen use efficiency (NUE) by preventing or slowing down these processes.

Such types modified fertilizers are described as 'enhanced efficiency fertilizers' which are able to reduce the risk of nutrient losses to the environment, retain nutrients in a less leachable forms, reduce solubility and maintain nutrients in the root zone by physical barriers (coating) (Trenkel, 2010). Furthermore, three different subtypes are characterised: (1) Stabilised fertilizers have a chemical inhibitor to slow down the hydrolysis of urea with further transformation to NH_4^+ and inhibitors to stop the oxidation of ammonium (NH_4^+) to nitrate (NO_3^-); (2) Slow-release fertilizers are less-soluble and N is initially not plant available but needs to be converted into plant available N forms; (3) Controlled-release fertilizers are quick soluble fertilizers with a coating of hardly soluble material with a predictable rate of Nitrogen release when used at the manufacturer specified temperature (Trenkel, 1997; 2010).

Prognoses for the development of the fertilizer industry development predict an increase until 2020 to 1.9 – 2.2 million tons of slow- and controlled-release fertilizer products. One of the drawbacks, particularly for the currently most widespread polymer-coating, is the remaining amount of useless polymer that is left in the soil after nutrient consumption (Trenkel, 2010). A perspective alternative - although not yet used on a technological scale - is to produce slow-release fertilizers by using Calcium Silicate ($CaSiO_3$) as a mineral coating material, which can easily be decomposed by silicate bacteria to environmental friendly inorganic elements. The new type of such a slow-release urea fertilizer was developed at the State Agrarian University of the Northern Transurals (Russian Federation). A combination of a physical barrier by $CaSiO_3$-coating and a chemical urease inhibitor was chosen to delay the release of plant available Nitrogen.

The objective of this study was to compare the performance of the novel slow-release urea fertilizer against common practice and to evaluate the potential for improving of the Nitrogen use efficiency under practical conditions.

METHODOLOGY

Study Area

We installed a 3.4 ha field trial with spring wheat in Ishim (Tyumen province, Russia, Fig. 1) in RCBD with 4 replications to compare 4 levels of coated urea 'CU' (100/75/50/25%) against 100% of conventional uncoated urea 'UU', 100% of Selitra 'S' and a unfertilized control 'C'. 100% equals 70 kg/ha N (Table 1). The fertilizer was applied directly into the seed furrow. The seed rate was constant over all variants by 240 kg ha^{-1} for 600 plants per m . The plots were sown with the regional variety 'Ikarus' on May 19th, harvest took place on September 28th, weed regulation was done only once as usual for the region.

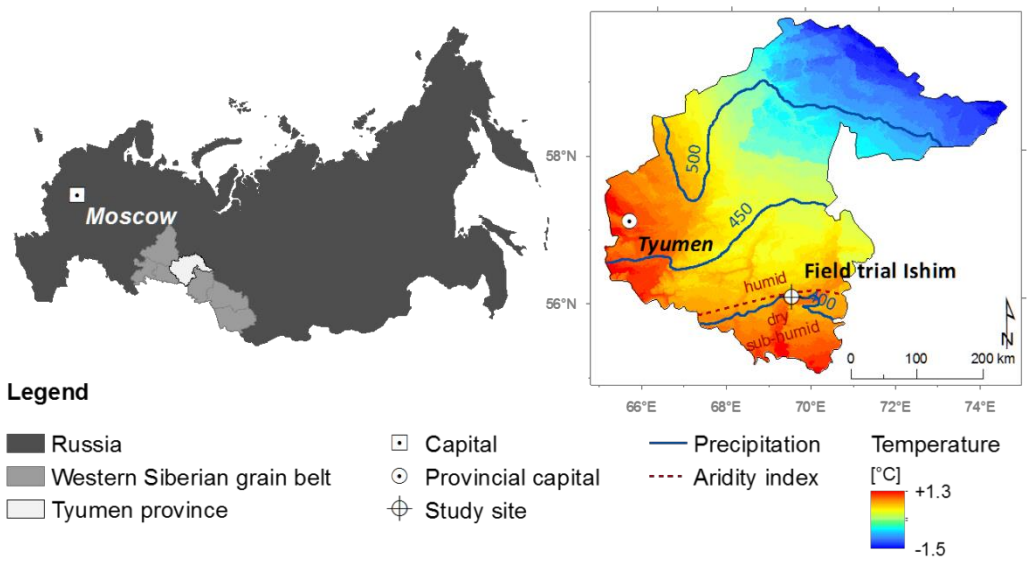

Fig. 1 Location and mean annual agro-climatic conditions of the study area
Souces: CGIAR-CSI (2009), GADM (2012), WorldClim (2013)

Table 1 Investigated variants with amounts of fertilizer and Nitrogen applied

variant	fertilizer type	N level [%]	applied fertilizer [kg ha^{-1}]	applied Nitrogen [kg ha^{-1}]
Control	no	0	0	0.0
S100	Selitra	100	203	70.0
UU100	uncoated urea	100	150	70.0
CU100	coated urea	100	153	70.0
CU75	coated urea	75	115	52.2
CU50	coated urea	50	77	35.0
CU25	coated urea	25	38	17.5

Fertilizer Production

The fertilizer was produced on the laboratory scale by ’Биотех‘ at the State Agrarian University of the Northern Transurals. Liquid Na_2SiO_3 was poured over usual urea in the first step. Secondly, liquid $CaCl_2$ was added which induced the drying process. Finally, urease inhibitor was applied on the coating. The coating material was between 1% and 3 % of the total mass of the fertilizer granules.

Analyses and Statistics

Soil N_{min} (NO_3 + NH_4) analysis for 0-30 cm was done reflectometric (Merck) and for determination of leaf chlorophyll content a SPAD-502 (Minolta) was used at the youngest fully developed leaf. Comparisons among means were carried out in R using the package agricolae (LSD-Test, p<0.05) (R Core Team, 2013). Between values with the same letter, there is no significant difference.

RESULTS AND DISCUSSION

Soil Nitrogen

The results of soil analysis showed significant differences in nitrate content but no significant differences in ammonium content (Fig. 2). Homogeneous preconditions were given by a constant level of both N_{min} fractions before fertilization. During leaf development, the variants Nitrogen availability differentiated, but only between the fertilizer types and not among the CU variants. Later in the growing season, only the S100 plots showed significant higher NO_3 content in the soil.

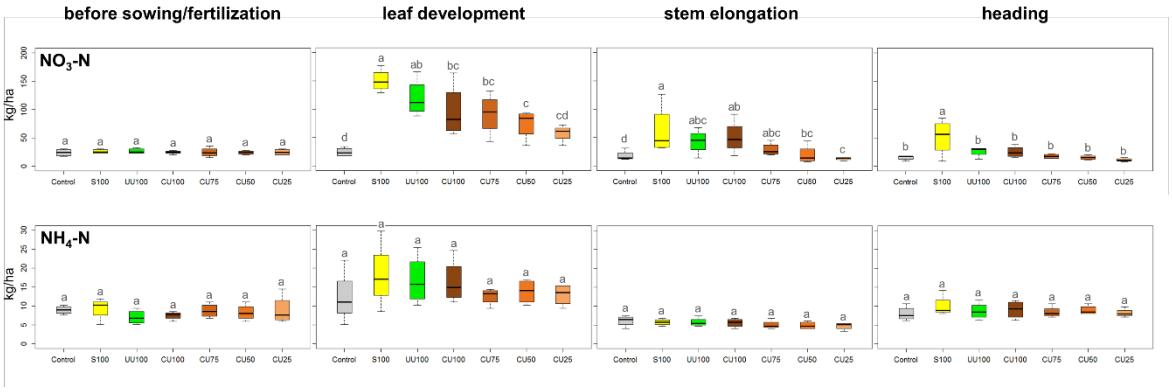

Fig. 2 Soil N_{min} components NO_3-N and NH_4-N in 0-30 cm before sowing/fertilization and at 3 development stages

Boxes show lower and upper quartiles, black line depicts the median, whiskers between min and max.

Even if there were no significant differences between soil ammonium contents, due to the differences in nitrate levels, a closer look on the proportions was necessary. Table 2 shows significant differences in the ammonium share, starting during leaf development, where values in unfertilized control plots were highest. This trend of low NH_4 proportion in conjunction with high nitrate content continued until the last measurement.

Table 2 NH_4-N proportion of total N_{min} (0-30 cm) at 3 sampling dates for all variants

development stage	Control	S100	UU100	CU100	CU75	CU50	CU25
before sowing/fertilization	28% a	27% a	21% a	23% a	27% a	26% a	26% a
leaf development	32% a	10% b	12% b	15% b	14% b	17% b	19% b
stem elongation	27% a	11% c	15% bc	13% c	16% abc	26% ab	27% a
heading	35% ab	23% b	27% ab	28% ab	33% ab	37% ab	43% a

Leaf Nitrogen

The SPAD-meter readings of the leaf-chlorophyll content are known to be a good indicator for leaf Nitrogen content (Uddling et al., 2007; Markwell et al., 1995). The results showed a plausible response according to the N-level since beginning stem elongation (Fig. 3). Reduced N levels resulted after heading in significant lower leaf chlorophyll contents.

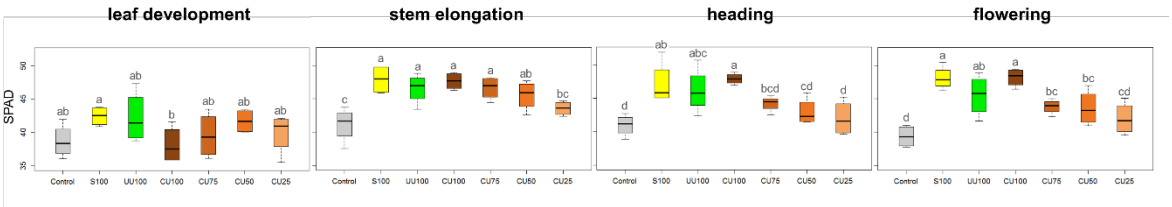

Fig. 3 SPAD-meter readings at 4 development stages

Boxes show lower and upper quartiles, black line depicts the median, whiskers between min and max

Yield Results and N Balance

The harvest results confirmed the observed soil and plant parameters, as there were no significant differences between the 100% variants of the three fertilizer types for all yield parameters (Table 3). The only significant differences occurred between unfertilized control and 75-100% fertilized plots for grain yield and the number of grains per ear.

Table 3 Selected yield parameters

	C	S100	UU100	CU100	CU75	CU50	CU25
grain yield [dt ha^{-1}]	26.7 c	39.9 a	40.2 a	39.6 a	35.1 ab	33.5 abc	30.4 bc
protein content [%]	9.3 a	8.7 a	10.8 a	9.1 a	10.2 a	9.7 a	10.6 a
1000 kernel weight [g]	38.3 abc	40.4 a	39.7 ab	39.7 ab	38.1 bc	37.2 c	39.1 abc
ears per m	356.4 a	393.3 a	398.2 a	406.2 a	361.3 a	378.2 a	357.3 a
grains per ear	19.9 c	25.2 a	25.3 a	24.6 a	25.4 a	23.7 ab	21.7 bc

All fertilizer types at 100% N-level resulted in comparable grain yields, among protein contents there were no differences at all (Fig. 4).

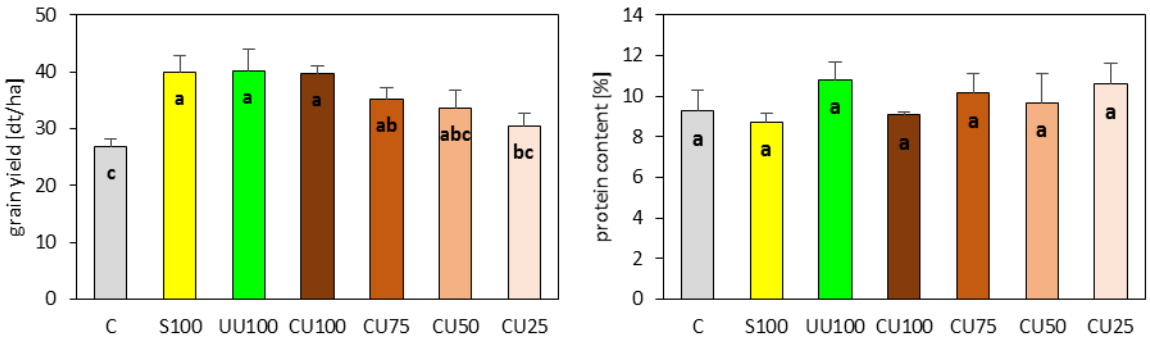

Fig. 4 Harvest results for grain yield (left) and protein content (right)
Error bars show 1 standard error of the mean

The last step was to balance the Nitrogen inputs and outputs for all variants and to calculate the N use efficiency (NUE=N uptake/fertilizer N). Table 4 shows a slight advantage for UU100 with an optimal NUE of 1.0, but also S100 and CU100 were on a good level. Higher NUE above 1.0 leads to unsustainable soil mining and should be avoided.

Table 4 Nitrogen balance and Nitrogen use efficiency (NUE)

	protein yield [dt ha^{-1}]	N uptake [kg ha^{-1}]	fertilizer N [kg ha^{-1}]	soil N [kg ha^{-1}]	balance	NUE
C	2.5	39.9	0.0	32.9	-6.9	-
S100	3.5	55.7	70.0	35.2	49.5	0.8
UU100	4.3	69.2	70.0	33.5	34.3	1.0
CU100	3.6	57.5	70.0	32.1	44.5	0.8
CU75	3.6	56.9	52.5	33.3	28.9	1.1
CU50	3.1	49.9	35.0	32.3	17.4	1.4
CU25	3.2	51.4	17.5	33.5	-0.4	2.9

CONCLUSION

The expected possibility to harvest the same with reduced fertilization by an enhanced fertilizer type did not fulfil since the grain yield was not significant higher than the unfertilized control for reduced variants. Therefore, we could not derive beneficial effects of the novel slow-release fertilizer from the results of this field trial. More field site years as well as further research on the laboratory scale to understand the short-term behaviour of the coated urea are needed.

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Research article

Effects of Pyroligneous Acid to Growth and Yield of Soybeans (*Glycine max*)

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Abstract In the Philippines, there is at present a Soybean Roadmap which has two major components, namely: Organic Soybean Production and Organic Soybean Utilization, Processing and Marketing. This research project compliments the Philippine National Soybean Program by developing appropriate organic technologies especially on its external inputs like fertilizer. The main objective of this research was to find out the effects of pyroligneous acid on the growth and yield of soybeans. Philippine Seed Board Soya 6 (PSB SY6) or commonly called Tiwala 8 is an approved variety for use in the country which was planted in field condition of the university research area in 2 x 2 meter plots. This was four (4) times replicated by using randomized complete block design (RCBD). Coconut shell vinegar (pyroligneous acid) was used in this study. There were three levels of pyroligneous acid being tested: 10%, 20%, and 30% which represented Treatment 1, Treatment 2 and Treatment 3, respectively. Treatment 4 served as the control. Statistical analysis revealed that all treatments had not affected to the growth of the soybean plants. However, it was noted that there was a significant effect of wood vinegar on the yield.

Keywords pyroligneous acid, soybean road map, external inputs

INTRODUCTION

The Philippine government has installed the National Soybean Development program which created the Soybean Roadmap 2010-2014 called "Building Sustainable Soybean Industry in the Philippines". This program will enhance the government's advocacy for sustainable agriculture and therefore achieve food security of the country.

According to Rosie Aquino of the Department of Agriculture-Cagayan Valley Integrated Agricultural Research Center, "farmers will have a benefit from the program in terms of enhanced productivity, improvement of soil fertility, improvement of household nutrition as a result of product consumption that is protein-rich, and income augmentation through utilization of soybean meal for backyard swine raising".

Aquino further emphasized that "The resulting soybean program strives to develop improved soybean varieties that are resistant to biotic and abiotic stresses, and are favorably responsive to organic production management practices," (Go, 2011).

In the province of Bohol, the Department of Agriculture has launched the Soybean Development Program to promote soybean production as source of protein and as a crop that can withstand adverse conditions especially drought as soybean is proven to be resistant to heat stress (Cartagenas, Daisy

personal communication). Several on site trials have been conducted in collaboration with the farmers to determine the best performing varieties for mass production.

One of the challenges in organic agriculture program is the availability of organic inputs for the cultural management of crops. As it is desired to pursue organic soybean production, there is a need to look for effective organic inputs that could positively contribute to the overall performance of the crop as soybeans. In a study on peanut, it was found out that Foliar application of wood vinegar increased vegetative growth and this might result in preventing the sunlight reaching the soil surface under the plant canopy and consequently higher in soil moisture content (Jothiyankoon et al., 2008).

Masaki Yokomori, a senior technical adviser of Japan Agricultural Exchange Council has established a demo farm and introduced the use of Mokusaku (Wood Vinegar) in the vegetable farms of Benguet, Mountain province. Wood vinegar is accepted by vegetable farmers as it has improved the performance of their vegetables (Yokomori, 2011).

As there is also a program on Organic Soybean Production, there is a need for organic inputs as a source of fertilizer and pesticides. Wood vinegar, as proven by other researchers, can be a good source of such organic inputs. Hence, there is a need to do research on this aspect with the hope of validating the usefulness of wood vinegar on the performance of soybeans as a crop for attention in the country as a source of protein and an adaptation to climate change.

METHODOLOGY

A randomized complete design (RCBD) of 2x2 meter plots was installed in the vegetable research area of Bohol Island State University by using soybeans as test crops. Soybeans were planted at the recommended distance by researchers of Department of Agriculture. Seasoned pyroligneous acid (Wood vinegar) from coconut shell was applied at one-week interval after planting at the rate of 10% (T1), 20% (T2) and 30% (T3). T4 served as control. Weekly growth of soybeans was taken and recorded. Yield parameters were taken by treatment and all data were subjected to statistical analysis.

Fig. 1 Research plots laid out in a Randomized Complete Block Design

RESULTS AND DISCUSSION

The study was conducted to evaluate the effectiveness of wood vinegar from coconut shell as organic input in the performance of soybeans. Specifically, it aimed to identify the impacts of wood vinegar on the growth and yield of soybeans and identify the effective level of application of wood vinegar for better performance of soybeans in terms of its growth and yield.

Weekly plant height (cm) of the plants was taken in all treatments as shown in Table 1. It was found out that there was a difference of height in all treatments compared with the Control. However, based on the analysis of variance, it was found that the difference was insignificant in all treatments over the control plots.

Table 1 Plant Height of Soybeans (cm)

Treatments	I	II	III	IV	Total	Mean
T1 - 10% WV	49.58	56.59	47.69	53.32	207.18	51.79
T2 - 20% WV	46.26	48.50	48.08	45.17	188.00	47.00
T3 - 30% WV	53.66	49.73	47.20	49.98	200.58	50.14
T4 - Control	45.62	49.08	48.33	51.35	194.39	48.60

Fig. 2 Soybean plants at the maturity stage (A) and the pods (B) ready for harvest

Yield in dry weight for each treatment was taken as shown in Table 2. Analysis of variance showed that Treatments 1, 2 and 3 were significant over that of Control. This means that all treatments of wood vinegar have a significant effect to the yield of soybeans. Treatment 3 (30% WV) got the highest mean yield of 1.26 (0.315 kg/sq.m. or 3.1 tons/ha), followed by Treatment 2 (20% WV) with the mean yield of 0.97 (0.242 kgs/sq.m. or 2.4 tons/ha) and Treatment 1 (10% WV) got the mean yield of 0.93 (0.232 kgs/sq.m. or 2.3 tons/ha). Treatment 1 and Treatment 2, however, showed no significant difference as to yield. Treatment 4 (no application of WV) got the mean yield of 0.55 (0.1375 kgs/sq.m. or 1.3 tons/ha).

Table 2 Yield of soybeans (kgs)

Treatments	I	II	III	IV	Total	Mean
T1 - 10% WV	0.90	0.88	0.99	0.95	3.72	0.93
T2 - 20% WV	1.00	0.94	0.99	0.95	3.88	0.97
T3 - 30% WV	1.05	1.15	1.56	1.28	5.04	1.26
T4 - Control	0.65	0.35	0.58	0.65	2.23	0.55

Table 3 Analysis of variance on the yield of soybeans

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	5%	1%
Block	.083	3	.028	1.803	.217	3.86	6.99
Treatment	.999	3	.333	21.727	.000		
Error	.138	9	.015				
Corrected Total	1.220	15					

a. R Squared = .887 (Adjusted R Squared = .812)

Fig. 3 Harvested soybean seeds in all treatments

CONCLUSION

Application of Wood Vinegar has no influence on the growth of soybeans based on weekly recorded height of plants. The effect was observed on the yield as all treatments showed the significant difference over its control plots. Plants treated with 10% and 20% wood vinegar showed no significant difference as to its effect on yield. It is concluded that the increased percentage of wood vinegar increased the yield of soybeans.

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Research article

Spatial Assessment of Ecosystem Services by New City Development – Case Study in Nay Pyi Taw, Myanmar

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Abstract Ecosystems provide many services not only for the environment, but also for human well-being. Land use and land cover change caused by development activities, have been increasing rapidly, and these are recognized as key factors for human-induced impacts on ecosystems. During the past few decades, ecosystem services (ESs) have deteriorated, especially as a result of urban development at the global scale, and changes have been severe in developing countries. For example, in Myanmar, the new capital city was developed on previously rural land during 2006. Consequently, large land use changes took place and many ESs were destroyed. To compare the loss of ESs before and after the development, spatial analyses of ESs were conducted in Nay Pyi Taw, Myanmar, as a case study. For the spatial analyses, two satellite images; namely Advance Land Observing Satellite (ALOS) for 2010 and Landsat 7 for 1999 were used for land classification. Information on ESs was collected through literature surveys, and existing unit values for ESs were estimated by using simple methods. Then, priority areas for conservation of ESs were identified by evaluating the spatial analysis results with the Zonation software. Finally, the overall changes in ES provisions due to land use changes were estimated along with the changes in priority areas.

Keywords ecosystem services, landuse, spatial analysis, conservation prioritization

INTRODUCTION

Ecosystem services (ESs) are the benefits that ecosystems provide to people both directly or indirectly, and they can be classified into four types, namely, provisioning, regulating, supporting, and cultural services (Millennium Ecosystem Assessment (MA), 2005).During the past few decades, ESs have deteriorated because of extensive land use change despite increases in economic and societal prosperity (MA, 2005). Manandhar et al. (2009) demonstrated that land use change is a key driver of environmental change and influences the provisioning of ESs. Methods to identify priority areas for ES conservation need to be developed (Casalegno et al., 2014). This study attempts to identify priority conservation areas in Nay Pyi Taw, Myanmar. Kong et al. (2013) evaluated land use change in Nay Pyi Taw and found that forests have gradually decreased due to agriculture expansion, dam construction, urban development, and so forth; Nay Pyi Taw is a site of new urban development and thus represents a good area to analyse the changes in ESs.

OBJECTIVE

The present study aims to understand the spatial distribution patterns of ESs in Nay Pyi Taw, Myanmar, and to identify priority areas for conservation. Comparisons were conducted before and after new urban development in order to understand the changes in ESs throughout the city and in priority areas.

METHODOLOGY

Study Area

This study was conducted in Nay Pyi Taw which is the new capital city of Myanmar (Fig. 1). It is situated at19°44′42.4"N, 96°07′46.8"E (Nay Pyi Taw City Hall). The population size of the city was approximately 1.56 million as of 2014 (Department of Population, 2014) and the city covers a total area of 7,054 km^2.

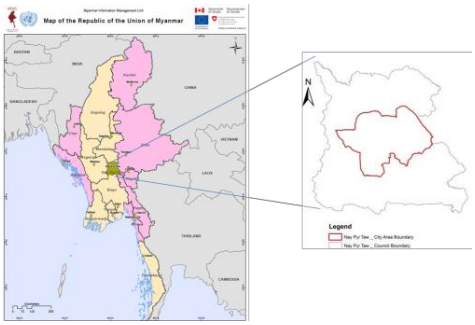


Fig. 1 Overview map of Myanmar and Council and city boundaries of Nay Pyi Taw in black and red respectively
Source: Myanmar Information Management Unit (MIMU)

(a) (b)

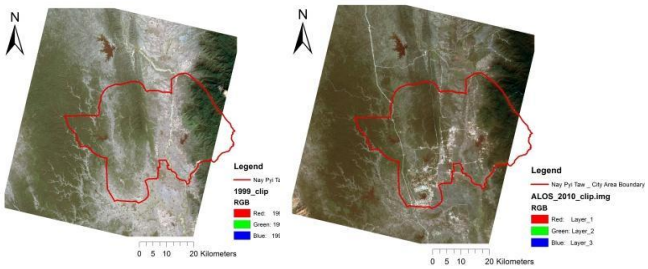


Fig. 2 (a) Landsat imagery and (b) ALOS imagery in Nay Pyi Taw City in red line
Source: (a) University of Maryland, NASA and GOFC-GOLDand (b) JAXA/Distribution RESTEC

Research Flow

This research study was conducted in four parts. The first part involved the collection of satellite images and the development of land use classifications by supervised and unsupervised classification procedures. The second part involved the determination of unit values for ESs by literature surveys and estimation of land surface temperatures by using Landsat7 data. For the third part, spatial analyses of ESs were conducted; and for the fourth part, a comprehensive assessment was conducted by using Zonation software (Moilanen et. al., 2012) to determine the priority areas for the conservation of ES provisioning potential.

Land use / land cover classification of satellite image: Land classification was conducted in ArcGIS10.1. For reference data, Google Earth and original satellite images were used and as an ancillary data, Normalized Difference Vegetation Index (NDVI), Digital Elevation Model (DEM), and slope data, calculated from the DEM, were applied. Before final land classifications were made, the NDVI was used to classify forested and non-forested areas. As there were overlapping values for forested and non-forested areas in the NDVI dataset, slope data were used to further refine the data. After that, unsupervised classification was used for the Landsat7 1999 image and supervised classification was used for the Advanced Land Observing Satellite (ALOS) 2010 image. In this study, land classifications were categorized into mainly four types, forest, water, urban, and agriculture areas. Then, an accuracy assessment for the 2010 land classification was conducted. The overall accuracy

was 94.67% based on the ancillary data, such as, google earth.

Satellite images: In this study, two satellite images were used for the analysis. The first satellite image was taken with the Advanced Visible and Near Infrared Radiometertype2 (ANVIR-2) on board the ALOS (dated 20101110, here in after, ALOS2010) image and the second image was a Landsat7 image (dated 19991230, here in after, Landsat7-1999). The source of ALOS2010was cited as "satellite image by JAXA/Distribution RESTEC"; its resolution was 10mx10m (Fig. 2(b)). The source of Landsat7-1999 was "satellite image by University of Maryland, NASA and GOFC-GOLD"and its resolution is 30mx30m (Fig. 2(a)). In this study, as the resolution of two satellite images is different, land use classification and spatial analysis of ecosystem services were conducted separately for two images. After that, the comparison was conducted based on each result of spatial analysis of ecosystem services and priority maps for two periods.

Types of ESs analyzed in this study and the unit values for each ES: Table 1 shows the types of ESs and the unit values used for the ESs. For the unit values of ESs, except for temperature regulation, data were collected through literature surveys. Because the unit values of ESs for Myanmar were limited in the literature, much of the data was estimated from other Asian regions to have enough information for the analysis. These data were based on elevations, forest types and slope conditions similar to those in Myanmar. In this study, three major types of ESs, namely, provisioning, regulating and supporting, were used and cultural services were not included in this study due to data limitation.

Table 1 Types of ESs and the unit values of ESs used in this study

Types of ESs	Forest	Agricultural area	Urban	Water	Source
Supporting Services:					
GPP (t/ha/yr)	30.7	12.093			Chenetal. (2013), Hirata et al. (2013)
Carbon stock (t/ha)	433.7	31.02			Oo(2009), Takeuchi (2012)
Regulating Services:					
CO_2 absorption (t/ha/yr)	2.737	3.250			Chen et al. (2013)
Soilerosionfactor (t/ha/yr)	0.038	3.9			Sidle et al. (2006)
Water infiltration (mm/h)	100	38.5		15	Chaplot et al. (2002)
Temperature regulation (°C)	3.86	1.14	20	4.73	Calculated by Landsat7 ETM+
Provisioning Services:					
Agriculture Products (t / ha)	-	5.38	-	-	FAO (2009)
Habitat (GDI)	-	-	-	-	Li (2014)

**GPP, gross primary production*

Estimation of temperature regulation: Estimations of land surface temperatures were calculated by using Landsat7'sEnhanced Thematic Mapper Plus (ETM+) band 6. First, the digital number of band 6 was converted to radiance by using Eq. (1) as follows (Kumar et al., 2012):

$$L_\gamma = \left\{\frac{L_{MAX}-L_{MIN}}{QCALMAX-QCALMIN}\right\} * DN - 1 + L_{MIN} \quad (1)$$

The value of L_{MAX}, L_{MIN}, Q_{CALMAX} and Q_{CALMIN} were obtained from the metadata file of Landsat image.Secondly, black body temperature was calculated by using Eq.(2) as follows (Kumar, et.al, 2012):

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

The value of calibration constant K_1 and K_2 were obtained from the Landsat data user's manual. Finally, land surface temperatures were calculated based on the Eq. (3) as follows (Yue, et al., 2007):

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

As land surface temperatures change depend on elevation level, an adjustment was conducted. Adjustment was made based on "going up 1000 m vertically, temperature goes down 6 degree".Then, the average temperature in each land use type was calculated and the differences of temperatures among land use types were obtained as temperature regulation units (Table 1).

Green index (GI): In this study, the GI was calculated to determine the habitat distribution. The GI was calculated based on the results of land classification maps for Landstat7-1999 and ALOS2010 by using the resample tool in ArcGIS (Li, 2004). In the GI, green areas and non-green areas were separated and assigned values of 255 and 0, respectively. In this study, forest and water areas were determined to represent green areas and other land uses were categorized as non-green areas.

Mapping with ArcGIS: Spatial analysis was conducted with ArcGIS to understand the spatial distribution of ES provisions. Seven ES maps were developed in total, and the land classification map data and unit values of ESs were applied. Before applying the unit values, a grid with a mesh size of 300 m × 300 m was developed for the land classification maps.

Determination of priority areas for conservation: Zonation is a software that can be used for the prioritization of conservation areas (Moilanen et al, 2012) The approach used by this software firstly sums the value of each ES layer and then discards the least valuable cells one-by-one until all cells are removed. There are four cell removal rules (Moilanen et al., 2012), and the present study used the additive benefit function (ABF). The ABF tends to produce a higher average proportion of feature distributions. In this study, equal weight was used for all ESs. By using the ABF, the present study achieved the best performance on average for all features or ESs. The main result of the Zonation analysis was a priority ranking map for the entire landscape.

RESULTS AND DISCUSSION

In the present study, geographic information system (GIS) based spatial analysis was conducted for the assessment of ES provision potential based on land classifications. Figure 3 shows the results of land classifications for 1999 and 2010.

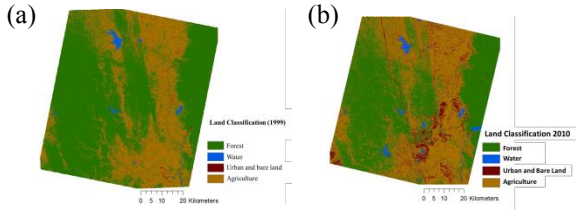


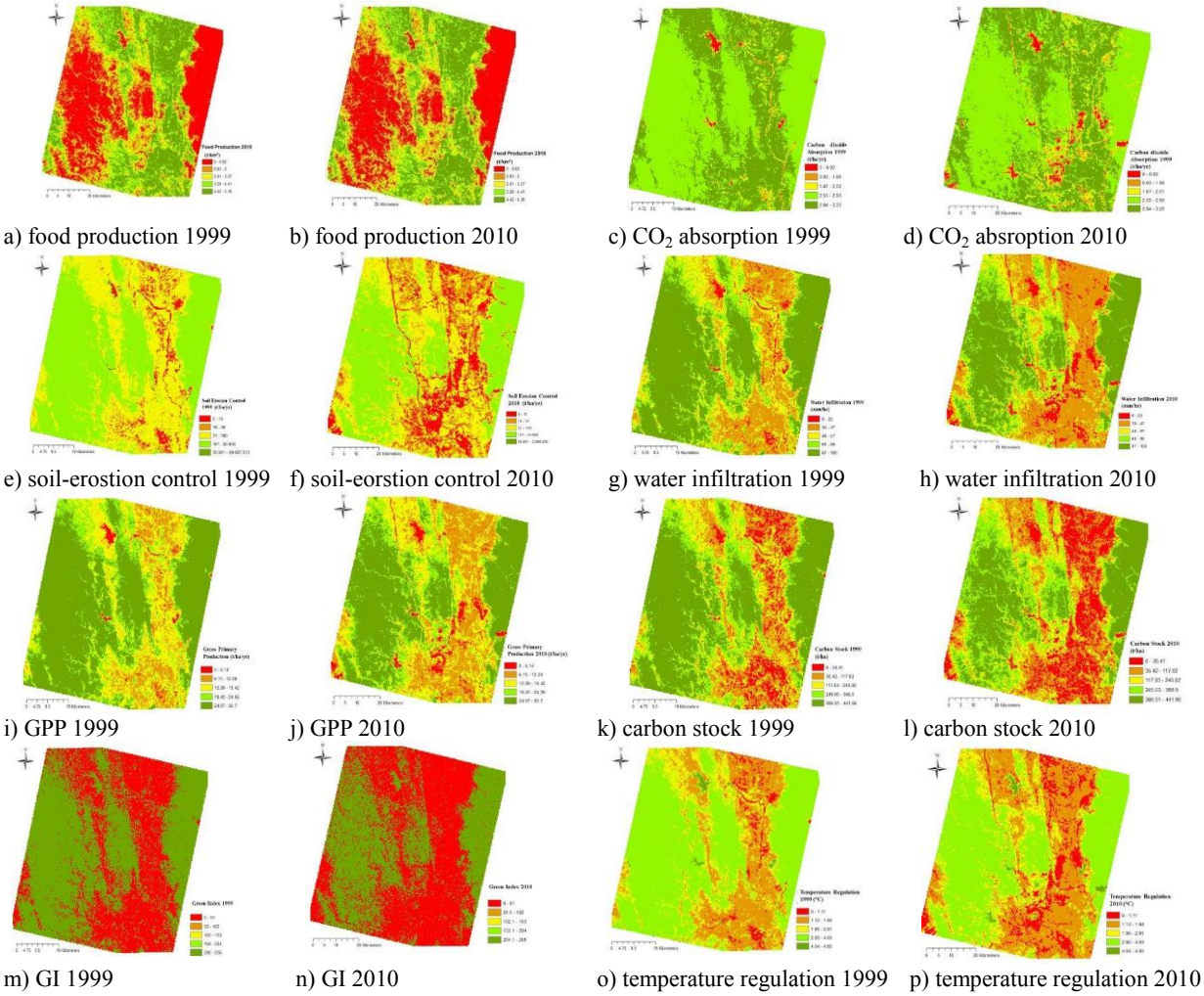
Fig. 3 Land use classification for (a) 1999 and (b) 2010

Based on the results of the land classification, spatial analysis was conducted by using unit values of the ESs on a 500 m mesh. The results are shown in Fig. 4. For food production services, the highest provisioning of the service was in agricultural areas. For the CO_2 absorption service, agricultural areas had higher levels of service provisioning than the forest areas. Perhaps this was related to the unit value used for CO_2 absorption, which was from Chen et al. (2013). Chen et al. (2013) mentioned that agricultural areas have high unit values because of the chemicals used for the crops. Even though many peer-reviewed papers were collected and studied to define the unit values, nevertheless, suitable data for Nay Pyi Taw were difficult to find. Therefore, we just applied the unit value for CO_2 absorption

from Chen, et al. (2013). For temperature regulation, water areas had the highest regulation rates followed by forest area. For the other remaining ESs in this study, forests were the highest providers of services.

The most important and valuable areas in terms of the potential distribution of ESs and conservation of ESs are shown in Fig. 5, and these data were derived from the Zonation analysis. In Fig. 5, the dark red color represents the top priority areas for conservation and the violet color represents the lowest priority areas. The top priority areas were mostly forested areas. It is well-known that forest ecosystems are the main providers of ESs. Therefore, it makes sense that forested areas were identified as the top priority areas for the conservation of ESs. In general, the lowest priority areas were urban developed areas and bare land.

Comparisons of 1999 and 2010 data showed that the amount of priority area decreased in some forested areas and increased in other areas. In 1999, some parts of agriculture areas were sparsely included in the top priority areas and some parts (mostly northern parts of the study area) were included in the least valuable areas. Sparse priority areas in 1999 were converted to the least priority areas in 2010 because of urban development. According to these results, the priority areas identified in 2010 should be protected for ES sustainability. Therefore, if infrastructure development projects are being planned, these priority areas should be avoided if at all possible.



a) food production 1999 b) food production 2010 c) CO_2 absorption 1999 d) CO_2 absroption 2010

e) soil-erostion control 1999 f) soil-eorstion control 2010 g) water infiltration 1999 h) water infiltration 2010

i) GPP 1999 j) GPP 2010 k) carbon stock 1999 l) carbon stock 2010

m) GI 1999 n) GI 2010 o) temperature regulation 1999 p) temperature regulation 2010

Fig. 4 Spatial analysis results of ESs in Nay Pyi Taw in 1999 and 2010

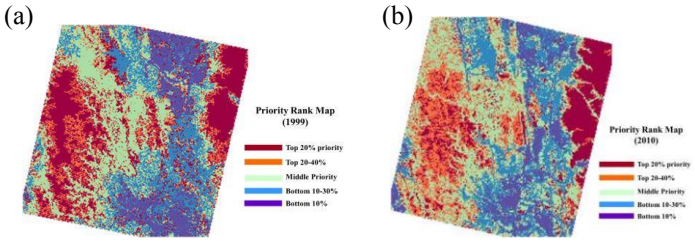


Fig. 5 Priority rank layer map for (a) 1999 and (b) 2010

CONCLUSION

In this study, a spatial analysis of ESs was conducted in Nay Pyi Taw, Myanmar, which is an area of rapid urbanization. Most of the ESs analyzed decreased over time, but food production services increased because of the expansion of agriculture areas. ES provisioning was at the lowest level in the urban development areas. Priority maps were made to identify the areas most important for ES conservation; much of this land consisted of forested areas.These priority maps should be useful for land use planning, policy development, and protected areas establishment in the Nay Pyi Taw region.Comparisons between 1999 and 2010 data showed that ES provisioning had decreased, especially in urban development areas, and several high priority areas in 1999 had changed to low priority areas in 2010 because of urbanization. Therefore, before any new development projects are initiated, we should seek to avoid construction in priority areas for ES provisioning as much as possible. In future study, we seek to include cultural services in this study and also the demand and supply of ESs will be estimated to be sustainable use of ESs in Nay Pyi Taw region.

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Research article

Effects of Surveying Methods between GNSS and Direct Leveling on Elevation Values over Long Distance in Mountainous Area

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Abstract Water use facilities such as irrigation and drainage channels, water gate, hydraulic drop etc. are constructed to make water supply to paddy field and upland field. In a planning of irrigation project, it is necessary to obtain elevation value with accuracy and efficiency around project site. In generally, elevation values are obtained by the direct leveling survey with specific instruments, e.g. digital or auto level, a couple of staffs and turning plates. The direct leveling survey also needs several benchmarks, which are points of reference with high accuracy location information including latitude, longitude and elevation. There is, however, a serious problem that survey work of the direct leveling survey must begin at several benchmarks. In the case of survey work in mountainous area, surveyors must carry out the direct leveling survey over several very-long routes, because there are few benchmarks. On the other hand, in the Global Navigation Satellite System (GNSS) surveying, elevation values can be obtained indirectly by observing carrier phase from multi positioning satellites such as GPS, GLONASS since 2011. This study started to install the new benchmark on a 920 m high mountain, about 5 km away from some known benchmarks in Karuizawa Town, Nagano Prefecture. After surveying the new benchmark by the GNSS and the direct leveling, we compared its elevation values. Furthermore, a streamlined survey process, the influence on most probable value and standard deviation by the difference of using satellite, "GPS-only" and "GPS and GLONASS" were investigated in the GNSS surveying. As the results, our tests found that dramatically streamlined survey process, "GPS-only" can obtain an elevation value that is consistent with the value from the direct leveling survey. Therefore, the GNSS surveying is useful to obtain accurate elevation values over long distance like very long channels.

Keywords GPS, GLONASS, rigorous network adjustment, observation duration

INTRODUCTION

In agricultural irrigation projects, channels are planned to distribute water to the upland and paddy fields within the project area. The channels in such project areas tend to be long. For distributing water in long channels, it is important to use surveying technologies that clarify the elevations of planned channel locations. Conventional survey techniques are time- and labor-intensive. Therefore, the development of survey techniques that are accurate and efficient has been promoted.

It is difficult for developing countries to prepare expensive surveying equipment and use highly advance surveying systems. Such countries request that advanced nations provide them assistance on surveying techniques. Japan once conducted a questionnaire survey on the GNSS continuous observation system in countries receiving overseas development assistance from Japan (Nakagawa el al., 2014). The GNSS continuous observation system uses GNSS-based control stations (i.e., observation stations with GNSS antennas and receivers) for data acquisition, and the system includes analysis and provision of the obtained data. The survey showed that 16 of the 23 countries surveyed had already introduced the GNSS continuous observation system (Nakagawa et al., 2014). Nine of those 16 countries reported using the system for agricultural purposes (Nakagawa et al., 2014). Judging from the questionnaire results, the use of surveying techniques using GNSS in agriculture is being promoted internationally. It is predicted that surveying using the GNSS continuous observation system will become the mainstream technique. The introduction of the GNSS continuous observation system can be expected to drastically eliminate the technical gap between developing countries and developed countries.

In conventional direct leveling, whereby the elevations of planned locations for channels are determined, the relative height are directly surveyed by using level, vertical leveling staffs and turning plates (Okazawa et al., 2014). Observations are made by repeatedly placing the level and the leveling staff at certain intervals along the route from the benchmark to the new point (Okazawa et al., 2014). The problem with this method is that considerable work is required to conduct leveling of a route for planned water channels if the route is in a mountainous area without any benchmarks nearby. The data used in this method are a series obtained in the observations from the benchmark to the new point; therefore, observation errors occurring between the benchmark and the new point greatly affect the final results. Even one error in the routes is not permissible, and the responsibility of the surveyor is always great. There are other problems, such as difficulties in determining what routes to use to access the survey points and the problem of traffic density and traffic safety at the survey points.

In GNSS surveying, which started to be used in 2011, the phases of carrier waves from GPS and GLONASS positioning satellites are observed. All that's required is for the GNSS equipment to be set at the new point. Three-dimensional coordinates of the new point are determined by obtaining the baseline vector from the GNSS-based control station to the new point. A geoid model is necessary for determining the elevation, because the datum of GNSS surveying is a reference ellipsoid and the datum for the elevation is the geoid. In Japan, Japan geoid model “GSIGEO2011”, which is a high-accuracy geoid model, was created (Kodama et al., 2014). The new geoid model has made GNSS leveling possible. GPS and GLONASS are separate systems and the observed data are different. Use of GPS-only or GPS and GLONASS is stipulated for public surveying in Japan. Use of GLONASS-only is not authorized. Studies have compared the use of GPS to the use of GLONASS (Ikeda and Sada, 2012; Mylnikova et al., 2015; Yasyukevich et al., 2015).

Based on such circumstances in Japan, GPS-only and combination of GPS and GLONASS were used in this study. The areas where GNSS leveling is done for agricultural channel planning tend to be far from the existing benchmark. Therefore, the authors selected a location for a new point at the elevation of about 920 m in a mountainous area. The new point was surrounded by large areas of paddy fields and of upland fields for cabbage and blueberry cultivation. Even though the target area already had irrigation channels, the local farmers requested that the accurate elevation of the area be determined.

To examine the conformity of the elevation values surveyed by GNSS leveling and those surveyed by direct leveling, both techniques were used in observing the new point. The most probable value and the standard deviation of the elevation obtained by each technique were determined by rigorous network adjustment and were compared. In GNSS leveling, the influence of the difference between GPS-only observation and GPS and GLONASS observation on the most probable value and the standard deviation was clarified. To investigate the improvements in observation efficiency achieved by GNSS leveling, the work volume of observation by GNSS leveling and by direct leveling were determined and compared.

METHODOLOGY

Methodology of GNSS Leveling

The new point location was set near a paddy field area in a mountainous area at an elevation of about 920 m and about 5 km from the first-order benchmark in Karuizawa Town, Nagano Prefecture. Table 1 shows the outline of the GNSS leveling and direct leveling done for this study.

Table 1 Outline of the GNSS leveling and direct leveling done for this study

Method	Number of new point	Used known point	Used satellite	Date
GNSS leveling	1	3 GNSS-based control stations	GPS, GLONASS	23.Sep.2014
Direct leveling	1	3 first-order benchmarks	None	19-20.Sep.2013

The observation technique used in GNSS leveling was static relative positioning with carrier phase observable. Because the static is most accurate method in GNSS surveying such as the fast static, RTK and so on. The GNSS leveling equipment used was Trimble R8 GNSS of Nikon Trimble Co., Ltd. (Fig. 1). The geoid model used was Japan geoid model "GSIGEO2011". The map of network plan for GNSS leveling was the Y-shaped connected traverse (Fig. 2). The GNSS-based control stations used in the GNSS leveling were the three points No.960610, No.950269 and No.960613. The new point is denoted as No.4101. No.4101 is denominated by the author to distinguish it from other points. Fig. 3 shows the GNSS-based control station No.950269. The provision of GLONASS data, in addition to GPS data, was started in 2013. This study used GPS-only, GPS and GLONASS data from GNSS-based control stations.

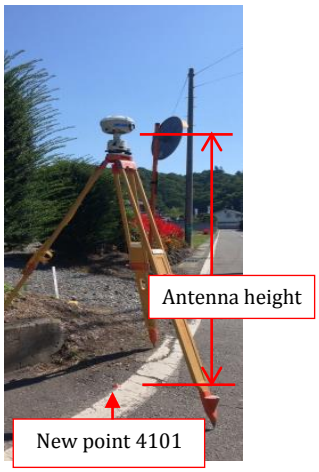

Fig. 1 GNSS leveling survey

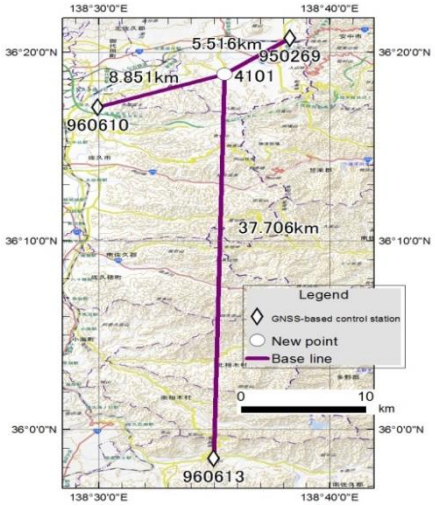

Fig. 2 Map of network plan for GNSS leveling

Fig. 3 GNSS-based control station No.950269

Methodology of Direct Leveling

The direct leveling was done to compare with GNSS leveling. Because the direct leveling is most accurate method in leveling survey. The equipment used for direct leveling was digital levels and bar-code leveling staffs of Leica Geosystems Co., Ltd. or Topcon Corp (Fig. 4). The digital level is accurate than auto level when reading the staff. Even though different levels used because surveyed at same time on different routes, there are no different results comparing Leica and Topcon level. Fig. 5 shows the map of network plan for direct leveling. The first-order benchmarks used in direct leveling were the three points No.18050 (Elevation 948.8876 m), No.18049 (Elevation 938.1914 m) and No.546 (Elevation 940.1693 m). Three intersection points No.1, No.2 and No.3 were set for examining each section. The new point is denoted as No.4101. Fig. 6 shows the first-order benchmark No.546. The first-order benchmark is the benchmark with the highest accuracy. The elevation is marked in units of 0.1 mm.

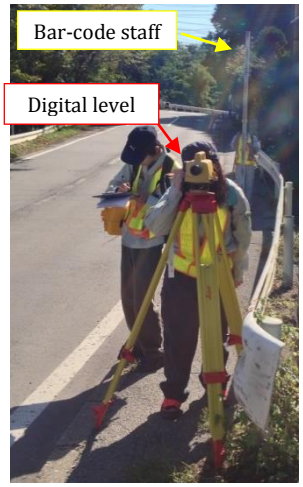

Fig.4 Direct leveling survey

Fig. 6 First-order benchmark No.546

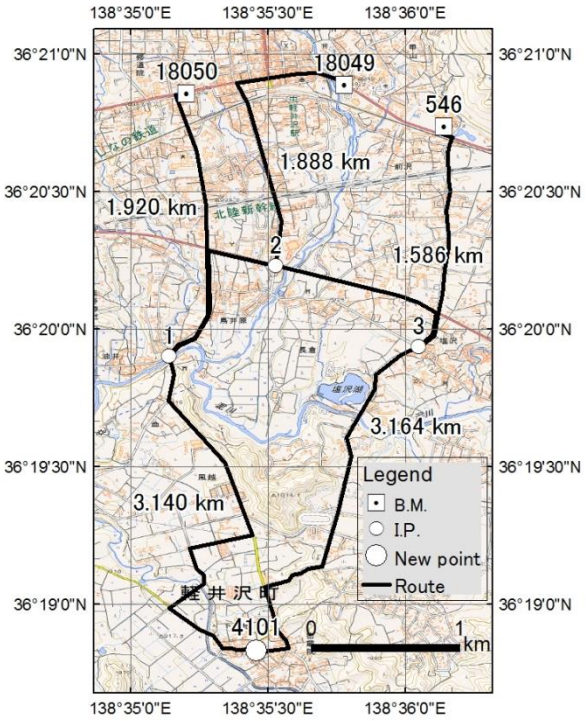

Fig. 5 Map of network plan for direct leveling

Results of Work Volume of GNSS Leveling and Direct Leveling

Table 2 shows the work volume for GNSS leveling and that for direct leveling. GNSS leveling was done by one person (the author). The observation hours in GNSS leveling were 5 continuous hours. The survey manual for elevation surveying by GNSS leveling specifies that the observation hours for GNSS leveling shall be at least 5 continuous hours (Geospatial Information Authority of Japan. 2015). Direct leveling was done by 24 people, including the author. The 23 people, excluding the author, were divided into 6 groups of 3 or 4 persons to survey within 2 days. The observation hours for direct leveling was 11 hours in 2 days. The total observation duration is the observation hours multiplied by the number of observation persons. The total observation duration for GNSS leveling were 5 hours,

and those for direct leveling were 264 hours. The total observation duration in GNSS leveling were about one-fiftieth (1/50) that of direct leveling. Even though the result varies depending on the length of the route for direct leveling, the examination clarified that GNSS leveling is able to dramatically improve observation efficiency. Based on the experience of conducting both leveling methods, the author is able to conclude that the use of GNSS leveling helped overcome many problems regarding direct leveling, including planning for routes to the survey points, problems of traffic conditions and traffic safety at the survey points, and the mental stress on the surveyor in work that does not allow even one error.

Table 2 Work volume for GNSS leveling and that for direct leveling

Method	Number of observation persons	Observation hours [h]	Total observation duration [h]
GNSS leveling survey	1	5	5
Direct leveling survey	24	11	264

Rigorous Network Adjustment

To determine the most probable value and standard deviation of the elevation of the new point based on the observed data (i.e., the relative height or baseline vectors), rigorous network adjustment was done for the data obtained by GNSS leveling and direct leveling. In rigorous network adjustment, an observation equation and a residual equation are formulated for the unknowns of the new point, a normal equation is formulated by using the least-squares method and that equation is solved (e.g. Tajima and Komaki, 2001).

Eq. (1) is the formulated observation equation.

$$\mathbf{AX} = \mathbf{L} \tag{1}$$

Where $\mathbf{A}$: Coefficient matrix
$\mathbf{X}$: Unknown vector
$\mathbf{L}$: Constant vector

The unknown vector is the unknown to be determined, and the constant vector includes the observed values and the values for the known points. Practically, each observed values contains error. Therefore, a residual equation shown as Eq. (2) is formulated.

$$\mathbf{V} = \mathbf{AX} - \mathbf{L} \tag{2}$$

Where $\mathbf{V}$: Residual vector

Then, a normal equation is formulated based on the least-squares method such that the sum of squares of the residual vector $\mathbf{V}^{\mathrm{T}}\mathbf{PV}$ for which the weight is considered is the smallest. Eq. (3) is the formulated normal equation. The weight is a function of distance.

$$\mathbf{A}^{\mathrm{T}}\mathbf{PAX} = \mathbf{A}^{\mathrm{T}}\mathbf{PL} \tag{3}$$

Where $\mathbf{P}$: Weight matrix

Eq. (4) shows the solution for the normal equation, and Eq. (5) shows the residual. To fulfill the requirement for high accuracy, the unknown is determined by using the observed value, which is greater than the unknown, and the least-squares method. The most probable value of the unknown, which is the most probable value for the elevation of the new point, is determined as a solution Eq. (4) to the normal equation obtained by using the least-squares method.

$$\hat{\mathbf{X}} = \left(\mathbf{A}^{\mathrm{T}}\mathbf{PA}\right)^{-1}\mathbf{A}^{\mathrm{T}}\mathbf{PL} \tag{4}$$

Where $\hat{\mathbf{X}}$: Solution of the normal equation obtained by using the least-squares method.

$$\hat{\mathbf{V}} = \mathbf{A}\hat{\mathbf{X}} - \mathbf{L} = \mathbf{A}\left(\mathbf{A}^{\mathrm{T}}\mathbf{P}\mathbf{A}\right)^{-1}\mathbf{A}^{\mathrm{T}}\mathbf{P}\mathbf{L} - \mathbf{L} \tag{5}$$

Where $\hat{\mathbf{V}}$: Residual of the normal equation obtained by using the least-squares method.

Eq. (6) shows the standard deviation of unit weight. The standard deviation of unit weight is the standard deviation of the observed weight.

$$m_0 = \sqrt{\frac{\hat{\mathbf{V}}^{\mathrm{T}}\mathbf{P}\hat{\mathbf{V}}}{n-m}} \tag{6}$$

Where m_0 : Standard deviation of unit weight

n : Number of the observation equations

m : Number of the unknowns

The inverse matrix of the coefficient matrix of the normal equation is shown as Eq. (7), which is called the weight coefficient matrix.

$$\mathbf{Q} = \left(\mathbf{A}^{\mathrm{T}}\mathbf{P}\mathbf{A}\right)^{-1} \tag{7}$$

Where $\mathbf{Q}$: Inverse matrix of the coefficient matrix of the normal equation

Eq. (8) shows the standard deviation of the most probable value of the unknown. This standard deviation is the standard deviation of the most probable value of the elevation of the new point.

$$m_i = m_0\sqrt{q_{ii}} \tag{8}$$

Where m_i : Standard deviation of the most probable value of the unknown

q_{ii} : Diagonal line element of $\mathbf{Q}$

However, rigorous network adjustment uses matrices to determine the many unknowns; therefore, computer applications are used in actual situations. Rigorous network adjustment for GNSS leveling was done by using TOWISE 4.1.1 (Japanese version) of Nikon Trimble Co., Ltd. and that for direct leveling was done by using BLUETREND XA (Japanese version) of FukuiComputer, Inc.

RESULTS AND DISCUSSION

Generally, the accuracy of the most probable value is evaluated by the standard deviation. The probability, the observed value vary within the standard deviation around the most probable value, is known as 68.3 %. The most probable value and standard deviation of the elevation of the new point No.4101 determined through rigorous network adjustment using the values obtained by GNSS leveling and those obtained by direct leveling are shown in Table 3. The most probable value determined by GNSS leveling using GPS-only was 919.928 m. That determined by GNSS leveling using GPS and GLONASS was 919.946 m. That determined by direct leveling was 919.921 m. The standard deviation of GNSS leveling using GPS-only was 0.018 m. That of GNSS leveling using GPS and GLONASS was 0.021 m. That of direct leveling was 0.010 m. The standard deviation of direct leveling was the smallest. That for GNSS leveling using GPS-only was the second smallest. That for GNSS leveling using GPS and GLONASS was the third smallest.

The most probable value and standard deviation of the altitude of the new point No.4101 determined through rigorous network adjustment of the values observed by GNSS leveling, those obtained by direct leveling, and the discrepancy between the two values are shown in Table 4. The discrepancy was obtained by subtracting the value observed by direct leveling from the value observed

by GNSS leveling. The discrepancy between GNSS leveling using GPS-only and direct leveling was 7 mm. The discrepancy between GNSS leveling using GPS and GLONASS and direct leveling was 25 mm. The results can be regarded as mutually consistent, even though the leveling techniques are different. We can conclude that elevation with high accuracy, i.e., sufficiently consistent with the results of direct leveling, was obtained by GNSS leveling using GPS-only. The reason for the discrepancy between the results of GNSS leveling using GPS-only and the results of GNSS leveling using GPS and GLONASS is thought to be that GPS and GLONASS are different systems. It is thought that GPS-only observation and analysis is better than GPS and GLONASS when and where enough satellites are available for GPS-only operation.

Table 3 Most probable value and standard deviation of the elevation of the new point

Method	Used satellite	Name of new point	Most probable value [m]	Standard deviation [m]
GNSS leveling survey	GPS-only	4101	919.928	0.018
	GPS+GLONASS	4101	919.946	0.021
Direct leveling survey	None	4101	919.921	0.010

Table 4 Discrepancy of elevations between GNSS leveling and direct leveling

	Used satellite	Name of new point	Most probable value [m]	Standard deviation [m]
Discrepancy	GPS-only	4101	+ 0.007	+0.008
	GPS+GLONASS	4101	+ 0.025	+0.011

CONCLUSION

As the conclusions, the points are summarized in the following.
(1) The total observation duration in GNSS leveling were about one-fiftieth (1/50) that of direct leveling. GNSS leveling is able to dramatically improve observation efficiency.
(2) The discrepancy between GNSS leveling using GPS-only and direct leveling was 7 mm. The discrepancy between GNSS leveling using GPS and GLONASS and direct leveling was 25 mm. The sufficiently consistent with the results of direct leveling was obtained by GNSS leveling using GPS-only.
(3) It is thought that GPS-only observation and analysis is better than GPS and GLONASS when and where enough satellites are available for GPS-only operation.

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Research article

Challenge and Prevalence of Fasciolosis in Cattle in Pursat Province, Cambodia

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Abstract Poor nutrition and fasciolosis have significantly decreased cattle productivity. Flood is one of the well-known Climate Changes affected cattle production in Cambodia. The present of permanent water bodies in these inundated areas may be provided favorable environment for lymnaeid snail, the intermediate host of *Fasciola gigantica*. Therefore, the study aimed to identify challenges in cattle production and the risk factors of *F. gigantica* infection in cattle after flood in Ou Tapong, Bakan, Pursat, Cambodia during December 2014 to June 2015. The 88 households were interviewed on challenges and risks of husbandry practice by using questionnaire. The total 171 fecal samples from flooding area (n=108) and non-flood area (n=63) depend on the number cattle in each area. Age, sex and health status were determined individually. Fecal were examined by using Modified Balivat Fasciola egg and counting technique. The result found that there was significance ($p<0.001$) between the prevalence of fasciolosis in flooded areas (25.00%) and non-e flooded areas (1.60%). It was noted that higher infection rates in female (19.70%) and male (2.90%) were found. The present of *F. gigantica* was found in older cattle (≥ 3years) that was significantly higher than young cattle (<3years) at the rates of 23.20 % and 7.90 %, respectively ($p<0.01$). The prevalence *F. gigantica* was highly different ($p<0.001$) among emaciated, thin, medium and fat of body condition score of cattle. Risk factor for cattle fasciolosis infection was demonstrated that cattle was fed by cut and carry water grass derived from inundated area (natural lake) and had significant association (OR=0.61) with prevalence of fasciolosis in cattle through logistic regression model. Following by focused group discussions, problems encountered in cattle raising caused flood including pen flooding, lack of feed and susceptible to disease. However, only 25.00% prepared feed before flood season and others did as habitation in local. Therefore, flood may be a factor to contribute to occurrence of fasciolosis in cattle. Traditional adaptation in cattle raising of farmers seems to be neglected to improve cattle production.

Keywords *Fasciola gigantica*, cattle, prevalence, flood, climate change, Cambodia

INTRODUCTION

Cattle production plays a vital role in the rural Cambodia economy, providing draught power, cash income and as a source of fertilizer. In 2013, livestock accounted for 14 percent of total agriculture

GDP (MAFF, 2014). Climate change has various impacts on the livelihoods of rural farmers in Cambodia as they majorly depend on agriculture for living. Flood, one of the well-known climate changes, is a core factor for low cattle productivity due to the loss of grazing pasture and shelter and occurrence of diseases (MoE, 2014). The presence of permanent water bodies in these inundated areas provided favorable environment for lymnaeid snail, the intermediate host of *Fasciola gigantica*. The lymnaeid snail population and its habitat are disturbed by flooding as they are dispersed by floodwater (Copeman, 2008). Alves et al. (2011) stated that flood might be associated with the presence of lymnaeid snail where prevalence fasciolosis in cattle was higher in flooded areas than non-flood areas. Cambodia experiences with flood every year, particularly the provinces along Mekong River and Tonle Sap (Leng, 2014). The anticipated impact of climate change and variability on agriculture include frequency increase and intensity of flood and incidence increase of pests and disease (MOE and UNDP, 2011). Flood causes economic loss, crop, and livestock destruction. As consequence, NCDM (2014) reported that an estimated cost that flood damaged and lost livestock was about US$3.33 million in 2013. Stock, poultry, and pig losses together with dying cattle during flood also found.

F. gigantica is being the major internal parasite of cattle health problem in Cambodia (Soun et al., 2006). Losses due to fasciolosis are mainly reduced meat production, draught performance, and lower fertility in infected animals (Spithill et al., 1999). The net benefit per head of cattle and buffalo in these high-risk zones of Cambodia is US$76-91.These losses and the costs were taken into account of implementing control program (Sothoeun, 2007). Tum et al. (2004) developed a geographic information system model for mapping the risk of fascioliasis in cattle and buffaloes in Cambodia. Mainly around Tonle Sap Lake and along the Mekong River and Bassac River, estimating that 28% of cattle Cambodia is potentially at risk of fascioliasis, with areas of high and moderate risk concentrated in southern and central areas. However, knowledge of the prevalence of parasitic infection including fasciolosis in relation to seasonal flood and challenge cattle production cause flood in these selected study areas is poor documented.

OBJECTIVE

The study aimed (i) to identify problems encountered in cattle and the solutions farmers responded to flood, and (ii) to estimate the prevalence and associated risk factors of fasiolosis in cattle in study area.

METHODOLOGY

Study Area

Two villages in Ou Tapong, Bakan, Pursat province were selected for this study and were taken place from December 2014 to June 2015. Geographically, Ou Tapong commune Bakan district is a peninsular area situated along Tonle Sap River, and these villages are different from Sdock klouk situated in the lower plain of Tonle Sap and are susceptible to flood damage in rainy season, while Robaoh Reang village is a higher land (non- flood area).

Survey of Fasciolosis

Fecal samples were sampling from 63 and 107 of the animals in Robaoh Rang and Sdock Khlouk villages, respectively. Samples were selected out from all cattle in both villages. Two cattle were sampling from household raise at least two cattle and a cattle from a household raise only one. They were randomly collected from male and female cattle with the age of less than 3 years old and above 3 years. Approximately 5-10 g fecal samples were collected from rectum.

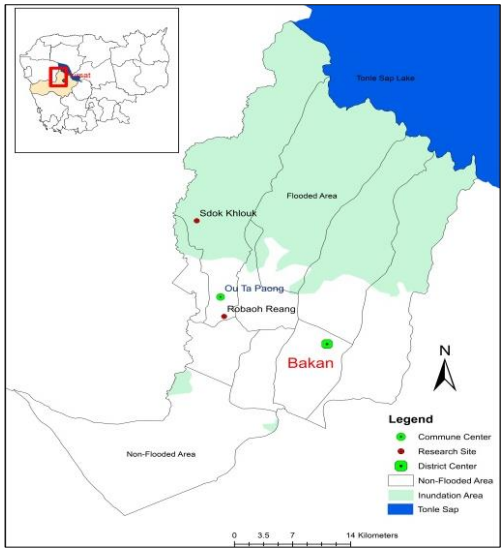

Fig. 1 Map of study area

The samples were independently labeled with the age, sex, body condition score, and village name and were stored in a cooled box containing ice. The samples were transported to Parasitology Laboratory of Research and Extension at Royal University of Agriculture and were analyzed using a Modified Balivat Fasciola egg counting technique to find prevalence of fasciolosis. The association between the independent factors and the prevalence of fasciolosis was calculated by using the Chi-square and confidence level was held at 95%. As part of the study, all cattle owners were selected for interviewing by a set of structured questionnaire that covered aspects of challenges and responses of farmers to flooding in cattle production and possible risk factors for fasciola, for example, feeding and water management, and presence of lymnaeid snail in particular site. Focused group discussion was also done for validation. Risk factors associated with case of fasciolosis were analyzed using a logistic regression model. All statistical analyses were conducted using SPSS version 16.0.

RESULTS AND DISCUSSION

General Characteristics of Cattle Production

Cattle production is considered the second major economic activity for smallholders while the main job is rice production. The majority of cattle production in both villages was raised for breeding purpose, as savings in family. Generally, cattle were grazed together on available pastures in the area, which was depended on the season and availability of feed. The cattle feeds were mainly grasses, rice straw, and stubble. After rice harvest, cattle were herded together in the grazing area where pasture and water are available, especially at floodplain and surrounding natural lake near Tonle sap river. The cattle were released from morning to evening in Sdock Khlouk. Unlike the cattle in Robaoh Reang, they were freely released to grass in paddy field or grassland (farm) with additional feed, such as rice straw.

Problems Faced by Farmers in Cattle Raising

Cattle raising in Sdock Klouk village is very sensitive to be impacted by flood. Water grass such as Brachiaria (buffalo grass) and *Oryza rufipogon* from flood plain and flooded natural lake are the main feeds for cattle in flood events.

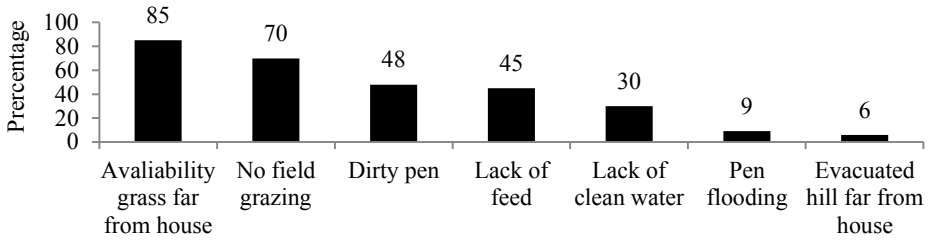

Fig. 2 Percentage of farmers faced by feed and pen problems in cattle rising during flooding

The survey result presented in Fig. 2 shows that 85% of farmers reported grass availability was far from household with the distance between 3 and 15 kilometers. Farmers (75%) said that there was no field grazing for cattle because grass field was flooded and 45% of farmers were lack of feed for cattle, a part of cattle lack of water grass due to no boat and destroyed grass. Pasture was also a major challenge to limit cattle productivity after flood because water grass was no longer grow or flower and that was not a suitable feed for cattle.

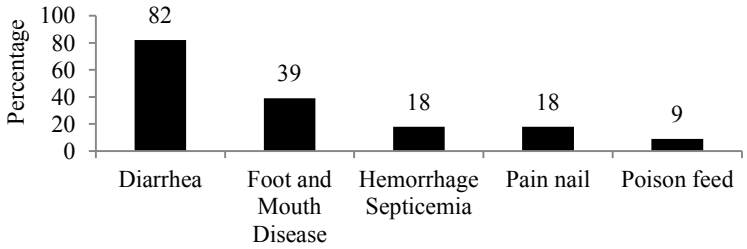

Fig. 3 Percentage of farmers noted disease in cattle during flood

Observation of farmers on disease in cattle during flood is shown in Fig. 3. There are 82% of farmers who found that their cattle had diarrhea during and after flood season. There were 39% of farmers who observed that cattle had Foot and Mouth disease, Hemorrhage septicemia (18%) and pain nail (18%). Lastly 9% of farmers reported poisoning cases on cattle. Those could be the result from flood related issues and evacuating conditions were susceptible to infectious diseases. Flood water was only a drinking source during flood duration and cut and carry moss grass were the main feed for cattle.

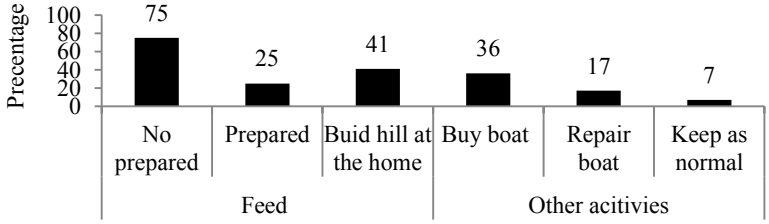

Fig. 4 Percentage of farmer adapted in cattle production

Adaptation of farmers keeping cattle in study site is illustrated in Fig. 4. Farmers were asked to share their experience of dealing with flood and to describe existing ways to adapt to flood. Up to 75% of cattle owners did not make any feed preparation while there was 25% prepared rice straw. Traditional adaptation of villagers, including 41% of farmers built an evacuated site for cattle at home, 36% bought a boat, and 17% repaired their boats before flood event because preparing boat was very

important to transport water grass. However, at least 7% absence of any adaptation means the farmers kept and did everything as normal due to living conditions.

Infection Fasciolosis in Cattle

Out of the total cattle examinded, an overall prevalence of 28 (16.4%) were recorded in the present study. The prevalence rate at Robaoh Reang and Sdock Khlouk villages were 1.6% and 25%, respectively (Table 1). Prevalence of fasciolosis was higher in cattle at non-flood areas than in cattle at flood areas. The study revealed a significant difference ($p<0.001$) of fasciolosis prevalence in the two study villages. Sdock Khlouk was higher than Robaoh Reang as it may be defined by the presence of more lowland or lake, which was the maintenance of flood prone areas. The mollusk dispersion and maintenance of the life cycle of fasciola are suited for those areas (Lima et al., 2009). High prevalence was observed in flood areas as it was supported by the model, which indicated that the area of high and moderate risk of fasciolosis in the closed distance river and lake (Tum et al., 2004). Moreover, cattle feeding method in Sdock Khlouk was mainly free grazing at bank of natural lake and the margin of flooded areas as water receded. This inundated area was a suitably permanent habitat for aquatic snails that were the intermediate hosts of *F. giganitca* (Tum et al., 2004). The higher in area surrounding large natural lake or pond was the location where Lymnaea snail was seen by villagers. The overall prevalence of liver fluke infection (13.4%) is supported by the finding of Dorny et al. (2011) which the result varied from 5%-20%. On the other hand, this result is higher than the earlier report of Tum et al. (2007) who found 6.2% prevalence of *F. gigantica* in cattle for Pursat province and concluded that there is a moderate predicted risk of information. The variation in the findings with the early reports may be due to the difference in sample size, place of study site, period of infection, time of collecting fecal sample, and availability of infected intermediate hosts (Lymnea snail). The present finding was gradually increased year over year and it might be closely associated to the presence of chronic cattle infection due to no deworming.

Table 1 Prevalence of fasciolosi base on site

Site	N examined	N infected	Prevalence %	x^2	P
None-flood	63	1	1.6	15.92	0.001
Flood	108	27	25		
Total	171	28	16.4		

As shown in Table 2, there was significant in variation of fasciolosis in male and female cattle ($x^2 = 5.59$, p=0.018). The infection rate in female was higher (19.7%) than male (2.9%). This finding was similar to the observation of Ardo (2014). Impact to the infection rate could not be explained, but these infections in female were higher than in male which could also be attributed to the proportion of more female samples (Table 2). The prevalence of fasciolosis was higher (23.2%) in old cattle while lowest prevalence in young cattle was up to three years old (7.9%). It showed a significant difference among age group ($x^2 = 7.18$, p=0.007). The lower prevalence rate in young cattle might be due to short time exposure to disease than old cattle. On the other hand, the old cattle were free grazing from near submerged area from morning to evening (Table 2). Base on body condition, it was significantly difference ($x^2 = 18.81$, p=0.000) of prevalence *F. gagantica* among emaciated, thin, medium, and fat body conditions of cattle. 40% was observed in cattle with emaciated body condition, while the lowest infection prevalence (1.6%) was observed among cattle with fat body condition which was consistent with the finding of Rast et al. (2013).

Table 2 Prevalence of faciolosis base on sex, age and body condition of cattle

Factors		N examined	N infected	Prevalence %	x^2	P
Sex	Female	137	27	19.7	5.59	0.018
	Male	34	1	2.9		
Age(years)	≥3	95	22	23.2	7.18	0.007
	<3	76	6	7.9		
Body condition	Emaciated	10	4	40	18.81	.000
	Thin	38	11	29		
	Medium	61	12	19.7		
	Fat	62	1	1.6		

Risk Factors for Fasciolosis in Cattle

Fourteen univariables were analyzed for association with the presence of fasciolosis reported by cattle owners. Of these 10 ($p \leq 0.25$) showed significant association risk variables of fasiolosis including cut grass from flood plain, natural lake, cut stubble, free grazing around Tonle Sap, free grazing around lake, drink water from lake, cannel, dung well, use cattle for ploughing in rice field, and use cattle fecal for fertilizer. This was eligible for the inclusion of the multivariable logistic regression. The results from this analysis revealed that cattle that were fed by cut and carry water grass from natural lake were more likely to have fasciolosis than cattle that were not feed by cut and carry grass from natural lake. There was a significant association (OR=0.61, P<0.01) with prevalence of fasciolosis in cattle (Table 3).

Table 3 Result of a multivariable logistic regression analysis of risk factors for fasciolosis

Risk factor	β	Association with Fasciolosis			P
		OR	95 CI for OR		
			Lower	Upper	
Constant	-1.193				0.000
Cut and carry grass from natural lake	-2.796	0.061	0.008	0.462	0.007

CONCLUSION

The cattle productions of small-holder farmers were in the limit productivity in terms of feeding and occurrence of diseases resulted by flooding. Traditional adaption may be neglected to improve cattle productivity, hence adaptation capturing good practice to enhance community resilience to flood should be introduced to farmers. Prevalence *Fasciola gigantica* was found in cattle and feed management in the areas that seemed to be exposure to fasciolosis infection. Accordingly, a disease prevention program and a control program are required. Inundated areas may be associated with habitat of intermediate hosts that contribute to higher prevalence of fasciolosis in flooded areas. It would also be a role as baseline data in the future study or for the relevant field.

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Research article

Efficiency of Two-Row Chinese Rice Transplanter Experimented at Royal University of Agriculture

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Abstract As a number of agricultural labors have shifted to urban industry, rice production is now experiencing labor shortages. Thus making transplanting is deeply unpopular. Despite producing higher yields, transplanting has dramatically been replaced by direct seeding. Therefore, this research paper aims to introduce the rice transplanter model TMRT 2 and to determine its working performance and efficiency by conducting an on-station experiment, starting from June to August, 2015, at the Royal University of Agriculture (RUA), Cambodia. The experiment was divided into 9 treatments with the size of 2 m x 7 m, and two main factors—plant age and water level—were studied and analyzed on different periods of 12 days, 18 days, and 25 days in age; an water depths of 2 cm, 5 cm, and 10 cm for water level. The findings indicate that in the treatment (25 days and + 2 cm), the hills contained a density of 4-5 plants and suffered low damage during planting operation. Though transplanted at various water depths, old rice seedlings tended to stand upright at the average of 650 to 750 degrees, whereas slow transplanting speed might greatly reduce seedling losses to 1-2 plants per hill. Additionally, hill-to-hill spacing varied from 21 to 23 cm when the rice seedlings age 18 and 25 days were mechanically transplanted. However, transplanting of younger seedlings produced many missing hills that ranged from 3 to 7 hills in the 2 m x 7 m plot, and this might substantially decrease the future yields. Planting depths varied from 4 to 5 cm when transplanting of seedlings age 18 and 25 days was performed at a water level of 2 cm. It might be concluded that rice seedlings, age 18 and 25 days, should be transplanted at 2 cm water level, in combination with slow enough operational speed, while transplanting of 12-day seedlings at varied water depths produced greater damage and losses.

Keywords rice transplanter, water level, root growth, hill spacing, operational speed

INTRODUCTION

Rice cultivation is known as traditional income-generating work practiced by 60% of rural Cambodian people and as a staple crop consumed in the country. Rice is also rich in vitamin B, which is important to keep the body running (MAFF, 2012). Recently, rice has been prioritized as a strategic crop to boost exports (FAO, 2014). Therefore, rice yields have increased, while workload has decreased. Despite its tremendous significance, rice cultivation is laborious and takes a long time to yield. In general, the cultivation time ranges from three to six months, depending upon the selected rice varieties and the seasons when crops are cultivated. Rice growth and yields are highly sensitive to variability of land preparation, climatic conditions, proper care, and water supplies. So, improper farming techniques

may obviously lead to a waste of invested capital and low outcomes. Since rice cultivation requires a great deal of available labor, lack of man-power may lead to late farming or little care which signifies a pressing need for machine aid to boost crop production (ADB, 2014).

At the present time, mechanization has started to appear as a useful farming method that accelerates agricultural work and cut down unnecessary labor use, as well as increasing crop yields per year. After years of globalization, Cambodia has imported hundreds of power tillers to quicken land preparation proportionally in the wake of youth out-migration for work abroad. This really demonstrates a noticeable trend in the Cambodian agricultural evolution, while labor shortages pose a serious challenge towards the existence of agriculture (Lay, 2009). Seldom introduced into the Cambodian domestic market, hand-powered rice transplanters have been widely marketed and utilized in the Asian regions to compensate for labor shortages and facilitate farming work. Such rice transplanters are of great importance to the rural economies as fewer people are needed to transplant rice crops than ever, seedlings are uniformly transplanted for the purpose of better field irrigation and weeding at a later stage. Apart from that, seedling uniformity results in proper nutrient intakes from the ground and enough solar absorption between rows, which means higher yields. Therefore, this research aims to introduce the rice transplanter model TMRT 2 and to determine its working performance and efficiency.

METHODOLOGY

The experiments were carried out at the Royal University of Agriculture during the period of June-August to test the performance of a hand-operated rice transplanter by selecting the mini hand cranked rice transplanter (2 row, 20 cm width), which was imported from China. Moreover, understanding different water levels in rice fields before, during, and after transplanting is crucial for the firm stance and survival of newly transplanted seedlings. Adequate water presence in the field also contributes to the ability of seedlings to take in nutrient dissolved in water, absorb oxygen from the air, and consume sufficient amounts of water to promote growth. Thus, the study was performed by selecting plots with three water levels above the ground: 2 cm, 5 cm, and 10 cm, which are similar to the real water levels observed in rice paddy field in Cambodia.

As the time frame of the practical experiment was about three months, the short-duration rice variety Sen Pidoa was chosen. The rice was germinated at the nursery prepared at RUA campus, and planted for the experiment. The age of seedlings strongly affects proper growth leading to low losses of transplanted seedlings and higher yields at the harvest time. So, experimenting with different seedling age categories can prove a premium seedling age that can assure high yields for the benefit of farmers. The tested rice seedlings were categorized into three different ages: 12 days, 18 days recommended in system of rice intensification (GDA, 2013); and 25 days to meet the optimum rice age for the rice transplanter. Both water level and seedling age affect rice growth. The 9 treatments were created with the size of 2 m x 7 m. Root growth, number of plants per hill, missing hills, damaged hills, inter-row spacing and stem angle were measured and analyzed using ONE-WAY and TWO-WAY ANOVA from Minitab-17.0 software packages. Transplanting speed was measured whereas machine depreciation cost and labor efficiency were calculated.

The seed rate for one square meter nursery was about 250 grams. During seedling preparation, organic matter was one ox-card for 100 m^2 nursery to obtain firm seedling stems, additionally 0.5 kg of Urea fertilizer was diluted into water to make seedling healthy. Rice needs to be fertilized three times, 2-3, 15, and 50 days after seeding, and weeding is needed after transplanting at 15, 30 and 45 days to prevent grass growth (GDA, 2013).

RESULTS AND DISCUSSION

Optimal Transplanting Speed Operational in Each Treatment

The seedling age and water level were tested to find the optimum transplanting speed necessary to streamline a whole transplanting process with little damage to seedlings. The seedlings transplanted at the age of 12 days tend to be associated with higher operational speed, which significantly variant from 0.24 $m.s^{-1}$ in 10-cm depth to 0.36 $m.s^{-1}$ in 2-cm depth, while the transplanting of 18-day seedlings might retard the machine mobility estimated at around 0.25 $m.s^{-1}$ in depths of 2 and 5 cm and at 0.30 $m.s^{-1}$ in 10-cm depth. It is clear that young seedlings were easy to be picked up and dug into the soil, hastening the operational speed. With 25-day seedlings, the transplanter was operated at slow speed of 0.20 $m.s^{-1}$ in each water depth. This shows slowness of the machine. As a result, the operational speed varies in uniformity to subsequent seedling ages, but may fluctuate due to soil conditions and constant mechanical pulling force.

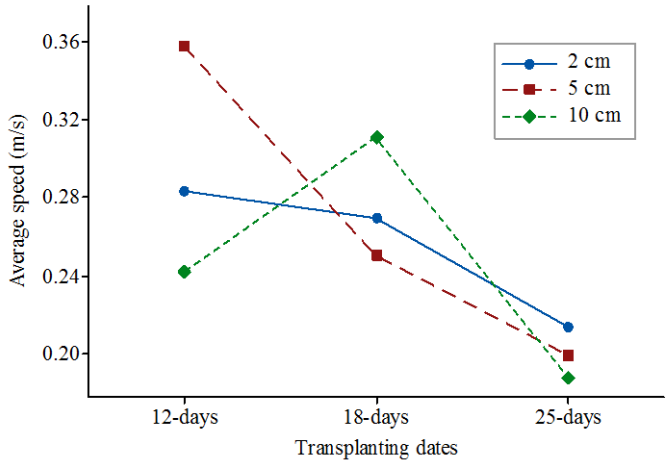

Fig. 1 Comparison in transplanting speeds operated in different seedling ages and water levels, with different speed means significant ($p < 0.001$) in transplanting date factor, non-significant ($p = 0.055$), and with significant interaction ($p = 0.019$)

Transplanting Speed Operational in Each Treatment

Missing hills and floating rates of transplanted seedlings were examined and counted in each treatment. This was to discover how significantly the age factor and the water-level factor affected the transplanter performance. As shown in Table 1, the difference in seedling damage in each hill is highly significant ($p < 0.001$), while the variation in an average floating rate of seedlings is also statistically significant ($p < 0.001$). As a result, the findings show that seedling damage in a density of 4 m^2 tend to be greater at high depth and young age, with the averages of 3 seedlings in the treatment (12 days + 5 cm), 4.5 seedlings in the treatment (18 days + 5 cm) and 7.5 seedlings in the treatment (18 days + 10 cm). The damage rate was non-significant in case older seedlings were transplanted, though at various depths. Water depth had a huge effect on a floating rate of seedlings in the vicinity of 4 m^2. High water level presented on the experimental plot signified a higher rate of seedlings afloat, and transplanting young seedlings was also influential in this rate. The seedlings age 25 days suffered a low floating rate at which very few drained seedlings were gathered in 4 m^2, which other treatments with younger seedlings had a floating rate of 4-7 seedlings.

Table 1 Effect of different depths and seedling ages on damage and floating rates

Treatment	Missing rate	Floating rate
12 days + 2 cm	1.70 b	4.50 abc
12 days + 5 cm	3.00 ab	4.00 abc
12 days + 10 cm	7.75 a	6.00 abc
18 days + 2 cm	2.00 b	-
18 days + 5 cm	4.50 ab	7.00 a
18 days + 10 cm	7.50 a	7.00 a
25 days + 2 cm	2.00 b	1.50 bc
25 days + 5 cm	-	0.75 bc
25 days + 10 cm	1.50 b	0.75 c
SE	2.164	2.050
F-test probabilities	< 0.001	< 0.001
CV (%)	19.65	18.18

Effects of Above-ground Water and Seedling Age on Root Depth

Seedling roots may penetrate as deep as into the ground depending upon the availability of water on the ground and the age of the seedlings, which is well illustrated in Fig. 2. The difference in average root depth penetrable into the soil is very significant. The roots of the seedlings transplanted at the age of 12 days shows obvious results as they had the lowest penetrability, but differed across different levels of above-ground water. In this seedling age category, the transplanter had the ability to dip the seedlings roots 3 cm into the soil at a water level of 2 cm, increasing the root depth by 1 cm at water levels of 5-10 cm. Deeper root penetrability occurred at higher level of water because the transplanter was manually adjusted to match the water level; otherwise, the seedlings were unable to be placed into the soil. Though transplanted at the same age categories, older seedlings tend to have deeper root penetrability, and the roots of the replanted seedlings age 18 days were averaged under 5 cm despite little depth variation across the water level. However, after replanting, the root depth of seedling age 25 days remained deeper than younger seedlings and was averaged 5 cm. This figure increased due to the rising level of water presented on the soil. The fact that older seedlings had higher penetrability could be explained by three reasons: the height of the seedlings, pulling mechanism, and periodic adjustment of the transplanter.

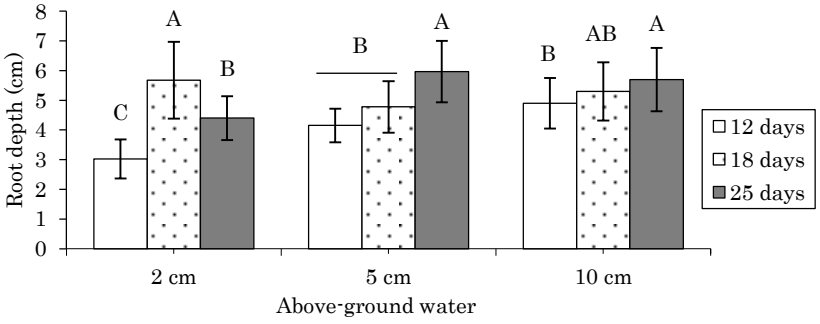

Fig. 2 Combined effects of seedling age and water level on seedling-root depth created during transplanting. The Mean ± SD of root depths are presented. Different used alphabets indicate measurement is significantly different *(p < 0.05)* from each other

Effects of Above-ground Water and Seedling age

Numbers of seedlings per hill, crop spaces, standing angles of seedlings and seedling losses per hill were timely measured to identify effects that the transplanter had on rice seedlings (Table 2). Different age groups strongly affected the ability of the transplanter to pick up the seedlings, being highly significant ($p < 0.001$), while the water level might not have any significant effect ($p = 0.964$) on its capability in picking seedlings at a time during the transplanting process. Interaction between the water level and age group factors was also not significantly different ($p = 0.147$), showing that replanting at different levels of water, regardless of seedling ages, the number of seedlings transplanted at a single time was similar. As indicated above, the seedlings age 25 days were suitable enough for the transplanter to pick up 4 seedlings per hill, when operated at 2-cm water depth. As the water level was deeper, the number of picked-up seedlings also increased by one unit. As the interaction was not detected, the suitable seedlings for the utilization of the rice transplanter should exceed 20 days in age, so the machine is capable to firmly grab them. In addition, the water level should be considered to remain shallow to reduce excessive use of seedlings.

Table 2 Combined effects of seedling age and water level on seedlings transplanted at a time, inter-row spacing produced, stance of seedlings, and damage rate

Treatment		Number of seedlings (stems/hill)	Between-row spacing (cm)	Stem angle (^{0})	Damaged seedlings (stem/hill)
Age	Water level				
12 days	2 cm	9.25^{a}	19.65^{bcd}	62.75^{abc}	2.65^{a}
	5 cm	7.70^{ab}	18.75^{cd}	65.00^{abc}	0.20^{d}
	10 cm	7.25^{abc}	19.15^{cd}	72.50^{ab}	1.40^{b}
18 days	2 cm	4.60^{bcd}	16.30^{d}	73.40^{ab}	0.75^{bcd}
	5 cm	4.40^{cd}	18.45^{cd}	53.25^{c}	0.90^{bcd}
	10 cm	4.90^{bcd}	24.85^{a}	57.25^{bc}	1.35^{bc}
25 days	2 cm	3.90^{d}	21.50^{abc}	65.65^{abc}	0.80^{bcd}
	5 cm	5.20^{bcd}	22.10^{abc}	77.35^{a}	0.45^{bcd}
	10 cm	5.25^{bcd}	23.70^{ab}	78.60^{a}	0.40^{cd}
SE		1.72	2.04	16.68	0.97
F-test probabilities					
Seedling age (S)		< 0.001	< 0.001	< 0.001	< 0.001
Water level (W)		0.964	< 0.001	0.379	< 0.001
Interaction (SxP)		0.147	< 0.001	< 0.001	< 0.001

Spacing produced by the manual operation of the transplanter varied significantly at each water depths ($p < 0.001$) and at each age group ($p < 0.001$). This shows that the older the seedlings, the wider the spacing. The interaction effects of the water depths and age groups on crop spaces were detected ($p = 0.001$), showing that the transplanter tended to produce distinct spacing because the required traction force for the operation varied. Older seedlings required machine transplanting to spend slightly more time. This is obvious because deeper water levels tend to be difficult for the transplanting machine to pull out due to friction produced on the water surface, retarding the movement of the transplanter at water depths of 5 and 10 cm. This explanation is strongly linked to widened crop spacing. Of all the treatments, seedlings transplanted at the age of 25 days, though at varied water depths, remained highest and varied from 21 to 23 cm compared to others replanted at a younger age.

Plant ages were significantly influential in the ability of plants to stand after transplanting ($p = 0.001$), while different water depths had no effect on the standing ability ($p = 0.379$). This means stem heights affects plant verticality. However, the interaction between the age group and water level is statistically significant ($p = 0.001$), indicating that plant verticality tends to vary due to combination of

plant age and water depths. Statistically, plants age 25 days were very suitable with the use of the transplanting machine as they slightly leaned at 80^0 on average when planted at water depths of 5 and 10 cm. Comparing to the replanting at a water depth of 2 cm, the seedlings of that age leaned to 65^0. High water levels seem to keep old and tall plants straight up. Younger rice plants age 12 and 18 days transplanted at high water levels caused the plants to stand less upright, while 18-day seedlings transplanted at a 2-cm water depth stood at 73^0.

Damage to plants per hill was measured in each treatment, while the seedling age and water level were both strongly influential in the degree at which plants might be broken ($p < 0.001$). These two factors interacted closely ($p < 0.001$) and might determine how much damage was done on seedlings transplanted when varying age groups and water levels were applied. Plants per hill were seen to suffer breakage at the age of 12 days more than older plants that were transplanted at different water levels. Rates of plant damage ranged from 1.40 to 2.50 plants per hill with too young seedlings. However, plants per hill suffered less damage when older seedlings were used. This damage was mainly caused by the way of operating the rice transplanter.

CONCLUSION

In short, it is deductible that the seedlings age 12 days are unsuitable for machine transplanting because substantial damage and seedling losses are frequently observed. Moreover, at higher water levels of 5 and 10 cm above the ground, machine transplanting may result in more floating and missing hills. Therefore, it is obvious that seedlings age 18 and 25 days should be considered for further experiments. Water depth of 2 cm is preferred as it leads to stronger seedling stance, low seedling density, easy machine operation, and marginal losses. Therefore, the rice transplanter should be considered as a good option to accelerate rice farming and reduce workload.

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Research article

Economic Analysis of Small-scale Pumping Machines Operated in Rice Production in Chum Kiri District, Kampot, Cambodia

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Abstract Water scarcity has become abnormally serious across the year, so timely irrigation aid is strongly required for healthy crop growth. Therefore, this paper aims to explore the characteristics of farmers' preferences over pumping machines in rice production and to analyze their break-even points. The study was performed during the period from January to June in 2015, by randomly selecting 80 pump owners from one farming commune in Chum Kiri District, Kampot Province, Cambodia. The data were collected using household interviews, in-depth interviews and a group discussion. The data were analyzed by utilizing descriptive statistics and the break-even formula to investigate repair costs, annual pumping hours and standard farm sizes. The result shows that water pumps were highly in operation during dry season to maintain the crop-water balance and were annually operated about 412 hours. The engine capacity of pumping machines, frequently purchased, ranged from 5.5 to 8 horsepower. The pumps lasted for five full-operational years and depreciated 25 dollars on an annual basis. Japanese-brand pumps were best-selling, still farmers were subjected to have excessive spending on annual repairs because of less care and little maintenance knowledge. Although water pumps were widely utilized across the studied area, each household only cultivated on an average of 1.20 hectare-farmland, whereas the break-even land was calculated to be at least 6 hectares of cultivated land, so that the pumps were fully operated, economically and effectively. In conclusion, though operated on a small land, water pumps have made a contribution toward improvement in crop production. However, they remained minimally useful in case of scarce water sources. Therefore, irrigation sources should also be considered and constructed, so crop production might be double or diversified with the presence of pumping machines.

Keywords dry season, operational hours, farmland, break-even point

INTRODUCTION

Water is crucial for cropping systems in Cambodia. However, rice is mostly cultivated once a year largely due to rainfall dependency. Thus, annual rice yields are even low during water scarcity. In comparison, annual rice crops are cultivated two or three times in Thailand and Vietnam because of the involvement of mechanization making the two nations become leaders in rice exports. In this case, usage of pumping machines is deemed an effective tool in adequate water irrigation (MAFF, 2012). In terms of rural economies, water for irrigation has nurtured approximately 500 million family farms

worldwide in the form of rainfall and water sources, while contributing toward securing world food adequacy for rural households. In fact, small farms—either irrigated or non-irrigated—are also managed by almost 60% of Cambodian farmers who rely mostly upon rice farming. Thus, farm mechanization is widely known as a driving force of agricultural transformation and development (Chhim Chhum et al., 2015). For this reason, watering innovation in obtaining irrigation water is required to improve rice production and yield along with technical support on agricultural machinery (FAO, 2014).

Furthermore, due to high demographic growth in Cambodia, rice cultivated areas have been expanded enormously and increased from about 2 million hectares in 2003 to roughly 3 million hectares in 2013. The expansion of farmland has resulted in higher machinery purchase increasing the number of power tillers from 13,700 units to 128,800 units and the number of pumps from about 100,000 units to 232,000 units over the same period of time (Saruth et al., 2014). The rising numbers of purchased pumping machines may either bring benefits to the nation or pose new challenges to rural mechanization in Cambodia when technical assistance is not widely available. Machines are heavily imported without providing adequate vocational training on mechanics to local distributors (Chhim Chhum et al., 2015). In this case, rural skills including economical operation of farming machinery are necessarily the best choice in enhancing rural economies (ADB, 2015), as Cambodian people that reside in the countryside possess relatively low skills and low educational achievement. Besides, technical skill shortages are largely apparent in countryside people. Due to the importance of machinery involvement and necessary skills relevant to the operation of machinery, especially small-scale water pumps, this study aims to explore the characteristics of farmers' preferences over pumping machines in rice production and to analyze their break-even points. By doing so, the optimum cultivated farmland may be found out.

METHODOLOGY

Site Selection and Sampling Procedure

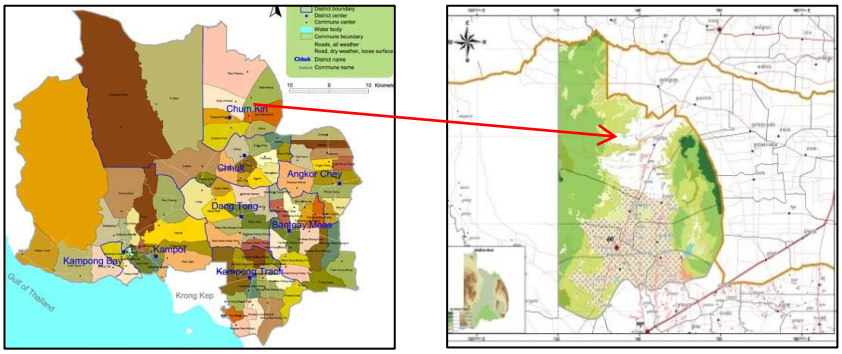

Fig. 1 Map of the studied area in Chompouvorn Commune, Chum Kirir District

Farmers who utilized pumping machines for irrigation were randomly selected from Chompouvorn Commune, Chumkiri District, Kampot Province, where rainy-season rice is mostly cultivated. To understand how portable water pumps are used to suit the current situation of the cropping systems, the farmers from two different villages were categorized into two low and high pump usages and then were sampled using Yamane Taro's (1992) formula (Israel, 2013), as shown below:

$$n = \frac{N}{1+N.e^2} \quad (1)$$

Where n is a number of selected samples; *N* represents a population of farmers operating pumping machines in the two villages; and *e* is the level of significance and accounts for 10%.

Table 1 Sample of farmers operating water pumps

Village names	Level of pump utilization	Number of households with pumps (person)	Number of samples (person)
Thmey	High	246	52
Koun Damrey	Low	133	28
Total		379	80

Data Analysis and Break-even Farm Size

Efficient operation of water pumps depends greatly upon how often they are utilized and how big the farmland is. Economically based pump usage is considered important for farm operation as long as profitability is highly aimed. Annual depreciation cost of machinery and break-even farm size, when one pump is purchased and operated, are calculated based on the following formulae:

$$D = \frac{PV-SV}{L} \quad (2)$$

Where *D* is a pump depreciation cost (USD/year); *PV* represents the initial price of one pump (USD); *SV* is known to be the price of pump salvage or 10% of initial price (USD); and *L* is a pump life span and is up to 6 years.

$$B_E = \frac{FC}{P-VC} \quad (3)$$

Source: Patterson and Painter (2011)

Where B_E represents break-even farm size cultivated for efficient pump usage (ha); *FC* is an annual pump ownership cost (USD/year); *P* is custom pump hired rate per hectare (USD/ha); and *VC* covers all operating costs such as fuel, labor, and repairs (USD/ha).

RESULTS AND DISCUSSION

Agriculture in Cambodia is dominated by paterfamiliases, accounting for 84.27% of farming families interviewed in the studied area, while only 15.73% represents materfamilias families. Table 2 indicates that men are still influential in decision-making for purchasing inputs and machinery for agricultural practices. Meanwhile, Cambodian farmers still have low literacy rates as 41.57% of the farmers could only spend a school period of 9 years, while 35% dropped out of school at young age. Dropout cases are very common in rural areas due to low budget and poor schooling infrastructure. However, 23.60% could finish high school. The 25-44 age categories of the rice growers living in the studied area account for about 57%, while 24.72% fall within the 45-60 age category, which means that the majority of the farmers are considered full labor. It is clear that the average age of the rice farmers equals to 42 years. The number of family members averages 4.39 persons per household, with 2 persons considered full labor. Because the active labor category of 1-3 persons accounts for almost 90% of the interviewed farmers, this signifies labor shortages. Furthermore, 65% of the rice farmers cultivate rice on the land that is smaller than 1 hectare, whereas 21.35% own rice fields varying in size from 1 to slightly higher than 2 hectares. In general, the cultivated farmland averages 1.15 hectares. According to the survey, the farmers have had 27 years of farming experience, and by investing an

average sum of 250 USD on land preparation, inputs and harvest; they could earn an annual income of 760 USD to cover all the expenses.

Table 2 Household characteristics of Chompouvorn Commune

Variable description	Frequency (n=80)	Percentage (%)	Mean
Gender of household head			
Male	67	84.27	
Female	13	15.73	
Educational level of household head *(yr)*			
No education	2	2.25	9.00
Primary school	26	32.58	
Secondary school	33	41.57	
High school or higher	19	23.60	
Family status of household head			
Married	62	77.53	
Divorced	18	22.47	
Age (yr) (>=25 years old)			
25 - 44	46	57.30	42.32
45 - 60	20	24.72	
> 60	12	14.61	
Household size *(Person)*			
1 – 4	48	59.55	4.39
5 - 10	32	40.45	
Active labor *(Person)*			
1 – 3	70	87.64	2
>3	10	12.36	
Farmland size *(ha)*			
< 1	63	78.65	1.20
1 – 2	4	5.62	
> 2	13	15.73	
Family experience in farming *(yr)*			27
Total expenses in farming *(USD/yr)*			250
Total income from farming *(USD/yr)*			760

Characteristics of Pump Operation and Its Working Capacity

The pumping machines that farmers commonly use are Japanese brands including Honda, Yamaha, and Yamasaki. Based on Table 3, brand-new pumps are more preferable as they are relatively inexpensive and have a long lifespan. Of all the interviewed farmers, 43.82% have utilized the pumping machines for at least 5 years, while others have owned the pumps for at least 3 years ($p<0.001$). The pumps have small engine horsepower from 5.5 to 6.5 horsepower and account for 70% of the farmers, while 30% select the engines that have 8 horsepower ($p=0.003$). Moreover, the pipes of 50 and 80 mm in diameter ($p<0.044$) are chosen for pumping, representing 61.80% and 38.20%, respectively. Besides that, the rotary speed of 3,600 rpm is preferred, and centrifugal-type pumps are chosen because they are capable to lift water up to 30 m in height. With this height, rice fields that are far away from the canals can be sufficiently irrigated. In terms of convenience, pumps with gasoline engine are best-selling, as they are light and easy to carry, so 77.53% of the farmers choose them. Diesel pumps ($p<0.001$) are still in use, representing 22.47% of the interviewees.

Pumps provide advantages during the peak demand for irrigation, but they may also cause farmers to spend more, when they are broken. The most common pump problems are related to fuel tank, ballast, spark plug, injection nozzle and wearing ring; as farmers utilize their pumps with little care

(p<0.010). New pumps break down occasionally throughout the year, and due to inadequate technical knowledge, farmers have to get them repaired (p<0.001) at mechanical shops, with about 80% of them paying a sum of between 10 and 20 USD. Around 20% pay less than 10 USD.

Table 3 Preferential characteristics of pump utilization in the studied area

Variable description of pump	Frequency (n=80)	Percentage (%)	Chi square	Significance level
Type of pump purchase			-	-
New	80	100.00		
Second-hand	-	-		
Years of pump use			24.32	<0.001***
< 3	6	7.87		
3 – 5	39	48.31		
> 5	35	43.82		
Horsepower *(hp)*			13.60	0.003**
5.5 - 6	28	34.83		
6.5 - 8	52	65.17		
Pipe diameter *(mm)*			04.05	0.044*
50	31	38.20		
80	49	61.80		
Rotary speed *(Round per min)*			-	-
3600	80	100.00		
Total head lift *(m)*			-	-
30	80	100.00		
Suction distance*(m)*			8.83	0.024*
5-7	30	37.50		
8	50	62.50		
Type of pump blade			-	-
Centrifugal	80	100.00		
Type of consumed fuel			24.20	<0.001***
Diesel	18	22.47		
Gasoline	62	77.53		
Broken pump parts			09.23	0.010*
Fuel tank and Ballast	23	28.75		
Spark plug & injection nozzle	29	36.25		
Wearing ring	18	35.00		
pump breakdown			36.45	<0.001***
Occasional	67	84.27		
Often	13	15.73		
Repairs of broken pump			51.20	<0.001***
Self-repair	8	10.11		
Repairman	72	89.89		
Repair spending *(USD/yr)*			28.80	<0.001***
< 10	16	20.22		
10 - 20	64	79.78		
Initial pump price *(USD)*			182.00	
Number of operating hours *(hr)*			415.24	

*Note: ***, **, and * signs mean very highly significant, highly significant, and significant*

Analysis of Break-even Farm Size

Pumps are commonly used during the rainy season. This situation is prevalent in the studied area due to no irrigation systems for water reservation. Accordingly, there is also no rice cultivation during dry

season. In consequence, farmers plant rice during the rainy season and resort to non-farm work during the dry season. Besides that, the price of a new pump is about 182 USD (Table 3) and is usable for 6 years; thus farmers have to incur an annual depreciation cost that is estimated at 25 USD. When the pump is operated on one hectare of land, its owner has to spend 90 USD annually on gasoline, lubricant and repair costs, as shown in Figure 2. So when it is custom-hired to irrigate farmland of one hectare, 15 USD may be charged. Thus, the pump is used to its full capacity, only if farmers have to work on 6 hectares of land per year. This does not mean that they have to possess exactly that size of land, but they can double cultivation, which leads to double usage of the pump, or they may use it in other ways for economic purposes. In terms of farmland, the farm size that each household has amounts for only 1.20 hectares, while the number of pump operating hours per year averages at 415.24 hours (Table 3). These two numbers shows that pumps are used for multi-purpose, not only for irrigation. They may use up their annual working capacity because in general, a pumping machine may be used for 500 hours per year. Therefore, it may be efficient when farmers double their cropping seasons in a case that irrigation systems are potentially available.

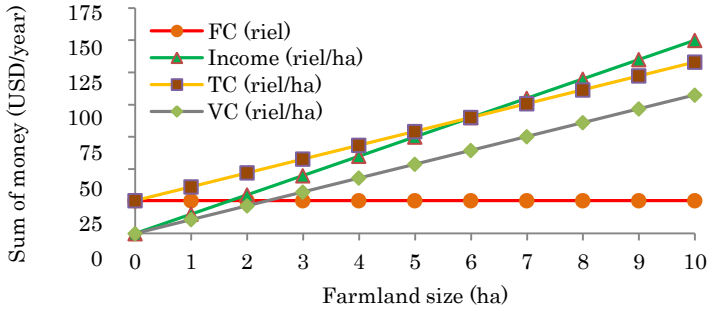

Fig. 2 Calculation of farmland size needed for efficient pump utilization

CONCLUSION

In conclusion, the pumping machines purchased are mostly imported products, but they do not cost much. The farmers possess small plots of farmland with labor shortages. Rice cultivation depends solely upon rainy season rice. This situation results in high depreciation costs and non-efficient pump usage. Besides that, farmers usually experience occasional breakdowns of the pumps and rely upon repairmen to solve the problem because of little mechanical knowledge. As calculated, the optimum farm size that is suitable for pump utilization equals at least 6 hectares, but in reality, available cultivated farmland remains smaller. Thus, all these problems are solvable if pump-repairing training is provided to target farmers to reduce unwanted costs. In addition, more irrigation systems should be built, so that farmers may access water in each season, thereby increasing their cultivation seasons.

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Research article

Comparison of the OTAKE and SATAKE Rice Mills Performance on Milled Rice Quality

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Abstract Rice is the main diet in Central Asia. Quality of milled rice is good or bad and meets the international standard in terms of quantity of head rice as a result of appropriate rice mill. The objective of this study was to find out the better rice mill for better milled rice quality. In this research, two rice species (jasmine and fragrant) were milled by SATAKE and OTAKE rice mill machines at different conditions. The paddy rice specimens were dried to obtain the moisture content of 14% (recommended milling standard). Physical properties, percentage of lose, percentage of cracked rice, and capacity of peeling for millstone peel data were collected and analyzed statically using SPSS version 16.0. The results showed that milling two species of rice by SATAKE mill brand at role's gap 0.7 mm obtained about 95% (Jasmine) and about 94% (Fragrant) on head rice, while using OTAKE brand at 3970 revolution per minute received about 84% and 78% of Jasmine rice and Fragrant rice, respectively in terms of head rice. Thus, milling rice using small-scale SATAKE rice mill is better than OTAKE machine based on more quantity of head rice of both paddy rice species.

Keywords rice mill, role's gap, fan speed, jasmine rice, fragrant rice, capacity of peeling millstone

INTRODUCTION

Rice is the staple food of more than half of the world's population (AQIP, 2003). Cambodia plans to produce 10 varieties of paddy to export and these varieties (some name in Khmer language) includes: Sen Pidor, IR66, Julasa, Pka Romdol, Pka Romdeng, Jasmine, Pka chan sen sor, Reang chey, Kha4 and Kha6 (Chan, 2011). Agricultural sector has created job opportunities approximately 80-85% to Cambodian people (Pit Khun, 1991). In recent years, high quality rice of Cambodia has increasingly and globally been recognized since it was ranked No. 1 and won the World's Best Rice Award in Indonesia in 2012 and in Hong Kong, China in (Hor Kim, 2013). At the present, Cambodia can produce paddy over demand for domestic market, in which the total production of 3-4 million tons per year (Chun, 2013). Since the official integration in the ASIAN association in 1999, Cambodia began

actively working in terms of reforming to be a member of the World Trade Organization (WTO) (Meas, 2015). An increase of both quantity and quality of milled rice plays a crucial role in pushing up the national economy. Due to lack of rice mill, Cambodia exported paddy rice to neighboring countries without milling stage (AQIP, 2003). With a recent trend of improving rice mill machine program, a perfect principle has been created to develop and reconstruct the economy of Cambodia to enhance domestic rice production toward international market standard (Rickman, 2015).

OBJECTIVE

This study aimed to improve milled rice quality in Cambodia to meet an international standard. The specific objective was to find the better rice mill for better milled rice quality.

METHODOLOGY

In this research, two rice species (jasmine and fragrant rice) were selected to mill using two small scale mills, made by SATAKE model SB-10D and OTAKE model PM 1500N. Six treatments (Table1) were designed and done triplicate, containing 3 samples in each replication. Each sample composed of 10 kg of paddy rice with the moisture content of 14%.

Pre-test of paddy rice standard: 100 gram from each paddy sample was selected randomly to peel by hand to observe broken or cracked conditions before passing mill. From the amount of broken and cracked grains, the results were then calculated to find the efficiency of the machines through the test of grain quality.

Peeling levels determination: Samples were milled by SATAKE and OTAKE rice mill machines at different role's gaps (0.6 mm, 0.7 mm and 0.8 mm) and fan rotation speeds (4620 rpm, 3970 rpm and 3320 rpm).

Dividing sample: There were 6 treatments in the milling stage. In each treatment, there were 3 replications of selected 100 gram of brown rice. In each replication, it was divided into three times by using a homogenizer. As a result, 4 samples (25 gram/sample) were derived from one replication. Finally, only 3 samples were kept for grain quality checking.

Quality control: Checking process of selected brown rice were done to measure peeling millstone capacity percentage, head rice percentage, broken rice, cracked rice level. The checking process was handled manually following the method of OTAKE (2014).

Analysis: All recorded data of peeling millstone capacity, head rice, broken rice and cracked rice level were collected and analyzed statistically using SPSS version 16.0 for descriptive frequencies of mean value and t-test.

Table 1 Experimental design

Treatments	Rice species	SATAKE Role's gap (mm)	OTAKE Fan speed (rpm)
1	Jasmine	0.6	4620
2		0.7	3970
3		0.8	3320
4	Fragrant	0.6	4620
5		0.7	3970
6		0.8	3320

RESULTS AND DISCUSSION

Peeling Capacity of Brown Rice

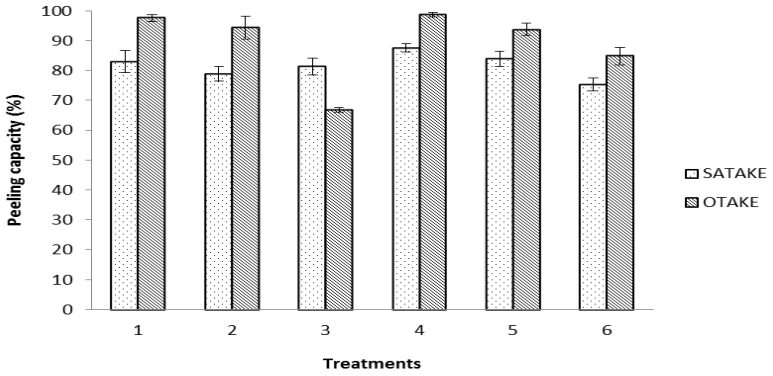

Fig. 1 Mean value of peeling capacity milled by OTAKE and SATAKE small-scale rice mills (treatment 1-3 are Jasmine rice and 4-6 are Fragrant rice)

Figure 1 shows peeling capacity of the two small scale mills on both rice species. The illustrated results were done by using different operation conditions of the two mills (OTAKE Company and SATAKE Company) on both rice species. The results show that there was no significant difference of the 3 different role's gaps of SATAKE on jasmine rice, whereas the percentage of peeling capacity of brown rice decreased a little when the role's gap increased from 0.6 mm (87%) to 0.8 mm (75%). On the other hand, the result of using OTAKE rice mill on peeling capacity showed a decreasing trend when using lower fan speed. The mean value declined between 4620 rpm and 3320 rpm and fan speed decreased from 98% to 67% and from 99% to 85% for jasmine rice and fragrant rice, respectively. Therefore, the obtained optimum percentage of peeling capacity was 87% (milled by SATAKE) and 99% (milled by OTAKE). The results met the standards, containing 84% and 99% for SATAKE and OTAKE rice mill (SATAKE, 2014 and OTAKE, 2014).

Percentage of Head Brown Rice

The results of head brown rice were indicated in Fig. 2 in the mean percentage value. Referring to this figure, by using SATAKE small scale rice mill with 3 different role's gaps, the obtained head rice were in ranges of 91-95% for jasmine rice, and 92-93% for fragrant rice. The maximum percentage was obtained by using 0.7 mm role's gap on both rice species. However, there was is no significant difference based on the number of standard deviation. Nevertheless, when milling the paddy rice specimens using small scale rice mill manufactured by OTAKE company model PM 1500N with the 3 sets of fan speed mentioned in Table 1, the achieved head brown rice ranged from 76% to 86% and from 73 to 76% for jasmine rice and fragrant rice, respectively. It can be concluded that, there will be more number of obtained head rice when applying lower fan speed (Fig. 2). Even though, there is no significant difference according to the number of standard deviation.

In comparison of the two small scale rice mills, SATAKE gave higher performance than OTAKE in terms of head brown rice percentage. The results agreed with the findings of OTAKE Agricultural Machinery Co. Ltd. (OTAKE, 2014) and SATAKE company (SATAKE, 2014), shown the quantity of head rice was 73.00% on average for OTAKE PM 1500N, and 85.10% for SATAKE SB-10D. The quantity of head rice after milling showed a marginal percentage difference when comparing to the Company's testing results. Proper physical characteristics of grain before milling and different experiment periods of time could influence the results of head rice.

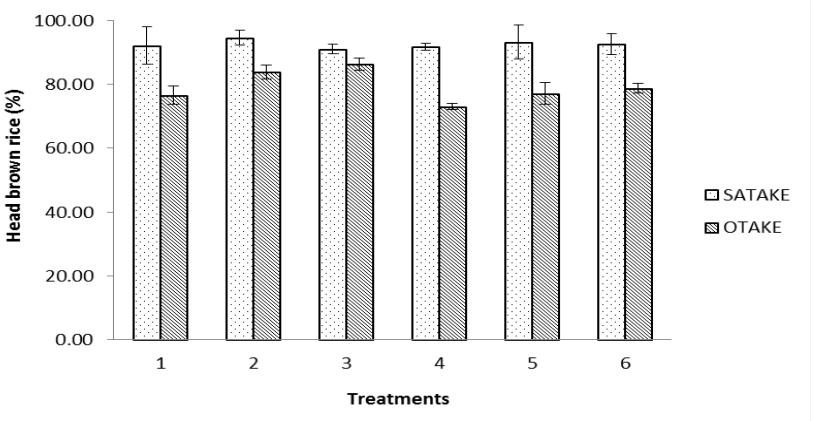

Fig. 2 Mean value of full milled brown rice in percentage

Percentage of Broken Brown Rice

The percentage of broken rice of paddy milled by the two milling machines from different companies is shown below (Fig. 3). It was no significant difference on milling the jasmine rice and fragrant rice in the 3 set role's gap operations (0.6 mm, 0.7 mm and 0.8 mm) of SATAKE. However, treatment number 2 (at 0.7 mm) provided the lowest broken quantity on average of 6%. In contrast, milling the two rice varieties by OTAKE with fan speed performance of 4620 rpm, 3970 rpm, and 3320 rmp, the results showed that the percentage of broken rice decreased when applying less speed on both rice species.

In terms of the broken rice percentage, milling by OTAKE at 4620 rpm was about 3 times higher than using SATAKE, while milling at 3320 rpm still obtained about 30% higher than that of SATAKE for jasmine rice. For fragrant rice, it was much higher in all treatments.

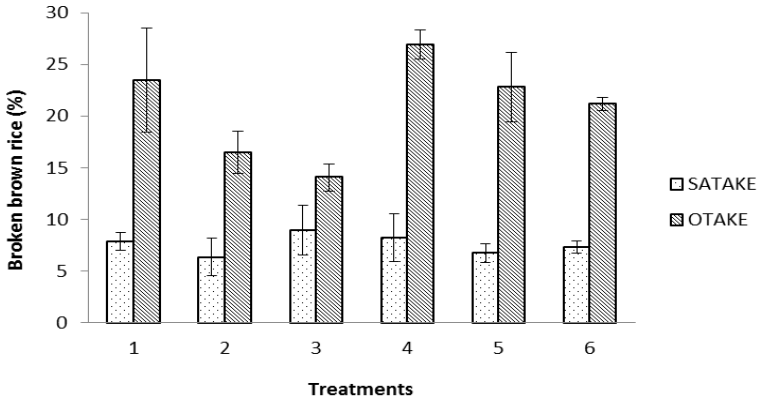

Fig. 3 Percentage of broken brown rice, as a result of milling jasmine rice and fragrant rice by SATAKE and OTAKE small scale rice mills

Percentage of Cracked Brown Rice

Figure 4 shows that even using 3 different role's gaps, brown rice milled by SATAKE model SB-10D consisted about 7% and 18% of cracked rice for jasmine and fragrant species, respectively. Comparing these findings to the brown rice milled by OTAKE PM 1500N using 3 different fan speeds, milling the rice by SATAKE composed more number of cracked milled rice for both of jasmine and fragrant. The average percentages of cracked rice milled by OTAKE rice mill were in ranges of 2.89% to 5.44% and

3.22% to 7.44% for jasmine rice and fragrant rice, respectively. The maximum percentage of cracked brown rice from OTAKE mill was at treatment 2 (jasmine) and treatment 3 (fragrant rice). Comparing with the standards of OTAKE Agricultural Machinery Co., Ltd., cracked rice was at 7% on average for OTAKE PM 1500N at 3970 rpm (OTAKE, 2014), and SATAKE SB-10D was at 23.33% on average for a role's gap of 0.7 mm for fragrant rice variety (SATAKE, 2014). Accordingly, they were dramatically lower than the standards.

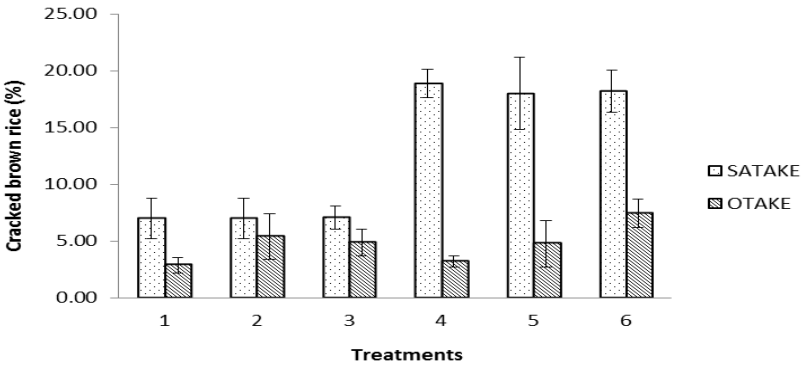

Fig.4 Cracked brown rice after milled by OTAKE and SATAKE small scale rice mills

Table 3 Comparison on efficiency of SATAKE and OTAKE mills on rice quality before and after milled brown rice

Mill types	Varieties	Treatments	Before milled (%)		After milled (%)		Efficiency (%)	
			Broken	Crack	Broken	Crack	Broken	Crack
SATAKE	Jasmine	1	1.33	7.33	7.84	7	6.51	0.33
		2	1.33	16.33	6.34	7	5.01	9.33
		3	1	14.66	8.98	7.11	7.98	7.55
	Fragrant	4	1.66	9.33	8.2	18.88	6.54	9.55
		5	1	10	6.75	18	5.75	8
		6	1.33	16	7.3	18.22	5.97	2.22
OTAKE	Jasmine	1	1.33	7.33	26.92	2.89	25.59	4.44
		2	1.33	16.33	22.81	5.44	21.48	10.89
		3	1	14.66	21.19	4.89	20.19	9.77
	Fragrant	4	1.66	9.33	26.92	3.22	25.26	6.11
		5	1	10	22.81	4.77	21.81	5.23
		6	1.33	16	21.19	7.44	19.86	8.56

Table 3 indicates the number of broken and cracked rice in percentage of both paddy rice species before and after milled by the two rice mills. Before getting milled is the results obtained from peeling by hand to check the origin of broken and cracked rice affected by other sources rather than the machine. After getting milled illustrates the quantity of the damaged rice as the effect of machine using at different conditions (different role's gaps for SATAKE and different fan speeds for OTAKE). Efficiency expresses the percentage of damaged level comparing between before milled and after milled.

As shown in Table 3, jasmine rice had 1.33%, 1.33%, and 1% broken rice and 7.33%, 16.33%, and 14.66% cracked rice before milling, representing treatments 1, 2, and 3 respectively. After milling by SATAKE, the percentages increased to 7.84%, 6.34%, and 8.98% (broken); 7.00%, 7.00%, and 7.11% (cracked). The efficiencies received by 6.51%, 5.01%, and 7.98%; 0.33%, 9.33%, and 7.55% of broken and cracked rice, respectively. Thus, using role's gap at 0.7mm offered the lowest percentage of broken rice after milled, but the highest of cracked rice in comparison with other two conditions (0.6 mm and 0.8 mm).

For fragrant rice, on the other hand, the rice was broken at 1.66%, 1%, and 1.33%; and cracked at 9.33%, 10.00%, and 16.00%, representing treatments 4, 5, and 6. The efficiencies were 6.54%, 5.75%, and 5.97% in terms of broken rice and 9.55%, 8.00%, and 2.22% of cracked rice. The results are similar to jasmine rice mentioned earlier that the minimum of broken rice obtained with 0.7 mm of role's gap, but the lowest percentage of cracked rice received when milling at 0.6mm role's gap.

When milling the same starting specimens of the two rice varieties at the same percentage of broken and cracked rice before milling. The efficiency of rice milled by OTAKE small scale rice mill accounted in a range of 20-25% and 4-11% for broken and cracked rice, respectively. The maximum percentage of broken rice occurred at higher fan speed used.

CONCLUSION

In conclusion, this study compared the quality of rice milled by two different small scale rice mills made by OTAKE Company and SATAKE Company. The results showed that OTAKE machine is better than SATAKE in terms of peeling capacity, lower cracked parameter, lower percentage of head rice quantity, and more number of broken rice on both rice types. The maximum of head rice milling by SATAKE rice mill was up to 95% using 0.7 mm role's gap, while OTAKE obtained just about 86% at 3320 rpm of fan speed. However, comparing with the standards of the machines, they were higher.

In addition, in terms of efficiency of broken and cracked rice parameters investigated to compare between before milled and after milled, the paddy milled by OTAKE machine received about 3 times higher on broken percentage with a slightly higher on cracked rice than milling by SATAKE machine. Based on the results, therefore, we can conclude that milling jasmine rice and fragrant rice using SATAKE machine at role's gap 0.7 mm or by OTAKE machine at 3320 rpm fan speed are the optimum conditions. In comparison between both machines, SATAKE machine performed better than OTAKE since it produced higher head rice with lower broken and cracked proportion.

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Research article

An Attempt to Use High Salinity Water for Irrigating A Green-Roof Garden

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Abstract Though a green roof has been implemented mainly in city area due to the mitigation of heat island effect, it can also offer the benefit of energy saving to a building in rural area. A reuse of wastewater for irrigation may be an efficient practice for water conservation, especially in the water-scarce areas. In this study, we assessed the influence of frequent and intermittent saline irrigation on evapotranspiration (ET), dry matter yields (DM) and water-use efficiency (WUE) in crassulacean acid metabolism (CAM) plants used in the green roof program. The CAM plants Sedum kamtschaticum Fischer and Sedum oryzifolium were evaluated with turf grass, Cynodon dactylon. A sharp reduction in ET with an increase in soil salinity was found in CAM plants as compared to turf grass; however, the dry matter yield of CAM plants was higher than that of turf grass at the same amount of cumulative ET. Principle component analysis (PCA) was performed to group the treatments into fewer groups characterized by similar features. CAM plants were categorized by high DM and WUE. These features were expected to make green roof management sustainable because they have low water requirements with keeping the high-density vegetation.

Keywords CAM plants, saline irrigation, evapotranspiration, water-use efficiency

INTRODUCTION

As recent climate change has raised the inconsistency of seasonal pattern of rainfall and temperature, it may cause decreasing precipitation and increasing temperature in some area (Kiem and Austin, 2013). In case such severe condition for human health continues, an air-conditioning based on the heat pump would be spread more rapidly for cooling in residential buildings regardless of their urban or rural location.

The growing energy consumption for cooling could adverse effect on the household economy. For reducing the thermal load into buildings, green roof is being used due to their protection from the solar radiation (Kumar and Kaushik, 2005). Especially the soil used in this study has a greater effect on the thermal property of insulating because with the large value of for porosity, much of the pore space is filled with air (Radcliffe and Simunek, 2010). However in dry climate regions, green roofs are not widely adopted because irrigation water for green roof is scarce. The irrigation water availability could be enhanced through the use of saline water, the recycling of drainage water and the reuse of wastewater (FAO, 1992; Rhoades, 1998; Ould-Ahmed et al., 2007). A considerable amount of poor-quality water is available in many dryland countries (FAO, 2003). The idea of using poor-quality water for irrigation to increase food production has been reported successfully for more than five decades; however, little study has been conducted with poor-quality water with the aim of improving thermal performance and landscapes, such as developing green roofs (Moritani et al., 2013).

Succulent plants that have a Crassulacean acid metabolism (CAM) have fleshy leaves. CAM plants open their stomata during night so that CO_2 is fixed into organic acids and eventually stored in the vacuoles. These characteristics prevent water loss from CAM plants and decrease the uptake of salt into plant bodies (Gravatt and Martin, 1992). In this study, we tested two kinds of CAM plants - *Sedum kamtschaticum* and *Sedum oryzifolium* - both natives of coastal areas with turf grass (*Cynodon dactylon*) as the control (Fujita, 2007). The purpose of this study was to examine the possibility of using these plants for green roofs with saline water in terms of its dry matter yield and water-use efficiency (WUE).

METHODOLOGY

Table 1 Physical and chemical properties of the experimental soil

Fraction (%)				Bulk density	Saturated hydraulic conductivity	pH (H_2O)	EC	T-C	T-N	CEC
Gravel	Sand	Silt	Clay							
>2.0 mm	2.0–0.02	0.02–0.002	0.002>	g cm^{-3}	cm s^{-1}		dS m^{-1}	%	%	$cmol_{(+)}$ kg^{-1}
48.9	32.1	10.6	8.4	0.48	3.6×10^{-2}	6.7	0.70	12.0	0.96	40.4

Description of Soil, Plants and Irrigation Water

The experiment was performed in a glass greenhouse (glasshouse) at Arid Land Research Center (ALRC) of Tottori University in Japan. The soil shown in Table 1 was overlaid at a thickness of 10 cm, on a gravel layer for drainage, in a plastic pot with a diameter and height of 0.16 m and 0.20 m, respectively.

In this study, two CAM plants, *S. kamtschaticum* Fischer and *S. oryzifolium*, and a turf grass, *C. dactylon*, which is one of the primary turf grasses used for green roof in Japan, were used. The transpiration activity of *S. kamtschaticum* was relatively higher under normal condition than of *S. oryzifolium* because of higher leaf area index. 6 plants of *S. kamtschaticum* and 25 plants of *S. oryzifolium* plants were transplanted into each pot in the middle of June, and seeds of the *C. dactylon*, which is a C_4-type plant, were sown (Aires et al., 2008). Bare soil packed in same pot was also prepared for measuring the reference evaporation. All plants were grown for one month by watering well before starting the experiment on August 1. The experiment lasted for two months during summer.

The irrigation water was prepared by mixing seawater and tap water shown in Table 2 (Al-Busaidi et al., 2007). The ratio of the Na ion content to the sum of Ca and Mg ions, expressed as the sodium adsorption ratio (SAR), is an important index to assess the quality of irrigation water. The definition of SAR is described in Eq. (1) below (US Salinity Laboratory, 1954):

$$SAR = Na^{+} / \sqrt{(Ca^{2+} + Mg^{2+})/2} \quad (1)$$

where Na^{+}, Ca^{2+} and Mg^{2+} are ion contents (mmeq L^{-1}) of sodium, calcium and magnesium, respectively. The quality of irrigation water used in this study was averaged to 12 dS m^{-1} with SAR of 50.4, which was classified as the most severe salinity condition (US Salinity Laboratory. 1954) with EC higher than 2.3 dS m^{-1} and SAR higher than 15.

Table 2 Chemical composition of irrigation water

Water type	pH	EC	Na^{+}	Ca^{2+}	Mg^{2+}	SAR
		dS m^{-1}	ppm			
Tap water	8.1	0.7	39.9	95.6	11.2	2.1
Saline irrigation water		12	2752	65	485	50.4
Sea water	7.5	38.5	11211	266	1976	104.0

Experimental Conditions

The humidity and temperature were measured every 15 minutes using a hobo logger (HOBO H8 PRO SERIES LOGGER). While the range of temperature was generally higher at averaged 32 ºC than that of an actual green roof setting Takebayashi et al. (2007), there was a slight wind blowing inside the glasshouse through open windows.

Two different irrigation intervals were used: frequent irrigation (FI) and intermittent irrigation (II) with averaged to 2 and 10 days interval, respectively. Evapotranspiration rate (ET) from the vegetation, evaporation rate from the bare soil (E), and pan evaporation rate were measured by weighing pots with and without plants and a small evaporation pan (internal diameter of 0.35 m). Daily ET ratio (ET_r) and E ratio (E_r) were calculated by dividing ET and E with pan evaporation rate, respectively. The amount of irrigation water (V_i) applied to each pot was 1.2 times the observed ET during each irrigation interval so that the excess of water V_d can be used to leach the salt from the soil by drainage (Yamamoto and Cho, 1987a,b ;Corwin et al., 2007). The EC of the drainage water (EC_d) was measured using a portable EC meter (HORIBA Compact Conductivity Meter/B-173). At the end of the experiment, the dry matter yield (DM) of each plant was observed by weighing the shoots after drying them at 80 ºC for 3 days. The water use efficiency (WUE) is defined as follows:

$$WUE = \frac{DM}{TotalET} \quad (2)$$

where total ET is the total ET during the irrigation experiment, which is measured by weighting pots. The soil water content and soil EC were calculated from the water and salt balances in pot soil, described in Moritani et al (2013).

Statistical Analyses

The experimental treatment under saline irrigation which was classified as the most severe salinity condition was replicated more than 3 times. These samples were subjected to a mean separation analysis using a one-way ANOVA with a significance level of P <0.05. (PCA) was used. Principal component analysis (PCA) was carried out under each irrigation method on the standardized data matrix for reducing the data complexity and extracting the latent patterns. The analysis of PCA can condense the variations in the treatments by loading in two orthogonal axes that summarize the main underlying gradients (Tamene et al., 2006). To analyze the direct impact of the parameters of EC_i, DM

and WUE on the gradients, regression methods between the loadings of PC1 or PC2 and the correspondents of each parameter were calculated (Moritani et al., 2010; Singh et al., 2005). All of these statistical analyses were performed with SPSS software (Ver. 10.0).

RESULTS AND DISCUSSION

Influence of Evapotranspiration on Soil Salinity

ET for all plants decreased with time as EC_s increased, however ET of C.dactylon was observed with greatest amount. An average pan evaporation rate of 4.4 mm day^{-1} was observed during the experiment. Fig. 1 shows the decrease in evapotranspiration ratio (ET_r) and evaporation ratio (E_r) with increase in soil water EC (EC_s). The maximum ET_r for *S. kamtschaticum*, *C. dactylon* and *S. oryzifolium* was 2.0, 3.0 and 1.4, respectively. While the E_r exhibited a unit value of approximately 1.0, a decrease in the ET_r was observed for all of the plants caused by salt stress. The EC_s value when the ET_r became less than the E_r was at 10 dS m^{-1} for *S. kamtschaticum*, while at 2 dS m^{-1} for *S. oryzifolium*. In the case of *C. dactylon*, the ET_r moderately decreased, reaching a value > 0.8 at an EC_s value of 60 dS m^{-1}. The sharp reduction of the ET, particularly for *S. kamtschaticum* and *S. oryzifolium*, was assumed to be the result of the soil osmotic potential, which decreased the water uptake of the roots. Another reason for decreasing the ET might be the closure of the stomata during the day (preventing water loss from the plant) under the condition of salinity stress, alternating with the opening of the stomata during the night, when the evaporative demand was low.

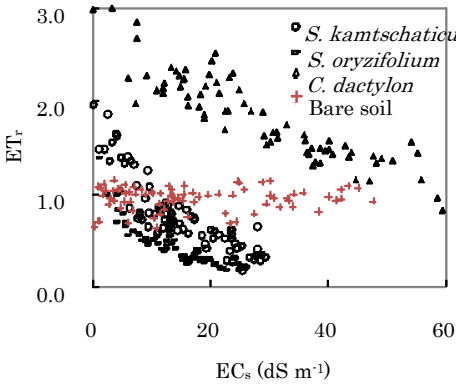

Fig. 1 The relationships between the EC of soil water (EC_s) and the evapotranspiration ratio (ET_r) of *S. kamtschaticum*, *S. oryzifolium* and *C. dactylon* and the evaporation ratio of the bare soil (E_r)

Dry Matter Yields and Water-use Efficiency

The total ET of *S. kamtschaticum*, *S. oryzifolium*, and *C. dactylon* in the control pots were 381, 192 and 574 mm, respectively. The 24 % reduction in total ET by soil drought condition under II was observed in *S. oryzifolium* compared to the control while those in *S. kamtschaticum* and *C. dactylon* were averaged to 64 %. Table 3 shows the total ET, DM, and WUE for all three types of plants under both saline irrigation methods. The total ET of *C. dactylon* under FI was the highest among others. However, this ET decreased by 48.2% under II that is statistically significant. The DM of all plants under the control showed similar values averaged to 15.7 (±0.8) t ha^{-1}. The DM of *S. oryzifolium* was the highest, although the ET was lowest; this led to the highest WUE (Table 3). While the WUE was not affected significantly by the irrigation method, the order of the WUE among these plants was as follows: *S. oryzifolium* > *S. kamtschaticum* > *C. dactylon*.

As mentioned above, CAM plants consume water efficiently when the stress is given however, the plant biomass decreases. The reduction of biomass is unfortunately not appropriate for improving the thermal performance and landscaping. A combination of high WUE and high DM are thus required for the high-quality green roof management. The quantification of this combination given as follows was undertaken as a factor of vegetated condition (FVC):

$$FVC = WUE \times DM \quad (3)$$

The FVC in Table 3 shows the relative value against the control in percentage. While the difference in the FVC between the FI and II conditions in each plant was insignificant (P <0.05), the FVC can be grouped depending significantly on the plant status. The FVC value was highest in *S. oryzifolium*, followed by *S. kamtschaticum* and *C. dactylon*.

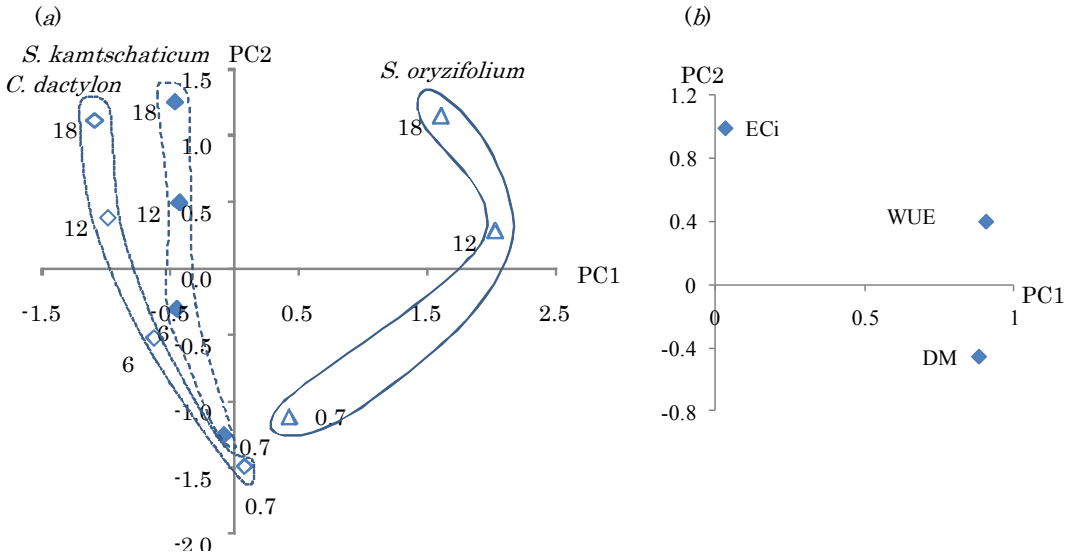

Fig. 3 Results of the principal component analysis under the frequent irrigation method. (*a*) Loadings: the enclosed lines indicate the group characterized the by underlying component associated with the factor scores. Numerical values indicate the EC of the irrigation water. (*b*) Factor scores: EC_i, DM and WUE indicate the EC of the irrigation water, dry matter yield and water use efficiency, respectively

Multivariate Analysis

The PCA resulted in two significant principal components (PC), PC1 and PC2, with eigenvalues > 0.8, which explained approximately 98% of the total variance in the dataset. The PCs provide information on the most meaningful parameters, which describe a whole dataset, affording a data reduction with a minimal loss of the original information. PC1 and PC2 therefore explain the most significant part of the variance within the variables (Pardini et al., 2003). Figs. 3 (a) and (b) show the loadings and factor scores from the results of the PCA, respectively, under FI. The treatments for each plant tended to be divided into same group, as shown by the enclosed lines in the figure. The factor scores indicate that the higher EC_i, for example, decreased the DM but increased the WUE. In the loadings, group of *S. oryzifolium* was distributed in the range of a high positive x-axis. From the factor scores, DM and WUE were gathered in the positive x-axes. This indicates *S. oryzifolium* meets the requirement of a high DM with a high WUE. *C. dactylon* tended to be in the lower DM and WUE ranges, while *S. kamtschaticum* was distributed between these two plants. These tendencies were also observed under II. One of the different results in PCA between two irrigation methods was that the y-axis of EC_i was closer to the DM and WUE under II. This indicates the influence of the EC_i on the DM and WUE decreased, as compared with that under FI. This is because the drought stress was added under II, which in turn decreased the influence of the salt stress expressed as EC_i, relatively.

Table 3 Total ET or E, DM, WUE and FVC of *S. kamtschaticum*, *S. oryzifolium* and *C. dactylon* in the two different of irrigation of frequent (FI) and intermittent (II) with saline irrigation

	S. kamtschaticum		*S. oryzifolium*		*C. dactylon*		Bare soil	
	FI	II	FI	II	FI	II	FI	II
ET or E (mm)	157.3 b	91.8 a	93.3 a	93.2 a	366.2 c	189.0 b	184.2 b	163.9 b
DM (t ha^{-1})	10.3 a	9.0 a	17.0 b	15.5 b	10.4 a	8.2 a		
WUE (kg m^{-3})	6.7 bc	9.9 c	18.3 d	16.9 d	2.9 a	4.4 ab		
FVC (%)	133.7 b	151.3 b	241.8 c	207.7 c	62.7 a	75.5 a		

Letters indicate significance level at 0.05

The higher WUE observed in the CAM plants, with a little reduction of the DM, highlights the benefit of using them as green roof vegetation, in terms of low water management requirements and a high quality of landscape. This study did not account for the leaf fall that is characteristic of *S. oryzifolium* during the winter season that may change the WUE and may damage the green roof landscape. Therefore, a year-round study needs to be performed in future to evaluate the WUE during the dormant season.

CONCLUSION

In this study, the performance of two CAM plant species, *S. kamtschaticum* and *S. oryzifolium*, were evaluated under frequent and intermittent irrigation conditions with saline water. A prompt decrease in ET with increasing EC_s was found under *S. kamtschaticum* and *S. oryzifolium* compared to that of turf grass, *C. dactylon*. As a consequence, the dry matter yield showed the following order: *S. oryzifolium* > *S. kamtschaticum* > *C. dactylon*. This is evidence that saline irrigation reduced the dry matter yield but increased the WUE in CAM plants, resulting in a decrease in the amount of irrigation water required. In other words, saline irrigation to CAM plants saves water. The paradox is that maximum plant growth would imply maximum dry matter yield, which would contribute to carbon sequestration, but would also require maximum irrigation water. However, the higher WUE seen in CAM plants with a little reduction of DM makes them suitable for green roofs in terms of low water management requirements with keeping high quality of landscape. This knowledge of CAM plants' response to saline irrigation, dry matter yield and WUE could help in selecting suitable plants and in designing optimal saline irrigation systems and scheduling for green roofs.

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Research article

Mechanism toward Resilience Building in the Face of Climate Change: A Review for Cambodian Rural Communities

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Abstract The article discusses the current climatic situations in Cambodia and existing mechanisms of the country to address climate change (CC) and the level of rural communities being able to adapt to CC. Reviews of various CC related documents indicate that structures and mechanisms at national level to address CC are adequate but limited at community level. The existence of the structures is beneficial to local people unless the adaptive capacity is enhanced with sufficient technological alternatives, implications and applications with wider sector involvement and a decentralization system. An emerging barrier to resilient building of community and the country is limited of fiscal decentralization as the current financial sources for CC resilient building are solely dependent on external funds for decades while these sources are declining. Additionally, informational, technical and managerial inputs are still strongly required for local communities in order to ensure that the least consequences of any occurred climatic hazards can be obtained. Involving private sector would, therefore, be a good option for local communities in the future provided that private investors have skills to effectively manage rural infrastructures, for example irrigation systems.

Keywords rural development, climate change mechanism, environment

INTRODUCTION

In the year 2012, Cambodia was ranked as the 26th most vulnerable country to CC in the world (Kreft and Eckstein, 2013). In 2011, Cambodia was ranked as the 10th most affected country in the world with more than 250 people being killed as a result of flooding (Kreft and Eckstein, 2012) and 270,000 hectares of cultivated land being destroyed, affecting more than 50,000 households (Wise, 2012). Despite being a fairly-small country (181,035 km^2), the temperature in the year 2030 is estimated to vary greatly per its geographical location with the average increase of about 2^{0}C (MoE et al., 2011). The variation in these conditions makes the country's level of vulnerability differ as well. Despite being in a high level of vulnerability, the country has paid attention to the problems of CC only in the last decade. Since early 2010, CC concepts have been integrated into several new emerging national programmes and onto the development agendas of more state institutions and civil societies development organizations, including National Strategic Development Plan (NSDP), Rectangular Strategy Phase II (Pheakdey, 2013), and Sub-National Reform Strategy. These concepts are eventually in the Cambodia Climate Change Strategic Plan 2014-2023 (RGC, 2013). These have been added to the CC resilience building agenda for the country at both national and sub-national levels. Despite CC concepts being arguably captured and integrated into various policy documents at national level with some tangible accomplishments to be proud of; exposure, sensitivity and adaptive capacity of local communities to CC have posted continuous questions and doubts.

OBJECTIVE

The purpose of this paper is to explore the extent to which local communities are ready to face up to the upcoming repercussions of the ever-changing climate. The objectives of the article are to provide an overall understanding on climate change issues and impacts on rural livelihood, to explore and assess the existing mechanisms to cope and build rural community capacity and resilience in the face of CC in rural communities in Cambodia.

METHODOLOGY

Literature reviews in combination with actual experience working in the field of climate change is a method being used for preparing this study. Various documents including research articles, government policy documents and project implementation reports of related institutions on climate resilience and mechanism had been consulted. The information relevant to climate change policy, studies, and decentralization and deconcentration (D&D) policies and mechanisms of three main stakeholders; Cambodian governments, development partners and civil society organisations; was gathered and synthesized so that insights of climatic issues and responses can be revealed and appropriate measures can be suggested. Prior to the analysis, the socio-economic context, particularly poverty and responses of rural people was studied to determine the relationships of climate change impacts on rural livelihood and effectiveness of the existing measures can be identified. From these associations, the possible approaches would be able to propose.

RESULTS

Cambodia Rural Livelihood

Agriculture and natural resources: In Cambodia, there is still a majority of poor inhabitants residing in rural area with agriculture as their main occupation, employing more than half of the country's labour force. Rice production, covering more than 80% of total cultivated land areas, is the most dominant crop. Nearly 80% rural families are rice farmers. Rice production contributed 10% of country's total export commodities in 2007 (Yu and Diao, 2011). Fishing is also an important part of rural people's daily life. Nearly 80% of Cambodian animal protein consumption is from fish (Hortle, 2007). Animal husbandry is one of the key drivers in rural livelihood, contributing to 7.6% of GDP. Cattle and buffaloes are the biggest share of the sector with nearly 80% of the total animals in the country (FAO, 2004) and number of animals in 2009 was 29 million being known as not only the source of draught forces but also savings (Bansok et al., 2011). Forestry is a subsistence source of livelihood for nearly 80% of the population in rural areas. However, the pressure being put on these forest areas by economic land concessions is gradually putting the livelihood of the rural people under threat (Bansok et al., 2011).

Poverty and migration: Poverty and inequality are still rampant in Cambodia. Poverty rate was reported to be around 25.8% in 2010 of which 91.1% of them were residing in rural areas (MoP, 2010) and the figure was 20.5% in the year 2011 (The World Bank, 2013). Despite the small proportion of the poor, the group that is sensitive to poverty is proportionally large, i.e. a small change in consumption should bring 41% of the rural people back into the group under the poverty line (The World Bank, 2013). The vulnerability of the rural people is very high as low income is unable to cope with natural shocks and migration to other parts of Cambodia and abroad is a kind of an autonomously adaptive mechanism to disaster events (Bylander, 2013). Floods caused migration as in the floods of year 2011, which caused around 9% of rural poor migrated to obtain jobs (RGC, 2012). This would be

greater in the near future because of the upsurge of rural labour forces and less available land for agricultural production due to economic land concessions (Scheidel, 2013).

Impacts of Climate Change

Direct impacts of natural phenomena such as storms, floods and droughts are significant. Typhoon Ketsana in 2009 resulted in large damages and losses. For rural road alone, the costs were estimated to be about USD 28 million (RGC, 2010). The adverse effect of the 2011 flood on rural infrastructure was one of the worst impacts in Cambodia's recent history resulting in immense damages on rural infrastructures (Wise, 2012). In addition to floods, droughts have been found to have the most frequent effect on rural people despite being paid less attention from related state authorities (UNDP, 2010). CC has a strong association with rural livelihood. Any changes can make profound impacts on food security and way of life in the rural areas. For example, changes in rainfalls and temperatures have a significant impact on productivity of rainfed rice (Mainuddin et al., 2012), resulting in decreasing rice yield (Johnston et al., 2010). The effect is even worse as agricultural production in rural areas generally depends mainly on rainfall and only 18% of the cultivated land areas have irrigation systems (Yu and Diao, 2011). Animal husbandry is reported to be sensitive to changes in temperature (Jhonston et al., 2010). Infections and diseases are more likely to occur (Seo and Mendelsohn, 2007), especially during the hottest period of the year (Bansok, 2011). All of these have made people think that agriculture is not a good choice (Bylander, 2013). These factors have made rural people greatly vulnerable to the impacts of CC as their adaptive capacity is weak (Gallopin, 2006).

Climate Change Adaptation Mechanism

National adaptation mechanism: Adaptive mechanism to CC in Cambodia is complicated with overlapping roles of institutions. The most well-known institution dealing with disaster and risk reduction is National Committee for Disaster Management (NCDM), albeit having limited authorities and budgets for implementation. A number of state institutions have declared that they have the mandates to tackle the issues. In late 2006, the National Climate Change Committee was established with a coordinating body under Ministry of Environment and a number of state institutions as members including the Ministry of Agriculture, Forestry and Fishery, Ministry of Water Resources, and Meteorology, Ministry of Health and Ministry of Planning as implementing agencies. Another agency is Ministry of Interior that involves mainly with deconcentration and decentralization reform (CCCN, 2014). The Ministry of Interior is leading a nationwide reforming programme of the country and is also involved in the process of integrating CC concepts into local authority plans and budgets. The state budget has channelled funding to local level authorities through this programme (Kimchoeun, 2011). Despite having a coordinating institution, the actual process in coordinating is difficult and time consuming.

Sub-national level mechanism: There is no specific study spelling out the mechanism at sub-national level in response to CC, except the common state administrative system; national, provincial, district, community, and village level. Each administrative area can have a chance to be supported on the topic of CC unless the area has been included in any CC programmes or projects. Apart from this common administrative structure, the system being used to respond to climatic hazards of the National Committee for Disaster Management and the CC capacity building of Ministry of Environment is almost the same to the existing administrative system of the government.

Non-governmental organizations: Non-Governmental Organizations and Civil Society Organizations are playing a major role in developing rural areas and communities. International development organizations coordinate for financial support, implement climate change related projects and advocate the establishment of policy documents. These organizations include UNDP, the World Bank, Asia Development Bank, DANIDA, IFRC-RCS, SIDA, Plan Cambodia, and Oxfam (AIT, 2010). The

organizations provide financial, technical, and policy advocacy in the country. Local organizations make proposals for financial support from these international development organizations to implement projects at community level.

Community Mechanism and Resilience

Sovacool et al. (2012) have indicated four domains of CC resilience: institutional, capacity, financial, and infrastructural; that should be included in any development project implementation. These four domains have been so far accomplished to some extent. Insight analyses of these domains depicting the level to which local communities that are capable to adaptation and being resilient to CC are provided below.

Institutional resilience: Cambodia has made its progress in sub-national reform. In the year 2001, a Commune, Sangkat Law, was established to decentralize the state authorities to local authorities. Another move was made in 2008 as the establishment of Organic Law giving birth to the deconcentration reform making the district and provincial levels closer to community level rather than national level (Niazi, 2011). Apart from the administrative reform, the efforts in integrating CC concepts at grassroot level have already been framed and legalized to some extent. These include the establishment of livelihood based groups, such as water user groups, livelihood improvement groups, and farmer water user groups at community level. However, these groups are not in a good position to respond to the challenge of climatic events in a broader perspective because their capacities are at the stage of requiring further supports, including technical, managerial and financial. Moreover, these groups minimally contribute to their livelihoods (Conan et al., 2013; UNDP, 2013a; Silva et al., 2013). In this regard, a number of established local organizations are unable to survive long after their support has ended. Additionally, poor governance in almost all sectors at all management levels is observed rampant and is hindered the country's sustainable development (Nguyen et al., 2010).

Capacity resilience: Institutional and individual capacity of Cambodian rural communities is weak. Cambodia is ranked as the 138th in the world Human Development Index (UNDP, 2013b). According to MoE et al. (2011), the Human Development Index of each province varies greatly based on location. Knowledge on CC is found to be limited among villagers who find it difficult to define and information regarding their problems for practical purposes. This has brought another barrier for local community to respond to CC as they have limited and irregular sources of information about the coming weather related events from Early Warning System or responsible institutions (CCCN, 2014). Without proper information and institutional support, the capacity of rural communities tends to be weak putting them at immense risk, particularly the poor and the near poor. In addition, the adaptive capacity of the communities is limited. These require continuous technical support to strengthen the capacity for both individual and communities.

Financial resilience: As the people of the country become aware of the concept of CC and external funding for providing this issue is more available, there is a shift in conventional development focus of NGOs toward CC resilience building and adaptation. One major concern of finance is that external sources contributed nearly 90% of the country's development investment since 2005 (Sato et al., 2011). The current external support of CC finance is reported to be worth about US$ 655.6 million out of which US$ 338.8 million has been disbursed and US$ 316.8 million is for the years 2014-2020 (Pheakdey, 2013). A decentralized system should have been a long-term source of budget for local development. However, fiscal decentralization is not in place for implementation (Kimchuen, 2011). Though, there is room for collective actions for communities - including water user groups, farmer water user groups and livelihood improvement groups - in mobilizing local resources for specific purposes. However, the groups are either more self-dependent or rely more on support of non-governmental organizations that are themselves generally facing the problem of viability. These have given the authorities limited financial solutions toward both conventional development needs and consequences of climatic events.

Infrastructural resilience: The majority of Cambodian rural infrastructures are designed for normal situations without consideration for climate hazards or natural phenomenon. As a result, these infrastructures can be damaged easily. According to RGC (2010), poor quality of foundations and subgrades, prolonged wet conditions and poor standard of designs, e.g. inadequate drainage systems are identified as factors contributing to rural roads being unable to withstand bad weather. The concept of climate resilience infrastructure has been newly introduced into various sector infrastructure developments. Climate resilient infrastructure projects are being integrated into various related Ministries with the support of Project for Piloting the Climate Resilience (PPCR) that allocates budget of US$86 million to improve the climate resilience of Cambodia's core sectors. This includes water management, agriculture, and rural infrastructure as well as institutional capacity development (CIF, 2012). There is no other sign of allowing for CC integration into the infrastructure development of the country.

DISCUSSION

Despite availability of provision for good CC structures and mechanisms at national level, and for decentralization and de-concentration systems at sub-national level, there are still major concerns regarding financial, capacity and infrastructural resilience building. Considering poor governance and management at all levels, in combination with dependence on external sources of finance, it is hard to forecast a strong future for Cambodian rural communities (Hill and Menon, 2013; Nguyen et al., 2011). This has become worse with the rural infrastructures being insensitive to environmental shocks and weak individual capacity. It will be difficult to reverse this situation because external funding is going to decline over time. The situation could become better when there are proper financial mechanisms to provide adequate sources of investment in each community and the introduction and implementation of fiscal decentralization. By making this reform, communities would be able to mobilize local resources and be able to respond immediately to the occurrence of any climatic disasters. This does not necessarily mean that the problem of making provision for CC in the future is insurmountable. Administrative reform in enhancing a community based taxation system, encouraging safe migration as an additional source of funds replacing agriculture, and strengthening the ecological system as a secondary source of livelihood would mitigate the problem. The concern related to water shortage could be solved by enhancing small scale irrigation systems. This would bring back community capacity to systematically cope with CC nationwide. For example, a government program on micro-finance credits – with low interest rates to involve more private sector participation to invest in the water sector – would help farmers escape from the water shortage which occurs frequently in Cambodia. Being aware of the possibility of natural disasters happening and being ready to respond to disasters should be encouraged. Farmers or local people should have adequate and accessible to information and knowledge on how risks can be mitigated. This needs more attention to the existence of CC and more understanding of the problems by both national and sub-national level of CC related institutions.

CONCLUSION

Cambodian rural communities are facing barriers in coping with CC with very limited resources including financial, capacity and infrastructure, albeit institutional mechanism slightly strengthened lately. Programmes based on *ad hoc* supports will not improve the situation since the financial and technical capacity of local people varies so greatly from one location to another. Construction and maintenance of irrigation systems and climatic event information dissemination need to be done regularly. As migration is the farmers' coping mechanism in response to environmental shocks, it measures to ensure that migration is safe for them is required. Additionally, natural resources

conservation is significant because migrants utilize natural resources as part of their livelihood activities. It would, therefore, be better for the farmers to be trained to be resilient so that all livelihood activities - including agriculture, forestry, animal husbandry, water and provision of climatic information - can properly interact and all the farmers and villagers can be reliably informed. In the face of CC and limited financial resources, fiscal decentralization for creating local sources of funds and encouraging private sector participation would be optimal for community people to give them freedom in choosing solutions to tackling the issues though technical and managerial supports should never be left out of the agenda.

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Research article

Farmers' Soil Conservation Practices of Maize Production, Paklay District, Sayabouly Province, Lao PDR

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Abstract Soil degradation is a big problem on the hill slopes in the Lao PDR where maize is the main crop and intensively grown. Due to this, maize yield was lower than 3.8 ton/ha which also impacted the environment as well as farmers' incomes. Soil Conservation Practices (SCP) are important alternative methodologies for soil conservation on sloping land. The objective of this study was to examine the farmers' current soil conservation practices for maize production in Paklay district, Sayabouly province. The study employed participatory rapid appraisal (PRA) methods and data was collected through focus group discussions and semi-structured interviews from three villages (Village 1: Palay 46 households, Village 2: Boumlao-Phakeo 90 households and Village 3 Senphon 25 households, totaling 161 households). The key informant interviews were implemented through the staff of the District Agriculture and Forestry Office (DAFO) and the village headmen. The results showed that 73% of farmers practiced SCP; the major SCP practices included 100% intercropping, 60% crop residue management, 12% crop rotation, 12% conservation tillage and 3% organic fertilizer application. The use of SCP showed an increase in soil fertility, an improvement in the maize yield and soil erosion prevention on hill slopes. The majority of maize farmers who adopted SCP applied the legume intercropping method. The legume (i.e. groundnut, red bean, mungbean and black bean) were planted two weeks before the maize harvest. Crop residue was used for mulching (conserving soil moisture and soil nutrition). Furthermore, knowledge of SCP systems such as chemical use, residual crops, intercropping, mulching, tillage, and chemical soil contamination needed to be provided to farmers by staff of the DAFO.

Keywords maize, soil conservation practice, crop rotation, intercropping

INTRODUCTION

In Laos, many rural farmers have traditionally been engaged in subsistence food production. Since the middle of 1980s, the government of Laos has publicized a slow liberalization of the national economy. Shifting cultivation was replaced by the intensive cultivation of cash crops such as maize, sugarcane, cassava and rubber (Viengpasith et al., 2012). Amongst the cash crops, maize has been ranked the first in terms of volume (Phanvilay et al., 2006). Therefore, the area of maize production has increased more than 7 times from 2003 to 2010 (Thanichanon, 2012).

Sayabouly province is one of the provinces which produces the largest amount of maize as maize covers more than 98% of the total area (Lestrelin and Castella, 2011). However, over the past decade, maize production has extended into preserved forest areas. Moreover, plowing practices and increased application of pesticides, herbicides and chemical fertilizers contribute to soil degradation (e.g. soil erosion, weed outbreak, and chemical contamination) (Lestrelin et al., 2012). In addition, an increase in

the volume of maize production combined with low productivity will need more farmland and this tends to cause a change in land use and land covers.

In the 2000s, conservation agriculture had been promoted in Sayabouly province by Application Site Southern Sayabouly or Point d'Application du Sud du province de Sayabouly (PASS) and the National Programme on Agro-Ecology or Programme National Agro-Ecologie (PRONAE) in order to maintain soil fertility for sustainable agriculture in the transitional period for agriculture while controlling the negative impacts on land use. Conservation agricultural practices such as no-tillage, cover crops, crops rotation and/or crop residue management have been shown to have positive impacts on preventing soil erosion, as well as having a positive impact on soil maintenance and/or the renewal of the soils' physical, biological and chemical properties and on soil moisture (Lestrelin et al., 2012).

Therefore, one of the key factors for improving the efficiency of maize production is to increase the technical efficiency of maize farmers (Southavilay et al., 2012). Moreover, soil conservation practices are the best way to enhance maize product and sustainable land use.

OBJECTIVE

The objective of this study was to examine farmers' current soil conservation practices on maize production in Paklay district, Sayabouly province.

METHODOLOGY

Samples were selected from the famers who currently cultivate maize and the famers who had been involved in the PASS and PRONAE projects in years 2000s in Paklay district. Data collection was done through the participatory rapid appraisal (PRA) approach in 3 villages (village1: Palay, village 2: Boumlao-Phakeo and village 3: Senphon). Village headman interviews, focus group discussions and household interviews were conducted. Semi-structured interviews were conducted with a total of 161 household representatives, which was made up of 46 households from Village 1, 90 households from Village 2 and 25 households from village 3. The topics for focus group discussions and interviews included a history of farmers' traditional practices, soil management practices, cropping patterns and physical characteristics of the study areas. The total numbers of samples were calculated by Yamane (1967) as shown in Table1.

Table 1 Household interviewees in three target villages

Village	Total Household (HH)	Percentage of household (%) Cultivating maize	Household interviewed (HH)
Village 1	348	98	46
Village 2	928	95	90
Village 3	295	98	25
Total			161

Source: Field survey, 2015

RESULTS AND DISCUSSION

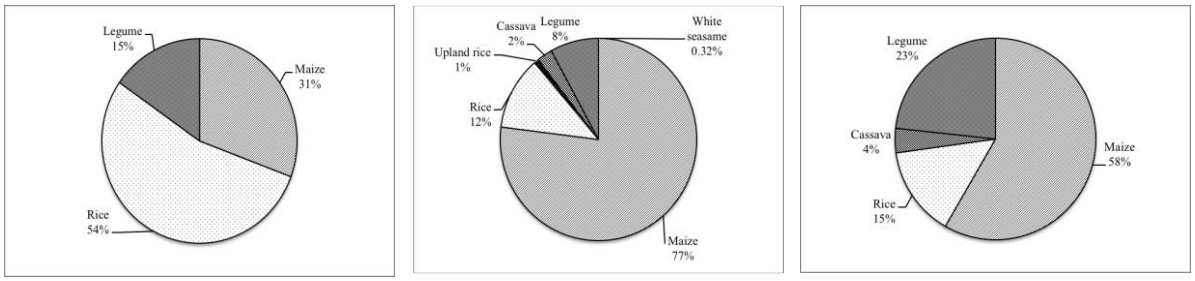
Background of Conservation Agriculture Promoted in Study Area

For intensive crops production in hill slope areas, conservation agriculture (CA) had been promoted through PRONAE (started 2001) and PASS (started 2005) in the 2000s. The concept of the projects

was direct seeding mulch-based cropping (DMC) systems. DMC systems are cropping systems that involve no-tillage and permanent plant cover on the soil. The government had set a policy to spread CA over all the country to reduce soil degradation, chemical use and improve soil fertility to help preserve the environment.

Main Crops and Soil Characteristic

Farm types: There are various crops which are grown in these areas. Rice is the main crop for household consumtion, while maize, legume and other crops are commercial crops. Farm types in all the three villages have a similar pattern because the environmental context and the livelihoods are similar in terms of the cropping areas in each village. In Village 1, maize production covered 31% of the planted area, rice covered 54% and the legume area covered 15%. In Village 2, maize production was highest at 77%, while the rice planted area was 12% and the legume planted area was 8%. For Village 3, rice covered 15% of the planted area, maize covered 58% and legume covered 23% as shown in Fig. 1.



Village1: Palay Village 2: Boumlao-Phakeo Village 3: Senphon

Fig. 1 Farm types in three villages of study area

Soil charateristics: According to the interviews with farmers, it was found that there are six different soil types in the study areas. The majority of soil types are loamy soil. This soil type is very suitable for cultivation, especially for maize production. The soil characteristics in the three villages are quite similar. Loamy soil contributes to 67%, 60% and 76% of the agricultural area in villages 1, 2 and 3 respectively. In addition, there is chalky soil at 12%, 17% and 20% for villages 1, 2 and 3 respectively.

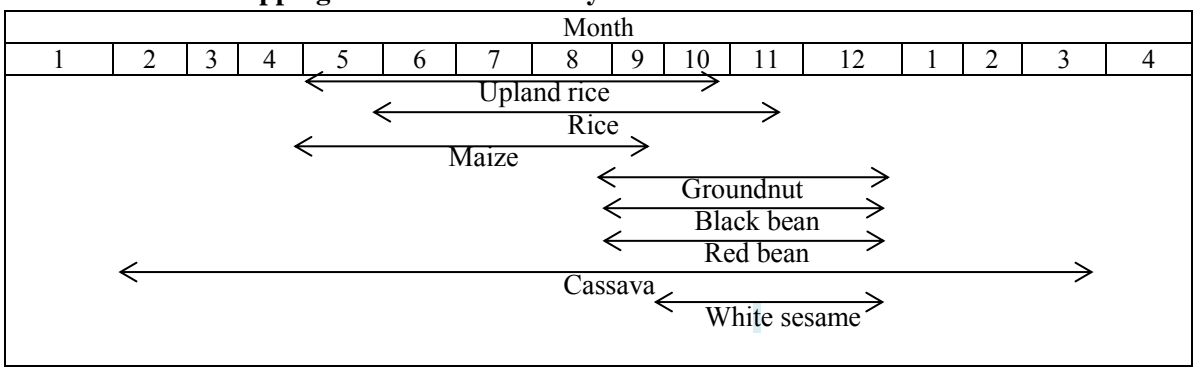
Table 2 Soil characteristics of three villages

Physical	Village 1 (n=46)		Village 2 (n=90)		Village 3 (n=25)	
Soil type	▪ Loamy	67%	▪ Loamy	60%	▪ Loamy	76%
	▪ Sandy	-	▪ Sandy	4%	▪ Sandy	-
	▪ Clay	8%	▪ Clay	1%	▪ Clay	-
	▪ Silty	14%	▪ Silty	10%	▪ Silty	-
	▪ Peaty	-	▪ Peaty	9%	▪ Peaty	4%
	▪ Chalky	12%	▪ Chalky	17%	▪ Chalky	20%

Source: Field survey, 2015

Cropping calendar: In the study areas, most of the cropping activities were concentrated during the rainy season because the area is sloping land. There were no irrigation systems for crop production in the dry season. Table 3 shows the duration of the cropping season for the three villages.

Table 3 Cropping calendar of the study areas



Source: Field survey, 2015

Famers' Practices in Maize Cultivation

Maize production systems: In the past, maize production was a traditional practice where farmers depended on indiginous knowledge. Since the government has introduced the policy of stopping slash-and-burn and shifting cultivation, the area was replaced by intensive, market-oriented agriculture. Maize became the first and most important cash crop which generally involved the use of hybrid varieties, fertilizers and pesticides, the burning of crop residues for land preparation and plowing on steep slopes, (even mechanical plowing with tractors). After a conservation agriculture project had been impremented, the maize production system has been changed to intercropping and crop rotation so the famers in the study areas mostly practice maize and legume relay intercropping. There are four kinds of legumes which include groundnut, red bean, black bean, and mungbean in this system.

Soil conservation practices: It was found that the farmers in the three villages practiced similar methods of SCP because the context of the area was also similar. In total, 73% of farmers practiced SCP. The major practice of SCP was 100% intercropping followed by 60% crop residue management, 12% crop rotation, 12% conservation tillage and 3% organic fertilizer application as shown in Table 4.

Table 4 Soil conservation practices of farmers in the study areas (N=161)

Study area	Soil conservation practices (%)		Soil conservation practices									
			Inter-cropping		Crop residue		Crop rotation		Conservation tillage		Organic fertilizer	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Palay	30	19	30	25	17	24	5	42	5	42	2	50
Boumlao-Phakeo	71	44	71	60	44	62	3	25	3	25	1	25
Senphon	17	11	17	14	10	14	4	33	4	33	1	25
Total	118	73	118	100	71	60	12	10	12	10	4	3

Source: field survey, 2015

The households interviewed were questioned about the methods of SCP that they had applied to their farmland and were asked to explain the details of each method. The current practices for SCP in the study areas had the following processes:

Intercropping: The farmers' responses showed that legumes have been used for intercropping with maize production. Legume cropping starts near the end of the rainy season because it's resistant to dry conditions and it is also a short duration crop. In practicing intercropping, farmers planted legume within one or two weeks before the maize harvest; they planted only some part of the maize area in one year and moved to other parts of the maize area for the next year. As the farmers observed, legume

intercropping could improve soil fertility. Furthermore, legume production could increase the family income.

Crop residues management: In general, crop residue management is not widely practiced yet but some farmers have used the agricultural residues for controlling soil erosion and suppressing weeds. In addition, maize residue can be bean trellis and livestock feed. There are a small number of farmers who burn crop residues after the harvest for land clearance before they plough the land to grow maize.

Conservation tillage: In the study areas, only 10% of farmers practiced conservation tillage. The condition of the areas is suitable for conservation tillage because land preparation for the high slopes must consider soil erosion. The conservation tillage methods are practiced for reducing soil erosion on the farmland and the plowing is conducted across the slope. Moreover, conservation tillage maintains soil fertility. There were farmers that do not plough or plough only some years to preserve soil fertility, decrease soil degradation and soil erosion. However, farmers are still concerned about conservation tillage as it may cause hard soil and extreme weed growth.

Crop rotation: Farmers grew legume as a part of a crop rotation program, especially groundnut. They would grow groundnut after maize, but the proportion of groundnut was less than maize. Aside from improving soil fertility, legume rotation also has the advantage of reducing soil degradation. It could also generate more income for the farmer.

Organic fertilizer: In the study area, not many farmers applied organic fertilizer in order to improve soil fertility, mainly by using manure from livestock. Organic fertilizer has not been well acknowledged and livestock production in the study area still uses traditional systems so famers do not have much manure from their livestock to apply to farmland. After the planting season, farmers let their cattle roam freely so their farmland gained manure from freely released animals. Although organic fertilizer is not enough for crop production, it can still help to improve soil fertility.

Farmers' adoption level on SCP: Depending on the number of SCP methods practiced, it was found that there were three levels of farmers' adoption of SCP, 11.80%, 33.54% and 27.95% of farmers had high, medium and low levels of adoption respectively. In addition, there were 26.71% of farmers who did not adopt any method of SCP.

Table 5 Adoption levels of farmers sampled

Adoption Category	Variable	Frequency	
		Number	Percentage
0	Non-adoption	43	26.71
1	Low adoption level	45	27.95
2	Medium adoption level	54	33.54
3	High adoption level	19	11.80
Total		161	100.00

Source: field survey, 2015

Farmers' understanding on SCP: According to focus groups discussions and semi-structured interviews, it showed that farmers understood the advantages and disadvantages of SCP methods before the adoption of SCP. In addition, the practices also showed that farmers understood soil conservation practices.

CONCLUSION

This study indicated that about 73% of farmers practiced SCP, which included the five main methods. 100% of farmers practiced SCP by intercropping, 60% by crop residue management, 12% by crop rotation, 12% by conservation tillage and 3% with organic fertilizer. Furthermore, it was found that there were three levels of farmers' adoption of SCP, 11.80%, 33.54% and 27.95% of farmers had high, medium and low levels of adoption respectively. In addition, there were 26.71% of farmers who did

not adopt any method of SCP. Moreover, farmers understood that SCP is the knowledge, perception and practice needed for soil fertility improvement. Therefore, in order to improve soil fertility, it is necessary to improve the knowledge, the perceptions, adoption levels and the practices of famers of SCP methods.

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Research article

Improving Waxy Maize, the Heritage of South East Asia

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Abstract Amylose-free (*waxy*), i.e. amylopectin maize has been a vegetable and staple food in East and South-East Asia for centuries, resulting in hundreds of landraces (LR). Eating preferences could have resulted in the additional selection for different starch properties of *waxy* maize, of interest in the food and feed industry. But within twenty LR from Vietnam and Thailand, disappointingly no evidence was found for special starch properties. For minority ethnic groups *waxy* LR are still the main staple food, well liked for their soft grains with favorable cooking properties. But maize protein is severely lacking in quality that makes waxy maize an unsuitable staple food especially for small children. High quality protein maize (QPM) developed by the International Maize and Wheat Improvement Center (CIMMYT) has 90% of the nutritive value of milk protein. We combined the recessive *waxy* and QPM alleles into modern high yielding lines resulting in double quality grains. In a second step this double quality was introgressed into two landraces of the Hmong minority by two backcrosses. Seeds are available now of the two improved *waxy* landraces, which possess high yield potential, high protein quality and good eating quality. Consumption of double-quality *waxy* maize as staple food will improve the diets of children, a good reason to produce it.

Keywords *waxy* maize landraces, starch quality, quality protein maize, ethnic minorities

INTRODUCTION

Maize was probably introduced to Asia in its native wild-type form during the 16th century from Central America. Normal grain starch consists of two glucose polymers, amylose and amylopectin, which assemble into semi-crystalline granules. Amylopectin accounts for 60 to 90% of the granule weight. It is a highly branched polymer in which the glucose units are linked via α-1,4 and α-1,6-glucosidic bonds. In contrast, amylose consist mostly of α-1,4-linked glucose, forming long linear chains inside the starch granule.

Soon after arrival, amylose-free (*waxy*) mutants were cultivated as a common vegetable and staple food from Japan down to Myanmar. This closely follows an old consumer preference for amylose-free rice, also called glutinous or sticky rice, in Asia that dates back 2000 years (Olsen and Purugganan,

2002). The selection for the recessive *waxy* allele can be attributed to a strong preference for soft grains with more desirable cooking and flavor properties (Fergason, 2010). Sequence analysis of *waxy* landraces (LR) from southwest China, suggest independent parallel selection for the *waxy* trait in this region (Fan et al., 2008).

South East Asia was successful in reducing hunger and poverty by less rice and more meat and milk consumption (FAO, 2008). However, in hilly marginal areas the majority of people belong to diverse minority ethnic groups. Beside global poverty and low educational level, the main problems of those minority ethnic groups are the access to land, water and markets (Huynh, 2002). For them, *waxy* maize landraces still remain the staple food and meat is only rarely consumed (Swinkels and Turk, 2006). This makes an urgent task to improve their protein uptake.

Waxy maize has soft grains that are especially suitable for preparing traditional dishes such as porridge or for the consumption of immature ears as a vegetable. Sensory acceptance of *waxy* maize is mostly determined by the right degree of firmness and the absence of stickiness of cooked kernels. In turn, both firmness and stickiness are controlled by the structure and composition of starch. In *waxy* maize, starch basically consists of branched high-molecular amylopectin; the linear amylose is virtually absent. Protein of maize is lacking both in quality and quantity. For the nutrition of humans lysine is one of the most important amino acids, followed by tryptophan. But the lysine and tryptophan contents of zeins, the main protein type in maize, are quite low (FAO, 1992). Therefore it is essential to raise the protein quality in maize based diets. Breeding for maize with enhanced protein quality started in the mid of the 1960s, when mutants with an increased lysine content, like opaque2 (o2) and floury2 (fl2), were discovered; the increase in essential amino-acids results from a change of the relative amounts of different fractions constituting the maize endosperm proteins (Vasal, 2001). An agronomically superior form of o2 germplasm with hard endosperm was named high quality protein maize (QPM) by the International Maize and Wheat Improvement Center (CIMMYT, Mexico), in opposition to the soft endosperm o2, called standard o2. This novel maize type has 90% of the nutritive value of milk protein for young children (FAO, 1992).

In recent years we were successful in combining two recessive traits, *waxy* and QPM (w/o), into one new kernel type with normal aspects, i.e. suitable for staple food (Dang et al., 2011; Sinkangam et al., 2012). Those findings were recently confirmed (Zhang et al., 2013). This provides now a firm basis to tackle the problem of protein malnutrition in a double approach, improving the staple *waxy* maize agronomically as well as nutritionally: as our new w/o lines are derived from modern agronomic stock, they should be suitable to upgrade by introgression the protein quality of traditional landraces and to improve the yield by residual effects. *Waxy* maize landraces from the Hmong minority in Vietnam were chosen as targets that excelled by good eating taste.

OBJECTIVE

The very low indigenous protein quality of *waxy* maize landraces must be improved by incorporating quality protein (QPM) genes. This requires that two grain mutants are expressed together without impairing the vitality of the grain. This double quality breeding material can then be implemented into the food chain of malnourished people in South East Asia. In a second approach, the starch quality of a representative set of Thai and Vietnamese *waxy* landraces was going to be analyzed for the potential of new types that could be of value for the food and feed industry.

METHODOLOGY

Starch Quality

Waxy maize landraces (LR) were chosen (Fig. 1) that are or had been used by ethnic majorities and minorities in Thailand (12 LR; Anonymous, 1983) and in Vietnam (8 LR; Maize germplasm section - National Maize Research Institute, 1997) in representative regions of cultivation. A commercial *waxy* feed grain hybrid (PR38A22, DuPont/Pioneer) was used as a control.

For amylose quantification, differential scanning calorimetry (DSC) and starch granule size distribution was utilized, extracted starch was analyzed for amylose content according to Hostettler et al. (2011). Starch granule size was quantified by digital image analysis coupled to light microscopy (Wilson, Bechtel, et al., 2006). Gelatinization temperature and enthalpy of starch suspensions were determined using a differential scanning calorimeter (DSC 2010) from TA instruments (Jacquier, Kar, et al., 2006).

Pearson product-moment correlation coefficient (r) for the relationships between starch properties and the level of significance (p) for two-tailed test were calculated in Excel.

Quality Protein Maize (QPM)

Two *waxy* Hmong landraces of good taste (White *waxy* Cao Bang 3-Highland, North Vietnam; WVN 3 and White *waxy* S2- Highland, North Vietnam; WVN 10), were crossed with two *waxy* x QPM (w/o) lines of modern agronomic background, ETH w/o (southern Chinese origin; Dang et al., 2011) and Agron w/o (Thai origin; Sinkangam et al., 2012), w/o types were selected from sib-mated plants. The resulting top crosses were then backcrossed once again to the parental *waxy* LR. Field experiments were conducted at Suwan Farm, Thailand (14.5°N, 101°E, 360 m above sea level; lowland climate) in 2011, 2013 and 2014. For further technical information see Sinkangam et al. 2012. Molecular analyses were needed to assay for the recessive opaque-2 and the *waxy* alleles and carried out according to methods described in detail by Sinkangam et al. (2012). Data of the quality and agronomic traits were analyzed according to a randomized complete block design (RCBD).

Table 1 Ear yield, eating and protein quality of improved landrace (LR) S2 after crossing with ETH W/O and AGRON W/O and back-crossings to LR S2

Pedigree	QPM = Yes QPM = No	Ear fresh weight	Bite test	Tryptophan in protein
		t/ha	(1-9)	%
Ratchata 1 (Hybrid)	No	7.81a	6.7a	0.48b
S2 (LR Vietnam)	No	6.41b	5.0b	0.41b
S2 *waxy* x QPM	Yes	7.73a	6.3a	0.82a

Rating score of bite test (1-9) = 1 is poor and 9 is good.

Table 2 Ear fresh yield, eating and protein quality of two test hybrids and a commercial hybrid

Pedigree	QPM = Yes QPM = No	Ear fresh weight	Bite test	Tryptophan In protein
		t/ha	(1-9)	%
Big White 852 (commercial hybrid)	No	7.39b	7.0a	1.19b
SW14D-B7-1055-11 x 34	Yes	12.35a	6,3ab	1,75a
SW14D-B7-1055-14 x 34	Yes	12.05a	5,7b	2,04a

Rating score of bite test (1-9) = 1 is poor and 9 is good.

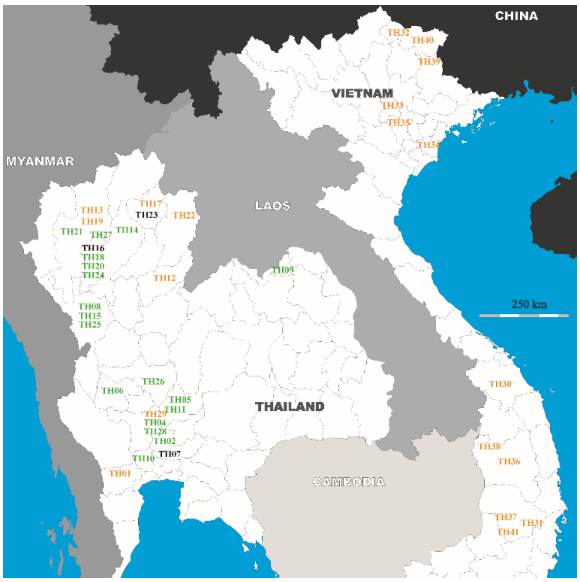

Fig. 1 Origin and purity of Thai and Vietnamese landraces used in the study
Amylose free landraces (waxy/waxy) are shown in yellow, landraces with mixed background (WAXY/waxy) in green and wild-type plants (WAXY/WAXY) in black.

RESULTS AND DISCUSSION

Starch

Genetic resources, like the hundreds or more, probably thousands, of *waxy* LR in South-East and East Asia, cannot be easily accessed for research due to their well protected status. On the other hand, they never made it to the international genebank of CIMMYT; their conservation unluckily depends on activities of individual nations. We had access to collections in Thailand and Vietnam but no information existed for tests on *waxy* purity, and for the maintenance history. The more recent Vietnamese collection was pure *waxy*. Within the Thai collection, three LR were wrongly classified as *waxy* and some other were mixed or heterogeneous (Fig. 1). A practical approach was successfully taken to regenerate pure *waxy* genotypes within the LR of mixed status. This was done by iodine staining for lack of amylose. This experience with national or local conservation of germplasm highlights the challenge to maintain essential but recessive traits.

For the now pure *waxy* LR, starch quality tests were done in comparison with a commercial *waxy* fodder maize from France for gelatinization fine structure of amylopectin and starch granule size. No significant differences existed for these traits within the Asian LR and between them and the commercial hybrid (data not shown).

The Thai and Vietnamese collections of *waxy* maize landraces (LR) have probably not been complete, considering the varied traditions in the mountainous areas of Southeast Asia. Zheng et al. (2013) analyzed the genetic diversity of Chinese *waxy* landraces, and modern *waxy* inbred lines proving a wide genetic diversity.

We identified four different *waxy* mutations in our LRs. Two of these are known from South Chinese genetic resources (Fan, Quan, et al., 2008), the other two have been first found here in South-East Asian LR. This suggests a strong and parallel selection for amylose free varieties by local farmers throughout the last centuries, as nowhere else in the world these rare mutations have been targeted for specialty food before varieties from Asia had been described (Collins, 1909; Weatherwax, 1922), and later on used for the production of quality feed. We investigated if the remaining amylopectin was also

targeted by selection rendering its structure to meet the eating preferences. However, we could not identify alteration in amylopectin in the LRs. Therefore, our hypothesis of concomitant changes in the branching pattern of amylopectin in *waxy* LR, leading to altered starch traits of economic interest had to be rejected.

QPM

This work started with collections of *waxy* maize landraces (LR) from Thailand and Vietnam (Fig. 1). From 48 initial LR, two vigorous Vietnamese of good taste were selected according to field vigor and excellent taste. They were crossed with two *waxy* x QPM lines that had been developed by us (Dang et al., 2011; Sinkangam et al., 2012), one with a southern Chinese and one with a Thai background. Their offspring was further selected in several generations at Kasetsart University, Thailand. Today, seeds are available from open pollinated varieties that are close to the original parental LR, but with the improved protein of QPM and quite some agronomic advantages.

As *waxy* maize is usually eaten as a vegetable, the right harvest time is at dough stage. In a tropical climate this was reached three weeks after flowering. On average almost 80% of the maximum grain yield was attained at this time with grain moisture content at about 45%. An example for the yield and quality potential of the new material is presented in Table 1. The protein content was 11% without differences between the genotypes. The commercial *waxy* hybrid had the highest yield, but the protein-improved LR S2 achieved similar values. Despite the good ratings for eating quality in Vietnam, the original LR was inferior in the test for grain softness by the biting test to the hybrid and the improved LR. Tryptophan is one of the essential amino acids lacking in cereal protein, it is well correlated with the quality of the whole protein fraction. Its content in protein was doubled in the grains in the improved LR S2. This is a great success indeed as it was not known before if two mutations, *waxy* and QPM could be combined within one grain without damaging the grain development.

As *waxy* maize is still an important vegetable or snack all over South East Asia to South Korea, we started a second approach on protein improved (QPM) hybrids that combine agronomic vigor with excellent agronomic performance. For this we used the *waxy* x QPM lines that had been originally developed by us (Dang et al., 2011; Sinkangam et al., 2012), one with a southern Chinese and one with a Thailandese background. The lines have been further adapted for a good seed production and a good combining ability in the last years, providing a promising platform to utilize general breeding progress in Thailand and southern China. Up to date 44 test hybrids have been analyzed for their field performance. Data are presented for two advanced test hybrids (Table 2). Both protein improved test hybrids are very high yielding in comparison to a commercial *waxy* hybrid, though a little bit inferior to eating quality as indicated by the biting test. However, the goal of fundamentally upgrading the protein quality was reached, as indicated by very high tryptophan contents in protein.

As both of our two *waxy* lines for QPM had a modern agronomic background, a positive residual effect on agronomic performance was expected and indeed achieved; which is a plus for convincing the ethnic minorities to accept new varieties bio-fortified for high protein quality (Dang et al., 2011; Sinkangam et al., 2012). The “Bite test” is a quality test using human preference. A “9” indicates a thin pericarp, a good tenderness and good aroma. It has to be kept in mind that this test has been developed for vegetable waxy maize, cooked at the doughy stage. Ethnic minorities, however, use a large proportion of their harvest as a staple, therefore the quality requirements for preparing food may vary. The protein content of mature grains had reached good levels above 11%, without significant differences between entries. Lysine and tryptophan contents are closely correlated in maize grains (Sinkangam et al., 2012). The high values in crosses corresponded well with findings by Vasal (2001) and Prasanna et al. (2001) who indicated that QPM genotypes had almost double the amount of tryptophan compared to normal maize, but were similar in overall protein content.

Based on this new w/o germplasm, the next step must be an introduction to carefully selected regions of ethnic minorities in Vietnam. The Hmong people, as a large minority, are the main target, often eating three times per day *waxy* maize as a staple. This germplasm has the genetic potential to be further adapted as it is still genetically broad, due to its Chinese and Thailandese QPM background. A successful integration of *waxy* x QPM could provide an extra advantage for local communities with new market chances selling healthy snacks.

CONCLUSION

The understanding of the uses and requirements of *waxy* maize LR may open new possibilities for its cultivation of this traditional maize type. Major changes had been expected in the structure of amylopectin as different mutations for the *waxy* mutation had occurred in Asia in the past; this would be of high interest for industry or specialty production. According to our investigations, however, there are no indications that *waxy* maize with additional new specific starch properties exist for economic purposes.

On the contrary, we are excited that we have developed two types of QPM x *waxy* materials, directly to be used to alleviate the protein deficiency for ethnic minorities depending on a maize diet, and secondly as high-yielding hybrids that can be used as a protein improved vegetable or healthy snacks, especially for school kids.

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Research article

Carbon Dioxide Release as an Index of Mineralization Rates of Organic Substrates

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Abstract Mineralization of nutrients from organic materials is vital for optimum plant growth and development. Various methods have been used to evaluate the mineralization rate of different organic substrates. Of these, carbon dioxide release is a reliable method to estimate mineralization rate. Four different substrates: dry chicken manure, *Azolla*, coconut coir dust (CCD), and *Gliricidia sepium* leaves and the combination of these substrates with SNAP solution on their rates of mineralization was determined. The results were significantly different in the amounts of CO_2 released from the substrates. CO_2 release from the substrates was stimulated by SNAP. Among all treatments, *G. sepium* with SNAP yielded the highest amount while coconut coir dust gave the lowest. Nitrogen mineralized to about fifty percent (50%) during the first week of all treatments. Using soil organic materials such as *G. sepium* leaves would quickly provide the soil with more mineralized nutrients which are available for plant growth and development.

Keywords mineralization, CO_2 release, organic substrates, *Gliricidia sepium*

INTRODUCTION

Mineralization is an important process which regulates the nutrient cycle (Curtin et al., 1997). It is also a continuous process which is controlled by many factors such as temperature (Curtin et al., 1997; Crohn, 2004; Gaskel and Smith, 2007; Li and Li, 2014), moisture (Curtin et al., 1997; Gaskel and Smith, 2007), pH (Curtin et al., 1997; Ouyang et al., 2008), microorganisms (Frankel and Bazylinski, 2003; Allison et al., 2009) or organisms of higher class such as earthworms (Coúteaux et al., 1995), herbivores (Schrama et al., 2013), soil properties such as clay types (Deenik, 2006), substrate quality and quantity (Howard and Howard, 1993; Eiland et al., 2001; Gaskell and Smith 2007; Li and Li, 2014), and the cultivation practices.

Understanding the processes involved in mineralization, and the factors that affect mineralization rate, would help estimate the right type and amount of mineralized material to guarantee optimum yield

and minimize the adverse effects of the over application of nitrogen (N) sources (Pereira et al., 2006; Hartz et al., 2000; Crohon 2004; Bordilio et al., 2013; Li and Li, 2014).

The contents of carbon dioxide (CO_2) determine the rate of mineralization by measuring the trapped CO_2 in the alkali solution, such as $Ca(OH)_2$, NaOH or KOH and titrate it against hydrochloric acid (HCl) with addition of barium chloride ($BaCl_2$) (Peirera et al., 2006; Hartz and Britton, 2003; Makende and Ayeni, 2013).

OBJECTIVE

The objectives of this study were to estimate the mineralization rates of different organic materials using the CO_2 release as an index, and to examine the effects of nutrient additions on the mineralization rates of these materials.

METHODOLOGY

Soil samples (Alipit Clay Soil) were collected from an unfertilized upland area of the U.P. Los Baños Central Experiment Station. The soil was air-dried, cleaned from vegetative material and passed through a 2.0 mm sieve. Fifty (50) grams of this sieved soil was placed inside incubation jars and mixed with 0.125 g of each nutrient source (5 t ha^{-1}). Complete Randomized Design (CRD) with three replications was used in this experiment. The treatments were: Control (CT)-soil alone with no additional nutrients, dry chicken manure (CM), coconut coir dust (CCD), *Gliricidia sepium* (GS), Azolla (AZ), simple nutrient addition program (SNAP) nutrient solution, CM + SNAP, CCD + SNAP, GS +SNAP and AZ + SNAP. The incubation study was conducted from April to May 2014 in the Soil Fertility Laboratory of the Agricultural Science Cluster (ASC), College of Agriculture, U. P. Los Baños, Philippines.

The Simple Nutrient Addition Program (SNAP) nutrient solution was formulated by the Institute of Plant Breeding, College of Agriculture, U.P. Los Baños. The solution was prepared by combining 20 ml of SNAP A and 20 ml of SNAP B, and adding this to one liter of distilled water. Forty (40) ml of the prepared SNAP solution mixture was added to each SNAP-treated jar.

Determination of Carbon Dioxide Release and Mineralized Nitrogen

Mineralization rate was measured by determining the amount of CO_2 released from the different treatments. The incubation jar set-up was prepared prior to the start of the experiment. Prior to application, the substrates were grounded and oven-dried overnight at 40°C. The appropriate amount of residue was added to 50 g soil at a rate of 0.125 g jar^{-1}. Based on the amount of soil, this application rate approximates to 5 t ha^{-1}, the amount of residue applied in many farming systems. For the control treatment, no organic material was added in the same amount of soil. The experiment was conducted for the duration of approximately 8 weeks.

The mixtures of soil and treatment nutrient sources were supplied with moisture at field capacity. A 50 mL beaker containing 30 mL of 0.3 *M* NaOH was placed in the center of the jar to trap the CO_2 released from each treatment. The trapped CO_2 was then transferred to a 100 mL beaker, and 3 drops of phenolphthalein were added before titration with 0.2 *M* HCl.

RESULTS AND DISCUSSION

The incubation experiment examined the mineralization rate of different organic materials over a 7-day period. Results showed that there were significant differences between treatments. The highest amount

of CO_2 released on the first day was measured from Azolla and AZ + SNAP with 78.3 and 76.6 mg kg^{-1} soil, respectively. These treatments were closely followed by *G. sepium* and CM + SNAP with 72.3 and 70.9 mg kg^{-1} soil respectively. Since the measured CO_2 from these four treatments were ranked closely, differences of the CO_2 released were found to be insignificant.

The measured CO_2 on the second day showed that soft, fresh materials with high source of N continuously exhibited faster rate of mineralization when compared with other organic materials. Treatments with Azolla and *G. sepium* demonstrated the highest amount of CO_2 with 74.2 and 72.7 mg kg^{-1} soil, respectively. The addition of nutrients hastened the mineralization rates as shown by Azolla + SNAP and GS+ SNAP. Similar effects were observed from Day 3 to Day 7 as those treatments with SNAP recorded high amount of CO_2 release. The *G. sepium* + SNAP Treatment dominated other treatments and their differences were found to be significant. Its performance is clearly presented in Fig. 1. Treatments with Azolla and *G. sepium* alone ranked second and third. It is also interesting to note that coconut coir dust played second on Day 3 to 4. Fontaine et al. (2003) reported that the increase in the amount of CO_2 released in the first week for all treatments may be attributed to the activities of microorganisms attacking the labile and readily decomposable substrates such as sugar, starch, and cellulose. The surge of CO_2 released from the soil in the first day (Fig. 1) might due to rewetting of the soil which allowed the surviving microorganisms to immediately attack SOM and the substrates (Keift et al., 1987). The control, although having a lower total CO_2 release, it had a starting point which was also as high as chicken manure and SNAP solution. The soil had high SOM content (6.3%) could increase mineralization.

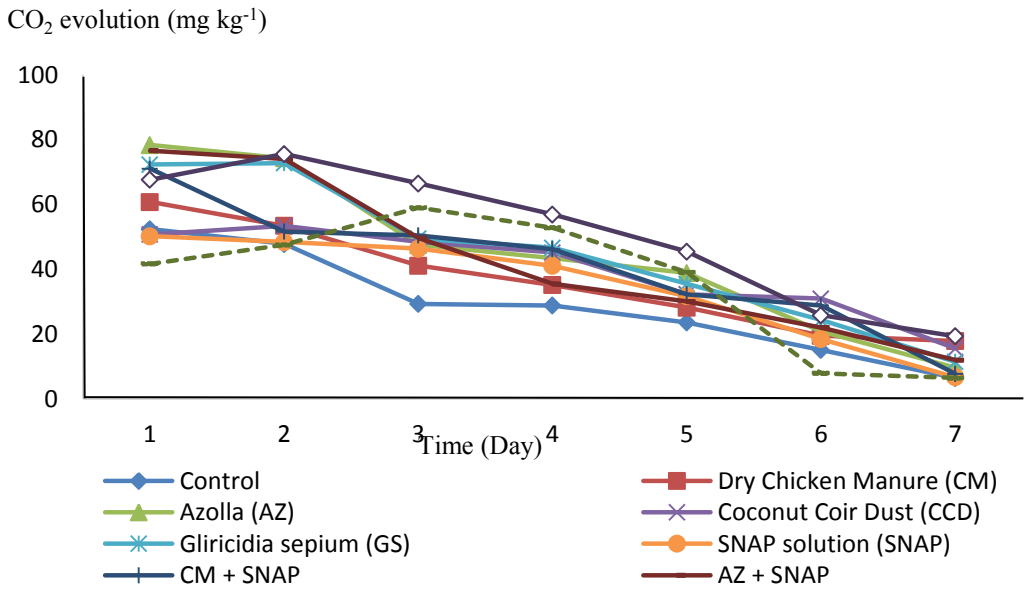

Fig. 1 Daily carbon dioxide (mg kg^{-1}) released from different organic substrates over the period of seven days

Franzluebbers et al. (1994) concluded that N mineralization can be related to the amount of SOM in the soil. Another study of Chuwdhury et al. (2014) on the effect of malic acid addition to CO_2 release found that treatments with or without nutrient addition had very high CO_2 production from 20 to 40 hours after incubation. According to Chen at al. (2014), fresh materials have faster mineralization rates and release more CO_2. *G. sepium* treatment was observed with consistent high amounts of CO_2 released, followed by Azolla and chicken manure.

Haney et al. (2008) also found a strong relationship between organic carbon sources and CO_2 release in the first day of incubation. In their study on the effect of drying and rewetting, the greatest CO_2 respiration lasted for three days. The reason which led to this highest rate of CO_2 release might be due to the active microbial biomass breaking it down when they were exposed to dryness.

The incubation experiment also examined the mineralization rate of different organic materials over an 8-week period. The results showed that there were significant differences between treatments. The highest amount of CO_2 released in the first week was measured from *G. sepium* + RR with 375.13 mg kg^{-1} soil. It was followed by Azolla and GS with 312.84 and 312.40 mg kg^{-1} soil, respectively. Notably, their values are almost equal. Azola + SNAP and CM + SNAP rank next with 299.72 and 288.14 mg kg^{-1} soil, respectively. There is a significant difference of the amount of CO_2 released from *G. sepium* compared the succeeding treatments ranked. In a similar study, Pangga et al. (2000) observed that more than 50% of total C has released during the first week of incubation.

A sharp decline in the amounts of CO_2 released was observed in Week 2. The highest amount of CO_2 released during this week was from CM and GS + RR, both yielding 93.28 mg kg^{-1} soil. This was followed by Azola and CM + RR with close values of 83.60 and 80.96 mg kg^{-1} soil, respectively. Differences of the CO_2 released among treatments were found to be insignificant since the measured CO_2 from these four treatments were ranked closely, From Week 2 to Week 6, CM and GS + RR recorded high amounts of CO_2 released compared to the other treatments. However, the highest amount of CO_2 released during Week 7 a nd 8 was measured from *G. sepium*.

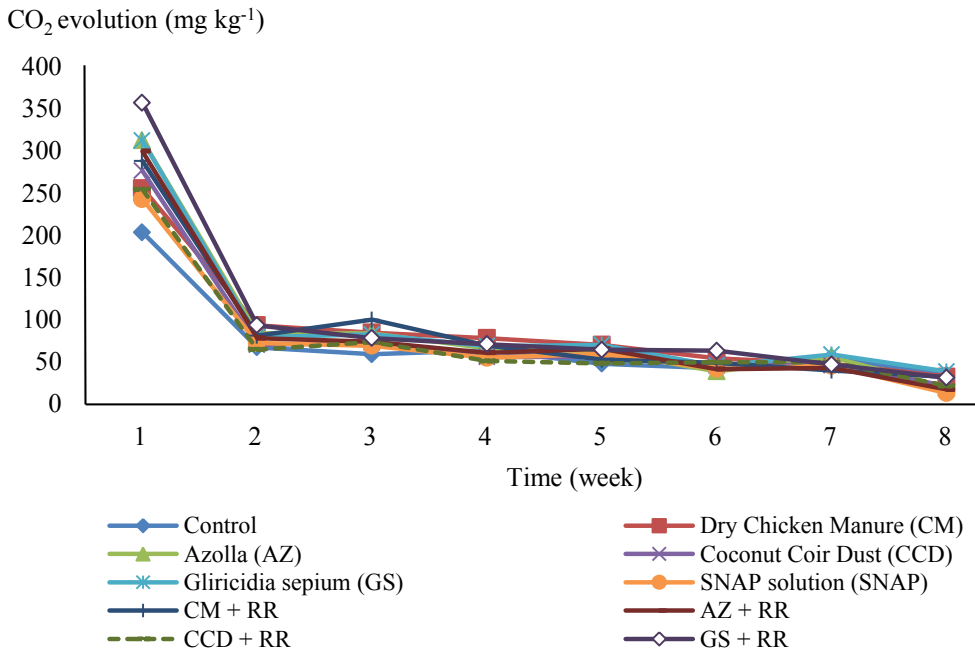

Fig. 2 Weekly carbon dioxide (mg kg^{-1}) released over the period of eight weeks from different substrates and with the addition of SNAP solution

Throughout the succession of weeks, the amounts of CO_2 lowered, although several peaks occurred, yet they were lower after each time. In the third week, there was an increased observation in CM+ SNAP treatment which measured 80.96 to 100.03 mg kg^{-1}. Then there was another peak in AZ+ SNAP (60.72 to 65.41 mg kg^{-1}). On the seventh week, there were three rises of CO_2 in GS, AZ and SNAP treatments (45.17 to 58.66, 38.72 to 55.78 and 41.65 to 45.32 mg kg^{-1}, respectively). Makinde and Ayeni, (2013) also observed several peaks of CO_2 release in their study. The decomposition of OM can be divided into three stages—(i) active (1-6 weeks), (ii) reduced or slow (7-8 weeks) and (iii) stable or moderately

stable (9-16 weeks) (Ayeni, 2011). In the active stage, the most readily available and easily decomposed substrates and OM will be decomposed. At the same time, microorganism populations also increase quickly. When substrate quality was reduced, microorganism population becomes stable or dead and decomposed to serve as the nutrient source for other microorganisms and plants.

Cumulative CO_2 release also showed that addition of substrates increased the amount of CO_2 as compared with the treatments with substrates only (Figs. 1 and 2). Fresh materials have faster mineralization rates (Chen at al., 2014), especially *G. sepium* which consistent high amounts of CO_2 released was observed, followed by Azolla and chicken manure. Additional nutrient sources will increase CO_2 and CH_4 production (Gogo and Pearce, 2009). Generally low-quality soil carbon limits microorganism activities as well as carbon mineralization. When additional nutrient sources are added to the soil, microorganisms will attack these sources and rapidly increase their population (Fontaine et al., 2003).

CONCLUSION

Mineralization of organic materials was about fifty percent (50%) in all substrates as compared to the amount of carbon dioxide released during the first week. The highest total CO_2 released was produced during the first week and the peak was between the first two days. The amount of CO_2 released less and less through time as the quality of the substrates eventually decreased. Using additional nutrient source (SNAP) to all organic materials resulted in faster rates of mineralization. Overall, the GS + SNAP treatment has the fastest rate of CO_2 release.

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Research article

Change in Effectiveness of Stung Chinit Irrigation System within a Social Economic in Santuk District, Kampong Thom Province

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Abstract Functional irrigation system is one of the most important mechanisms for preventing or minimizing crop failure, and increasing crop yields and cropping calendars. It is functional, if it is properly designed, built, operated and maintained, as well as climate-proofed. It is projected that the climate change effects – flood, drought, and temperature rise – will adversely affect water availability, hence impacting the reliability of the irrigation system and its services. The findings illustrate that Chinit Irrigation System faces several challenges such as insufficient budget for operation and maintenance, especially for repairing the broken earthen canals caused by heavy traffic, cattle, crabs and mice, and flooding. After construction, rice yield, land size and seasonal growing are increased and most of the farmers within the system coverage could access enough water for irrigation, so farmers' livelihood is improved. After completing the infrastructure, households' average net-income increased from 2.44 to 3.14 million riel per household. There are other income sources such as small business, construction and factory workers, taxi-driver and so on that can be further diversified as the competition for water use is expected due to climate change and an increase in water demand in this Watershed.

Keywords Stung Chinit, irrigation system, effectiveness, climate change

INTRODUCTION

Irrigation system is an artificial construction which ideally can store water and drain in or out the water when it is needed. Currently, construction and rehabilitation of irrigation have become one of the top priorities set by the Government, international organizations, private companies, and other donors. They have actively involved in its development to support farmers and water users to secure water to irrigate their farming in both rainy season's supplementary irrigation and wet season (Sakhoeurn, 2006). Construction of irrigation systems, including their maintenance and operations are supposed to contribute to poverty reduction and achievement of the ambitious milled rice-export target set by the Government (CGIR, 2014). According to the Food of Agriculture Organization (FAO, 2010), the average dry season rice yield has increased from 1.39 tons to 2.07 tons per hectares. However, their

prospects may be challenged by the current climate hazards and long-term climate change as they have been identified as significant environmental and developmental issues in Cambodia. Climate variability and extremes are presently manifested in ways such as floods, droughts, storms, increased coastal erosion, heat waves, and outbreaks/intensification pests and diseases (MOE 2013). All these changes have both positive and negative impacts on the agriculture including the irrigated farm land. These challenges affect the irrigation system's reliability and effectiveness because of drought and whereas overflow and extreme flood can damage the system (MOE, 2014). For the last 15 years, Cambodia has severely affected by the climate variability and change's events such as extreme flood, windstorms, and droughts. These frequent disasters and poor maintenance and operation damaged many infrastructures such as road, street and irrigation system (FAO/WFP, 2012). Climate change is expected to exert compounded pressure on Cambodia's water resources, which will be significantly altered by hydropower development and withdrawals for irrigation expansion within and beyond Cambodian borders. Prevailing poor infrastructure conditions and operation and maintenance of the system also remain a significant factor contributing to current and future vulnerability of systems to climate change (MOE, 2013).

OBJECTIVE

The research was conducted for the following two main objectives:

1) To identify the potential and constrains of Irrigation System;
2) To compare of farmers' livelihood level before and after constructing irrigation infrastructure

METHODOLOGY

The research was conducted in 3 villages, namely, Khvaek, Banteay Yumreach, and Pleyplo villages. To collect the data, primary data and secondary data (asking households, key informants, related institutes and observation) was implemented. 84 households were sampled for interviews and three Focus Group Discussion were also carried out to validate and obtain more quantitative information. All the collected data was analyzed by Statistic Package for Social Science (SPSS and Excel).

RESULTS AND DISCUSSION

Change in Rice Cultivation Calendars

The result in Table 1 indicates that before irrigation scheme, most of the farmers in the three villages cultivated their rice later in rainy season from June to December, because of concern over the water availability during the early phase of rainy season, as most of them heavily relied on rainfall for 61%, 82%, and 67% respectively in Khvaek, Prey Phlu, and Banteay Yumreach villages. Whereas after the Chinit irrigation infrastructure was put in place, 65% of households in Khvaek and 77% in Prey Phlu started to cultivate the rice from May to November relying on water from the irrigation system. However, the farmers in Banteay Yumreach still continue with old cropping calendar from June to December, because of their higher land elevation, and lack of paddy level irrigation canals through their rice field, and some farmers near the canal do not allow the water to the other fields. Furthermore, because of the canals in the upper-land are deeper than the paddy field, it has to operate by more costly pumping.

Table 1 Farmers' calendar rice before and after constructing irrigation scheme

Villages	Wet rice before scheme			Wet rice after scheme		
	May-Nov	Jun-Dec	Jul-Jan	May-Nov	Jun-Dec	Jul-Jan
Khvaek	21.70%	60.90%	17.40%	65.20%	34.80%	0.00%
Prey Phlu	11.77%	82.35%	5.88%	76.50%	23.50%	0.00%
Banteay Yumreach	16.70%	66.70%	16.60%	31.80%	61.40%	6.80%

Means for Irrigation

Fig.1 illustrates that there were only 4.34% of households irrigated their farm by gravity, 21.73% by pumping and gravity, and 73.91% by rainfall before constructing irrigation system. Whereas the farmers in Prey Phlu village, there were only 5.88% of households irrigating their farm by gravity, 5.88% by pumping and gravity, and 88.25% relying on rainfall while the farmers in Banteay Yumreach were 27.27% by gravity, 18.18% by gravity and pumping, and 55.55% by rainfall. After construction of the Chinit irrigation system, 100% of farmers in Prey Phlu, 52.17% in Khvaek, and 72.73% in Banteay Yumreach irrigated their farming by gravity, and they stopped relying on rainfall.

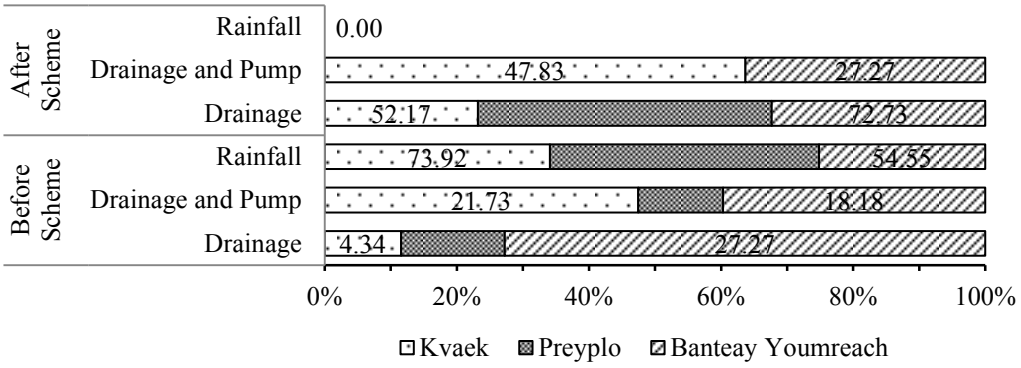

Fig. 1 Ways of farmer for irrigating their farming before and after scheme

Farmland Size Before and After Constructing Irrigation Scheme

Figure 2 shows the paddy field and crop-land size per hectare per household before and after constructing the irrigation scheme. The rice-land of the two villages, Khaek and Banteay Yumreach was slightly increased of 0.04 and 0.12 hectare per household, respectively, whereas the paddy field size of Prey Phlu remained the same. Increasing in paddy field size and production in the two villages were possible because the farmers could get enough water and reclaim available forest land, and increase their outputs to generate more income for supporting the everyday lives of their growing families. In contrast, the other crop-land size of three villages has decreased marginally from 0.55 to 0.122, 0.32 to 0.30, and 0.37 to 0.30 respectively in Khvaek, Prey Phlu and Banteay Yumreach. This was because some of the farmers could not grow vegetables in the cropland and the fields have too much water coming from the canal, and some others grow rice instead of cropping.

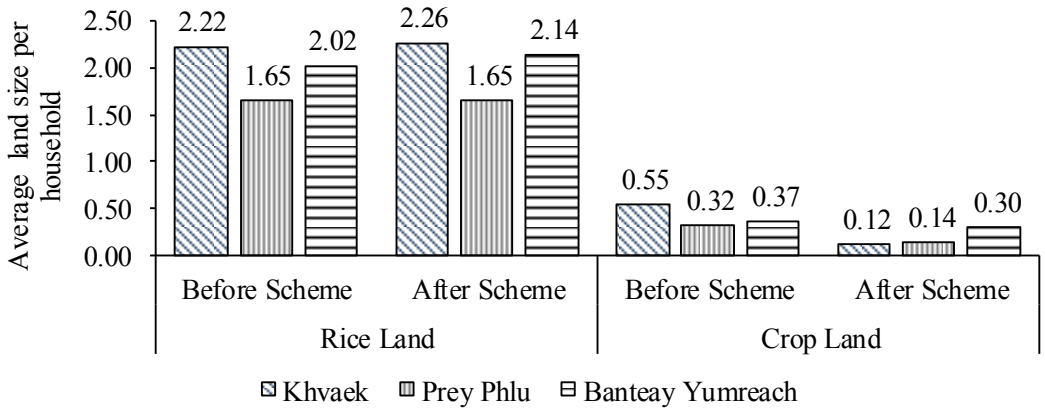

Fig. 2 Average farmland size/household before and after constructing irrigation scheme

Rice Yield Before and After Constructing Scheme

According to the data in the Table 2, farmers do not grow any rice during dry season before irrigation construction. After Chinit system's completion, Banteay Yumreach and Khvaek cultivate dry season paddy rice with a higher yield. But Prey Phlu villagers do not grow any dry-season rice, because the concern over the rampage by domestic animals, insects and so on. Furthermore, because of labor shortage and low profit from rice cultivation comparing to other occupations in urban areas, factory, collecting/working in the forestry, or other countries. After completing construction irrigation system, the average of rainy-seasonal rice yield increases only from 0.24 to 0.69 tons per hectare among the three villages.

Table 2 Average rice yield by seasons before and after scheme

Villages	Before scheme		After scheme	
	Dry-season rice	Rainy-season rice	Dry-season rice	Rainy-season rice
Khvaek	0	1.45	3.95	2.14
Prey Phlu	0	1.59	0.00	1.96
Banteay Yomreach	0	1.66	3.23	1.90

Access to Water Before and After Scheme

Table 3 illustrates the accessibility of water used by farmers among the three villages. According to the table, it showed that after constructing irrigation scheme, 74% of farmers in Khvaek and 88.20% in Prey Phlu villages have enough water for irrigating while the water security for farmers in Banteay Yumreach decrease by 15.90%. It was because the lack of paddy field water distribution canals and arrangement as well as, upland areas, and high water evaporation and seepage.

Table 3 The situation of farmers' accessible enough water use before and after scheme

Villages	Before scheme	After Ssheme	Changes
	Percent (%)	Percent (%)	Percent (%)
Khvaek	30.4	73.9	43.5
Prey Phlu	29.4	88.2	58.8
Banteay Yumreach	61.4	45.5	-15.9

Causes of Damaging Irrigation System

Farmers around 88% thought that the irrigation system had been broken by three main factors such as operating of transportation including trucks, cattle, mice, and crab, or over flow (heavy rain and flood). Fig.3 indicates that the main canal, distributary canal, release canal and release gates were dramatically damaged by flood and heavy rain. These canals were broken due to heavy rain and over flow from the river and Tonle Sap including cattle stamping, mice and crap digging holes caused the canals eroding and breaking. The sub-canals were severely affected by cattle, mice, and crab; flood and heavy rain while the small sub-canals, 50%, were crucially damaged by cattle, mice and crab, because these canals seemed as dike through the rice field so they were easily affected by cattle, mice, and crabs.

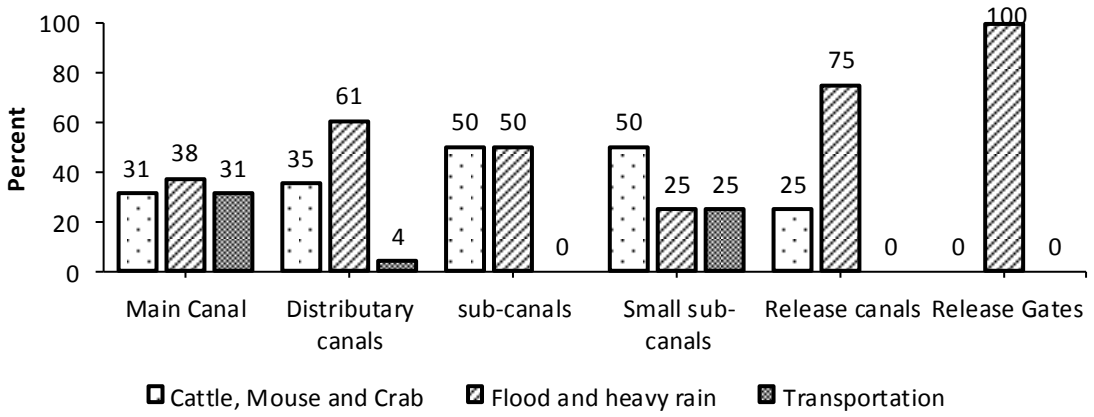

Fig. 3 the causes of damaging irrigation system after constructing irrigation system

The Efficiency of Farmers' Livelihood Before and After Constructing Irrigation Scheme

The farmers generally expended on agriculture products, general expense (food, electric etc.), and farmers' income are mostly from on-farm (cultivation crop, husbandry, fishing etc.) and non-farm income (small business, teaching, wage, factory worker etc.). The changes of average net income increaseed 2.51 million riels/household in Prey Phlu, 2.44 million riels/household, in Khvaek, and 3.15 million riels/household in Banteay Yumreach; however there was no significant difference among the three villages due to P-Value is greater than 0.05 ($p>0.05$). The efficiency of income in Khvaek village before constructing irrigation system shows that the farmers invest 1 riel per unit then they gain income 2.75 riel means that they got profit 1.75 riel. After constructing irrigation system indicated that farmers invest 1 riel per unit then they received income 2.11 riel which means that they gain profit 1.11 riel.

Table 4 Comparison of efficiency before and after construction irrigation scheme

Items	Prey Phlu			Banteay Yumreach			Khvaek		
	Before	After	Changes	Before	After	Changes	Before	After	Changes
TR (MR)	92.33	188.11	95.78	285.83	592.40	306.57	113.04	315.41	202.37
TC (MR)	33.58	89.17	55.59	101.11	306.37	205.26	49.56	177.08	127.53
Π	58.75	98.94	40.18	184.73	286.03	101.30	63.48	138.33	74.85
Aver π/HH	3.46	5.97	2.51	2.33	4.77	2.44	2.84	5.99	3.15
E (Riel)	2.75	2.11	-0.64	2.83	1.93	-0.89	2.28	1.78	-0.50

P=0.84>0.05 (Change in the average of net income/household)

**TR (Total Revenue), TC (Total Cost), π (net income), Aver π (average of net income), * MR (Million Riel), *E (Efficiency)*

In conclusion, the research demonstrated that even though the average net income of farmers increased in all three villages, but if we look through the efficiency of households decreases 0.64 riel in Banteay Yumreach, 0.89 riel in Khvaek, and 0.50 riel in Prey Phlu village, because farmers heavily pay for agricultural input (fertilizers and pesticide, rice broadcasting or transplanting, harvest, plough etc), on food, children, illness and inflation.

CONCLUSION

Irrigation system is one of the key tools to boost the agricultural products. Most of the farmers could access enough water to irrigate their farm, and double their cropping calendar with higher yield, and cultivate the farm on time. Moreover, after constructing irrigating system, it can ensure minimize vulnerability to flooding and drought. Furthermore, it also sustains farmers' livelihood because most of the farmers rely on agriculture. But there are several problems such as extremely flood, heavy rain, over flow, cattle, mice, crabs, and transportation, as well as lack of adequate fund for operation and maintenance.

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Research article

Soil Loss Mitigation by Applying Animal Waste Slurry

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Abstract The application of excreta wastes is beneficial for soil conservation, especially in degraded soils and soils being susceptible to erosion. In this study animal dung was used as a resource for protecting soils against erosion. The objective of this study is to measure the effectivity of animal waste slurry for mitigating soil loss in leptosol from Mixteca Region, Mexico. For this purpose, a splash erosion model and a surface runoff model were used. Splash erosion model consisted in stainless steel cores of 1.0 cm long with inside diameter at 1.1 cm. Soil was placed inside at a dry density of 1.0±0.1 g/cm^3. Fifty drops of artificial rain were dripped into the soil inside the core and soil loss was measured. On the other hand, surface runoff model consisted of a plot of 91 cm x 3.15 cm x 1.4 cm, with a triangular section. Soil was filled in with the same dry density of raindrop model and 1.2 cm^3/s of deionized water was supplied during one hour on a 12 degrees' slope. Discharge was collected every ten minutes and soil loss was measured. As treatment for both models, animal waste slurry was used. Horse dung was collected in the Horsemanship Club of Tokyo University of Agriculture and passed through a sieve at 212 μm in order to obtain slurry. 2 treatments were set up: the first was cattle slurry incorporated with soil and the second was crust formed with animal waste slurry; and control. Soil losses were compared among these 2 treatments. Raindrop experiment results showed that the addition of slurry decreased significantly soil loss rate from 6.4% to 1.3% in slurry incorporated cores and 0.2% in formed bio-crust cores. The same tendency was observed in the slope model experiment, where the application of slurry reduced significantly the soil losses from 558.6 g/m^2 to around 60 g/m^2 in both plots where slurry was added. Therefore, it can be concluded that the application of animal waste slurry was effective to reduce significantly soil losses by protecting the soil against kinetic energy of raindrops, as well as against shearing force of runoff on a 12 degrees' slope in leptosol soil of Mixteca Region.

Keywords slurry, soil erosion, horse dung, leptosol, Mixteca Region

INTRODUCTION

Several studies point that the application of excreta wastes could be beneficial for soil conservation, especially in degraded soils and soils being susceptible to erosion (Pinamonti and Zorzi, 1996). The use of compost or mulch blankets as a soil cover could help control soil erosion and provide sustainable alternatives to disposal for many biomass resources (Faucette et al., 2009).

Mixteca Region is located in Oaxaca State and has an average annual precipitation of 1988 mm and an average mean temperature of 15.0 ºC (Servicio Meteorológico Nacional, 2010). Oaxaca State is the main state by numbers of goats (Around 952,000 goats), which represents 10.9% of the national production (SAGARPA, 2008). Moreover, according to García Hernández (1996), the majority of units of production are extensive, where goat dung is left in the croplands. Animal dung was used as a

resource for protecting soils against soil erosion. For that reason, the objective of this study is to measure the effectiveness of animal waste application for mitigation of soil loss by raindrop and surface runoff and to discuss effective conservation measures with animal waste slurry application based on the amounts of soil and nitrogen component losses.

METHODOLOGY

For this experiment soil samples from Mixteca Region were used. The samples were collected from a rainfed corn field located in a slope of 12 degrees. Physical and chemical properties are summarized in Table 1.

Table 1 Physical and chemical properties of soil experimental design

Soil	Specific gravity	Particle size distribution, %					Soil texture	pH	EC (μ S/cm)	IL (%)
		Gravel	Coarse sand	Fine sand	Silt	Clay				
Leptosol	2.59	5.4	25.6	29.9	19.5	19.6	SCL	5.81	15.5	25.76

For this experiment, as animal waste, horse dung was used. It was obtained from the horsemanship club of Tokyo University of Agriculture. Analysis of total nitrogen, total phosphorus and coliform bacteria was conducted (Table 2).

Table 2 Properties of soil and animal waste

Sample	T-N (mg/kg)	T-P (mg/kg)	Coliform bacteria (cfu/g)
Soil	920.20	124.28	0
Slurry	6744.19	13466.06	3.2×10^7

The preparation of slurry was carried out through the sieving of the horse dung through a sieve of 212 µm to eliminate straw residues. Deionized water was used for this process. Since the slurry had a high water content after this process, and for reducing the amount of coliform bacteria (Saito and Mihara, 2010), slurry was dried up during four weeks (Fig. 1).

Horse dung from horsemanship club of Tokyo NODAI

Sieve of 212 µm
Air dried for four weeks

Horse dung slurry

Fig. 1 Animal waste slurry

For measuring the effectiveness of animal waste slurry, two experiments were carried out. The first experiment was splash erosion model conducted with the purpose to measure the ability of slurry

added soil to decrease erosion by kinetic energy of raindrops. The second experiment was surface runoff model with the purpose of measure the ability of slurry added soil to decrease surface erosion. For both experiments, two treatments were applied.

Splash Erosion Experiment

For this experiment stainless steel cores were used, which are averagely 1.0 cm long with an internal diameter of 1.1 cm. They were filled with soil under a dry density of 1.0 ±0.1 g/cm^3 to keep a similar compaction between samples. Constant water pressure was controlled by means of a Mariotte's bottle (Fig. 2). A needle from the DIK-6000 rainfall simulator equipment was used for this experiment. The kinetic energy of raindrops was 2.36 x 10^{-5}J, calculated based in the equation Ek= ½ m v^2.

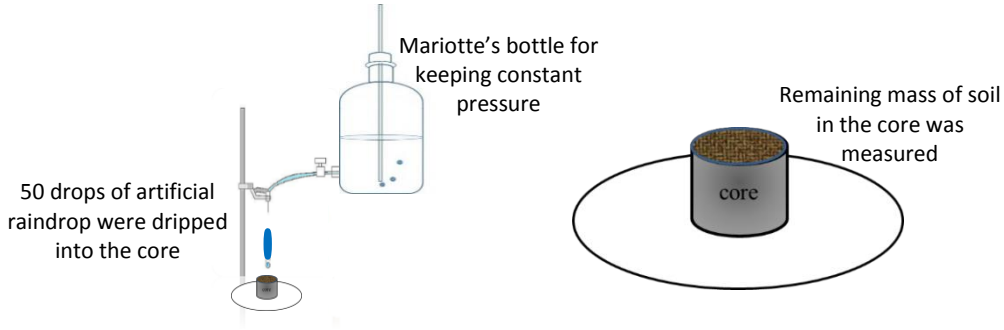


Fig. 2 Splash erosion model

For both experiments (Fig. 2), two treatments were defined. In these two treatments, the same dried mass ratio of soil : slurry was kept at 66:1. The first treatment consisted on incorporating the slurry into the soil by mixing both materials and placing the mixture into the stainless cores (incorporated with soil treatment). The second treatment consisted in placing the soil into the stainless core, compacted under the above mentioned dry density, and then covering completely its surface with animal waste slurry (formed bio-crust treatment).

For each treatment, 10 cores were used. 50 drops of artificial rain (deionized water) were dripped into every stainless core. Then, the remaining mass of soil inside the core was calculated (Eq. 1).

$$\left(1 - \frac{Remained\ soil\ mass\ in\ the\ metal\ core}{Initial\ soil\ mass\ in\ the\ metal\ core}\right) \times 100 \quad (1)$$

Surface Runoff Experiment

In this experiment, a triangular-section plot was used. The length was 91.0 cm and the triangular section had a height of 1.4 cm and a base of 3.1 cm (Fig. 3). Similar to the previous experiment, the compaction was keep under a dry density of 1.0 ±0.1 g/cm^3. And for this experiment the constant supply of deionized water (1.2 to 1.3 cm^3/s) was done by the use of a Mariotte's bottle during 60 minutes. The slope of this plot was determined as 12 degrees for all the samples.

The percolation water and runoff water was collected every 10 minutes for analyzing the amount of soil loss and the contents of total nitrogen.

Similar to the previous experiment, two treatments were defined for the surface runoff experiment. The first treatment consisted on incorporating the slurry into the soil by mixing both materials and placing the mixture into the plots. The second treatment consisted in placing the soil into the plot and then covering completely its surface with animal waste slurry. In both treatments, dried mass ratio of soil : slurry was kept at 66:1 (equivalent to 10 tons of slurry per hectare with a water content of 5.87).

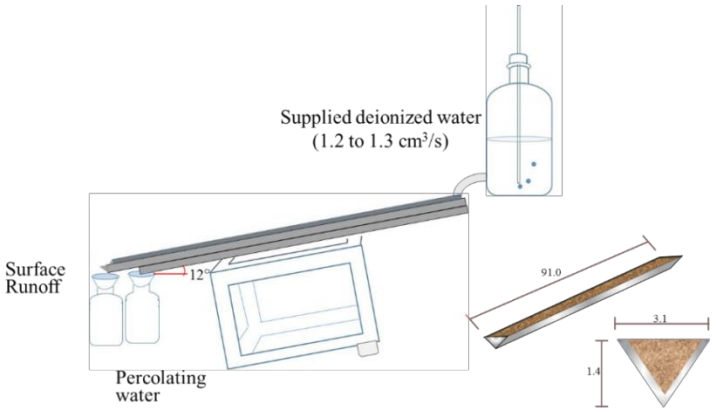


Fig. 3 Surface runoff plot model

RESULTS AND DISCUSSION

Splash Erosion Experiment

For every treatment ten stainless cores were used. After the 50 drops were applied, the samples were dried and then the weight inside every can was measure. Figure 4 shows the cores after the experiment. As can be observed, the cores in control showed a higher dispersion of soil particles.

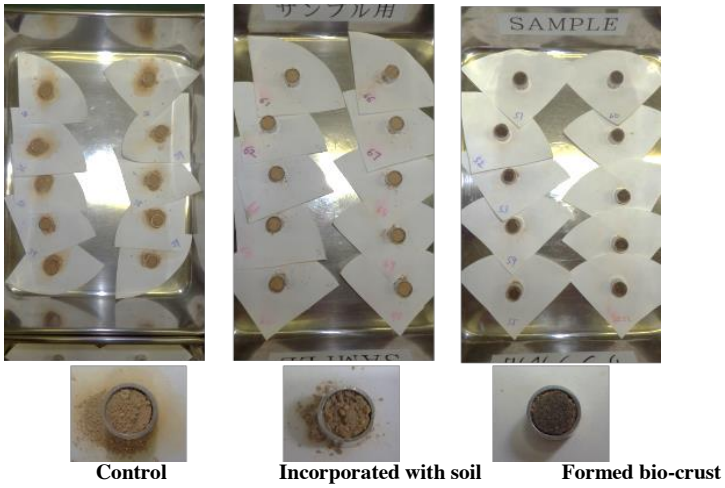


Fig. 4 Cores after raindrop experiment

After the fifty drops were dripped into the stainless cores, the soil loss rate was calculated. As can be observed in Fig. 5, control samples showed a higher dispersion of soil particles caused by the impact of raindrops compared to the treatments were animal waste slurry was added into the soil.

The average soil loss in control was 6.4%. The incorporation of slurry into the soil reduced the soil loss to 1.3%, and the application of slurry into the surface reduced the soil loss until a 0.2%. It was found that there was a significant difference between the control samples and the treatment with slurry. However, there was no significant difference between treatments. This can suggest that either way of applying slurry, being incorporated into the soil as a mixture or just applied on the surface is effective for reducing soil loss caused by the raindrop energy.

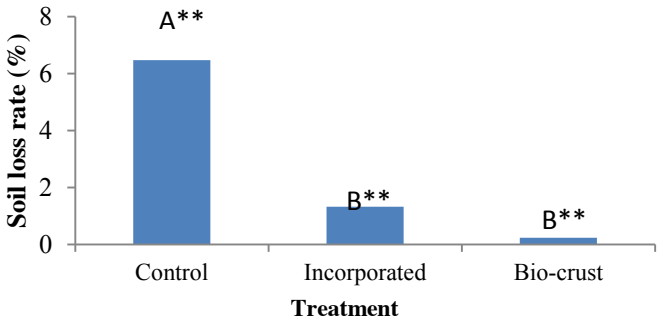
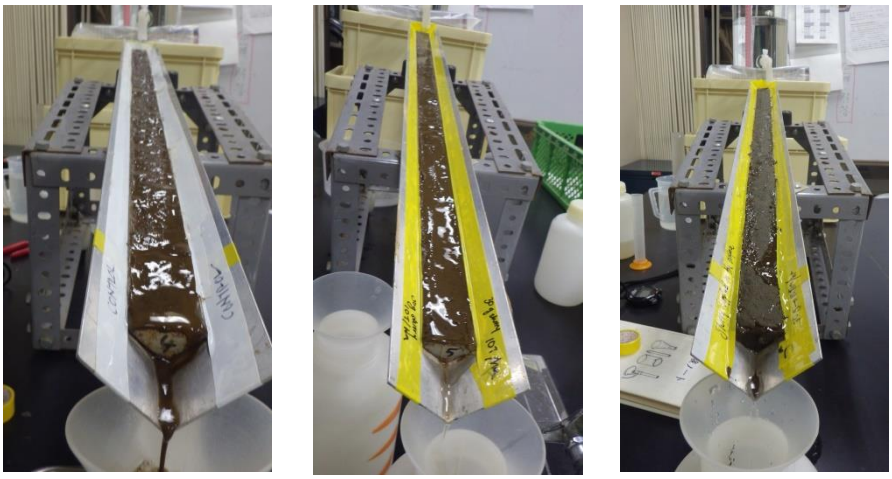


Fig. 5 Soil loss rate between treatment

Surface Runoff Experiment

The collection of runoff samples was carried out every ten minutes during one hour in the surface runoff experiment as shown in Fig. 6.



Control | Incorporated with soil | Formed bio-crust

Fig. 6 Runoff experiment plots

Figure 7 shows the results of the samples after being analyzed for cumulative soil losses and total nitrogen. Fig. 7(c) showed that there was no significant difference in the amount of discharge among treatments during the hour the experiment last. However, as can be observe in figure 7(a), control plot presented a much higher amount of soil losses, compared to the plots where slurry had been added. Concerning the amount of total nitrogen, in Fig. 7(b) can be observe that control plot shows a higher amount of nitrogen released, compared to treatments where slurry has been added. So even if slurry contains nitrogen, when added to the soil there was a fewer release of nitrogen into the runoff water samples.

It is considered that between the treatments, the addition of slurry, incorporated to the soil as well as applied in the surface to form a bio-crust significantly reduced the amount of soil losses compared to the control plot, in both the raindrop experiment and the runoff model. This could be due to the cohesion force produced by adding organic materials of animal waste slurry into the soil particles being beyond the kinetic energy of raindrops or shearing force of surface runoff.

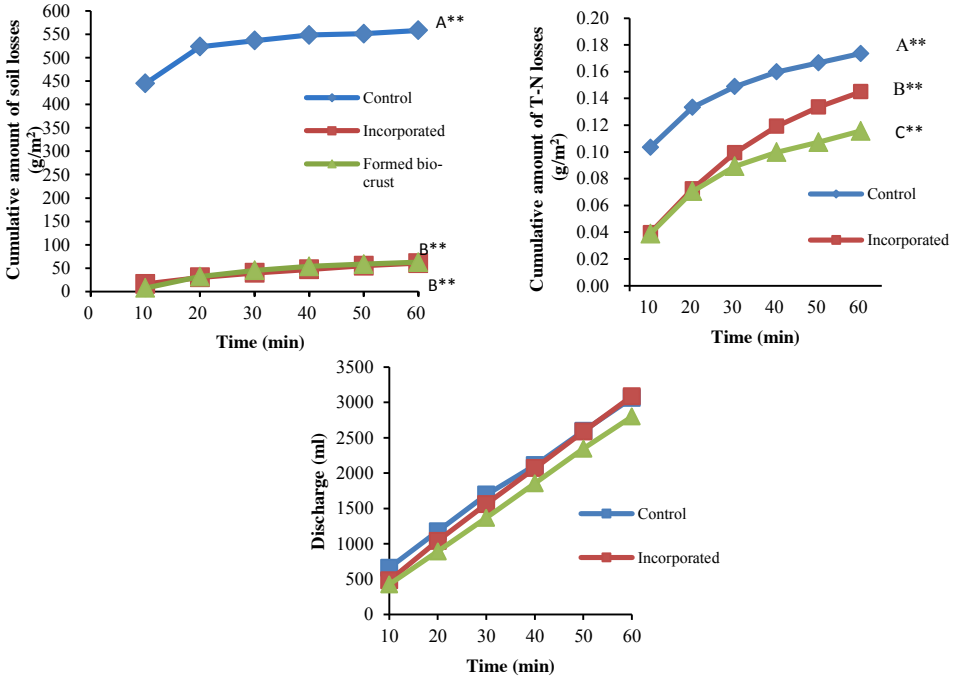


Fig. 7 Analysis of runoff experiment samples

CONCLUSION

Adding slurry into the soil, incorporated or applied on the surface, reduced splash erosion rate significantly in leptosol of Mixteca Region, as well as soil and nitrogen loss in the surface runoff. This could be because the addition of organic matter into the soil in the form of slurry improved the soil aggregation (Six, 1998), making it stronger against the kinetic energy of raindrops or the shearing forces of surface runoff. However, future research has to be conducted in order to ensure that the addition of slurry is not harmful for the environment. Furthermore, from a view point of nitrogen loss in the runoff experiment, formed bio-crust may be recommendable to apply as a conservation strategy above the incorporation of slurry into the soil.

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Research article

The Comparison of Liquid Bio-slurry and Rice Husk Biochar Application on the Production Yield of Dai Neang Chili Pepper (*Capsicum annum L*)

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Abstract In Cambodia, Dai Neang chili pepper (*Capsicum annum* L) has mostly grown in areas around Tonle Sap Lake and some other provinces such as Prey Veng, Kandal, Kampong Cham, and Kampong Thom. However, farmers keep practicing conventional methods, which do not get high yield. Liquid bio-slurry and rice husk biochar which obtained from biodigester and rice production residues, could be applied to improve soil fertility for the chili production. The key objectives of this study were (1) to analyze the fertility compositions [nitrogen (N), phosphorous (P), and potassium (K)] contents in the liquid bio-slurry and rice husk biochar and (2) to investigate the effects of liquid bio-slurry and rice husk biochar on yield of Dai Neang chili pepper. In the research, different proportions of combination of liquid bio-slurry and rice husk biochar were applied on Dai Neang chili pepper in a total quantity of 1.4kg/m^2. Data of total yield, plant height, plants diameter, roots length, number of branches, leaves area, fruit length, and fruit weight per plant, good fruits and damaged fruits were collected as the primary data. As the results, the percentages of N-P-K compositions in the liquid bio-slurry and in the biochar were 0.52%, 1.22%, 0.30% and 0.78%, 0.73%, 3.00%, respectively. The treatment using liquid bio-slurry 25% and rice husk Biochar 75% obtained highest yield and more number of branches compared with other treatments and the control. In conclusion, liquid bio-slurry, a waste of biogas and rice husk biochar could improve the soil fertility and yield of Dai Neang chili pepper.

Keywords liquid bio-slurry, rice husk biochar, Dai Neang chili pepper, fertilizer

INTRODUCTION

Currently, 80% of Cambodia's population lives in rural areas and 60% depend on agriculture, which makes the government determined that the development of the agricultural sector is a key priority to reduce poverty and contribute to increase macroeconomics (MoP, 2014). The agricultural sectors have contributed 31.6% of Gross Demonstrate Products in 2013 (MAFF, 2013). In the Cambodia, vegetable crops are the most important after rice crop as foods for human consumption. Dai Neang chili pepper is one of a supplementary vegetables which favored by consumers countrywide. It contains high vitamin C. which helps to prevent oxidation and many other nutrients that are importance to human (LPI, 2011).

In general, fertilizer application is a common practice of farmers in crop cultivation in order to add nutrients into soil for growing crops. Most of agricultural production often uses chemical fertilizers and pesticides. As a result, substances of these chemicals remain in fruits and vegetables, which make most products to be tainted and to affect the human's health. Meanwhile, long term of chemical fertilizers application resulted in soil degradation, soil pH fluctuations and losing soil microbes which improve the soil fertility (Kim, 2003). Hence, Ministry of Agriculture, Forestry, and Fisheries in Cambodia has urged farmers to produce crops by applying natural fertilizer to improve soil fertility, obtain high yield and less effect on human's health as well as environments (MAFF, 2013).

Rich husk biochar is one of the natural fertilizers, a coal derived from burning rice husk (pyrolysis condition). Its function is to help improve soil quality by increasing the pH, phosphorus, and, porosity in the soil to let plant roots absorb minerals and water easier. In addition, to increase shift level between potassium and magnesium to have a strong valid for making photosynthesis. The core of rice husk biochar contains small holes that absorb liquids well. It helps to increase micro-organs in the soil, reduce the number of insects and other harmful diseases to crops. The rice husk biochar contains other minerals that plants can absorb into subsistence for rapid growth and healthy. Especially, it helps to neutralize the acid and alkaline substances stable in the soil, which contains chemicals that these features have made the convenience for farmers' cultivation (Oyetola, and Abdullashi, 2006).

Meanwhile, considering agricultural waste management, National Biodigester Programme, Cambodia has suggested a liquid bio-slurry, which is fertilizer that obtained from stocking cattle manures in anaerobic conditions of biodigester that animal wastes were kept under high temperatures in the biodigester for 40 days at least (NBP, 2013).

Considering the availability of liquid bio-slurry and rice husk biochar in rural areas of Cambodia, farmers should pay attention to apply these natural fertilizers to their crops instead of chemical fertilizers. However, the nutrients component and the suitable amount of liquid bio-slurry and rice husk biochar apply in agricultural crops are needed to be determined.

OBJECTIVE

The objectives of this study are: (1) to analyze the composition [nitrogen (N), phosphorous (P), and potassium (K)] in liquid bio-slurry and rice husk biochar and (2) to investigate the effects of liquid bio-slurry and rice husk biochar on yield of Dai Neang chili pepper.

METHODOLOGY

The Dai Neang chili pepper was grown at faculty of Agricultural Engineering in Royal University of Agriculture, Cambodia from May to September 2015. The experiment was designed in a randomized block design with applying liquid bio-slurry and rice husk biochar at different proportion following the

standard of organic fertilizer application of 1.4 kg/m^2 or 14 t/ha. There were six treatments in this study. Each treatment was conducted in four replications. The size of one experimental plot was 2 m^2 and all plots of this experiment covered 80.75 m^2.

Treatment

- 1.T1: RHB (100%) 14 t/ha
- 2.T2: RHB (75%) with LBS (25%) 14 t/ha
- 3.T3: RHB (50%) with LBS (50%) 14 t/ha
- 4.T4: RHB (25%) with LBS (75%) 14 t/ha
- 5.T5: LBS (100%) 14 t/ha
- 6.T0: Control (No Fertilizer)

Note: RHB=Rice Husk Biochar, LBS=Liquid Bio-slurry.

Fig. 1 Liquid bio-slurry (left) and rice husk biochar (right)

Table 1 Total fertilizer allied for chili pepper

Treatments	RHB (kg)	LBS (kg)	Rep.	Surface (m^2)	Total RHB Quantities (kg)	Total LBS Quantities (kg)	Total (kg)
T0	0.00	0.00	4.00	2.00	0.00	0.00	0.00
T1	1.40	0.00	4.00	2.00	11.20	0.00	11.20
T2	1.05	0.35	4.00	2.00	8.40	2.80	11.20
T3	0.70	0.70	4.00	2.00	5.60	5.60	11.20
T4	0.35	1.05	4.00	2.00	2.80	8.40	11.20
T5	0.00	1.40	4.00	2.00	0.00	11.20	11.20
Total	3.50	3.50	24.00	12.00	28.00	28.00	56.00

(RHB=Rice Husk Biochar, LBS=Liquid bio-slurry, Rep= Replicates)

After 25 days of seeds sowing, chili pepper seedlings were transplanted with 0.5 m X 0.5 m between rows and plants.

The soil in experimental plots was sandy with silt, with pH 7.5, humus 0.8%, containing total nitrogen (0.035%), total phosphorous (0.0197%), total potassium (0.12%), total carbon (0.156 mil/100 g soil), a C/N = 5, with organic matter 0.26% (Bona, 2007).

In order to get rice husk biochar, rice husk has burned in pyrolysis apparatus for 6 hours. Liquid bio-slurry and rice husk biochar was determined for some compositions and nutrients such as pH, N-P-

K, and moisture content. nitrogen has determined by Kjeldahl method, phosphorus measured by spectrophotometer, and potassium determined by flame photometer (Latiff et al, 1996).

Chili fruits were harvested manually when they had reached maturity in 3 stages. Data collection was conducted on 50% flowering day, 100% flowering day, branch of plants, leaves area, fruit length, roots length, plant diameter, height, weight per plant, good fruits weight, bad fruits weight, and total fruit weight. Data subjected and to analyze of variance in Statistic 8. If interactions were significant, they used to explain all of data. If interactions were not significant, means have separated with Tukey test.

RESULTS AND DISCUSSION

The results showed that the N-P-K percentage of LBS and RHB were 0.52%, 1.22%, 0.30% and 0.78%, 0.73%, 3.00%, respectively (Fig. 2). Furthermore, total chili pepper yield was shown in Fig. 3. Moreover, plant growth parameters such as plant height, plants diameter, roots length, number of branches, leaves area, fruit length, fruit weight per plant, good fruits and damaged fruits weight were shown in Table 2.

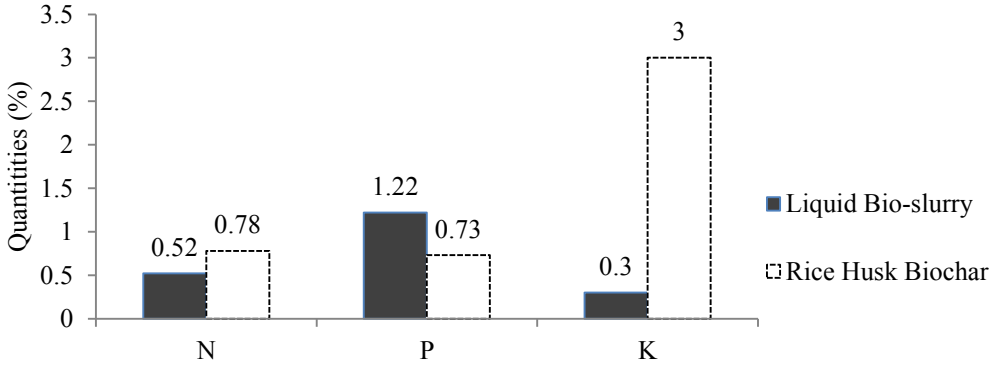

Fig. 2 Quantities of N-P-K substance in both fertilizers

Table 2 Means of plant growth parameters and yield of Dai Neang chili pepper

Treatment	T0	T1	T2	T3	T4	T5
50% flowering day	29.00	29.25	28.50	30.00	28.50	28.00
100% flowering day	35.75	36.75	36.00	36.50	35.50	35.00
Plant Height (cm)	58.05	62.90	69.45	64.20	65.50	74.55
Plant Diameter (mm)	6.28	6.89	8.23	7.23	7.56	8.23
Branch/Plant	6.66	8.35	9.35	8.34	8.72	7.28
Leaf Area (cm^2)	13.72	19.48	20.39	19.90	18.31	25.06
Fruit Length (cm)	5.18	5.83	5.39	6.32	5.77	5.44
Root Length (mm)	26.20	31.65	35.40	30.60	31.50	31.75
Fruit weight per plant (g)	95.45	106.35	129.85	107.75	117.20	113.00
Bad fruit weight (t/ha)	0.18	0.11	0.19	0.11	0.14	0.17
Good fruit weight (t/ha)	2.43	3.44	4.58	4.02	3.94	4.33
Total fruit weight (t/ha)	2.60	3.55	4.76	4.13	4.08	4.50

The result obtained from counting days of 50% flowering showed that the treatment that experienced first flowering was T5=28 days in Table 2, and T3 was the treatment in which 50% flowering appeared the latest because it used 50% of RHB and 50% of LBS. The difference in 50%

flowering days was highly significant (p-value < 0.01, CV = 1.70%). Days of 100% flowering were also counted, and the result indicated that the treatment which first reached full flowering was T5, which took 35 days, whereas T1 took the longest time until flowers fully appeared. This difference in 100% flowering days was significant (p-value = 0.05, CV = 2.03%). In addition, plant diameters measured in each treatment were significantly different (p-value < 0.01, CV = 6.21%), and the largest diameter was 8.23 mm both in T2 and in T5. Moreover, fruit length in each treatment was significantly different (p-value < 0.01, CV = 2.86%), and the treatment which had the longest fruit length (6.23 cm) was T3 and T0 had the shortest fruit length (5.18 cm). Fruit weight per plant in each treatment differed significantly (p-value < 0.01, CV = 4.71%), and the treatment that had the heaviest fruit weight (129.85 g/plant) was T2, while T0 had the lightest fruit weight (95.45 g/plant). Furthermore, the weight of damaged fruit in each treatment did not differ (CV = 34.03%), but the difference in weight of good fruit was significant (p-value < 0.01, CV = 2.16%), and the maximum weight of good fruit was 4.58 t/ha in T2 and 2.43 t/ha in T0.

As shown in Table 2, plant height, leaf area, branch of chili plant, and root length were also detected. As a result of the ANOVA test, plant height in each treatment differed significantly, and T5 had the greatest plant height (74.55 cm), followed by T2 with plant height of 69.45 cm, whereas T0 was the shortest in height (58.05 cm). Leaf areas in each treatment were significantly different, and the biggest leaf areas were 25.06 cm^2 in T5 and 20.39 cm^2 in T2, and the smallest leaf size (13.72 cm^2) was found in T0. Branches per plant in each treatment differed significantly. T2 had 9.35 branches per plant, but T0 had the fewest branches (6.66 branches). Furthermore, the lowest plant diameter was T0, and the difference in root length measured in each treatment was very significant. Among all of the treatments, T2 had the longest root length (35.40 mm). In addition, shortest roots length was T0=26.20 mm.

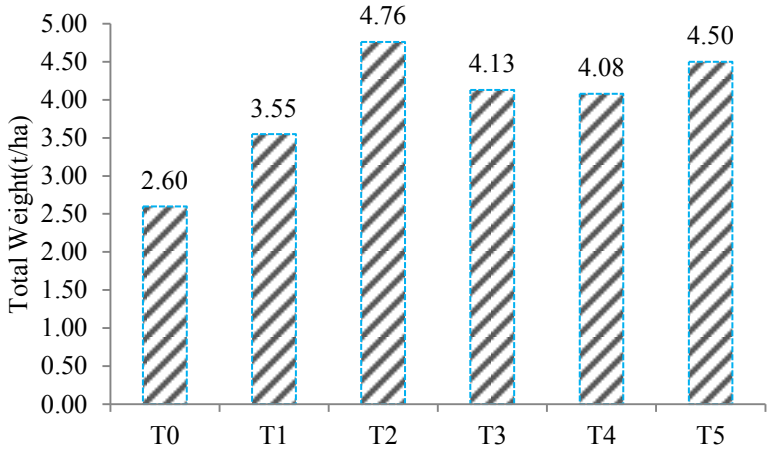

Fig. 3 Total yield from each treatment

Figure 3 showed that total weight of chili from each treatment. The highest yield was T2=4.76 t/ha followed by T5=4.50 t/ha and the lowest yield was T0=2.60 t/ha. However, yield of each treatment were different from previous research as Kbal Koh vegetable research station mentioned that non-fertilizer application on chili can gain the yield from 2.5 to 2.70 t/ha same as the experiments in Royal University of Agriculture (KKVRS, 2000).

Furthermore, considering other factors that might affect chili pepper growth that can be observed in this experiment include soil type in experimental plots, mulching for weed controlling or keeping moisture, ditching for crop's irrigation or fertilizer application (burying, spraying and etc.).

CONCLUSION

According the rice husk biochar (RHB) and liquid bio-slurry (LBS) application on Dai Neang chili pepper, it can be concluded that the fertilizers improved the chili pepper yield effectively. The results showed that the N-P-K percentage of LBS and RHB were 0.52%, 1.22%, 0.30% and 0.78%, 0.73%, 3.00%, respectively. And according to the results, where the criterion for fertilizer selection and its application rate is based on total chili pepper yield, then the following fertilizer application can be recommended: T2= rice husk biochar 75% add liquid bio-slurry 25% which obtained the highest yield of 4.76 t/ha in this experiment and next suitable was T5= liquid bio-slurry 100% that obtained yield of 4.50 t/ha.

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Research article

Proposed the Model for Estimation of Nitrogen Load in the Agro-Forestry Watershed

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Abstract Increasing nitrogen concentration in the river water caused by agricultural activities was reported in the Tokachi River basin, Hokkaido, Japan. The water quality conservation is required for the compatibility between the agricultural production and the environmental protection. It is important to analyze the nitrogen load in the watershed for water quality restoration. Nitrogen load is estimated by the nitrogen concentration in the river water and the water discharge. However, this model needs frequent samples of the nitrogen concentrations and water discharges. Also, many observations at multipoint have been required to figure out where and how much the nitrogen load occurs in the watershed. Here, we proposed a model to estimate the nitrogen load by land use in a watershed. The land use data such as watershed area and land use classification could be taken easily from a satellite image. Also, it can estimate the nitrogen load at any investigation point by using land use data for the estimation model. In the Tokachi River basin, the nitrate-nitrogen concentration in the river water had a positive correlation with the proportion of agricultural land in the watershed. Further, the water discharge was proportional to the watershed area. Thus, the estimation model of nitrogen load could be substituted the nitrogen concentration with the proportion of agricultural land, and the watershed discharge with the watershed area. From this, there is a high possibility to estimate the nitrogen load in the watershed by the agricultural land area in the Tokachi River basin. Future subject of this model is how to correct for the variations of nitrogen concentration and river water discharge at different investigation periods.

Keywords nitrogen load, estimation model, land use, nitrogen concentration, water discharge

INTRODUCTION

The Tokachi River basin is a large scale agricultural land located in the eastern part of Hokkaido, Japan. Although Japan's food supply is heavily dependent on imports from overseas because of the low self-sufficiency in food production, the Tokachi River basin plays an important role as a major food base of Japan and has been expected to help develop a sustainable food supply. However, pollution of the river water by nitrogen caused by agricultural activities has been reported in this basin (Okazawa et al., 2011; Muneoka et al., 2013; Yamazaki et al., 2013, 2014). From the investigation in 2007 carried out by Okazawa et al. (2011), total nitrogen (T-N) concentrations in the river water were in the range of 0.30-7.00 mg/L (mean: 1.81 mg/L), and positive correlations were observed between the T-N concentration in the river water and the proportion of agricultural land in the watershed in the Tokachi River basin. Methods to mitigate the nitrogen pollution of the river water in the Tokachi River basin

include changing the method and amount of nitrogen fertiliser, proper management of livestock manure and modifying the land use in the watershed. The development of adequate and effective measures to determine the source and amount of the nitrogen component runoff into the river is essential for reducing the amounts of the nitrogen load from agricultural areas.

Estimation of Nitrogen Loads

Different methods exist for estimating loads in rivers. For example, one method is to estimate the amount of emerging toxic substances by a basic unit and then multiplying by a runoff ratio. Another method is to calculate the load based on the water discharge and the concentration of substances in the river water. For the first method, we need to validate the accuracy and time variation of the basic unit and the runoff ratio. The second method, Walling and Webb (1985) introduced a typical model formula for toxic substances. The basic model formula to estimate the river loads was computed by multiplying the river discharge and the concentration of substances in the river water (Eq. 1).

$$N_{load} = C \cdot Q \tag{1}$$

where N_{load} is the base flow of nitrate load in the river water (g/s), C is the base flow of the T-N concentration in the river (mg/L), and Q is the river discharge rate (m^3/s).

Walling and Webb (1985) provided some comments regarding the reliability of load estimates derived using instantaneous water sampling data. They reported that high frequency (i.e. continuously sampled) and multipoint observation data was required to obtain correct river loads. However, extensive work is required to obtain the water sample, investigate the discharge rate and analyse the water quality at high frequency and accuracy in large-scale watersheds.

The nitrogen concentration present in one of the parameters of the model formula to estimate the nitrogen loads of the river has been correlated with the land use in the watershed (Eq. 2). Muneoka et al. (2012) reported that there is a significant and positive correlation between the nitrate-nitrogen (NO_3-N) concentration in the river water and the proportion of agricultural land in the Tokachi River basin. Also, the river discharge has a proportional relationship with the associated watershed area in general (Eq. 3).

$$C = \alpha \cdot \frac{A_{crop}}{A} \pm \beta \tag{2}$$

$$Q = \gamma \cdot A \tag{3}$$

where A_{crop} is the agricultural land area in the watershed (km^2), A is the watershed area (km^2) and α, β and γ are the coefficient factors.

Substituting Eq. 2 and Eq. 3 into the Eq. 1 provides a method to estimate the nitrogen loads (Eq. 4):

$$Nload = \alpha' \cdot A_{crop} \pm \alpha'' \cdot A \tag{4}$$

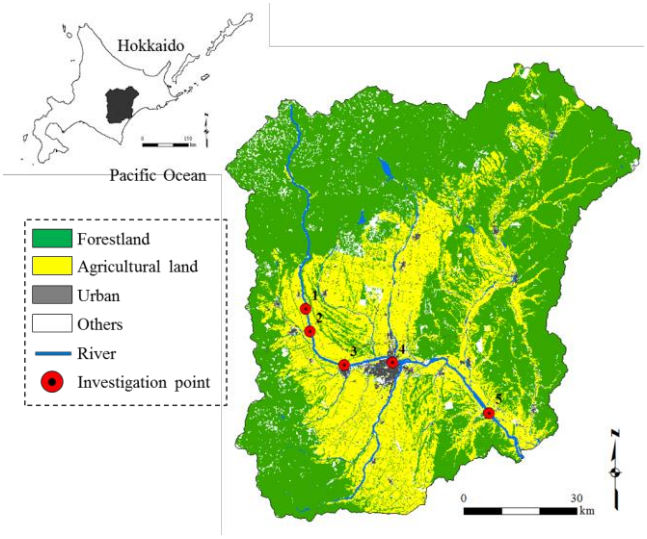
where α' and α'' are the coefficient factors. The agricultural area of the watershed can be calculated easily from the public land use information or satellite images.

In this study, we examined the correlations between the T-N concentration and proportion of agricultural land, river discharge and watershed area using a decade of investigation data. Additionally, we considered the construction of a model formula to estimate the nitrogen loads from the size of the agricultural area in the Tokachi River basin.

METHODOLOGY

The Tokachi River basin is located in the eastern part of Hokkaido, Japan (142.68–144.02°N, 42.55–43.65°E, 0–2,077 m altitude), with a stream length of 156 km and a drainage area of 9,010 km^2 (Fig. 1). The annual mean air temperature is 6.8°C, with the highest and lowest recorded temperatures of 25.2°C (in August) and −13.6°C (in January), respectively, as measured in Obihiro City from 1981 to 2010. The annual precipitation is 887.8 mm/year. The soil types in the Tokachi River basin are volcanic, lowland, upland and peat soils. The upper part of the Tokachi River and the tributaries are forested areas covered with mixed forests of conifers and broad-leaved trees. The low-lying areas are used for agricultural purposes, such as cropland, grass and pasture. The crop cultivation period of this basin is from May to November, and the cultivated crops are rotated through wheat, potato, sugar beet and beans. Both chemical fertilisers and livestock manure are applied to the agricultural land to provide the required nutrients for crop growth.

The daily river discharge rates and the total nitrogen concentration of the river water were obtained from the Water Information System provided by the Ministry of Land, Infrastructure, Transport and Tourism, Japan to determine the trends and fluctuations of the water information on the Tokachi River. Five investigation points on the Tokachi River were selected in the decade between 2004 and 2013. However, we selected the water information during April to November to exclude the impact of snow cover in the winter season and subsequent melting.



Investigation point	Area km^2	Proportion of land use (%)		
		Agriculture	Forest	Urban
1	806	3	92	5
2	858	5	87	8
3	1,531	19	73	8
4	2,686	32	59	9
5	8,224	33	62	5

Fig. 1 Watershed and land use information in the Tokachi River basin

We analysed the land use in the watershed with GIS software to utilise the watershed information as an influencing factor on the river discharge and water quality. The National Land Numerical Information provided by the Ministry of Land, Infrastructure, Transport and Tourism, Japan was used for basic watershed information. The watershed area of each investigation point was calculated based on the 'river' and 'watershed boundaries' of the National Numerical Information with GIS. We also calculated the area and proportion of agricultural land in the watershed based on the 'Land use fragmented mesh' released in 2009 because there was almost no variation in the cultivation area in the Tokachi River basin from 2000 to 2015 according to the Census of Agriculture and Forestry provided by the Ministry of Agriculture, Forestry and Fisheries, Japan.

RESULTS AND DISCUSSION

Correlations Between the T-N Concentration and the Proportion of Agricultural Land, River Discharge and Watershed Area

Figure 2 (a) shows the correlation between the T-N concentration of the river (decade mean values) and the proportion of agricultural land, and Figure 2 (b) shows the relationship between the river discharge (decade mean values) and the watershed area. In the Tokachi River basin, the T-N concentration had a positive correlation with the proportion of agricultural land ($y = 0.043x + 0.26$, $r = 0.96$), and the river discharge also had a positive correlation with the watershed area ($y = 0.036x$, $r = 0.95$) over the investigation points. Based on these results, the T-N concentration could be replaced by the proportion of agricultural land and the river discharge could be replaced by the watershed area to develop an estimation model of the nitrogen load of the river. Thus, the nitrogen load of the Tokachi River basin could be estimated by the size of the agricultural land area in the watershed and the associated coefficients.

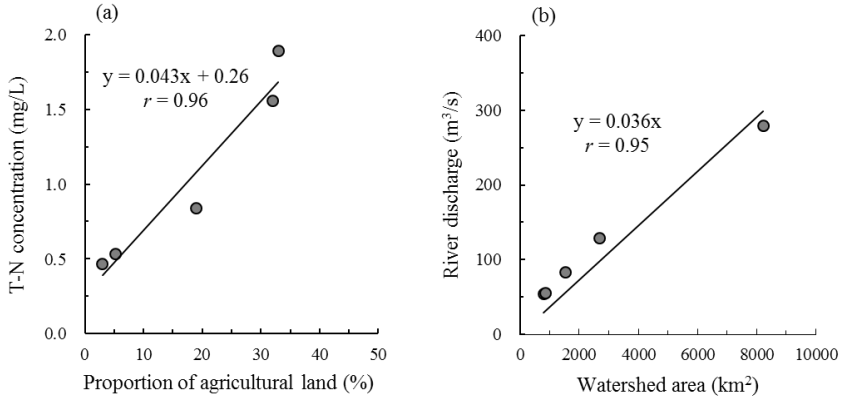


Fig. 2 (a) and (b) Relationships between the T-N concentration and the proportion of agricultural land (a); the river discharge and the watershed area (b)

However, there were variations in the correlational equations between the T-N concentration and the proportion of agricultural land and the river discharge and the watershed area by annual mean values (Table 1). Muneoka et al. (2013) reported variations in the correlational equations between the NO_3-N concentrations and the proportion of agricultural land from their water quality investigation in the Tokachi River basin from 2007 to 2009. Yamazaki et al. (2013) also reported similar variations in their investigation of the northwestern region of the Tokachi River basin from 1992 to 2012. The nitrogen concentrations of the river were considered to have been affected by the agricultural schedule

and the meteorological environment, and the river discharges fluctuated due to daily and seasonal changes in the precipitation and evaporation in the Tokachi River basin. In other words, we had to set some parameters that considered the impact of the fluctuation of the T-N concentrations and the river discharges to estimate the nitrogen loads accurately by the agricultural land area in the watershed.

Relationships Between the Nitrogen Load and the T-N Concentrations or the River Discharges

Table 1 Regression expression and coefficient correlation (*r*) between the T-N concentration and the proportion of agricultural land and the river discharge and the watershed area by annual mean values

	T-N and proportion of agricultural land		River discharge and watershed area	
	Regression expression	*r*	Regression expression	*r*
2004	y = 0.035x + 0.21	0.99	y = 0.030x	0.96
2005	y = 0.040x + 0.26	0.99	y = 0.032x	0.94
2006	y = 0.043x + 0.37	0.98	y = 0.041x	0.98
2007	y = 0.036x + 0.15	0.92	y = 0.030x	0.88
2008	y = 0.043x + 0.16	0.91	y = 0.021x	0.89
2009	y = 0.047x + 0.34	0.99	y = 0.039x	0.96
2010	y = 0.048x + 0.46	0.99	y = 0.043x	0.96
2011	y = 0.043x + 0.38	0.99	y = 0.043x	0.94
2012	y = 0.056x + 0.31	0.96	y = 0.039x	0.95
2013	y = 0.041x + 0.32	0.99	y = 0.041x	0.98

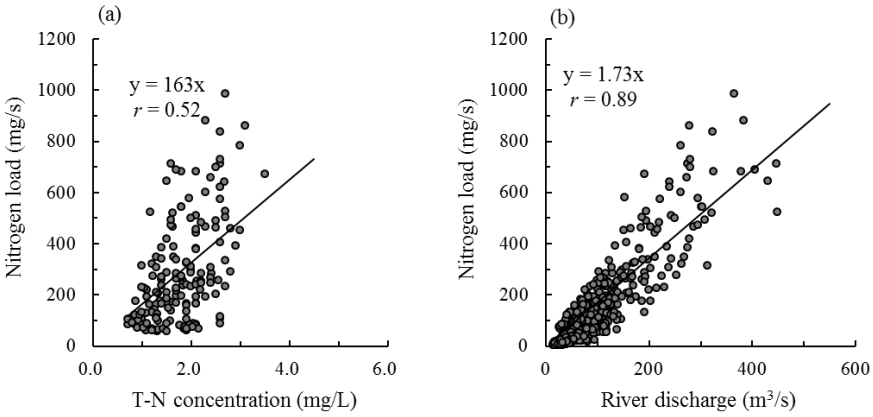


Fig. 3 (a) and (b) Relationships between the nitrogen load and the T-N concentration (a) and the river discharge (b)

We calculated the nitrogen load of the river by the T-N concentrations and the river discharges at 5 investigation points in the Tokachi River basin. The T-N concentrations and the river discharges used for calculation of nitrogen load were investigated once a month for a year from 2004 to 2013. Figures 3 (a) and (b) show the correlations between the nitrogen load of the river and the T-N concentrations (Fig. 3 (a)) or the river discharges (Fig. 3 (b)), respectively. From this figure, the nitrogen load had a strong positive correlation with the river discharge (y = 1.73x, r = 0.89); i.e. the fluctuation of the nitrogen

load was dependent on the fluctuation of the river discharge more than the T-N concentrations. This result suggested that the parameters for calculating the river discharge fluctuation were required to estimate the nitrogen load in the river water.

CONCLUSION

In this paper, we examined the correlations between the T-N concentrations and the proportion of agricultural land, as well as the river discharges and the watershed area based on a decadal investigation in the Tokachi River basin located in the eastern part of Hokkaido, Japan. The decadal mean T-N concentration had a positive correlation with the proportion of agricultural land, and the decadal mean river discharge also had a positive correlation with the watershed area. Also, the nitrogen load of the river, calculated by multiplying the T-N concentration and the river discharge, had a strong correlation with the river discharge. From the basic model formula of nitrogen load and the results as discussed above, the nitrogen load of the Tokachi River basin could be estimated by the agricultural land area of the watershed. However, the parameter could also be set by considering the impact of the river discharge fluctuation because the nitrogen load strongly depends on the river discharge. Also, the results could potentially be used to verify the nitrogen runoff behaviour during flood conditions as a future subject.

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Research article

Characteristics of the River Water Quality Under Base Flow Condition in the Tokachi River Basin, Japan

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Abstract The Tokachi River basin has an important role as a food base of Japan. It is one of the significant challenges that achieve a good balance between a food production and water quality conservation for the sustainable agriculture in this basin. Here, we carried out the river water monitoring in the Tokachi River basin and evaluated the river water quality under base flow condition. 37 sampling points in the main stream and the tributaries were monitored in late June, late August or early September, and late October 2007 to 2011. Five-year mean values and standard deviation of pH, BOD, SS and EC were evaluated. The water quality of the Tokachi River showed variations at each investigation period. However, there were no change trends of seasons or years. The mean pH values of the Tokachi River basin were the range of 7.1-7.5. The river water quality was neutrality and stable at each sampling point. The mean BOD showed comparatively low values in the Tokachi River basin (0.9-1.8 mg/L). However, the BOD values increased gradually with the main stream flow. The mean SS values were less than 25 mg/L at all sampling points. Also, the SS values tended to increase basically with the main stream flow. The mean EC values increased from upstream to downstream of the main stream (6.8-12.4 mg/L). Also, the EC values in 13 of 20 sampling points of the tributaries were higher than the main stream values (5.0-22.2 mg/L). There were significant correlations between the EC values and the proportion of the agricultural land or forest land. From these results, it was considered that the dissolved matter in the river water increased with a high proportion of agricultural land in the Tokachi River basin.

Keywords river water quality, base flow condition, the Tokachi River basin

INTRODUCTION

One of the most important challenges that the world is facing today is the development of a sustainable food system. The world population is expected to reach 9.1 billion people by 2050, and hence, we have to double the current food production to accommodate the world food demand. Japan has a lower self-sufficiency rate than the United States and EU and depends on food from overseas for domestic

consumption. The Tokachi River basin in the eastern part of Hokkaido, Japan, is a large area of cropland and dairy farming and is focused on as a food base of Japan. However, there are large challenges with not only increasing the crop production such as improving the cultivation method, crop breed and management of water resources but also reducing the environmental load from agricultural land. For example, hydrosphere pollution caused by agricultural activities has been widely reported (Parris, 2011). Increasing nutrient runoff from agricultural land causes eutrophication of lakes, ecosystem collapse and landscape deterioration. In the Tokachi River basin, increasing nitrogen concentrations in the river water and a positive correlation between agricultural land and nitrogen concentrations in the river water have been reported (Okazawa et al., 2011; Muneoka et al., 2013; Yamazaki et al., 2013). Also, the water pollution in the agricultural area is considered to be caused by materials other than nutrient salts, such as pesticides, minerals, bacteria and metals. Until now, there was no report of water quality evaluation by indicators other than nitrogen and phosphorus in the Tokachi River basin.

Here, we report the result of a 5 year observation of pH, biological oxygen demand (BOD), suspended solids (SS) and electrical conductivity (EC) measurements of the river water and evaluate the current status of river water quality in the Tokachi River basin to improvement of water quality with a goal of sustainable food system.

METHODOLOGY

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

The river water quality was monitored at 37 sampling points located on the main stream (nos. 1–17) and each tributary (A–T) of the Tokachi River basin in June, either August or September and October from 2007 to 2011 under base flow conditions. Water samples were analysed for pH, BOD, SS and EC.

RESULTS AND DISCUSSION

Mean pH, BOD, SS and EC Values and the Standard Deviations in the Tokachi River Basin

Figure 2 shows the mean values and standard deviations of the pH, BOD, SS and EC measurements of the main stream and the tributaries in the Tokachi River basin. The pH values of the main stream and the tributaries ranged from 7.2 to 7.3 and 7.1 to 7.5, respectively, indicating that the pH values in the Tokachi River basin were neutral and stable. The standard deviations of the pH values were small and stable.

The mean BOD values of the main stream ranged from 1.1 to 1.8 mg/L and gradually increased from upstream to downstream. The mean BOD values of the tributaries ranged from 0.9 to 1.8 mg/L and were comparable with the values from the main stream. Since there were some variations in the BOD values by each observation year and season, the BOD in the Tokachi River basin ranged from 0.5 to 3.0 mg/L.

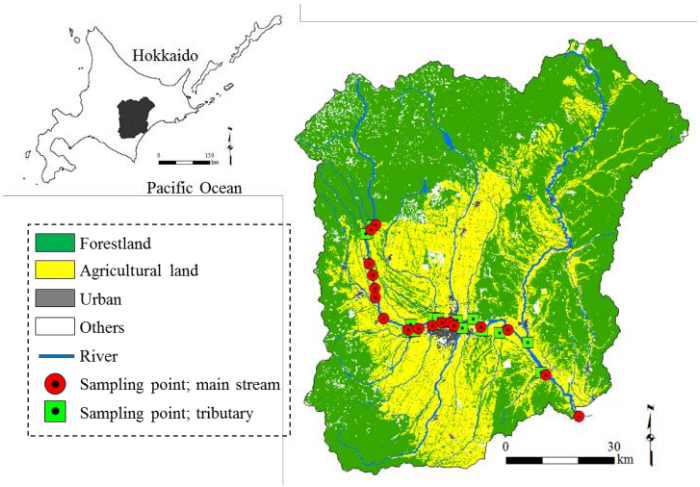

Fig. 1 Locations and land uses in the Tokachi River basin

The mean SS values of the main stream ranged from 4.2 to 18 mg/L. Although the values fluctuated at each sampling point, there was an increasing trend from upstream to downstream. The SS values of the main stream fluctuated by observation year and season, resulting in comparatively high standard deviations. On the other hand, the mean SS values of the tributaries ranged from 1.1 to 20 mg/L, and except 2 sampling points, the mean SS values were ≤10 mg/L. The standard deviations of 16 of the 20 sampling points were small, and the SS values of the tributaries were stable at these sampling points.

The mean EC values of the main stream ranged from 6.8 to 12 mS/m and increased from upstream to downstream. The mean EC values of the tributaries ranged from 5.0 to 22 mS/m. The tributaries located in the upstream area had lower EC values than the main stream; however, the tributaries located in the downstream area had EC values of approximately 20 mS/m. There were different trends in the EC values according to the location of the tributaries. The standard deviations of the EC values were small and stable.

From these results, the river water quality in the Tokahi River basin was at neutrality and stable with a pH value of approximately 7, and there were small variations between observation periods. However, the BOD, SS and EC values showed an increasing trend from upstream to downstream. In particular, the EC values of each sampling point of the tributaries had a different trend according to the upstream area or the downstream area. Based on these results, the river water quality in the Tokachi River basin was considered to have been affected by land use and anthropogenic impacts in the watershed.

Table 1 Watershed and land use information in sampling point

Name	Area (km^2)	River langth (km)	Forestland Proprotion (%)	Agricultural land Proportion (%)	*SC* ($\times 10^{-2} km^2$)
Mainstream					
1	632	613	94	1	29
2	658	637	94	1	25
3	801	773	93	3	55
4	806	777	92	3	60
5	840	815	89	4	112
6	858	832	87	5	128
7	1,289	1,247	78	14	187
8	1,531	1,546	73	19	244
9	1,777	1,782	71	21	266
10	1,798	1,801	70	21	272
11	2,669	2,664	60	32	425
12	2,683	2,678	60	32	427
13	2,686	2,679	60	32	421
14	4,479	4,243	59	35	399
15	5,098	4,714	54	39	471
16	8,224	7,074	62	33	241
17	8,982	7,856	58	31	228
Tributaries					
A	23	22	98	0	0
B	48	47	96	2	31
C	72	71	97	2	26
D	337	313	68	25	134
E	210	255	53	40	361
F	26	21	11	73	474
G	35	44	18	79	275
H	180	165	74	16	220
I	164	166	17	73	856
J	33	27	44	52	74
K	667	660	44	47	772
L	693	630	61	18	240
M	197	557	70	71	674
N	704	201	12	30	319
O	316	276	28	65	419
P	127	98	12	79	917
Q	449	333	25	70	899
R	2,850	2,104	76	19	90
S	173	145	73	23	90
T	66	54	51	44	101

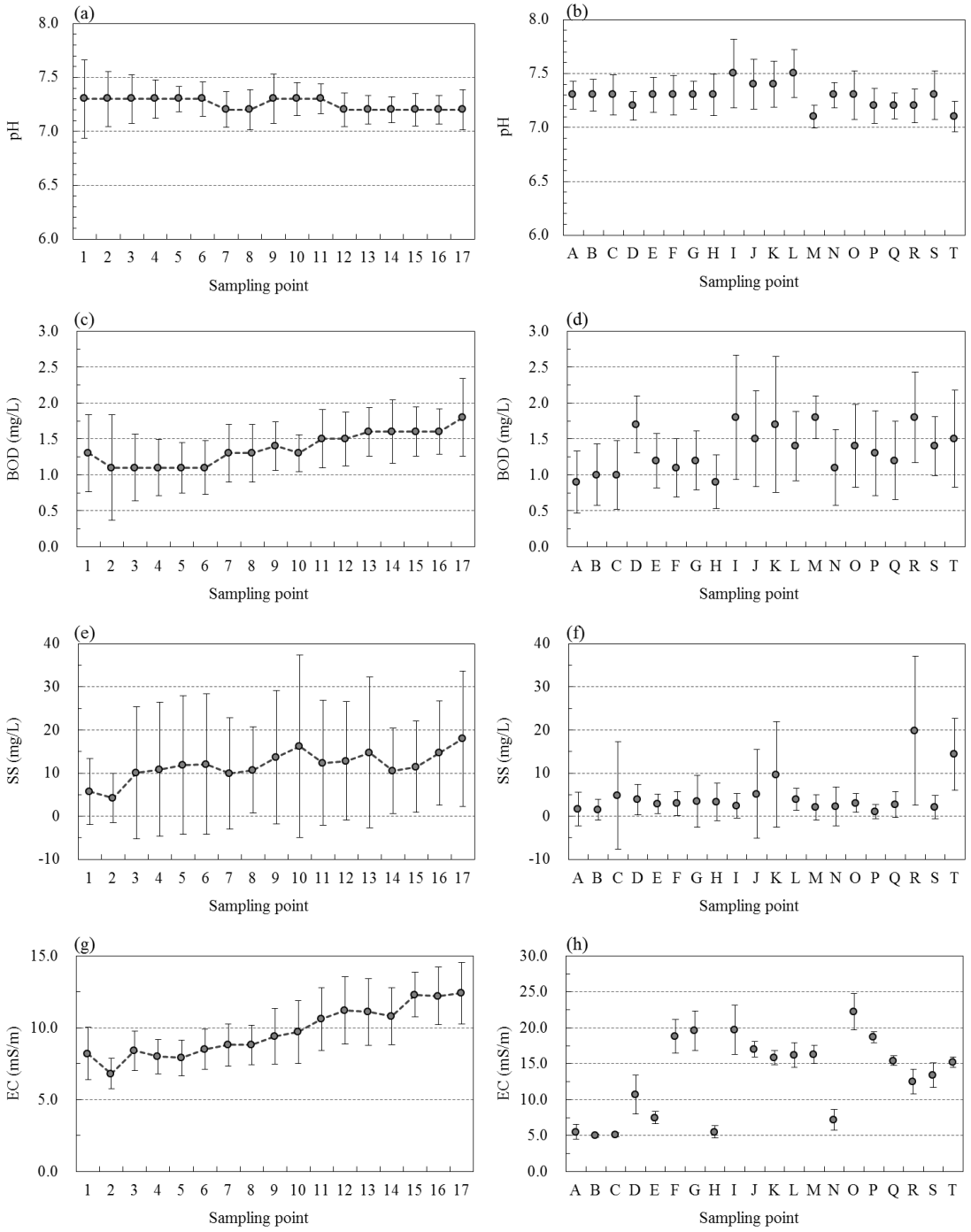

Fig.2 Results of water quality in the main stream (a), (c), (e) and (g); that of tributaries (b), (d), (f) and (h); mean pH values (a) and (b); mean BOD values (c) and (d); mean SS values (e) and (f); mean EC values (g) and (h).

Correlation Coefficients Between the River Water Quality and the Land Use in the Watershed

We further examined the relationships between the river water quality and the proportion of land uses (agricultural land, forest land and other land use). Table 2 shows the correlation coefficients of the relationships between the mean pH, BOD, SS and EC values obtained from the Tokahi River basin (i.e. the main stream and the tributaries), and the proportion of the agricultural land, forest land and other land use (such as urban areas) at each sampling point. The EC values had a significant correlation with the proportion of agricultural land and forest land ($p < 0.01$), where the EC values of the river water tended to be higher with a higher proportion of agricultural land and tended to be lower with higher proportions of forest land. In general, the EC of river water is correlated with dissolved materials such as ionic components in river water (de Sousa et al., 2014; Pawlowicz, 2015). The results indicated that the dissolved materials in the river water might have increased with the intensity of agricultural land use in the watershed because the fertilizer components, livestock manure and cropland soil runoff into the river easily in an agricultural watershed.

Table 2 Correlation coefficeints between the river water quality and the land uses in the Tokachi River basin

	Proprotion of land use (%)		
	agriculture	forest	urban
pH	0.08	− 0.08	0.00
BOD	0.26	− 0.28	0.21
SS	− 0.28	0.26	0.01
EC	0.78	− 0.76	0.22

The mean BOD and SS values of the Tokachi River basin had no correlation with the proportion of land uses. However, the BOD and SS values in the river water tended to increase with higher contents of dissolved materials and nutrients in the river water.

CONCLUSION

In this study, the river water quality in the Tokachi River basin, which is the most important area for agriculture in Japan, was determined to have deteriorated due to agricultural activity in the watershed. At the main stream, the BOD, SS and EC values tended to increase from upstream to downstream, with the EC values of the tributaries particularly showing higher concentrations in the downstream area. Since the EC values of the river water had a positive correlation with the proportion of agricultural land, the increase in dissolved materials in the river water was attributed to the presence of agricultural activities in the Tokachi River basin.

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Research article

Can Organic Farming Be an Alternative to Improve Well-Being of Smallholder Farmers in Disadvantaged Areas? A Case Study of Morogoro Region, Tanzania

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Abstract This study assessed the contribution of organic farming to improvements in the well-being of smallholder farmers as measured by crop productivity, profit, and food security among smallholder farmers in Morogoro Region, Tanzania. The results showed that organic farmers had diversified crops and availability of water for irrigation, and they had better selling situation of their crop products. It also showed significant differences in profit and food security between organic and conventional/traditional farmers. Profit among organic farmers was revealed to be more than ten times of profit among conventional/traditional farmers, with less expenditure for farm activity and higher income from their crops. Food security was analysed using food consumption score and dietary energy comsumed, and showed significantly better results among organic farmers. The factors that significantly influenced productivity included sex of the household head, number of household member, access to constant markets, and livestock keeping. The number of years of practising organic farming showed a significant association with profit, and livestock keeping and age of the household head had significant impacts on food security. It was revealed that there are challenges to organic farming, including difficulty of land preparation, access to markets, getting premium price for organic products, and contamination from other non-organic farms. In conclusion, organic farming has the potential to improve the well-being of smallholder farmers in disadvantaged areas, especially with regard to profit and food security. Therefore, it is recommended that more emphasis should be placed on the promotion of organic farming by agricultural stakeholders.

Keywords organic farming, smallholder farmers, disadvantaged area, alternative development

INTRODUCTION

As countries develop, there are always people in the shade of that development who do not benefit, and are the ones who should actually be targeted. A country's development sometimes skips people at lower levels, allowing them to remain in poverty. There are approximately 2 billion smallholder farmers worldwide who depend on themselves for their livelihood. Rural poverty is a problem that has been discussed for decades (IFAD, 2011), and it is generally said that peasants have not benefitted from development efforts thrust upon them by governments, multinational corporations, and international agencies (Leonard, 2006). In terms of Gross Domestic Product (GDP), Tanzania is steadily developing by more than 7% as of 2014 (WB, 2015). However, this economic development does not appear to affect rural citizens, and they have not seen improvement in their lives with regard to economy and food security (NBS, 2014). Due to limited opportunities for agricultural modernization

and inactive public support, organic farming has been suggested as a possible alternative development method to improve smallholder farmers' well-being in agriculture-based countries.

Organic farming is defined as a system that relies on ecosystem management rather than external agricultural inputs (FAO, 2014). Although organic farming has the potential to help smallholder farmers improve their well-being, it has been minimally practised by smallholder farmers in disadvantaged areas in Tanzania (UN, 2008; Aher et al., 2012; Anderssonet al., 2012). Therefore, the goal of this study was to assess the contribution of organic farming to improvements in the well-being, as measured by crop productivity, profitability, and food security, of smallholder farmers in disadvantaged areas. Specifically, we wanted to assess this in a non-conducive environment where farmers are geographically, politically and relationally limited to external advantages such as good markets, financial services and export contracts.

Specific objectives of this study were to examine how farmers implement farming practices and sell their products; compare productivity, profit, and food security between conventional/traditional farmers and organic farmers; determine factors affecting productivity, profit, and food security; and identify challenges of organic farming.

METHODOLOGY

This study was conducted from September 2014 up to January 15 in Morogoro Region, Tanzania. The Morogoro Municipality, Morogoro Rural District and Mvomero District were purposively selected for the study as all have small-scale organic farmers conducting multi-crop organic farming for their local consumption. For quantitative data, a total of 324 farmers including 160 organic farmers and 164 conventional/traditional farmers were selected, and a face-to-face structured questionnaire survey was conducted. To collect qualitative data, 24 organic farmers from three villages with different environmental conditions were chosen purposively to participate in focus group discussions.

Frequencies and percentages were used to summarise farming practices and products selling. Productivity, profit and food security were compared between organic farmers and conventional/traditional farmers by using independent samples T test. Food security was analysed with indicators of food consumption score and dietary energy consumed, and compared between two farming groups by using independent samples T test. Each respondent was asked about food items consumed at home over a period of previous 7 days. Multiple linear regression was used to determine impacts of some variables on productivity, profit and food security. Content analysis was used to analyse the challenges of organic farming

RESULTS AND DISCUSSION

Implemented Farming Practices and Selling Situation

The average number of different crops grown by organic farmers was 8.54 while that of crops grown by conventional/traditional farmers was 4.70. More than 70% of organic farmers had water available for their farms because many were living in mountainous areas with rivers, whereas, more than 80% of conventional/traditional farmers depended on rain. Mountainous areas are disadvantaged with regard to transportation and marketing. However, the geographic situation provided the benefit of water availability for irrigation in organic farming. Out of a total number of conventional/traditional farmers, 21.3% used chemical fertilizers and pesticides. The low percentage of farmers using agrochemicals showed that there were many traditional farmers who did not utilize synthetic fertilizers and pesticides. For this reason farmers were categorized into organic farmers and "conventional/traditional farmers" in this study.

Constant markets were more available to organic farmers. More than two-fifths (43.1%) of organic farmers had constant markets, compared to only 8.5% of conventional/traditional farmers. This situation may result from a trend in crops grown and the farmers' motivation to sell crop products. Specifically, because conventional/traditional farmers grow fewer crops in comparison with organic farmers, they do not have much crop variety available to sell. Furthermore, since starting organic farming, organic farmers seemed to be more motivated to sell their crop products specifically as organic products. Of the organic farmers, 38.1% sold at least some of their crop products as organic products, and other organic farmers sold their crop products without mentioning that they are organic. Among those who sold their crop products as organic, 18.1% sold their crop products, or at least a portion of them, for a higher, premium price. This implies difficulty in gaining customer attention with regard to crop status, and connecting that attention to a premium price.

Comparison of Productivity, Profit and Food Security between Organic Farmers and Conventional/Traditional Farmers

Maize, cow peas, and pumpkins were the most grown crops in both farming groups. These crops showed higher levels of productivity among organic farmers, but the differences between organic farmers and conventional/traditional farmers' outputs were not significant, as shown in Table 1 ($p > 0.05$). Significant differences were seen in some other crops such as tomato, Chinese cabbage, and amaranth, but these crops did not have enough samples. Those three crops are often said that they can show immediate changes along with organic farming practice such as organic fertilizers and pesticides, and they are often used in organic farming training sessions (University of Kentucky, 2007). Therefore, those results imply that crops that farmers are taught on how to grow more likely show higher productivity. There are two possible reasons for the higher productivity of organic farms. First, organic farming practices promote high productivity by creating a richer environment for crops. Second, farming techniques learned in organic farming training, such as how to arrange crops in a farm promote high productivity. One farmer in Bamba explained that they did not know how to arrange crops in a farm, and used to plant crops very roughly. After training on organic farming, they got to know the necessary length between crops in a seed bed, and many of them had feelings that productivity had increased.

Table 1 Crop yields' mean productivity per ha

Crops	Farming style	n	Mean (kg)	F	Sig.
Maize	Organic	141	1156.30	1.251	0.264
	Conventional/traditional	162	1039.44		
Cow peas	Organic	80	207.77	0.250	0.875
	Conventional/traditional	92	186.31		
Pumpkins	Organic	95	409.62	2.436	0.120
	Conventional/traditional	81	261.83		

The mean profit among organic farmers was significantly higher than that among conventional/traditional farmers, with a smaller minimum amount and larger maximum amount as shown in Table 2 ($F = 13.652$, $p \leq 0.001$). In 2013, the mean profit of conventional/traditional farmers was less than one-tenth that of organic farmers. This large difference was due to a large proportion of conventional/traditional farmers experiencing an income deficit. Among conventional/traditional farmers, 44.5% had no income from their crop production, and 58.5% had a deficit. By contrast, only 13.1% of organic farmers had a deficit, because organic farmers can lower farm by taking advantages of hand-made organic fertilizers and pesticides, and can bring higher income by making farmers

connected to markets with more crop varieties. The mean income among organic farmers was more than four times that of conventional/traditional farmers. This combination of lower expenditures and higher income for organic farming is supported by several studies that showed a reduction in input costs and an increase in income in organic systems (Peramaiyan et al., 2009).

Table 2 Profit (Tanzanian Shillings*) among farmers

Farming group	n	Min	Max	Mean	F	Sig.
Organic farmers	160	-391,000	5,4736,000	1,636,608.14	13.652	0.000
Conventional/traditional farmers	164	-1,879,000	16,625,500	146,970.55		

** US $ 1.00 = Tanzanian Shillings (TZS) 2,165.02 in September, 2015*

The mean food consumption score of organic farmers was 51.17, higher than that of conventional/traditional farmers (49.45). Scores were calculated for three categories: poor (1), borderline (2), and acceptable (3). Scores were compared between the two farming groups, and the comparison showed higher means among organic farmers with a significant difference ($F = 6.514$, $p \leq 0.05$). With regard to dietary energy consumed, households of organic farmers had a higher mean for dietary energy consumed (2,976.53 kCal per adult equivalent per day) than the households of conventional/traditional farmers (2,912.25 kCal per adult equivalent per day). Households were classified as food-insecure and food-secure based on a cut-point of 2,200 kCal, the national caloric poverty line per adult equivalent per day in Tanzania (NBS, 2014). Among households of conventional/traditional farmers, 24.4% were below the cut-point, whereas only 19.4% of the households of organic farmers fell below the cut-point. The score of the food-insecure group, which consumed below 2,200 kCal (1), and the score of the food-secure group, which consumed more than 2,200 kCal (2) were compared, and the difference between organic farmers and conventional/traditional farmers was significant ($F = 4.793$, $p \leq 0.05$). From a food security perspective, organic farmers had better scores. Therefore, it could be said that organic farming contributes to food security at the household level. There are two possible reasons for this better household food security. First, increased quantities of crops in organic farms provided increased access to food. Second, the higher income of organic farmers increased their purchasing power.

Table 3 Independent sample T test comparing food security

Variable compared	n	Mean	F	Sig.
Food consumption score of organic farmers	160	2.77	6.514	0.011
Food consumption score of conventional/traditional farmers	164	2.70		
Scores of dietary energy consumed of organic farmers	160	1.81	4.793	0.029
Scores of dietary energy consumed of conventional/traditional farmers	164	1.76		

Factors Influencing Crop Productivity, Profit and Food Security

Multiple linear regression was performed to determine impacts of several independent variables on crop productivity, profit, and food security (Table 4). For maize, results showed that female-led households had higher maize productivity. This is in contrast to a number of previous studies (Koru and Holden, 2010). These results imply that female-led households no longer suffer from the traditional disadvantages that have previously led to lower productivity than male-led households. This could be explained by women's high commitment to maize production activities. Results also showed

that those households with more household members had higher maize productivity. We suggest that a large number of household members leads to a bigger labour force. Results also indicate that having a constant market leads to higher maize productivity. Households with constant markets may have more motivation to sell and therefore care more about their farms.

For pumpkins, the results revealed that livestock owners tended to have higher productivity. Total income from livestock keeping was found to have a significant impact on productivity of maize in regression ($p \leq 0.05$). The income from livestock may help farmers purchase farm inputs and equipment and allow them to prepare a separate farm for pumpkins. Many households did not have a separate farm of pumpkins, because maize, cow pea and pumpkins are the crops used most for intercropping. It may cause lower productivity of pumpkins in this study, since the study did not consider whether they intercropped or not when calculating productivity. In addition, farm yard manure from the livestock could be utilized to help the pumpkin crop thrive.

Profit was influenced by the number of years practising organic farming. This implies that more experienced organic farmers tend to have higher profits. One possible reason for this is that experienced organic farmers easily take advantage of organic fertilizers and pesticides by utilizing local materials instead of purchasing them, whereas some new organic farmers have not yet found a reasonably priced source of animal manure. Moreover, experienced organic farmers could achieve higher incomes by establishing markets to sell their crop products.

Factors affecting food security were analysed using aspects of the food consumption score and dietary energy consumed. Multiple linear regression of food consumption scores showed that scores were affected by whether the farmer owned livestock and age of the household head. Specifically, households with livestock had a higher food consumption score, as did households headed by an elder. The higher food consumptions scores for households with livestock could be related to additional income associated with livestock ownership. In 2013, about half of the livestock keepers received income from selling their livestock or livestock products such as eggs and milk. The additional earnings from crop production may have improved the economic situation of those households and led to better food security. The age of the household head may have a positive effect on food security because of their richer experiences. Multiple linear regression did not show a significant effect of any of the variables with regard to dietary energy consumed.

Table 4 Impact of some of the independent variables to productivity, profit, and food security

Dependent variable	Independent variable	n	B Coefficients	Beta	T	Sig.
Productivity of maize	Sex of a household head*	324	-0.337	-0.296	-3.105	0.002
	Number of people in a household	324	0.061	0.248	2.599	0.011
	Whether they had a constant market	324	-0.203	-0.216	-2.287	0.024
Productivity of pumpkins	Whether they owned livestock	324	-0.937	-0.380	-3.384	0.001
Profit	Years of practising organic farming	324	337206.131	0.375	3.839	0.000
Food consumption score	Whether they owned livestock	324	-6.377	-0.244	-2.831	0.005
	Age of a household head	324	0.169	0.226	2.622	0.010

** This table only shows the independent variables which showed significant impacts on the dependent variable*

Challenges of Organic Farming

Challenges of organic farming were grouped into categories using content analysis (See Box 1).

Box 1: Difficulties of conducting organic farming

Below are some quotations from farmers with regard to difficulties in conducting organic farming.

1. Difficulty of farm land preparation
"If you have a farm of 1.5 ha, you cannot make terraces by yourself. Hiring a temporary worker for making one terrace costs TZS 5,000*. It is expensive." (Old woman in Ruvuma)

2. No market place
"There is nowhere to sell the products. Sometimes amaranths stay at farm until they get rotten." (Young girl in Kireka)

3. Difficulty of selling for a premium price
"Prices of our organic products should be the same as those of neighbours." (Old woman in Kauzeni)
"People know organic farming, but they do not know values of health. You can tell a customer that your one bunch of carrots is for TZS 1,500. She/he goes for carrots of TZS 600 which are grown with agrochemicals." (Old man in Ruvuma)

4. Contamination of soil by conventional farmers
"Some neighbours are using chemicals. Our crops get contaminated on farm." (Old woman in Kauzeni)

5. Water requirements
"When you grow vegetables, it is necessary to have water." (Old woman in Ruvuma)

** US $ 1.00 = Tanzanian Shillings (TZS) 2,165.02 in September, 2015*

It was revealed that land preparation was a big burden on organic farmers. With regard to the market place, there were organic farming groups which could access the organic shop for selling and some which could not. In addition to this accessibility issue, meagre scale of the organic shop was also a constraint. One farmer mentioned that, "If you order for only five crop products, others get rotten in a big farm". The issue of premium price is important to consider when promoting organic farming. One farmer in Ruvuma explained that when they promote organic farming to other farmers, some farmers are not attracted because the selling price is the same. Contamination of soil by nearby conventional farmers is a difficult issue. Even though there were not many conventional farmers using agro-chemicals during the time of this research, according to the country's trend, the number of users of agro-chemicals will increase in the future. Especially in mountainous areas where no efficient coping strategies against soil erosion are used, soil is likely to suffer serious damage. The availability of water is important. Organic farming organizations provided hose pipes or sprinklers to farmers when beginning organic farming training. One traditional farmer in Lukobe mentioned, "If I buy water for TZS 200 per bucket for growing vegetables and sell one bunch of them for TZS 200, can I really get profit?" This water issue is an essential concern for conventional/traditional farmers considering beginning organic farming.

CONCLUSION

This study found that organic farmers take advantage of organic farming practices including crop varieties and water availability. Organic farmers had a more beneficial market situation for their crop products, but there were still difficulties in being able to sell their crop products as organic and receive a premium price due to low awareness of the value of organic products. Therefore, increased awareness of organic branding is a key to the practice of organic farming. It was also revealed that organic farming may be an avenue for higher profit by balancing expenditure and income, and also an avenue to better food security in terms of food consumption scores and dietary energy consumed. As access to a constant market significantly influenced productivity of maize, construction of additional market places would help smallholder farmers achieve higher crop productivity. The number of years practising organic farming showed significant association to profits and supported the contribution of

organic farming to profitability. Because food consumption scores showed that livestock keeping was a significant determinant of food security, livestock keeping is an important factor to be taught in farm training for improvement in socio-economic well-being. For smallholder farmers to conduct organic farming smoothly, solutions for challenges of land preparation in mountainous areas that need terraces are required. Moreover, further support is required to address the soil contamination problem.

This research demonstrates that organic farming can be an alternative to improving the well-being of smallholder farmers with respect to profit and food security. It could be said that organic farming, which is enhanced by accessible local resources, can replace former development efforts as a sustainable rural development approach.

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Research article

Impact of Smallholder Agricultural Cooperatives on Market Participation of Vegetable Farmers in Cambodia: A Case Study of Svay Rieng Agro-Products Cooperative

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Abstract Agricultural cooperatives play a crucial role in improving Cambodian farmers' participation in vegetable markets. Cambodia's vegetable sector is afflicted by the dual problems of supply and quality; the country imports huge amounts of vegetables from Vietnam and Thailand, and most domestic vegetable production is still inorganic. This quantitative study shows the impacts of Svay Rieng Agro-Products Cooperative (SAC) on its members' participation in vegetable markets. Data was collected from a survey of 44 SAC members and 20 non-SAC members in Svay Rieng province. A market participation index was used to measure the level of respondents' market participation. Based on the quantity of vegetables sold, the 64 sample farmers represent four levels of market participation across 52 market participation scores: level 1 includes scores 4-16 (35.9% of total respondents); level 2 scores 12-32 (32.8%); level 3 scores 24-36 (17.2%); and level 4 scores 32-52 (14.1%). T-test analysis shows that the participation in vegetable market of SAC members is higher than that of non-members. Logit model reveals that variable of growing vegetables as a primary source of household income is positively related to the probability of selling vegetables to SAC. Tobit model is used to determine factors affecting market participation levels of SAC members. The study revealed five factors as critical variables affecting effective market participation: 1) education level of household head, 2) receiving market information, 3) volume of vegetable production, 4) distance to main market, and 5) the extent to which vegetable growers supply SAC. The study stresses the importance of agricultural cooperatives in improving famers' participation in vegetable markets. Plus, the results concerning the probability of selling vegetables and level of participation in vegetable markets can usefully contribute to informing and improving the royal decree and prakas on agricultural cooperatives in Cambodia.

Keywords agricultural cooperative, market participation, Cambodia

INTRODUCTION

Cambodia's agriculture sector contributed about 27.5% of total GDP in 2012, and crop production alone accounted for 55% of agricultural GDP (MAFF 2013). Although vegetable production in Cambodia increased between 2007 and 2013 (MAFF 2013), Cambodia supplements 40-50% of its vegetable consumption with imports from Vietnam and Thailand. In 2010, for instance, vegetable imports amounted to 70 to 80 tonnes a day (Vietnam Business News, 2010). This huge volume of imports is affecting most stakeholders in the vegetable sector. The Cambodian government is committed to improving agricultural development and promoting smallholder livelihoods through the establishment of agricultural cooperatives. Agricultural cooperatives play an important role in rural

economic development and poverty alleviation (Chea, 2010). Yet few studies have examined the impact of agricultural cooperatives on farmers' participation in vegetable markets in Cambodia.

OBJECTIVE

The objectives of the study are to evaluate the impacts of SAC on market participation of SAC members, and to determine the factors affecting the extent of their market participation.

METHODOLOGY

Household survey: A structured questionnaire was used to gather information from 44 SAC member households and 20 non-member households. Household heads or other adult family members were interviewed face-to-face. Six of the 20 areas covered by SAC were selected for survey. These areas were chosen because the farmers there are more likely to grow the crops of interest, namely cucumbers, Chinese cabbage, Chinese greens, pickle cabbage and dwarf cabbage, than in the other areas. All farmers in the six areas who had produced these five crops in the previous growing season were engaged in face-to-face interviews.

Data analysis: Market participation index, T-test, logit and tobit regression models were used. Following Gani and Adeoti (2011), the market participation index was used to measure the level of market participation among respondents in the study areas. Table 1 describes the index used in computing the total market participation index (TMPI).

Table 1 Market participation index

Quantity sold (L)	Scores									
	Market location (X)					Period of sale (Y)		Buyer (Z)		
	Home-stead (X1)	Farm gate (X2)	Village market (X3)	Town market (X4)	City market (X5)	On-season (Y1)	Off-season (Y2)	Consu-mer (Z1)	Trader (Z2)	SAC (Z3)*
>0 - <450kg (L1)	1	2	3	4	5	1	2	1	2	3
451 - 1000 (L2)	2	4	6	8	10	2	4	2	4	6
1001-1450 (L3)	3	6	9	12	15	3	6	3	6	9
>1450 (L4)	4	8	12	16	20	4	8	4	8	12

*Note: * Developed by authors*
Source: Gani and Aeoti 2011

The total market participation index (TMPI) represents each respondent's score, and the score regulates the level of participation in the market. When the scores for the quantities of vegetables sold and other indices including market location, period of produce sale, and buyers were computed, the minimum market participation score 3 indicates the lowest level and 96 the highest level of participation.

$$Minimum\ Score = X1(L1)+Y1(L1)+Z1(L1)=3$$

$$Maximum\ Score = X1(L4)+X2(L4)+X3(L4)+X4(L4)+X5(L4)+Y1(L4)+Y2(L4)+Z1(L4)+Z2(L4)+Z3(L4)=96$$

In addition, the different levels of farmers' participation in vegetable markets were determined using the following formula:

$$\frac{RTMPI}{NMPWC} X \frac{100}{1}$$

where RTMPI = replication/frequency of total market participation indices, and NMPWC = number/size of market participants within a given category.

T-test as modeled by the t-distribution was used to test the statistical difference in the average market participation score of SAC members and non-members. Logit model was used to determine the probability of farmer-members selling vegetables to SAC. Tobit model was used to determine factors influencing the level of SAC members' market participation in the study areas.

RESULTS AND DISCUSSION

Impact of Svay Rieng Agro-Products Cooperative on Market Participation

The four levels of market participation signify that although the 64 surveyed farmers participated in the market, they did so to different degrees. The various levels of market participation in the study areas and their scores are shown in Fig. 1; the main features of the data are described below.

At level 1, 23 respondents (35.9% of the total) participated in the market; score level 4 (4.35%) has the fewest and score level 16 the most participating farmers (4.35%). Majority of farmers in this level fall into score levels 8, 10, 13 (17.39% at each score level).

At level 2, 21 respondents (32.8%) participated in the market; score level 12 (4.76%) has the fewest and score level 32 the most participating farmers (4.76%). Most farmers in this level are concentrated in score levels 16 and 20 (19.05%) and 24 (23.81%).

At level 3, 11 respondents (17.2%) participated in the market; score level 24 (45.45%) has the fewest and score level 36 the most participating farmers (9.10%). Most farmers in this level have a score level of 24 or 30 (45.45%).

At level 4, 9 respondents (14.1%) participated in the market; score level 32 (22.22%) has the fewest and score level 52 the most participating farmers (44.45%) in this level. Most farmers have score levels of 52 (44.45%) or 30 (22.22%).

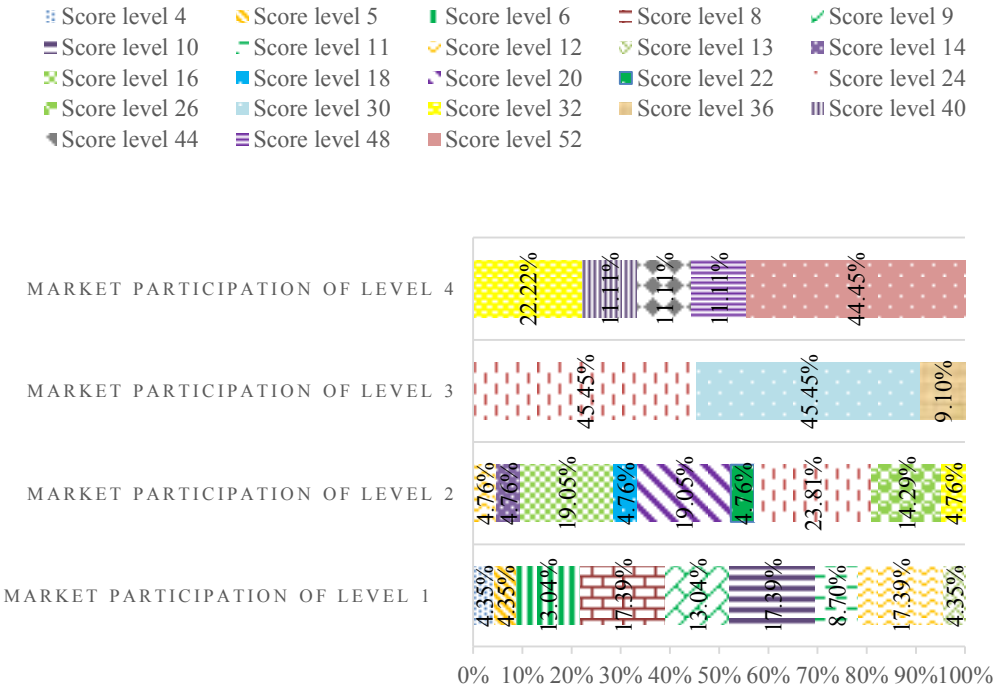

Fig. 1 Four levels of participation in vegetable markets

The level of SAC members' market participation is higher than that of non-members; the difference is statistically significant at the 5 percent level. The average market participation score of SAC members is 23.4, whereas that of non-members is 16.8 (Table 2).

Table 2 Comparison of market participation level between SAC members and non-members

Dependent variable	Members	Non-members	Difference	t-test
Market participation score	23.4	16.8	6.6**	1.97

*Note: ** statistically significant at the 5% level*

The logit regression model was used to determine the factors influencing the probability of selling vegetables to SAC; Table 3 presents the regression results. The fit of the data is statistically significant at the 5 percent level; the concordant is R^2=0.22. The results indicate that the specific regressors are 22 percent able to explain the probability of selling vegetables to SAC. The main income source (vegetables are a primary source of household income), which is positively statistically significant at the 10 percent level, relates to the probability of selling vegetables to SAC. A natural increase in main income implies a higher probability of selling vegetables to SAC. Six other variables positively affect the probability of selling vegetables to SAC but the results are not statistically significant. Those variables are age, education, male household head, family size, farm size and vegetable prices. Three other factors that negatively affect the probability of selling vegetables to SAC, and are also not statistically significant, are married status, dependency ratio and distance to main market.

Table 3 Logit model results for factors influencing the probability of SAC members selling vegetables to SAC

Variable	Definition of variables	Coefficients	Std.Error	Z-value	P-value
Age	Age of household head	0.026	0.038	0.680	0.497
Education	Number of years household head attended school (years)	0.193	0.121	1.590	0.112
Male	Household head is male (dummy)	15.407	1836.572	0.010	0.993
Married	Household head is married (dummy)	-16.909	1836.572	-0.010	0.993
Family size	Number of family members	0.253	0.183	1.380	0.167
Dependents	Dependency ratio (adults aged 15-65 years)	-0.765	0.827	-0.930	0.355
Farm size	Area of cultivated land (m^2)	0.000	0.000	0.520	0.605
Major income	Vegetable production is primary source of household income (dummy)	1.221	0.695	1.760	0.079
Vegetable price	Vegetable price (riel per kg)	0.000	0.000	1.190	0.236
Distance	Distance to main market (km)	-0.136	0.147	-0.920	0.356
Constant		-3.293	3.089	-1.070	0.286

Note: Number of observations 64; X^2= 18.55 (P<0.05); log likelihood = -33.54 (P<0.05); concordant R^2=0.22

Factors Affecting Market Participation of SAC Members

In estimating the determinants of the extent of market participation, the tobit model involved nine regressors (Table 4). Chi-square of 75.21% at the 1% level of significance implies a good fit between the model and data. The log likelihood is -137.14 at the 1% level of significance; the R^2 of 0.22 signifies that independent variables account for 22% of the variability in the level of market participation. Education of household head, which has a positive sign, is significant at the 5% level; a

unit increase in the level of education will increase the level of market participation by 60%. Receipt of market information, which has a positive sign, is significant at the 5% level. Members who receive market information are at least three times more likely to take market participation more seriously than those who receive none at all. Vegetable production, which has a positive sign, is significant at the 1% level; a unit increase in vegetable production will increase the level of market participation by 1%. Distance to main market, which has a positive sign, is significant at the 5% level, meaning a 1 km increase in distance will increase the level of market participation by 68%. Because SAC cannot buy all the vegetables its members produce, farmers nearly always have to travel to sell their produce at more distant markets such as the Svay Rieng market and other district markets, where they get higher prices. If members sell their produce to wholesalers at the farm gate, they receive lower prices than if they were to sell directly on the main market. Supplying SAC, which has a positive sign, is significant at the 1% level. Members who supply vegetables to SAC are at least six times more likely to take market participation more seriously than those who do not. Two variables that positively affect the level of market participation but are not statistically significant are family size and vegetable prices. Four variables that negatively affect the level of market participation and are also not statistically significant are male household head, main income source, farm experience and number of training subjects.

Table 4 Tobit model results for factors affecting market participation of SAC members

Variable	Definition of variables	Coefficients	Std.Error	Z-value	P-value
Education	Number of years of household head attended school (years)	0.605	0.283	2.140	0.040
Family size	Number of family members (person)	0.416	0.492	0.850	0.403
Male	Household head is male (dummy)	-1.718	3.871	-0.440	0.660
Market information	Receipt of market information (dummy)	4.666	2.247	2.080	0.046
Main income	Vegetable is primary source of household income (dummy)	-0.259	1.984	-0.130	0.897
Farming experience	Years of growing vegetable (years)	-0.047	0.105	-0.450	0.657
Vegetable production	Total amount of vegetable production (kg/m^2)	0.014	0.001	10.390	0.000
Training	Number of training subjects covered	-0.246	0.671	-0.370	0.716
Distance	Distance to main market (km)	0.681	0.298	2.280	0.029
Vegetable price	Vegetable price (riel per kg)	0.000	0.000	0.700	0.490
Supply to SAC	Members selling vegetables to SAC (dummy)	6.479	1.901	3.410	0.002
Constant		-3.505	5.366	-0.650	0.518

Note: Number of observations 44; X^2= 75.21 (P<0.01); log likelihood = -137.14 (P<0.01); concordant R2= 0.22

CONCLUSION

The study found that the vegetable market participation of SAC members is better than that of non-members. Vegetables are the primary source of household income, which is positively related to the probability of selling vegetables to SAC. The study identifies five factors that affect effective market participation: 1) education level of household head, 2) receipt of market information, 3) amount of vegetable production, 4) distance to main market, and 5) the extent to which farmers supply vegetables to SAC. The analysis emphasises the importance of agricultural cooperatives in improving farmers' participation in vegetable markets. Moreover, the insights into the factors that affect the probability of

selling vegetables and the level of market participation can usefully contribute to improving the royal decree and prakas on agricultural cooperatives in Cambodia.

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Research article

Appropriate Extension Approaches in Disseminating Livestock Production Technology in Cambodia

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Abstract Understanding the current local livestock-disseminating approaches was very crucial for the study to present an extension work plan by a technical staff with specific discussion on the framework in identifying the appropriate extension approaches suitable to Cambodia's local situation. Primary data were collected using a structured, comparative criteria-guided questionnaire from 7 interviewees within 4 purposively-selected extension institutions. Regarding the comparative criteria for applicable and strongly applicable utilization of extension approaches, livestock technology extension approaches in Cambodia tended to range from the top-down general agriculture to more bottom-up, participatory approaches based on its frequency of all its characteristics. The most applicable livestock extension approach was participatory integrated with farming systems development, cost sharing, project, and education institution because the growth in overseas-donored development aids created a desire for more decentralized, participatory extension approach. Therefore, the diffusion of livestock technology from Cambodian local farmers increasing farmer livestock production perhaps thereby farmer livelihood would be increased using the participatory approach integrated with others. The planning key points for disseminating livestock technology was also based on the strongly applicable participatory approach.

Keywords extension approaches, livestock production technology, Cambodia

INTRODUCTION

To increase livestock production, it seems to be extremely important to keep farmers in updated information regarding various production process and marketing practices. Inadequate access of developing-country farmers to relevant livestock information/technology has an effect on all livestock subsectors and different stages of livestock production. The livestock technology dissemination therefore is very important for improved smallholder farmer livestock production and consequently increased farmily income (Khan et al., 2014; Sani et al., 2014). In Cambodia, pluralistically-characterised agricultural extension (Mak, 2012; MAFF, 2015) is a key mean to increase farmer crop and livestock production thereby generating farmer income (Axinn, 1988; Touch, 2000; Millar, 2009; Christoplos, 2010; Mak, 2012; Khan et al., 2014; Sani et al., 2014). Many approaches to technology dissemination have also been developed and used in both public and private extension services, and

those run by non-governmental organizations in the developing countries (Davis, 2004; Lukuya et al., 2012; Mak, 2012; Khan et al., 2014; MAFF, 2015) such as Cambodia (Mak, 2012; MAFF, 2015). This effort could be contributed by technical personnel becoming the subject matter specialists of their own generated technologies (Blalock, 1963; Fetsch et al., 2010; Patil and Kokate, 2011; Kahan, 2013). However, if the new specific generated knowledge could not be diffused to the end consumers especially, livestock farmers without any appropriate, efficient extension approach and with insufficient combined efforts from all extension provider institutions despite many approaches used in those institutions (Axinn, 1988; Davis, 2004; Lukuya et al., 2012; Mak, 2012; Khan et al., 2014), such the technology is not practically applied and has no value. Consequently, one or more effective livestock extension approach (es) is required to deliver new technologies to farmers in Cambodia and thereby the considerable focus of currently local approaches/methods of disseminating the livestock information to Cambodian farmers is very important to determine if the information of improving livestock production will be able to be disseminated to the right farmers at the right time.

OBJECTIVE

The study was conducted to present only an extension work plan by the technical staff affiliating to the livestock production institution with specific discussion on the framework in analysing the suitability of an appropriate extension approach in Cambodia's local situation.

METHODOLOGY

Data Collection: Secodary and primary data were collected. The latter was collected at a period of April 2015 using a structured questionnaire from 7 key informants each of whom it took around 1 hour for interviewing, within purposively-sampled 4 extension institutions (Royal University of Agriculture, Department of Animal Health and Production, Centre for Livestock and Agricultural Development, and Centre for Study and Development in Agriculture) based on their most potential activities of livestock extension and availability in Cambodia. The questionnaire was guided by 6 of 7 comparative criteria introduced by Axinn (1988) in identifying the appropriate extension approach in Cambodia. The considered criteria with their individual indicators included program (C1), clientele (C2), field personnel (C3), financial requirements (C4), organizational structure (C5), and leadrship characteristics (C6); and 2 key important options (Applicable or Strongly Applicable) to be selected by the interviewee (Table 1 and Table 2).

Data Analysis: Using Axinn's (1988) comparative analysis as framework of the eight extension approaches (Table 3), analysis of responses indicated which approaches were most likely to fit the condition of Cambodia. For each comparative indicator (denoting contrasting local conditions), an interviewee responds by answering either, "Applicable" or "Strongly Applicable" which was counted and calculated as percentage. The analysis of the gathered information was based on the descriptive criteria given. The highest percentage for each criterion indicated the most likely appropriate extension approaches that could be used in disseminating the generated livestock technologies from the research studies.

RESULTS AND DISCUSSION

Table 1 shows that all pairs of comparative indicators exception with a few pair of the Axinn's comparative criteria were practiced in Cambodia. Table 2 shows that best fit extension approach (es) based on the analysed indicators of each criterion should be noticeable in the study. At least the applicable indicator with higher percentage of the study can be considered as one indicator of each approach given (Axinn, 1988).

Table 1 Analysed livestock extension approaches using Axinn's descriptive criteria considered

Descriptions of Criteria (*with comparative sub-components or indicator*)		Informants' Responses (%)	
		Applicable	Strongly Applicable
Program (C1)	Nationally oriented scope	42.9	42.9
	Provincial oriented scope (including district, commune, or village)	14.3	85.7
	Goal to increase livestock production for export	28.6	28.6
	Goal to increase livestock production for farmer family and national consumptions	0.0	100.0
	Change the extension messages in response to feedback from rural villages	28.6	71.4
	Not Change the extension messages in response to feedback from rural villages	42.9	0.0
	More focused on livestock technology than on lifting social standards of rural life	42.9	28.6
	Prioritize on lifting social standards and livestock technology also	42.9	57.1
	Technical information decided upon by people inside the local rural village	28.6	71.4
	Technical information decided upon by people outside the local rural village	85.7	14.3
	A simple standardized technical message	71.4	14.3
	Wide-ranging extension message to meet local needs and interests	28.6	71.4
Clientele (C2)	Focused on larger, commercial, single livestock producers	42.9	14.3
	Focused on broader range of people including poor farmers	14.3	85.7
	To likely deal primarily with male farmers	28.6	0.0
	To most likely deal with male, female and youth farmers	0.0	100.0
	Most likely focused on limited ethnic and social groups	28.6	28.6
	Likely focused on different ethnic and social groups	28.6	71.4
	Target clientele at national level	71.4	28.6
	Target clientele in limited areas within Cambodia	14.3	71.4
Field personal (C3)	Field personnel from outsiders	57.1	28.6
	Field personnel from insiders	14.3	85.7
	Central government pay the salary	57.1	28.6
	Local government pay the salary	28.6	71.4
	High level of education of the field personnel	42.9	42.9
	Lower level of education of the field personnel (under Bachelor's Degree)	28.6	71.4
	Likely to include women and men as personnel	0.0	100.0
	Not likely to include women as personnel	14.3	14.3
	Extension personnel likely to transfer frequently from post to post	28.6	71.4
	Extension personnel likely to remain at post for longer periods of time	57.1	28.6
	Personnel with permanent status	42.9	57.1
	Personnel with contractor/temporary status	57.1	42.9
Financial requirements criterion (C4)	Provide jobs for urban educated unemployed	28.6	71.4
	Provide jobs for rural trained people	57.1	42.9
	Incur high cost for information support	42.9	14.3
	Incur low cost for information support	71.4	28.6
	Provide farmer family high cost for producing livestock	42.9	28.6
	Provide farmer low cost for producing livestock	57.1	42.9
	Incur high cost for transportation	57.1	28.6
	Incur low cost for transportation	57.1	42.9
	Major support from central government	85.7	0.0
	Support from other sources	14.3	85.7
Organizational structure (C5)	Tends to fit centralization of control of organization	42.9	0.0
	Tends to fit decentralization of control of organization	14.3	85.7
	Emphasize the use of Subject Matter Specialists (SMS)	14.3	85.7
	Emphasize less the use of Subject Matter Specialists	42.9	0.0
	Require little participation of rural people to be served	14.3	0.0
	Require high participation of rural people to be served	0.0	100.0
	Use prominently information media support	71.4	14.3
	Not use information media support	42.9	14.3
Leadership (C6)	Leadership of organization to be part of central government/authority	42.9	42.9
	Leadership of organization to be part of local government/authority	0.0	85.7
	Leadership of organization to originate from professional	0.0	85.7
	Leadership of organization to originate from clientele	57.1	14.3
	To address a few technical fields	42.9	42.9
	To address broader rural development fields	28.6	57.1

The higher rate of responses on the strong applicable indicators of the C1 (Tables 1 2) indicated that PA would be commonly used for extesnion probably due to the limited funds and different projects of the institutions, and farmers' insufficient access to export business. It is also caused likely by the integration of the to-be-disseminated technologies generated by subject matter specialists (SMS) and the knowledge interest of farmers, and it requires the masses of extension messages (e.g. specific livestock knowledge with human health and farmer needs) without being so far from the planned goal.

Additionally, analyzing the indicators of the C2 and C3 (Tables 1 and 2), PA, FSD, T&V, PR, and/or CSH would be utilized within the studied institutions due to the more applicable tendency for the extension dealing with a multitude of stakeholders at limited areas; local insiders employed as field personnel; both gender, permanent personel with low qualification; frequently personnel transferring; and the personnel salary from the local government (Table 1). This may be based on the extension consideration for poor smallholder farmers at specific areas as priority of projects funded by the jointly national and international supports.

The analyzed indicators of C4, C5 and C6 (Table 1) also refered the PA (as the most common), GA, T&V, FSD, CSH, CA, EI, and/or CS as the commonly used approaches (Table 2) explained by the strong applicable tendency for supports of extension finance from other sources (e.g. loans, international funds and projects), provision of more job opportunities for the urban educated students, decentralization control, SMS emphasis, high rural participation, local authority as leadership, professional organization, and solutions for broader rural development fields (Table 1). This would be also based on the more sufficient and efficient international funding projects jointly with the national funds which is not only extension supportive source, and the urban educational institutions with more available facilities produces the more qualified personnel for the extension. Being applicable was more likely for incurring the low cost for the information support and farmers producing livestock (Table 1).

Regarding the studied criteria, livestock technology extension approaches tended to range from the top-down general agriculture to more bottom-up, decentralized, participatory approaches in Cambodia. However, the latter was more applicably used to disseminate the knowledge to farmers because the extension supports and personnel payment were mostly from local government with other sources and the growth in development aids from oversea donors created a more desire for such the approaches (Touch, 2000; Race and Millar, 2008; Mak, 2012). The strongly-applicable livestock extension approaches also tended to be the agricultural extension participatory and the cost sharing (6 criteria), the farming systems development (4 criteria), the education institution (3 criteria); and the general agricultural extension project, the commodity specialized (1 criterion). This indicated that there were current combination of livestock extension approaches in Cambodia which was similar to the utilization of extension approaches in Ghana (DAES, 2011) and other studies (Quizon et al., 2000; Touch, 2000; Mak, 2012). Not only an approach can success in the livestock technology dissemination, but at least 2 various approaches are jointly used; the dissemination is for more than one specific circumstance; and the advantages of one extension approach in a circumstance could provide disadvantages in another (Axinn, 1988; Rivera et al., 2001; Rivera and Quamar, 2003).

Understanding the mentioned extension approaches, prior to dissemination of the survey and experimental-generated livestock technology/knowledge to specific local Cambodian farmers, the key points to be considered and planned were (Rivera et al., 2001; Millar, 2009; Mak, 2012; MAFF, 2015) 1) conducting pre-study (feasibility study) on a specific areas (national, provincial, district, commune or village levels) to understand mainly key needs and interests of local farmers; 2) using livestock technology extension participatory approaches combined with others; 3) specifying livestock knowledge for the respectively specific livestock farmes/groups (e.g. associations or community-based organizations) in the specific areas with sufficient availabilities and resources for livestock production; 4) conducting the dissemination with supports from extenal donors or projects especially in a large scope of the extension; and 5) empolying the qualified local or outside field personnel with communication skills and close relationship with farmers.

Table 2 Matrix of Axinn's descriptive criteria for the 8 extension approaches

Criteria for Extension Approaches (*with indicators)*		Extension Approaches *							
		GA	**CS**	**T&V**	**PA**	**PR**	**FSD**	**CSH**	**EI**
Program (C1)	Life quality focus				x			x	
	Responsive to feedback				x		x	x	
	Flexible message				x	x	x	x	x
	Goal to increase farmer family consumption				x				
	Production goals	x	x					x	
	Outside information				x	x		x	x
	Area or provincial scope		x		x	x	x		
	National scope	x							
Clientele (C2)	Spread status				x		x	xx	
	Men, women, youth				x		x	x	x
	Narrow focus				x		x	x	x
	Area target		x	x	x	x	x	x	x
Field Personal (C3)	Broad staff base				x				
	Temporary	x	x				x	x	
	Frequent transfer	x		x		x	x		x
	High training	x		x				x	
	Local salary				x			x	
	Outside origin	x		x				x	
Financial Requirement (C4)	Low information	x	x		x		x	x	
	Low transport	x	x		x		x	x	
	Urban source	x	x	x			x		
	Low cost				x			x	x
	Other funds	x	x	x	x	x	x	x	x
	Central funds	x	x	x	x	x	x	x	x
Structure (C5)	High participation				x		x	x	
	Media prominent				x				x
	Specialists emphasized	x	x	x			x		x
	Decentralized				x			x	x
Leadership (C6)	Professional origin	x	x	x					
	Broad representation				x		x	x	x
	Local origin				x			x	

** Eight extension approaches identified by Axinn (1988) including General Agriculture (GA), Commodity Specialized (CS), Training & Visit (T&V), Extension Participatory (PA), Project (PR), Farming System Development (FSD), Cost Sharing (CSH), and Educational Institution (EI). Additionally, "XX" is strongly applicable and "X" is applicable.*

CONCLUSION

Livestock production can increase as farmers adopt and practice the new introduced knowledge. In livestock extension organizations, at least 2 different extension approaches were used concurrently to disseminate new knowledge and technology generated by researchers to Cambodian farmers while using the participatory approach would be optimum.

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Research article

SWOT Analysis of Systematic Land Registration's Procedure under Order 01 for Strengthening Land Tenure Security in Cambodia

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Abstract In 2011, the conflicts over economic land concession (ELC) were hardened and became more violent than before. Hence, Order 01 on "measures for strengthening and increasing effective management of economic land concession" was decreed on 07 May, 2012. The aims of this study were 1) to evaluate the strength and the weakness of the land registration procedure under Order 01, and 2) to assess the challenges and opportunities for improving land registration. A qualitative approach, incorporating observations and semi-structural interviews with 96 local families based on questionnaires survey and 23 key informants, were applied in this study. Secondary data were collected from Cambodia's ministry of land and land administration sub-sector program (LASSP). The results of this study showed that land conflicts were reduced and solved, measures for preventing land conflicts were taken, illegal land occupations were regularized and 361,734 titles were provided to the people. The process was fast. Local people were satisfied and confident on its implementation. Moreover, the local people's livelihoods were improved as well as the public awareness of systematic land registration (SLR) was spread throughout the country. However, the weaknesses of its implementation were: technical problem, lack of information and quality control, poor governance, state land decreased and it impacted on educational institutions and on the environment, wildlife and indigenous culture. Its opportunities were found that the investment on land will be more active from now on due to the investors' confidences and trust on land titles. Its challenge was identified that financial support of technical assistances was pulled out from LASSP. In conclusion, its implementation was very useful for the landless people, and the poor. Quality control should be included into the process and land occupants should be seriously identified. SLR should be sped up to register in hot-issue sites.

Keywords Order 01, Systematic Land Registration, effectiveness, challenges and opportunities

INTRODUCTION

In 2005, one fifteenth of the Cambodian households were involved in land disputes due to the lack of tenure security (LHWGC, 2009). In order to improve the land tenure security, a sub-decree on the procedures to establish cadastral index map and SLR and sub-decree on sporadic land registration (LR) were formulated. In particular, to solve land conflicts, sub-decree on organization and functioning of

the cadastral commission were established as well (RGC, 2002). However, the land conflicts still occurred throughout Cambodian territory. Furthermore, according to the NGO Forum (2011), rural communities are heavily relied on land and forest resources, but landlessness has become a significant cause of widespread poverty for rural Cambodians and landlessness has risen to 20%, beside 40% of rural households have farms that are smaller than 0.5ha (Üllenberg, 2009). Moreover, statistics showed that out of 282 land dispute cases, 14% or 39 cases have been rooted in development projects, especially in the granting of Economic Land Concessions (ELCs). Most land disputes triggered by ELCs can be found in Kratie, Rattanakiri and Kampong Cham (NGO Forum, 2011). Moreover, it was estimated that in total about 1.5 million hectares of ELCs were granted to investors as of April 2010 (Ngo and Chan, 2012).

Hence, Order 01 on "measures for strengthening and increasing effective management of economic land concession" was established on 07, May 2012. One part of this Order is a temporary postponement of granting new ELCs in order to prevent land conflict occurring (RCG, 2012). Moreover, RCG decided to provide land ownership to people who occupy and use the ELCs land, forest cover and protected area within the framework of land distribution reform. The campaign of SLR in 21 provinces of the country was established and it was called "New Action on Existing Policies for Land Sector". Volunteer youths were engaged to survey land for people under the ministry of land management urban planning and construction (MLMUPC)'s instruction and guideline. They were trained only 2 days about how to register and survey the land (Yeang, 2013).

OBJECTIVE

The objectives of this study were to evaluate the strength and the weekness of the land registration's procedure under Order 01 and to assess the challenges and opportunities for improving LR.

METHODOLOGY

The qualitative and quantitative approach, incorporating observations semi-sturture interviews and focus group discussion had also been done as well as recorder was used to record participants' point of view. Survey with questionnaires had been used to know the respondents opinions. The research study focused on systematic land registration under Order 01 that has been carried out since June, 2012 in Pi Tnou commune, Snoul disctrict, Kratie province located in forest cover, protected area (National Park) and economic land concession area. Furthermore, 96 local families and 23-key informants were chosen to be interviwed. Secondary data were collected from Cambodia's ministry of land and LASSP.

RESULTS AND DISCUSSION

Strength of the Procedure of Systematic Land Registration under Order 01 (SLR BB01)

Land conflict resolution: The study showed that there were 39 people among 96 interviewees involved in land conflicts. Most of land conflicts were happening to LECs companies and others occurred with forest and environmental department. 33 cases out of 39 cases were solved by the implementation of SLR under order 01 (BB01). These were because its implementation had cut the land from ELC company, measured and gave to people who were actual occupants even though the company claimed that the areas were belonging to it. Most of the land conflict had been solved, but 6 cases were not solved due to in the fact that they encroached environmental land. According to Müller (2013) the implementation of SLR BB01 was to solve the land conflicts over forest land and ELCs for the targeted 700,000 parcels in only one year. The campaign had to speed up the normal title

production levels of 350,000 per year during SLR and went countrywide into 21 provinces where these types of conflicts exist. MLMUPC opted for staffing up and bringing in extra workforce from outside.

Land conflict prevention: The research found that 15.88% of interviewees expressed their opinion that the implementation of directive BB01 really prevents land conflict occurrences in the future. They added that its implementation measured the land and provided the titles for them, and no one could seize their land now.

Regularizing not-yet-legal land occupation and its main achievement: According to Im (2012), the implementation of SLR BB01 had solved irregular issues: regularizing not-yet-legal land occupation in rural areas through donation of completed land ownership, providing a small-scale economic land concessions and social land concession in order to improve and guarantee land tenure security, to improve people's livelihood and to enhance national economy. The achievement of its implementation for 12 months (June 2012 - June 2013) was the 361,734 titles with approximately 595,534 hectares have been granted to probably 200,535 families (MLMUPC, 2013).

Local people satisfaction and confidences: The study found that 94% of interviewees satisfied with its procedure and were also confident on the land certificate (title) that government issued to them. They reported that once they have a certificate, no one could seize their land anymore. However, 6% of the respondents were not satisfied with the implementation of the procedure and they were less confident in it. This was mostly because they were occupying the land located in protected area so their land have not been measured and registered. They further added that if they get the certificate they will be satisfied with its implementation and they will be confident in the certificate.

Improving local people's social economic: The implementation of Order 01 provided the full ownership to the people as well as securing on their land. As a result, some villagers could be able to use the land title provided/registered from government to borrow some loan from micro finance or bank which the interest rate is low (1.2% - 2% per month) comparing to the loan borrowing from money leder which it is high in interest rate. The bank will not provide loan for villagers if their land titles would not be appropriately registered, so some villagers had to borrow money from other money lenders with a high interest (7% - 10% per month). The interest rates varies in accordance with kinds of land certificates and titles (commune, provincial or governmental level). For instance, if the land certificate is certified at commune level (from commune chief), the interest rate would be around 4% - 5% per month. Consequently, being implemented by this Order, the poople's social economic would be improved through borrowing loan with low interest rate for their small business or farming such as buying crop seeds, seedlings, fertilzers and agricultural equipments etc.

Improving and speeding up the procedure of SLR under LASSP: The research found that it is an opportunity for the MLMUPC to receive additional modern equipments and materials for land administration during and after its implementation. Moreover, 600 out of the total youth volunteer were recruited to be MLMUPC's new staff. According to Sar (2013), to strengthen the quality, effectiveness of field work management and to continue the smooth and high effective procedure of SLR, the 25 provincial department directors in the department of land management, urban planning, construction, and cadaster have been proposed to readjust and reorganize the SLR team. The team number of SLR was adjusted from 26 to 15 members per team in order to reduce the expense and to increase the number of SLR teams that can be implemented throughout 25 provinces.

Strengthening land concession economic management: Concerning the implementation of Order 01, the Royal Government has decided to abolish economic land concessions which have not followed the agreements and has given the expropriated lands to the Provincial State Land Management Committee to manage those lands for social land concession programs. Meanwhile, state land in the area where RGC implemented SLR BB01, was to be cut off in the form of Leopard's skin to existing land occupants using and cultivating it and also to the provincial committee for state land management and be used for social land concession programs. Therefore, this land can be used in the future for land distribution program of the Royal Government in a larger scale than before.

Spreading out the public awareness through country: The implementation of SLR BB01 was carried out throughout 21 provinces at one time. So far though the rural areas are, the land registration teams could manage to reach those places. Previously the LSR under LASSP always avoided to provide registration in those areas, yet the donors (world bank, GIZ, Finmaland and CIDA) always force LASSP to do so. As a result, its implementation is appreciated by all stakeholders including donors.

Weakness of Its Procedure and their Causes

Technical problem: The weakness of the LR procedure was divided into three categories, losing of parcel size, lacking of neighbors' printed thumbs and losing parcel size and lacking of neighbor' printed thumbs. Fig. 1 illustrates that only 63% of respondents' neighbor could participate in LR process and have their thumbs printed while registering the parcels, whereas 37% out of 100% had some troubles during the land demarcation registration in which 12% of respondents mentioned that the area of their parcels showing on the land title had lost some compared to the actual area on the ground due to handheld global positioning system (GPS) and volunteers and land officers probably did not accurately measure their land as the respondents said, 19% told that their neighbors were absent to print their thumb and 6% were losing of parcel size as well as figureprint had not been done. The volunteers had been trained about its procedure and technical work for only 2 days.

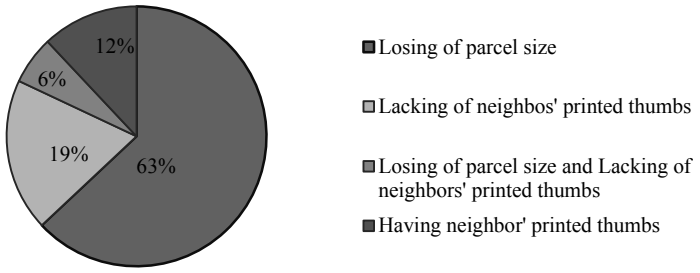

Fig. 1 Technical problems associated with the land registration procedure

The other weakness of technical problem was that the monument poles have not been installed on adjudicated boundaries. Installed-boundary poles had been done for parcels which were registered, but the poles were just small sticks to recognize the boundary, such as a small wooden stick, digging small holes on boundary, and using color spray as some villagers and some volunteers said.

Lack of information and poor governance: Due to lack of information that implementation under directive Order 01 could not spread widely across the country, many villagers did not know how to prepare documents for applying to register their land; as a result, some people haven't had their land regiestered. According to the survey, it was because of poor governance as some villagers said that they could not find the person who was responsible for this registration; for instance, when they came to meet land officers or students to certify some documents: residential certificate, widow's certificate or land occupied certificate, they were told that it was not the land officers' responsibility, but the commune chief's responsibility, and when they went to meet the commune chief, they were told that it was not commune chief's responsibility, but the land officers' and students' responsibilities. Moreover, LR was so fast to follow by people as all people could not have thier land registered because some people were absent due to thier personal tasks while LR team implemented the registration. This was because when the LR teams completed registration of one area they would move to other area and they would not come back to register the land title of those who were absent during registration process.

Impact on educational institutions: The implementation of SLR BB01 had used approximately 2,000 volunteer youths who were mostly students which 305 students were from Royal University of Agriculture (RUA). The registration exercise had caused two faculties of RUA to be closed for one semester namedly, faculty of land management and land administration and faculty of forestry. While studnets returned to study, their studies were incomplete because some subjects were taught for less hours than regular curriculum did.

State land loss and negative impact on environment, wildlife and culture: According to Council of Ministers, (2012), the ownership was donated for the requests of people who actually occupy the land not exceeding 5 hectares. Furthermore, for people occupying more than 5 hectares, whether the land contains a residence or not, the part of the land that has truly been cultivated shall be donated as ownership. Parts of the land claimed that has not been developed shall be registered as State private land and the claimant shall be given the right of "small economic concession". In such a case, the land shall be registered in the name of the Governor as the chairman of the provincial state land management committee, and the Governor shall be granted the mandate to establish the contract of "small economic concession" with the concessionaire. However, the researcher found that the actual implementation has not followed guideline above and the more than 5 hectares land where are not only the clear land but also forest land have been registered via SLR BB01 as well as sporadic land registration. Consequently, some area of forest cover were lost during its implementation and the land cover has changed very fast. According to Rabe (2013), the Directive BB01 caused numerous issues for indigenous people in Ratanakiri Province. Moreover, it would cause loss of indigenous land, livelihoods, identity, and culture and it divides communities. For example, for those who received the private land during this implemenaiton, will stop doing the slah and burn cultivation because they do not have the reservation land.

Lack of quality control of the parcel and land owner: The research showed that the quality control of the implementation of SLR BB01 was not mentioned in the guideline. Particularly, most of the students were not skillful in technical and practical work such as, using of GPS, geographic information system (GIS) and land law. As a result, some people had taken this chance to claim the state land as their own land. According to the guideline of SLR under LASSP, it claimed that 5% of parcels which have already been registered, have to be selected to cross check in the field such resurveying parcels, database of parcels owners.

Opportunity of the Procedure of SLR BB01

Positive external influences can be taken advantage from this implementation in order to solve land conflict in city because some development partners provide funding for urban land dispute conciliation. Furthermore, communal land registration for indigenous people is implemented because of development fund. For instance, GIZ not only supports the implementation of circular 03 "resolution of temporary settlements on state land illegally occupied in the capital, municipal and urban areas" but also supports communal land registration for indigenous people. Land policy will be successfully established because all stakeholders understood about the importance of land. It is still supported by the politic and development partner, GIZ. Investing on land will be more active from now on because investors have confidence and trust on land title. Hence, land price will be increased mostly in rural area.

Threat of the Procedure of SLR BB01

According to Rabe (2013), in Rattanakiri province, the students and local government officials threatened indigenous people who said that a regular statement was from the Commune Councils, District Governors, and Provincial Governor, who told villagers, "If you do not choose the private titles and if you have a conflict with the company in the future, we will not help you resolve the issue." This

made villagers believe that dispute resolution mechanisms would be unavailable to them, and that the BB01 titling was the only solution to protect their land against the companies.

Financial support from another development partner will be pulled out from Cambodia for instance, Finnmap, Finland and CIDA, Canada. The government thought that Cambodia can implement by itself but MLMUPC still needs the development partner's assistance of technical issues. The database of parcels has been stored in Microsoft office Access, so all parcels throughout country cannot be used as one database because the data of parcels in whole country is bigger than 2 GB while Microsoft office Access enables to store only 2 GB.

CONCLUSION

It could be inferred that the implementation of SLR BB01 was very useful for landless people, and the poor. It was also the crucial chance to devide land from the rich and the companies in order to grant to citizens in the rural areas. The land conflicts were reduced and solved, measures for preventing land conflicts were taken, illegal land occupations were regularized and 361,734 titles were provided to the people. The local people's livelihoods were improved as well as the public awareness of SLR was spread throughout the country. However, the weaknesses of its implementation were: technical problem, lack of information and quality control of the parcel and land owner, poor governance, state land decreased and it impacted on educational institutions and on the environment, wildlife and indigenous culture. The opportunities of its implementation were: land policy which will be successfully established and investing on land which will be more active from now on due to land title. Enventually, the financial support of technical assistances was pulled out from LASSP.

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Research article

Farmers Perceptions on the Causes and Effects of Cassava Witches' Broom (CWB) on Cassava Production in Three Provinces of Cambodia

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Abstract Cassava production in Cambodia has been increasing due to favorable market and agro-ecological conditions. However, damage to cassava crops by pests is posing significant concerns, due to the impact on yield and starch quality. Among the most important diseases is Cassava Witches' Broom (CWB), that has only recently been identified in Cambodia which is increasing in severity, and for which there are limited control. A survey on causes and effects of CWB was undertaken in 2015 with 150 cassava growers in the three provinces of Kampong Cham, Prey Veng and Svay Rieng. A further 30 cassava farmers participated in a focus group discussion. The main objectives of this study were to get an understanding of the current level of damage caused by CWB on cassava production, the causes of the disease, and the control measures taken by the respondents in relation to the disease. CWB is perceived by cassava growers as the most serious disease in their cassava crops, potentially causing more than 50% decline in tuber yields (from an average of about 19.5 t/ha in a normal year, to 8.5 t/ha in a year of CWB infection and damage). From the perceptions of respondents, four reasons were given for the incidence and damage of CWB. These included, poor soil fertility (28.70%), drought (28%), the side effects of pesticide use (20%), and the quality of planting materials/varieties planted (18%). Even though these are the reasons provided by cassava farmers, they do not have the capacity to control the disease, despite the following initiatives: pesticide application (55%), change to CWB resistant varieties (15%). Farmers reported that pesticide application is not an effective strategy to control CWB, and recommended that improved agricultural extension services could help them get access to CWB resistant varieties, as well as to address other production issues, in a timely manner.

Keywords Cassava Witches' Broom, cause, effect, cassava production, poor soil fertility

INTRODUCTION

In Southeast Asia, cassava is the second most widely cultivated crop after rice. The crop supports an estimated of 40 million people, and underpins steadily growing local starch and biofuel industries (ACIAR and CIAT, 2013). Cassava is of growing importance, since it is regarded as a food security crop. It is either consumed directly, processed, or cultivated as a source of income for the poor (Hoat, 2014).

The cross-border trade of cassava is also well known, since the Cambodian cassava provides feedstock for the processing sectors in Vietnam and Thailand. The value of cassava products traded from Cambodia is estimated to cover USD250 million per annum (El, 2008). However, the rapidly emerging pests and diseases problems pose a significant threat to farmer's yields and income, as well as to the local industry. A key threat of Cassava Witches' Broom disease (CWB), has been threatening up to 40 million small holder farmers in Southeast Asia who have strong dependence on cassava to support their livelihoods. Witches' Broom is a disease that spreads through contaminated cuttings, and can also be transmitted by insects. The most common symptoms are the presence of dwarfism in the plants, small leaves along the stem, and lower quality cassava roots. The disease has been detected in Vietnam, Thailand, Cambodia, Laos, Indonesia, and the Philippines. The impact of CWB is clear: it increases the loss margin between 10 and 15% (but as high as 50%), with starch content being reduced by 25 to 30% (CIAT, 2015a; 2015b).

Even though CWB was first reported in Cambodia as recently as 2009, it has been causing severe damage in cassava plantings, especially during the early wet season. In Cambodia, CWB is currently the most serious disaster for cassava farmers. Since the disease has a direct impact on farmer incomes, it is very important that action needs to be taken to equip cassava growers with some capacity to control the disease. In addition to the CWB constraint, cassava is usually cultivated by poor farmers without having access or knowledge to fertile their land. These marginalized farmers can often suffer from crop losses due to their limited capacity to address pest and disease issues. These ultimately lead them to become in-debt, resulting in asset sales and landlessness (Cambodia Daily, 2014).

This study has been conducted with 180 cassava farming households in three provinces of Prey Veng, Svay Rieng and Kampong Cham to understand the current status of their cassava production, particularly to identify the causes and effects of CWB on this crop production.

METHODOLOGY

Samples for the survey were selected from the three districts of the three provinces named above. The survey randomly selected 150 respondents in the survey areas, with approximately 50 households being randomly selected from each of the survey districts. To ensure representativeness and accuracy of the data, the survey employed both quantitative and qualitative methods which allowed information from both approaches to be cross-checked. From the quantitative side, the questionnaire tool was designed to accommodate individual interviews with cassava cultivating households in the target area, while from the qualitative side, group discussion interviews were conducted with another 30 experienced cassava farmers so that the discussion could be directed to cover the topic of the study.

For the individual interviews, the survey samples were selected from cassava growing households in the three provinces. A questionnaire involving, 32 questions was designed for this household survey. The questionnaire contains both typical and critical questions ranging from the general bio-data to the status of cassava production, the causes and effects of CWB production, and other technicalities related to the management of this disease.

Epidata Software was used to build a data entry template and the data was further exported into SPSS Software for final cleaning and analysis. Basic statistical procedures include frequency, cross-tabulation, multiple responses, numeric descriptive statistic, and pair sample T-Test which were applied in the quantitative data analysis.

RESULTS AND DISCUSSION

Causes of Cassava Witches' Broom Occurrence in the Community

Farmer perceptions on the of CWB disease in the target communities were recorded in terms of respondents perceptions as to reasons for the CWB outbreaks in the last two years (2013-2014). The reasons provided were within the context of the knowledge and observations of farmers. Roughly 28% of households claimed that among the contributing factors were poor soil fertility, drought, and other unknown reasons. Around 20% of respondents mentioned that the outbreaks of CWB might be related to the use of chemical pesticide and fertilizer, while another 18.7% believed that the incidence of the disease was based on the use of contaminated planting material. A small proportion (ranging from 6% to 8%) of households reported that the cause of CWB could be due to sources of planting material, and insect outbreaks (Fig. 1).

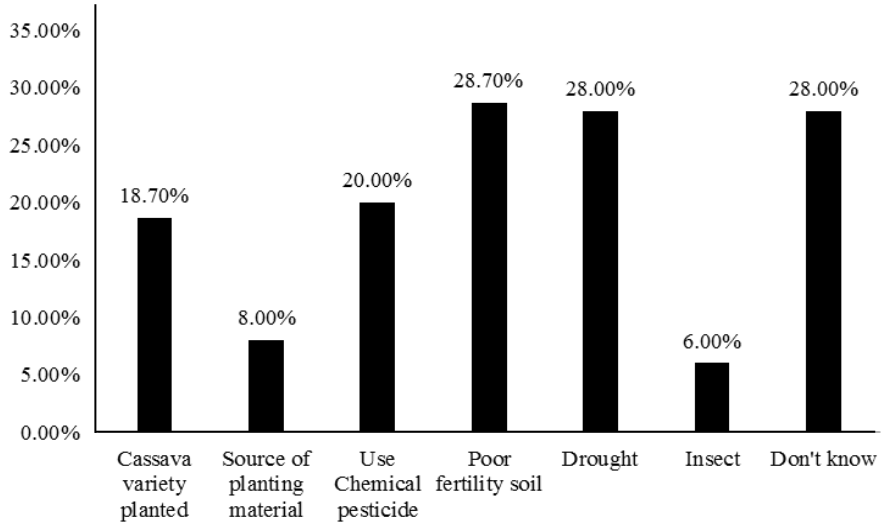

Fig. 1 Farmer perceptions of the causes of CWB in the survey target areas

Effects of Cassava Witches' Broom Disease on Cassava Production

Witches' broom disease attacks the starch in cassava roots, and looks set to aggressively spread unless farmers take action on time. In Cambodia, the disease results in 10-15% yield loss when compared with normal yields (CIAT, 2013). This spells disaster for farmers. The same source also adds that the disease remains a major problem since Cambodian cassava growers often import cassava planting material from Vietnam, especially during the planting time in April. The disease is more prevalent in Vietnam and the use of the Vietnamese planting material is the main source of the disease in Prey Veng and Svay Rieng provinces which have borders adjoining Vietnam.

Regarding the impact of CWB on cassava cultivation, each household covered by the survey was asked to quantify the damage in relation to different aspects of cassava production, including land size, yield per hectare, price per kg, bunches per hectare, and price per bunch. The level of impact of each parameter was estimated by comparing the production in normal years with production in years when CWB has affected the cassava crop on the same unit of land.

To understand the cassava crop production losses caused by the CWB disease, land size, price, and yield during a normal year were compared to those in a year of CWB infection. Regarding to the proportion of land infected by CWB, those households that encountered the disease reported that nearly all of their land (99%) was affected by cassava witches broom disease. In the years of infection, nearly all of the respondents (98.7%) received significantly lower cassava tuber yields when compared to the production in a normal year. In reference to price, the CWB affected cassava was sold at a lower

price than for the produce from healthy cassava crops, with 84% of households reporting a 40% lower price than for uninfected crops in a normal year (from 200 to 280 riel/kg) (Table 1).

Table 1 Growing area, yield and price of cassava in normal and CWB affected years

Items	In normal year	In affected year	Significant
Growing area (ha)	2.22	1.37	0.00**
Yield (kg/ha)	19,591	8,520	0.00**
Price (Riel/kg)	280	200	0.00**

The symbols (**) indicate a highly difference significant

Farmers' Actions after First Observe Cassava Withes' Broom Disease in their Crops

Cassava farmers have applied many techniques to control the CWB disease after they first observed it in their crops. Those techniques (as reported by the survey farmers) have included: the use of pesticides, the use of disease resistant varieties, the removal of infected plants, the changes in the planting time, and other measures (Fig. 2). The use of pesticides remains the most common strategy (47.30% of respondents) since this technique did not require a lot of time and resources. Removing affected plants was the second most common option of the respondents. Even though some farmers perceived that this is a waste of their capital resources, more than 20% of the respondents applied this technique in the belief that the disease can be managed over time, and that they can prevent the spread of the disease to other healthy plants. A small number of farmers also applied other techniques, including the application of more fertilizer to the crop (10.10%), the use of a disease resistant variety (8.80%), the change of planting materials (4.70%), and the change to an earlier harvesting period (4.10%), even though the crops were not fully mature and the yield could be lower when compared to that of mature plants (Fig. 2).

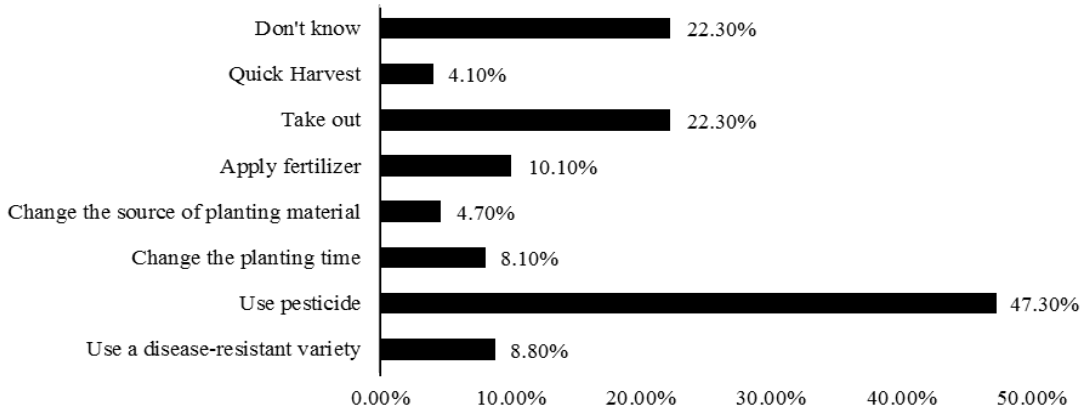

Fig. 2 Farmers' actions after first observed the Cassava Witches' Broom disease on their cassava crop

Key Suggestions from Farmers

From the experience of farmers, CWB is regarded as the most serious yield constraint for their cassava crops, and it ultimately brings harm to their livelihoods. While being in need of assistance to control this disease, the support services for cassava growers in the study areas remain perceived as

insufficient. Even though most farmers have made attempts to manage the disease, their knowledge, capacity, and accessibility to the right products and services remains limited, and thus their control initiatives have generally not been effective. To overcome the constraints, farmers have suggested that stakeholders, especially the agricultural extension service of the Ministry of Agriculture, Forestry and Fisheries (MAFF), provide more practical training on CWB control (72.50%), training on CWB symptoms identification (56.49%), training on effective pesticide application (54.40%), and effective fertilizer application (10.10%). Cassava growers also indicated that they wish to see immediate interventions from MAFF and from local authorities, in the event of any outbreak of disease, and in relation to other issues that they feel the need of urgent assistance (Fig. 3).

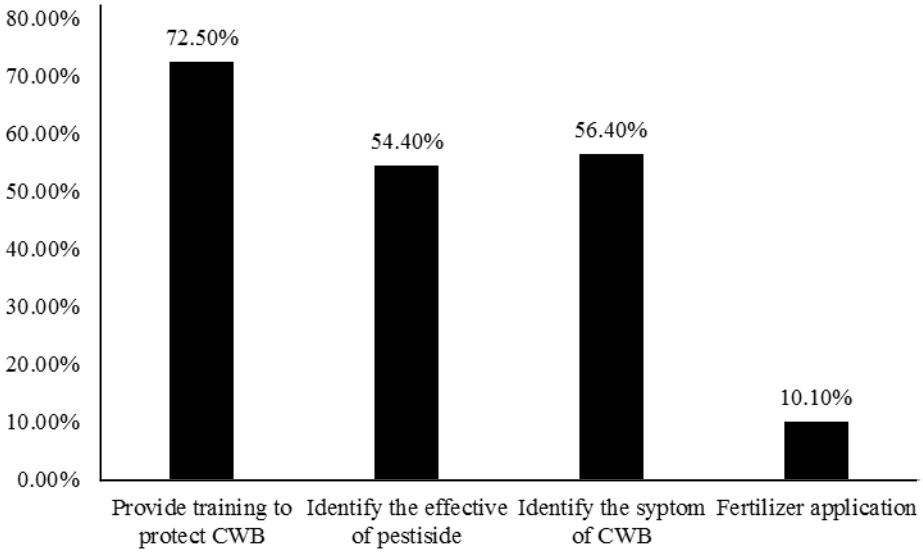

Fig. 3 Key suggestions from farmer survey respondents

CONCLUSION

While more cassava is cultivated by Cambodian farmers due to certain selected preferences, the growth of this crop can potentially be severely affected by Cassava Witches' Broom disease, which can lead to severe crop losses and the downgrading of the quality of cassava roots and starch content. From the survey on the causes and effects of CWB on cassava production in the survey area, the following conclusions can be drawn:

Cambodian farmers still do not have a lot of experience in growing cassava, particularly in large scale production. In general, farmers still do not have the accessibility to quality cassava planting materials from within the country. At the same time, the improper application of pesticide does not enable farmers to effectively control the pest factors on their cassava. They often had limited capacity to address significant issues, such as the problems particularly caused by CWB. A lack of access to local agricultural extension services has also resulted in cassava growers facing difficulties in relation to getting advice on management and production issues.

The issue of reducing the future ongoing impact of CWB is critical, as most cassava growers are still committed to growing this crop in the future. This requires an improved management practice as well as a timely support to farmers in need. Thus, this also highlights the importance of agricultural extension services in providing guidance to cassava growers for the management of their cassava crops. To mitigate the consequences of using chemical pesticides, the introduction of the CWB resistant

cassava varieties is the best option for the future and this could motivate farmers to continue growing this crop in a more secured environment.

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Research article

Assessing Climate Change Vulnerability in Rural Areas: Cases of Apple Farming in 4 Municipals in Gyeonggi Province, Korea

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Abstract Climate change poses a major threat to the environment, economic and social components in agricultural sector in rural communities. If rural agricultural communities are to respond adequately to future climate change, they will require to develop adaptation measure and to do so, it is required to assess vulnerability in their communities. One of the most notable climate change impact in Korean agricultural communities is that fruit cultivation sites are moving northward. In the past, apple cultivation was not preferred in the Gyeonggi province. However, with changing climate, farmers in Icheon and Gapyeong in Gyeonggi province started to cultivate apple. In addition, governmental support through apple cultivation promoting projects increased apple cultivation in the province in recent years. This paper aims to assess climate change vulnerabilities of 4 apple cultivation communities in Gyeonggi province by developing vulnerability indices as function of climate exposure, sensitivity and adaptive capacity. Using z-score normalization, the quantitative analysis was conducted in this study. The main results of vulnerability assessments are founded as follow: Icheon and Gapyeong showed higher vulnerability by higher level of exposure and sensitivity to changing climate than Paju and Yeoncheon. However, adaptive capacity showed that Paju and Yeoncheon as more vulnerable than the Icheon and Gapyeong. Therefore, the study concludes that albeit the same crops cultivated in one province, for effective local-level adaptation measures, identifying components comprising the vulnerability in the community is required. Vulnerability assessment using indices should provide quantitative backgrounds to develop appropriate and effective agricultural community adaptation measures.

Keywords climate change, local-level adaptation, vulnerability assessment, apple farming

INTRODUCTION

Responding to additional challenges from climate change impacts will require significant adaptation measures within agricultural communities (IPCC, 2007). Agricultural communities in Korea have already experienced impact of climate change, including crop and livestock loss from severe drought and flooding, large-scale losses from weather-related disasters, shifts in planning and harvesting times and cultivation lands. According to Ministry of Environment (2015), one of the most notable and critical climate change impact in Korea on agriculture sector is that fruit cultivation sites have been shifting northward and this impact has been appeared mostly in apple cultivation. Total area of apple cultivation in formerly famous southern areas, Daegu and Gyeongsang province, has been decreased about half from 34,770 ha in 1995 to 18,889 ha in 2014 (East-North Regional Statistics Korea, 2015). On the other hand, apple cultivation is increasing in provinces in north, such as Gyeonggi and

Gangwon. Farmers in Gyeonggi province, particularly in Icheon and Gapyeong municipals, adapted apple crop in their cultivation site since early 2000s. Moreover, regional government started to recognize apple as one of important crops in the areas. In recent years, through 'Demilitarized Zone (DMZ) apple cultivation community' project in Paju and Yeoncheon, government supports local farmers who wish to grow apple by providing financial and technical supports. To respond adequately to future changing climate in relatively new and increasing apple farming communities in Gyeonggi province, it is required to assess the risks and vulnerability. The most mutual quantitative vulnerability assessment method is the employment of a composite index comprising a set of indicators. These indicators represent the vulnerability of a studied system and are mathematically combined into a single composite index (Moss et al., 2001). Although there are studies on quantifying vulnerability using indicators, most of the studies are done in macro-level to assess national and regional level of vulnerabilities (Yoo and Kim, 2008; Moss et al., 2001). Effective planning for climate change adaptation programming in agricultural communities requires an assessment of local vulnerabilities so as to bridge the gap between community needs and priorities at the local level (Burton et al., 2002). Not only it is important to assess local level vulnerabilities but it is vital to have crop specified vulnerability assessment considering environment, economic and social conditions of the agricultural communities. This paper will conduct in-depth analysis of the local level vulnerabilities, to compare the differences among apple growing communities by developing vulnerability index and integrating quantitative analysis based on the intensive review of previous studies and policy reports.

OBJECTIVE

The main objective of this paper is to conduct quantitative assessment of climate change vulnerability of four apple farming municipals (Icheon, Gapyeong, Paju and Yeoncheon) within Gyeonggi province in Korea. By developing and using three indices, vulnerability assessments of the areas are done to analyze the variables that determine vulnerability of the communities and compare the differences that exist among the apple farming communities in Gyeonggi province.

METHODOLOGY

As shown in Fig. 1, Gyeonggi province is located in the central western part of Korea and it surrounds the cities of Seoul and is bordered by North Korea. The province has a typical continental climate that the annual temperature is between 10 ℃-13 ℃.

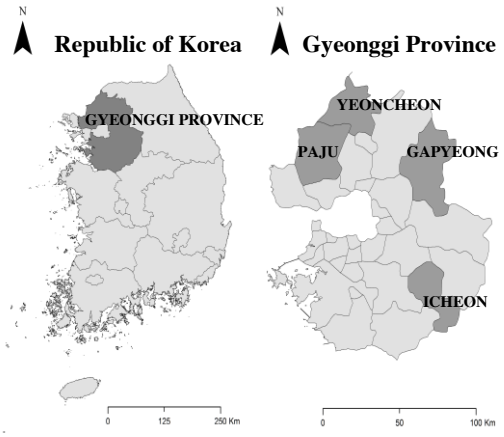

Fig. 1 Study areas

Table 1 Overview of Gyeonggi province and 4 apple farming municipals

Indicators	Gyeonggi	Icheon	Gapyeong	Paju	Yeoncheon
Population (persons)	12,793,556	210,908	62,774	426,733	46,180
Population Density (person/km^2)	1,234	457	74	598	69
Agricultural Land (ha)	176,854	17,349	3,706	11,445	9,012
Apple Cultivation Area (ha)	500	80	88	47	25

Source: Annual Statistics Report of Gyeonggi Province (2014) and statistical year book of each province

Intergovernmental Panel on Climate Change (2007) defines vulnerability to climate change as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2001; Moss et al., 2001; Yoo and Kim., 2008). In this framework, IPCC (2007) defines the terms in climate exposure, sensitivity and adaptive capacity as follow: 1) exposure is the degree of climate stimuli received from either long-term changes in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events, 2) sensitivity is the degree to which a system will be affected by, or responsive to climate stimuli (Smit and Wandel., 2006) and it can either be biophysical effect climate change and socio-economic changes, and 3) adaptive capacity is the capability of a system to adapt to impacts of climate change, or, it is the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (Smit and Wandel., 2006). As in Eq. (1) this paper takes IPCC (2007) approach of defining climate change vulnerability that a system's total vulnerability is composed of climate change exposure and sensitivity subtracted by adaptation capacity.

$$Vulnerability = (Climate\ Exposure + Sensitivity) - Adaptation \quad (1)$$

Proxy variables are selected as function of exposure, sensitivity and adaptive capacity, as framed by IPCC and in scrutiny based on the intensive review of previous studies, particularly on Vulnerability Resilience Index (VRI), composite index composed of 33 indicators to conduct climate change vulnerability assessment of 16 provincial governments in Korea (Yoo et al., 2008). Moreover, in this paper, since the indicators are selected particularly for the assessment of apple farming, review of various government reports and guidance on apple cultivation are conducted. For exposure proxy variables, apple cultivation guideline developed by Rural Development Administration (2015) is referenced. Unlike previous macro-level studies, this study assesses local level communities that limit authors to select the variables based on availability of the data. Finally, 12 proxy indicators are selected include: number of years with annual average temperature above 8℃ and below 11℃; number of days with maximum temperature over 26℃; maximum rate of precipitation per day; number of days with maximum wind speed over 3m/s; damages from storm and flood per capita; area of apple cultivation per total area; rate of elderly agricultural households; beneficiaries of national basic livelihood; Gross Regional Domestic Production per capita, productivity rate of apple per area; rate of household with Speed Spray holder; and rate of cooperative membership, to assess climate change vulnerability of four apple farming municipals namly, Icheon, Gapyeong, Paju and Yeoncheon, in Gyeonggi province.

Selected proxy variables are analyzed by calculation of the z-score normalization of data. Among other normalization methods, such as scale transformation, rescaling by min-max and distance to a reference, z-score is generally applied in the previous vulnerable assessment studies and this method allows to compare the data that are from different unit. This study uses z-score method that is done by subtracting the mean from the observed value and dividing by the standard deviation for each indicator. This ensures that each of the rescaled variables has a mean of zero and a standard deviation of 1,

allowing them to be combined directly. The results of z-score normalization are able to determine positive and negative relations of components.

RESULTS AND DISCUSSION

Exposure is a level of acquaintance to climate risks including temperature, precipitation and wind influencing production and quality of apple for this paper. A system is more vulnerable when it has higher exposure to climate. In analyzing the result of climate exposure, a system is relatively vulnerable if it has a greater z-score. Although production and the quality of apple are influenced by many different elements during a year around, for the purpose of this paper, annual temperature, maximum temperature during April to August, precipitation rate and wind during apple harvest period, April to October, are considered. Apple can be grown satisfactorily with annual average temperature between 8 and 11. Moreover, temperature over 26□ during April to August can produce undesirable effect on the shape of apple. Sweetness of apple is affected by precipitation rate during April to October. With higher precipitation, level of sweetness of apple will fall. In addition to quality of apple, abscission of apple also influences the production of apple cultivation. Abscission occurs with wind speed over 3m/s during cultivation season. As shown in Table 2, with regard to climate exposure index, z-scores for the total vulnerability show positive for Icheon (1.64) and Gapyeong (1.28). The positive z-scores indicate that Icheon and Gapyeong are more exposed to climate risks than Paju and Yeoncheon. More specifically, Icheon and Gapyeong are found to have relatively higher vulnerability to be exposed to climate risks such as in adequate temperature and precipitation for shape and sweetness of apple. In other words, this results indicate Paju (-2.81) and Yeoncheon (-0.09) are less vulnerable to be exposed to the climate risks related to temperature and precipitation for developing adequate shape and sweetness of apple. However, Paju and Yeoncheon show relatively higher vulnerability in climate exposure with strong wind. This indicates that apple farms in Paju and Yeoncheon are more vulnerable to abscission from wind. By developing prevention of impact from strong wind, farmers in Paju and Yeoncheon can increase the production of apple.

Table 2 Result of Z-scores on climate exposure index of 4 apple farming municipals

Proxy Variables	Icheon	Gapyeong	Paju	Yeoncheon
Number of yrs. with annual avg. temperature, ＜8 ℃ or ＞11 ℃*	0.79	1.14	-1.31	-0.61
Number of days with maximum temperature over 26 ℃**	0.00	0.97	-1.62	0.65
Maximum rate of precipitation per day***	1.36	0.35	-1.40	-0.30
Number of days with max. wind speed over 3m/s***	-0.51	-1.18	1.52	0.72
Total vulnerability in climate exposure	**1.64**	**1.28**	**-2.81**	**-0.09**

Source: National Climate Data System (http://sts.kma.go.kr/, accessed October 28, 2015)
**data for 2004-2014, **data for April to August of 2014, ***data for April to October of 2014*

Sensitivity proxy variables are selected to reflect a degree to which the apple farming in study areas will be affected by, or responsive to changing climate. If a system is sensitive, it can be affected by small changes in climate. In this paper, proxy variables are selected by taking the system's geographical and socio-economical elements into account. For geographical elements, apple cultivation area and total cost of damage from storm and flood variable are selected. For population elements such as higher rate of single household with over 80 years old residents and socially vulnerable population are selected to analyze how the community is sensitive to climate stimuli. Sensitivity indicators are positively related to climate change vulnerability. This means that if the z-scores show positive and greater numbers, then the variables are relatively more sensitive to changing climate and by the definition, sensitive system is more vulnerable to climate change. In Table 3, Icheon (0.75) and Gapyeong (3.05) municipals show positive z-score in sensitivity whereas Paju (-3.07) and Yeoncheon

(-1.17) show negative. More specifically, except for damages from storm and flood, Gapyeong is found to be the most vulnerable relative to other areas in all other factors. Unlike climate exposure, it is possible to lessen vulnerability related to sensitivity to climate change by developing policies that focus on moderating risks of vulnerable population, elderly people and beneficiaries of national basic livelihood, living in the area.

Table 3 Result of Z-scores on sensitivity index of 4 apple farming municipals

Proxy Variables	Icheon	Gapyeong	Paju	Yeoncheon
Damages from storm and flood per capita (won)	1.61	-0.10	-1.11	-0.39
Area of apple cultivation per total area (%)	1.53	0.16	-0.52	-1.17
Rate of elderly (+80) agricultural households (%)	-1.00	1.66	-0.45	-0.21
Beneficiaries of national basic livelihood (%)	-0.94	1.33	-0.99	0.60
Total vulnerability in sensitivity	**0.75**	**3.05**	**-3.07**	**-1.17**

Source: Annual Statistics Report of Gyeonggi Province (2014) and statistical year book of each province

Adaptive capacity refers to potential or capability of a system to adjust to climate change, so as to moderate potential damages, to take advantage of opportunities, or to cope with the concerns. Economic capacity including Gross Regional Domestic Production (GRDP) and productivity rate of apple can determine how the system can economically, moderate, recover or even prevent itself from impact of climate change. Physical infrastructure, such as Speed Spray, can be used to prevent damages from insects and this can eventually support production to increase. Being member of cooperative can influence adaptive capacity of a system by acquiring information and support easier than nonmembers. Unlike exposure and sensitivity to climate, higher adaptive capacity is negatively related to vulnerability that negative and smaller z-core means higher level of vulnerability. Less adaptive capacity means that a system is less capable of adapting to changing climate that is associated with more vulnerable circumstances. The results in Table 4 show that compared to Paju (-1.14) and Yeoncheon (-2.75), Icheon (2.71) and Gapyeong (1.20) are higher in adaptive capacity. Among the areas, Icheon is the highest in adaptive capacity and this is due to higher development level of apple community in Icheon than other areas. On the other hand, Paju and Yeoncheon show lower level of adaptive capacity, however, in these areas, increasing government support for apple farming by providing Speed Spray and education on apple cultivation have potential to increase adaptive capacity in the future which will make the areas to have favorable condition of apple production.

Table 4 Result of Z-scores on adaptive capacity index of 4 apple farming municipals

Proxy Variables	Icheon	Gapyeong	Paju	Yeoncheon
Gross Regional Domestic Production per capita (won)	1.37	-0.79	0.53	-1.11
Productivity rate of apple per area (kg/10a)	0.42	1.44	-0.79	-1.06
Rate of household with Speed Spray holder (%)	0.57	-0.16	-1.54	1.13
Rate of cooperative membership (%)	0.34	0.71	0.66	-1.71
Total vulnerability in adaptive capacity	**2.71**	**1.20**	**-1.14**	**-2.75**

Source: Annual Statistics Report of Gyeonggi Province (2014) and statistical year book of each province

CONCLUSION

Agricultural communities are highly depending on natural resources that are affected by climate change. Adequate adaptation measures are required for agricultural communities to moderate potential damages and to take advantage of opportunities related to changing climate. Particularly in Korea, changing climate moves the fruit cultivation sites to north-ward to Gyeonggi province. Moreover, increasing damages from extreme events increased needs for adaptation measures for fruit cultivating

communities. To develop effective adaptation measures, it requires vulnerability assessments in the communities. In our study, to increase adaptive capacity of apple farming communities, climate change vulnerability assessment for four apple farming communities in Gyeonggi province in Korea are conducted. A climate change vulnerability assessment index was developed to include climate exposure, sensitivity and adaptation to assess climate change vulnerability of Icheon, Gapyeong, Paju and Yeoncheon in Gyeonggi Province, in Korea. The main results of the vulnerability assessments can be grouped into three different parts, climate exposure, sensitivity and adaptive capacity. Vulnerability related to climate exposure assessed the community's climate condition whether it is adequate for the apple cultivations or not. Among four apple farming communities, Icheon is shown to be the most vulnerable followed by Gapyeong, Yeoncheon and Paju. The result shows that inadequate temperature and precipitation in Icheon and Gapyeong could lead the communities more vulnerable. Although Yeoncheon is less vulnerable in total climate exposure, Yeoncheon is highly exposed to wind that the community should develop the adaptive measures, such as windshield, to prevent damages from strong winds. Moreover, the vulnerability assessment found Gapyeong as the most sensitive to climate change followed by Icheon, Yeoncheon and Paju. The reason that Gapyeong was more vulnerable was most likely related to its demographical characteristics: increasing rate of elderly agricultural households and beneficiaries of national basic livelihood. Thus, it is recommended that Gapyeong municipal to support agricultural labor productivity in the region to maintain apple cultivation. Unlike climate exposure and sensitivity, adaptive capacity was found to be higher in Icheon and Gapyeong compared to Paju and Yeoncheon. The higher adaptive capacity was associated with earlier adaptors of apple cultivation, Icheon and Gapyeong, who have already created their own communities to share their know-how and developed technologies to cope with climate damages.

The results of this study can provide vital information on allocation of critical resources in each apple farming municipals to develop effective adaptation measure and policies. This can prevent and reduce the damages from climate change impact in apple communities in Gyeonggi province. By understanding different elements that induce climate change vulnerability, apple farming communities can increase its adaptive capacity and lessen the damage from the impacts. However, a broader application of vulnerability assessment index should have clearer understanding of climate change vulnerability in apple farming communities. Moreover, this study can be more developed to be applied to other regions and other sectors to be referred in integrated climate change vulnerability assessment of rural agricultural communities.

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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.

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