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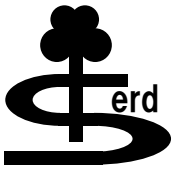

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Contents

Research article

Area Based Management Extension for Sustainable Rice Production: Lessons Learned from Sustainable Rice Farmers Groups in Det Udom District, Ubon Ratchathani Province

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Abstract Lessons learned by farmers' groups in Thailand who received area based management extension for sustainable rice production were investigated. Objectives were to 1) study area based management extension for sustainable rice farmers' groups, 2) analyze the current situation regarding area based management extension of these groups, 3) identify key actions for group improvement, and 4) determine the lessons learned. Qualitative data were collected from 77 sustainable rice farmers belonging to two farmers' groups in Det Udom district, Ubon Ratchathani Province during an organized forum. Additional data were collected and analyzed from key informants including group chairmen and extension officers using in-depth interviews. Results were as follows: 1) the farmers' groups were founded as Community Rice Centers producing seed, and later joined the Area Based Management Extension Program initiated by the Ministry of Agriculture and Cooperatives to increase their knowledge capacity and market linkage. They also participated in the Sustainable Rice Production Pilot Testing Project organized through collaboration between the Thai Rice Department and Better Rice Initiative Asia Project to link with sustainable rice new value chains. 2) Farmers were assessed regarding their current practices against their compliance score of the Sustainable Rice Platform (SRP) standard and received scores averaging 74.5%. After knowledge transfer, their scores were audited by an external auditor and increased to an average of 84% classified by the 'Working toward Sustainability' level. 3) Actions for group improvement were identified as follows: (i) Farm record, (ii) Land preparation, (iii). Planting method, (iv) Seeding service management, (v) Fertilizer management (vi) Weed management, (vii) Combine harvester machine management, (viii) Selling, and (ix) Internal control system management. 4) Valuable lessons learned concerning sustainable rice area based extension included: (i) Good knowledge transfer of sustainable rice production through group actions, (ii) Limited access through machinery service of introduced technology, and (iii) Economy of scale in area based management extension planning between cultivated areas and market capacity.

Keywords sustainable rice production, area based management extension, Ubon Ratchathani Province

INTRODUCTION

Present day Thai rice farmers are smallholders with around 2.88 hectares per household (Apichart, 2014). Generally, only 1-2 elderly people work on each farm as husband and wife and employ no permanent labor. To provide effective extension support to smallholder farmers, the Ministry of Agriculture and Cooperatives (MOAC) has promoted area based management extension to enhance capacity to capably deal with the rice value chain. Furthermore, the current trend of the global rice sector is looking toward sustainability in sourcing rice production and resource consumption through global collaboration under the Sustainable Rice Platform (SRP). This is a multi-stakeholder platform co-convened by the UN Environment Programme (UNEP) and the International Rice Research Institute (IRRI) to promote resource efficiency and sustainability in trade flows, production, consumption and supply chains in the global rice sector (Overview of Sustainable Rice Platform, 2017).

The two farmers' groups in Det Udom District, Ubon Ratchathani Province as shown in Fig. 1, follow Good Agriculture Practice (GAP) as 'Best Practices Group', and are keen to learn about new rice farming methods. They operate as Community Rice Centers (CRCs) and have also been participating in Area Based Management Extension and Sustainable Rice Production Pilot Testing Projects run by the Thai Rice Department and Better Rice Initiative Asia (Thailand) Project through cooperation between GIZ, Bayer, and Olam. These two farmers' groups have objectives to improve the capacity of their members by applying area based management extension to deliver rice to the market at a sustainable value. Therefore, this research was conducted to investigate group improvements regarding their objectives.

Fig. 1 Location of farmers' group

OBJECTIVES

The following issues were investigated to 1) study area based management extension for sustainable rice farmers' groups, 2) analyze the current situation regarding area based management extension of these groups, 3) identify key actions for group improvement after applying area based management extension, and 4) appraise the lessons learned.

METHODOLOGY

Research Approach

Qualitative research was administered in the case study.

Research Population

The research population consisted of 77 farmers as members of Bua Ngam Community Rice Center (32 farmers) and Klang Community Rice Center (45 farmers) in Det Udom District, Ubon Ratchathani Province. These two community rice centers also received support from the Ministry of Agriculture and Cooperatives (MOAC) and the Better Rice Initiative Asia (BRIA) Project for an area based management extension approach.

Data Collection

1) Forums were organized to assemble qualitative data from 32 Bua Ngam Community Rice Center Members and 45 Klang Community Rice Center members including group leaders and committee members.

2) Semi-structured in-depth interviews were conducted with key informants to collect data involved in transferring knowledge of sustainable rice production and market linkages including group chairmen, committee members and extension officers.

Data Analysis

Data were analyzed for content.

RESULTS AND DISCUSSION

1. General Information Regarding the Groups Participating in Area Based Management Extension for Sustainable Rice Production

Bua Ngam Community and Klang Community Rice Centers consist of rice farmers' groups in Det Udom district, Ubon Ratchathani Province, Northeastern Thailand. Fundamentally, Community Rice Centers (CRCs) are organized to provide quality seed supply to rice farmers. Seed production requires intensive cultivation and good crop knowledge; however, the Thai seed market is limited, with pre-orders insufficient to share among all members in the group, and farmers also need to produce their own grain. Usually, farmers produce gain as uncertified or conventional rice. The Ministry of Agriculture and Cooperatives has been promoting area based management programs or mega-farm projects by supporting CRCs to increase their capacity for knowledge transfer and market linkage. These two CRCs participated in area based management extension programs to gain knowledge regarding input supply management and good cultivation techniques such as seed selection, organic fertilizer, bio-pesticides, straw and stubble management. They also received support through the provision of certified seed, soil test analysis, and seeding machines.

In addition, these two CRCs participated in the Sustainable Rice Production Pilot Testing Project. They now have high potential to reach a sustainable rice standard and become part of a new sustainable rice value chain with economy of scale and good basic rice cultivation. During the pilot testing project, these two CRCs were encouraged to gain knowledge of sustainable rice production and sustainable rice value chain, designed with reference to SRP standards and indicators developed by the IRRI and SRP. The project began by recruiting 77 interested farmers as volunteers. An introductory meeting was held with the two CRCs and project officials to formulate operation plans. Initially, all interested farmers were asked to change their production practices and a production target of sustainable rice was set at 550 metric tons for the 2016/2017 crop, with purchase guaranteed at a competitive market price.

2. Analysis of the Current Situation Regarding the Area Based Management Extension for Sustainable Rice Farmers' Groups

The CRCs desired to improve their rice cultivation practices and attain certification as 'sustainable rice standard', with ability to link with the sustainable rice value chain. Some committee members and members of the CRCs volunteered to implement sustainable rice production. Sustainable rice production knowledge was new to all the farmers. The two farming groups interacted with the project by joining the pilot testing process implemented by the Thai Rice Department and BRIA (2017b). The objectives were to 1) receive sustainable rice production program introduction, 2) benchmark current practices to the sustainable standard, 3) analyze the risks faced during rice production, 4) attend training, 5) undergo participatory monitoring and follow-up farmers' practices, 6) be audited by an external auditor, 7) organize a participatory harvesting plan, 8) monitor a selling plan, and 9) participate in an after action review workshop. Before participating in the program, all 77 interested farmers were assessed based on their current practice against the compliance score of the SRP standard. Average score was 74.5%. After participating in the program, their average compliance score assessed by a third-party auditor increased to 84% classified by the 'Working toward Sustainability' level.

Farmers were trained to apply sustainable rice production, which complied with the standard; however, the sustainable rice produced by these farmers also required good management and delivery to the market as sustainable value chain. Sustainable rice was distinguished from conventional rice. Economies of scale in terms of numbers of participating farmers, expected paddy volumes, milling capacity and internal group management were all considered by the groups for market linkage planning. Initially, the farmers planned to produce around 500 metric tons of sustainable rice but when the selling season ended only 298 metric tons were delivered for milling. Furthermore, the market linkage aspect of area based management extension enhanced farmers' capacity to reach the market. This is an important incentive mechanism for farmers, similar to the market-oriented extension paradigm that links the private sector and farmer (Swanson & Rajalahti, 2010).

Table 1 Challenge topic, objective, Group Action, and action result in year 2016

Challenge Topic	Objective	Group Action in 2016	Action Results in 2016
1. Farm record	100% Farmers must be able to monitor farm records by themselves.	1. Farmers' groups attended a step-by-step farm record workshop organized by extension officers, 2. Farmers' groups continued recording by themselves.	90% of farmers could record their own data with around 80% completing the record sheets.
2. Land preparation	To attain good land leveling.	1. Farmers' groups received direct training from extension officers.	Only 50% of farmers applied conventional leveling in small areas due to financial difficulties and technology/service provider availability in the area.
3. Planting method	Reduce seed rate by applying a seeding method.	1. Farmers' groups received direct training from extension officers.	80% of farmers applied broadcasting methods while only 20% applied a seeding machine due to lack of machine availability.
4. Seeding service management	Provide services to all members on time.	1. Farmers' groups received seeding machines from the Area Based Management Extension Program. 2. Farmers' groups conducted Demo Training on a plot for the seeding machine together with extension officers.	Only 20 % of farmers used the seeding machine as time constraints resulted from late machine arrival and some farmers had already planted their crops. More planting machines are required.
5. Fertilizer management	Increase yield and lower input cost by applying suitable fertilizer formula at appropriate rate and time.	1. Farmers' groups received direct training in soil and nutrient management by experts. 2. Farmers' groups sent their soil to be analyzed.	80% of farmers applied suitable fertilizers. Soil test results came late. Farmers applied fertilizer following general recommendations.
6. Weed management	Improve yield and apply safety methods if the farmer uses herbicides.	1. Farmers' groups received direct training from extension officers.	Only 10% of farmers applied herbicides. 20% of farmers used hand weeding and 70% used hand weeding and cutting.
7. Combine harvester machine management	All farmer can access a combine harvester on time.	1. Group harvesting and selling plans were organized for farmers' groups.	60% of farmers had access to a combine harvester machine on time.
8. Selling	Deliver sustainable rice volume as agreed.	1. Group harvesting and selling plans were organized for farmers' groups.	60% of the total crop was sold to the selected millers. This did not meet the agreed amount because farmers kept some rice for personal consumption and seed.
9. Internal control system management	To have self-inspection within farmers groups.	1. Farmers' groups have been implementing internal inspection for seed production.	70% of farmers could do self-inspection for seed production. This was not yet implemented for sustainable grain.

3. Action Identified for Farming Group Improvement after Applying Area Based Management Extension

The two area based management extension farmers' groups also participated in a pilot testing project as mentioned earlier. At the end of the sustainable rice production in 2016, the 77 farmers participated in a workshop to review their actions and the results of their actions. Challenge topics were identified and selected by the farming group committees, the Thai Rice Department and the BRIA Project. Audit reports were also examined by third-party auditors. Results of the challenge, group action and action results are shown in the Table 1.

4. Lessons Learned

Valuable lessons learned from the sustainable rice area based extension model were categorized into three aspects as follows:

4.1 Good knowledge transfer of sustainable rice production through group actions: Farmers were audited and received an average compliance score of 84% of the SRP standard (Thai Rice Department & BRIA, 2017a). Scores indicated a good understanding, with improvement shown by these farmers after implementing the participatory actions of attending direct training from extension officers (experts regarding the topics), attending special workshops, attending demonstrations at training plots and also receiving some machines or service. There were no major issues noted by the farmers at either of the two community rice centers; however, no farmers implemented good land leveling due to lack of a reliable and efficient technology service providers available in the area. Most of the farmers did not use any herbicides, pesticide, or fungicides and this resulted in a high weed problem. Refer to post survey report from BRIA demo training plot in 2017. Farmers who implemented good seeding machine technique and good weed control increased gross profit margin by 53.90% through input cost reduction and higher yield (Department of Agricultural and Resource Economics, 2017). The Farmers' Diary workshop that provided step-by-step training was a key success factor and encouraged farmers to record important data related to crop production by themselves. Group actions significantly improved sustainable rice production.

4.2 Limited access through machinery service of introduced technology: The Farmers had a good understanding of sustainable rice production with intention to apply the newly introduced technology; however, there were limitations with regard to machine hire service providers including seeding machines, good land leveling machines, and combine harvesters. The farmers realized that seeding machines could reduce their seed rate but numbers of seeding machines were insufficient. Demonstration of a large field project trial in Thailand using mechanized seeding (drum seeder) indicated significant gains in rice farming profitability. Farmers realized that yield can be improved using mechanized seeding machines (Stuart et al., 2017). Farmers tried to reserve combine harvesters when 80% to 85% of their rice grains were ripe but numbers of these machines were limited. Therefore, as well as knowledge transfer, machine management or service provider management should be considered in area based management extension projects.

4.3 Economy of scale in area based management extension and planning of cultivated area and market capacity: Sustainable rice segregation requires matching milling capacity (drying and storage capacities) and wet paddy. Participating farmers had to be well-organized with proper management. Most farmers grew the Hom Mali rice variety. This variety is photoperiod sensitive and ready for harvest by early November. In addition, farmers used combine harvesters and sold wet paddy to the miller. The number of farmers and the harvested area size must match the available milling capacity. The capacity of one drying machine is around 500 metric tons per day. Farmers' groups planned, through the project, to deliver 500 metric tons from 77 farmers. It was impossible to harvest the rice of 77 farmers in one day and deliver the product to the selected miller to maintain full milling capacity. Another issue was that when the crop was harvested, only 298 metric tons were sold to the selected miller because the farmers kept some of their production for consumption and seed supply. Therefore, area based management extensions must address the economy of scale between market capacity and farmers/cultivated area as one of the key success factors to build a new sustainable rice supply chain.

CONCLUSION

A total of 77 farmers from two community rice centers in Det Udom District, Ubon Ratchathani Province participated in the Area Based Management Extension Project organized by the MOAC, and also SRP pilot testing through cooperation between the Thai Rice Department and BRIA Thailand. The farmers received training regarding sustainable rice production through learning activities with extension officers including attending direct training sessions and special workshops. After participating, using the existing farmers' group structure of mega-farm projects, benchmarking with current practices and receiving additional sustainable rice production knowledge, the 77 farmers were able to produce rice sustainably. In addition, the area based management extension should involve more farmers. When farmers are introduced to a new technology, machine and service provider management should be taken into account. Furthermore, market linkage management in terms of economy of scale between market capacity (especially drying capacity of the miller) and cultivated size under area based management extension were determined as key success factors for farmers to link with the market and develop a new sustainable rice supply chain.

ACKNOWLEDGEMENTS

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Research article

Policy and Socio-ecological Assessment of the Integrated Social Forestry Program after 25 Years of Implementation in St. Bernard, Southern Leyte, Philippines

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Abstract The implementation of Integrated Social Forestry (ISF) program involved huge investments from the government and donor agencies. Considering these investments, is ISF program effective enough in attaining its objectives? In view of this question, an in-depth analysis of the Panian ISFP model site was conducted. The study was conceptualized to assess the policy implementation status and socio-ecological impact of ISFP to the Certificate of Steward Contract (CSC) holders after 25 years from project implementation. The results of the study showed that CSC holders considered reforestation and agroforestry activities successful due to the increase in biomass and litter production that considerably enhances soil fertility. Likewise, the CSC holders had noticed that the water yield in the community significantly improved and there is a reduction of harvest losses because of reforestation and agroforestry interventions. However, site assessment revealed that most of the CSC holders have not planted 20% of the area with trees as required in the contract. In fact, it is common to find CSC areas fully planted with coconuts. This manifests that the government recognition of forest claims further enhance the conversion of forest land into agricultural plantations. On the other hand, the result indicated that policy concerning delegation of responsibilities within ISFP devolution was unclear and confusing since LGUs' responsibilities on forest land are still under the supervision, control, and review of DENR. The LGUs pointed out that financial problems, lack of capability, deficiency in the management and cooperation, and lack of personnel were the factors that deter them to continue the support for Panian ISFP model site.

Keywords community forestry, devolution, tenurial security, forest policy

INTRODUCTION

Philippines has lost a substantial portion of its forest (Era, 2005) which arose in the 1960's to 1970's (Harrison et al., 2004) due to high domestic and export demand for tropical timber, intensive practice of the traditional slash-and-burn or kaingin farming (Weerd et al., 2002), and urbanization (Era, 2005). The forest degradation contributed to an alarming problem in the country such as drought, flash floods, soil erosion, siltation, and sedimentation to water bodies (Dolom, 1986).

In response, the Philippine government through the Department of Environment and Natural Resources (DENR) has implemented various forestry programs to minimize the denudation of the forestlands. However, continuous conversion of forestland into agriculture driven by the influx of people that have low economic opportunities in the lowlands is an incessant challenge of the government. Hence, the government adopted the community-based forest management approach on the premise that sustainability of managing forest resources necessitates building around communities living within the forestlands and adjacent barangays. This was realized through the implementation of Integrated Social Forestry Program (ISFP) that was launched in 1981 through

the Bureau of Forestry Development (BFD), now the Forest Management Bureau (FMB) of the DENR pursuant to the Executive Order 192 and Letter of Instruction (LOI) 1260.

ISFP aims to uplift the socio-economic condition of the upland dwellers through improved incomes from the use of appropriate upland technologies while protecting the environment within 25 years duration and renewable for another 25 years as stipulated in the Certificate of Stewardship Contract (CSC). Implementation of the program involved investments (i.e., labor, supplies and financial resources) from donor agencies, such as the World Bank-funded Central Visayas Regional Project (CVRP), the Ford Foundation-funded Upland Development Program and the USAID-funded Rainfed Resources Development Project (RRDP) (Guiang et. al., 2001). Considering the abovementioned investments, is ISF program effective enough in attaining its objectives especially upon reaching the expiration date of each beneficiary's contract? In view of this question, an in-depth analysis of the program implementation was conducted in Barangay Panian, St. Bernard, Southern Leyte.

OBJECTIVE

This study was conducted to assess the policy implementation status and the socio-ecological impact of ISFP on the CSC's holders and to the model site after 25 years of implementation. Likewise, factors that facilitates the success of the program and problems were documented and could be used as basis to revisit and improve the policies of upland development projects in the country.

METHODOLOGY

Selection and location of the study site: The existence of an ISF model site, the availability of the secondary data and accessibility of the area were the major criteria considered in the selection of the study site. The study site is located in Brgy. Panian, St. Bernard, Southern Leyte along longitude 125° 07'05.9" and latitude 10°17'13.1" under the supervision of Community Environment and Natural Resource (CENRO) San Juan, Southern Leyte (Fig.1).

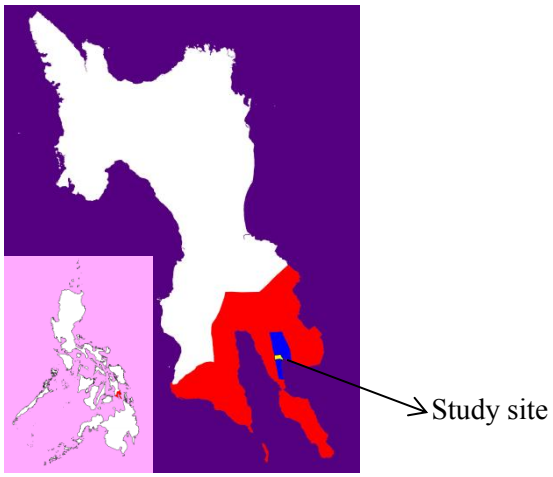

Fig. 1 Location of the study site

Formulation and pre-testing of survey instrument: A semi structured interview schedule was formulated in English and was translated into Cebuano dialect. The survey instrument answers the following objectives; namely: (a) social, economic, and demographic characteristics of CSC holders; (b) CSC holders' perceptions and opinions regarding the impact of ISFP; (c) problems encountered during project implementation; (d) factors that facilitate the success of the program; and (e) lessons learned of the CSC holders and project personnel during the policy implementation process. The survey instrument was pre-tested among 10 selected upland farmers in Inopacan,

Leyte. The purpose of the activity was to test the instrument on the following: a) comprehensibility of the instrument; b) respondents' sensitivity to questions; and c) appropriateness of terms used.

Calculation of sample size: The total number of respondents was calculated using the equation for sample size determination (Dargantes, 1996).

$$n = \left(\frac{Nz^2s^2}{Nd^2} \right) + z^2s^2 \quad (1)$$

Where n = number of respondents to be included in the survey; N = total number of respondents in the lists; Z = coefficient at 95% level of reliability; d = error level expressed in units of the normal variable; s^2 = sample variance of the normal variable. The sample variance used in the equation was attained using summative size (in ha.) of CSC farms per cultivator as normal variable. Forty-seven respondents were randomly selected out of the 81 CSC holders. Of the 47 respondents, 26 were original CSC holders, 20 were the next-of-kin and one was the successor of the original holder who was not physically capable of cultivating the land.

Data collection and focus group discussion: The data collection was conducted through the coordination with the CENRO-San Juan headed by CENR Officer (For. Alejandro Bautista); the Municipal Mayor (Hon. Napoleon Cuaton) and Panian Brgy. Captain (Hon. Ruperto Rafols). The data collection includes: gathering of the secondary information, key informants interview, and individual CSC holder's farm visit. The results of the key informant' interview (KII) were presented during the focus group discussion (FGD). The FGD participants were composed of representatives from all sectors that were involved during the implementation of the ISF program (i.e., CSC holder-beneficiaries, from CENRO and the Provincial Environment and Natural Resource Management Office (PENRMO), community organizer of the Panian Model Site, Brgy. officials and representative from Municipal Local Government Unit (MLGU)). The FGD was done to triangulate and validate the results obtained during the interview. Secondly, the FGD provided an avenue for the CSC holders to raise their concerns and listen to the plan of the PENRMO (local government) and CENRO-San Juan (national government) regarding the renewal of their individual CSC.

Data collating and statistical analysis: The data gathered during the interview and FGD were collated and tabulated using Microsoft Excel. Likewise, descriptive statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS).

RESULTS AND DISCUSSION

Table 1 shows the duties and responsibilities of the CSC holders and their perception if each duties are done and implemented. Most of the CSC holders assumed and implemented their duties and responsibilities as reflected in the agreement. This manifest that the CSC holders are qualified to apply for renewal. As stipulated in Administrative Order No. 4 (dated Feb. 27, 1991), the issuance and renewal of CSC is the main responsibility of the CENRO. On the other hand, during the FGD, the representative from CENRO-San Juan Field Office revealed that the DENR is not anymore processing any issuance and renewal of CSC contract. The representative cited Executive Order 263 which states that forestland areas with issued CSC are included under the Community-Based Forest Management Program and a new tenurial instrument (CBFM Agreement) will be issued. Hence, he strongly recommended that the CSC holders should reactivate their organization to qualify and apply for the CBFM agreement. The expert advice of the CENRO representative and the information regarding the change in DENR policy on tenure instrument (from CSC to CBFMA) causes more confusion and even doubt of the holders to apply for the renewal of their CSC contract. Furthermore, Table 1 shows a considerable number of respondents opted to abstain in answering the questions during the assessment.

This was clarified during the FGD that those respondents who abstained were the next-of-kin of the CSC holders. The reason of abstaining was they have less information and no personal involvement during the project implementation since most of them were still very young and not qualified to attend and participate any of the program related-activity.

Table 1 CSC holders' compliance to the duties and responsibilities of the ISF Program (n=47)

Duties and responsibilities	Yes	No	Abstain
1. Participate in delineation of project area and parcellary surveys	36%	36%	28%
2. Develop the allocated lands to productive farms	70%	4%	26%
3. Devote at least 20% of the land within the project area to tree farming of suitable species	43%	17%	40%
4. Protect and conserve the forest growth within the project area	70%	2%	28%
5. Preserve monuments and other landmarks indicating corners and outlines of boundaries	57%	0%	43%
6. Prevent and suppress fires	62%	11%	28%
7. Protect and preserve trees and other vegetation within a 20-meter strip of land from the edge of the normal high waterline of river and streams with channel of at least 5-meter wide	53%	2%	45%
8. Abstain from cutting or harvesting naturally growing timbers within and adjacent to social forestry area	49%	19%	32%
9. Refrain from transferring or assigning their allocated land	55%	13%	32%

The study of Asio and Bande (2005) revealed that project sustainability and transfer of local knowledge can be attained through active involvement of the youth on association's project activities. In the case of Panian ISF program, the implementers failed to involve the youth sector. Hence, the social sustainability of the project was jeopardized specially that most of the original members were dead or physically incapacitated to perform their duties and responsibilities.

Impact Assessment of the Panian ISFP Model Site: Maximize Land Productivity and Ecological Stability

The area's terrain was rolling to steep (60 to 80% slopes) with elevations ranging from 100 to 500 meters above sea level (Tabada & Escasinas, 1993) which classified the areas under timberland. The beneficiaries were encouraged to adopt appropriate agroforestry technologies since it is the only way to harmonize productivity and conservation efforts. Contour canal and hedgerows were the intervention as part of the agroforestry activity. However, during ocular inspection, it was observed that contour canals and hedgerows were left unmaintained. Despite of this, the respondents indicated that the landslide and flooding were significantly minimized which considerably improved their harvest. Likewise, the holders pointed out that the soil-water conservation measures had significantly increased their on-farm income which could be one of the indicators that the agroforestry intervention was effective. According to Mr. Fredo Ramada[1], before the implementation program, the area was dominated by cogon *(Imperata cylindrica)* and carabao grass *(Paspalum conjugatum)*. Cogon grass is one of the vegetative indicators that the area is aggravated by relative low pH, highly leached infertile soil, lack of surface organic matter and high evapotranspiration rate which causes water stress (Sajise, 1990). Other factor that exhilarated the beneficiary to participate in the reforestation was their area needs immediate rehabilitation because it is prone to landslide and flashflood due to the geologic characteristics of the site. Moreover, the result showed that CSC holders consider reforestation activity successful because of the following observations: (a) biomass and litter production considerably increased that enhances soil fertility on their CSC-issued farms, (b) water yield in the community was significantly improved due to watershed rehabilitation, and (c) reduction of harvest losses due to minimized flooding and soil erosion.

[1] Mr. Fredo Ramada - project leader of the Panian ISF model site from 1989 until 1992

Impact Assessment of the Panian ISFP Model Site: Improvement of Socio-economic Conditions of the Forest Occupants

Majority of the respondents depend on farming as their major source of livelihood wherein 71 percent of their total farm income was derived from the CSC-issued parcel. The agroforestry perennial crops [i.e., abaca (*Musa textilis*), coconut (*Cocos nucifera*), and fruit trees] that were distributed during the operation had significantly increased the on-farm income of the beneficiaries. Some of the respondents revealed that they had started harvesting the trees [i.e., yemane (*Gmelina aborea*) and mangium (*Acacia mangium*)] planted on their individual farm. According to the respondents, the income was used to finance the school expenses of their children. Presently, some of the project beneficiaries' children got decent and stable jobs because they finished a college degree. This was one of the manifestations of direct economic benefits of the project to the beneficiaries. On the other hand, self-confidence, trust of the local people, development of their leadership abilities, and establishment of good rapport with the local government units including DENR personnel were documented as positive outcomes in relation to the social impact of ISF program.

Policy Assessment of Panian ISFP Model Site: CSC Implementation After Devolution

Based on the ocular inspection vis-à-vis CSC policy implementation assessment, the results showed that most of the CSC holders have not planted 20% of their area with trees as required in the contract. In fact, it is common to find CSC areas fully planted with coconut and banana. Hence, the community acceptance and government recognition (e.g. Certificate of Stewardship Contract) of forest claims enhances intensive cultivation of food crops or the conversion of forest land into agricultural plantations (i.e., coconut and abaca). On the other hand, it was mentioned during the FGD that there had never been support provided by the Municipal and Provincial government after transferring the responsibility of Panian ISFP model site to the LGU. Presently, the CSC holders are faced with problems of management, technical capability, and lack of knowledge about the change of government policy on natural resource management and renewal of stewardship agreement. During the FGD, it was pointed out by the Municipal Agriculturist that the minor involvement of the municipality in the monitoring of ISFP activities was because these are usually initiated in forest areas, and therefore, it is under DENR's authority. The formulation of the LGUs responsibilities within the Local Government Code on forest land is that they are under the supervision, control, and review of DENR. Hence, the LGU's responsibilities seemed to be barely recognized by DENR whose officials often claimed that forest lands are under DENR's authority exclusively (Groetschel et al., 2001).

Policy Assessment of Panian ISFP Model Site: CSC Renewal

A serious concern brought up during the FGD was the renewal of CSC. All CSC agreements issued during the implementation of Panian ISFP model site had expired in 2016. As stipulated in the contract, the CSC holder is qualified for a renewal for another 25 years provided that he/she complied with the agreement. However, the DENR has adopted and implemented Executive Order 263 (CBFM strategy) which resulted to non issuance or renewal of CSC. Considering this change on DENR policy, it indicates that the CSC holder will lose their legal claim over the land they cultivated and developed for 25 years. The results of this study indicated that the CSC holders were not informed about the CBFM program. This could probably lead to a conflict between the CSC holders and government agencies.

Policy Assessment of Panian ISFP Model Site: Delegation of Responsibilities within Devolution of ISFP

The results of this study indicated that policy concerning the delegation of responsibilities within ISFP devolution was unclear and LGUs were confused. One example was the DENR's responsibilities and the functions of the Environment and Natural Officers in the LGUs (both Provincial and Municipal). It becomes difficult to distinguish respective tasks, mandates, responsibilities, and authorities. It creates difficulties when some responsibility for ISF program should have been completely devolved but in fact still partly under DENR's authority. The Municipal Agriculturist of St. Bernard reported that beneficiaries under the devolved ISF sites are coming to their office with questions concerning stewardship renewal, demonstrating public confusion with respect to the continuity of the program and the responsible institutions.

Socio-ecological Factors that Influence the Panian ISFP Model Site

Majority of the problems encountered during and after the project implementation were not solved and even continued to create conflict among project participants and implementers. The major problems were identified, namely: (a) non-processing of CSC renewal which is inconsistent with the existing DENR policy as stipulated in the CSC contract; (b) no proper turn-over of project documents during the devolution of the program; and (c) failure to transfer the knowledge and information about the program to the *next-of-kin* which became a barrier in attaining social, economic, and ecological sustainability. However, the implementation of reforestation and adoption of agroforestry systems significantly improved the bio-physical and environmental conditions of the area. During the socio-ecological assessment, the success of ISFP as a strategy in community-based forest conservation was due to the following salient factors: a) security of tenure; b) environmental awareness; c) commitment and community empowerment; and d) external support. In addition, the upliftment of the community's general living conditions and change in attitude of residents towards forest conservation and biodiversity protection in relation to increase in on-farm income was the major achievement of the ISF Program. However, government recognition through the issuance of CSC over forest land claim further increases conversion of timber land into agricultural plantations.

CONCLUSION

Even with the policy in place to ensure covering at least part of the land with trees, these areas are still converted into agricultural plantations as many other cultivated areas (without CSC) in timber land. Hence, the CSC strategy to get commitment from, and time control over forest dwellers who are operating as *kaingineros* is not clearly established and implemented under the ISF guidelines. If the CSCs are to be renewed, there must be a strong commitment to comply with the rules and regulations. Noncompliance with the policy should lead to the cancellation of CSCs and reallocation of the land. Demonstrating the commitment to enforce the laws, combined with public awareness campaign will further enhance the motivation of the CSC holders to follow the stipulations in the contract for improvement and development of their individual land. On the other hand, the municipal and provincial local government units are the key players in all efforts to reach the rural population. Burdened by the devolution of offices and related tasks, and hit by weak economic activities within the boundaries and subsequently low tax revenues, the LGUs could sustain the basic services for their population through sound management of their assets. Hence, policy on increasing LGUs assets through communal forestry could be one of the major concerns of the ISF program right from the start of the implementation.

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Research article

Environmental Education and Sustainability in Mataneedol School: A Case Study of "Turning the School Kitchen Waste into the Healthy Soil and Safety Food" Project

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Abstract Environmental education and sustainability practices in schools have been emerging as an important trend in 21st century education as the Decade of Education for Sustainable Development (DESD) launched by the United Nations. Mataneedol School is a unique school in a beautifully landscaped setting and environmental friendly located in Khon Kaen city, Northeast of Thailand. Mataneedol School is a pioneering school where the students and teachers from all over the world can learn and thrive together. The aim of this study was to conduct the environmental education through practices of ESD in order to enable the children to grow in an environment that helps imbibe awareness, sensitivity and the necessary skills to be environmentally responsible citizens of mother earth. The objective of this project was to study the benefits of the project on "Turning the school kitchen waste into the healthy soil and produce the safety food" toward the attitude of students. The student project on school waste management has been conducted. The 3 R (reuse, recycle and reduce) has been taught. Plant biodiversity has been monitored by students. Workshop on vermicompost was conducted by student council president. In the process, students learn that food waste is not totally useless, but can be used as organic fertilizers for plants. Students help to separate and record how much the school waste produced per day. We become more aware about re-using waste and saving the earth. The children are able to participate in activities that help to protect the environment, such as sorting of waste, making vermicompost and use the vermicompost as a biofertilizer for the school's garden. As they take part in these daily activities, the children understand better how to actively protect the environment and get the safe food for them. They learn a scientific thinking through the experiment on their environmental project. The Schools programme encourages young children to take actions to protect their environment and to be the change for sustainabilityl.

Keywords green school, education for sustainable development (ESD), active learning, agriculture

INTRODUCTION

Environmental education and sustainability practices in schools have been emerging as an important trend in 21st century education as the Decade of Education for Sustainable Development (DESD) launched by the United Nations.Environmental Education for Sustainable Development (EESD) is as an essential tool to change student's commitment, motivation, stewardship, behaviour and attitudes (UNESCO, 2009). To achieve the goals EESD, the active learning approach is widely recommended by several researchers. Further research demonstrated that when students are involved in active learning process, retention of knowledge is significantly increased (Henderson and Tilbury, 2004), there is enhanced motivation and higher-order learning and development of

practical skills (Lipscomb, 2014). Learning through experiences has both process and outcome dimensions, with basic content mastery integrated with opportunities to manage complex projects, apply critical thinking, and develop skills in inquiry that have applications beyond the classroom (Kemp, 2016).

Active learning has become an important issue for student learning. Mataneedol School, which is located in Khon Kaen, Thailand combines the use of British and American Curriculums and takes the approach that active learning should also be a fun experience for its students. Mataneedol School is a unique school in a beautifully landscaped setting and environmental friendly located in Khon Kaen city, Northeast of Thailand. Mataneedol School is a pioneering school where the students and teachers from all over the world can learn and thrive together. Active teaching learning methods involve students in the learning process such as discussions, writing, asking and answering questions and engaging in their own learning. These activities in turn require students to use critical thinking skills such as analysis and evaluation.

OBJECTIVES

The aim of this study was to conduct the environmental education through practices of ESD in order to enable the children to grow in an environment that helps imbibe awareness, sensitivity and the necessary skills to be environmentally responsible citizens via the project on "Turning the school kitchen waste into the healthy soil and produce the safety food".

METHODOLOGY

Active Learning of Environmental Education through "Turning the school kitchen waste into the healthy soil and safety food Project of Grade 1-6 students was conducted. This project came from the student's committee lead by student council president. This approach includes students in meaningful leadership roles in making the school more environmentally sustainable.

The methodology was a case study; the target audience were Grade1-6: 80 students from Mataneedol School who are in their second semester of 2017 (Purposive Sampling). Research instruments used were workshop, lesson plans, participatory observation, interviews, and student's tasks assessments. Data were analyzed using Qualitative interpretation.

Research Design

This research uses a case study design on "Turning the school kitchen waste into the healthy soil and safety food" Project.

RESULTS AND DISCUSSION

The student project on school waste management has been conducted. The 3 R (reuse, recycle and reduce) has been taught. Plant biodiversity has been monitored by students. The project on "Turning the school kitchen waste into the healthy soil and produce the safety food" was success case. Workshop on vermicompost was conducted by student council president. In the process, students learn that food waste is not totally useless, but can be used as organic fertilizers for plants. Student helps to separate and record how much the school waste produced per day. We become more aware about re-using waste and saving the earth. The children are able to participate in activities that help to protect the environment, such as sorting of waste, making vermicompost and use the vermicompost as a biofertilizer for the school's garden. As they take part in these daily activities, the children understand better how to actively protect the environment and get the safe food for them. They learn a scientific thinking through the experiment on their environmental project.

Results found that workshop on vermicomposting that conducted by student council president is a good way to educate students about data collection, scientific observation, decomposition, nutrient cycles, natural biological systems and waste management. It also offers an opportunity for them to learn a practical way that they, as individuals, can make a positive impact on the environment. It is opportunities to integrate math and science in school. Added food could be weighed and recorded. The time that it takes for individual food items to decompose can be observed, as earthworm food preferences. Student could will also see earthworms at different stages of their life cycle. Students leant about the important role that this type of worm plays in natural systems. When vermicompost was finished, student used vermicompost in plant growth experiments. Students enjoy their science experiment to compare the growth of vegetable compared the treatment with and without vermicompost. Student learn how important on nutrients and they could produce the healthy vegetable and use for their school lunch. These activities promote knowledge retention and make active learning a thoroughly enjoyable experience.

Active learning in the school gardens could an inculcate scientific outlook food behaviour, positive social and environmental attitudes/behaviours (Blair, 2009). Place-based approaches in environmental education are valuable for several reasons. These approaches provide students with opportunities for learning in real situations. School garden's practice is one component of active environmental education advantageous for learning in the biosciences. Active learning methods involve students in the learning process such as discussions, writing, asking and answering questions and engaging in their own learning. These activities in turn require students to use critical thinking skills such as analysis and evaluation (UNECE, 2012). The goal of knowledge processing is that the learner can elaborate on applications of knowledge and student may also produce new knowledge using cognitive processes, rather than being a passive listener

CONCLUSION

It may be concluded that the active teaching learning approach is more effective in facilitating environmental education for sustainable development among school children. Students become more aware about re-using waste and saving the earth. The students are able to participate in activities that help to protect the environment, such as sorting of waste, making vermicompost and use the vermicompost as a biofertilizer for the school's garden. As they take part in these daily activities, the children understand better how to actively protect the environment and get the safe food for them. They learn a scientific thinking through the experiment on their environmental project. The active learning encourages young children to take actions to protect their environment and to be the change for sustainability. It starts in the classroom, expands to the school and fosters change in the community.

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Research article

Agroecological Assessment of Different Cultural Practices of Pineapple, *Ananas comosus*, (Linn) Mer. (Var. Red Spanish) for Sustainable Fiber Production in Geo-Textile Industry in Balete, Aklan

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Abstract Pineapple fiber offers a promising contribution in the developing geo-textile industry in Balete, Aklan. To support this initiative, a study was conducted to assess the different agroecological production systems of *Ananas comosus* var. Red Spanish for fiber production and determine the biomass production, fiber yield, and fiber recovery of Red Spanish grown under different agroecological production systems. Five study sites were selected with varying socio-cultural management systems which included a) intensive pineapple monoculture; b) traditional pineapple monoculture; c) pineapple-rambutan-gmelina; d) pineapple-rambutan-banana and e) pineapple-indigenous trees. Results showed that the pineapple planted underneath the indigenous trees significantly ($p \leq 0.05$) produced lower biomass but higher fiber yield ($p \leq 0.05$) as compared to the other four production systems studied. It was found out that there was a significant correlation ($r=0.93$) between leaf weight, length, and fiber yield. However, no significant difference on fiber recovery was observed between study sites. On the other hand, pineapple-indigenous trees agroecological system had higher NPK contents compared to those in the other study sites. Therefore, integrating the pineapple with indigenous trees is the most sustainable production system since this will lead to better soil fertility and provide optimum fiber yield.

Keywords pineapple fiber, geo-textile industry, production systems, agroforestry

INTRODUCTION

The Red Spanish pineapple is highly recommended in the Philippines not just for its fruit but also for its fiber. The Red Spanish pineapple is an asexually propagated crop and is normally multiplied by using crown, sucker, and slip. It adopts to a wide range of soil and climatic conditions, although a well-drain soil which has a pH range of 4.5-5.5 was considered ideal. Most pineapple plantation, usually has an average planting density of 33, 333 plants/ha. The Red Spanish variety yields an average of 12-16 long leaves per plant. The leaves are usually harvested 18-24 months after planting to obtain the well-formed fibers. The first layer of fiber - is locally known as the "Bastos" (coarse) and the second layer – the "Liniuan" (fine) fiber. These are manually extracted from the leaves (FIDA, 2010). The inappropriate application of fertilizer, poor weed management, and irrigation are some of the factors that may affect the production of fiber (Tabora, 1977).

According to Montilona (1991), the Red Spanish should be grown in shaded or partially shaded area for it to produce long and pliable fibers. However, the Fiber Industry Development Authority (FIDA, 2010) reported that when the crop is grown in an open field it produces stronger fibers. The pineapple fiber has a good tensile strength which makes it a good material in making geo-textiles. This makes the pineapple fiber an important material in Aklan. The Aklanons believe that these fibers could be a great potential in the local and world market. This study was conducted in Balete Province of Aklan, Philippines to assess the different cultural management practices of

the growers involved in cultivating the Red Spanish pineapple. The result of this study will provide valuable information and identify gaps to be used in improving sustainable production and supply of pineapple fiber for geo-textile industry in Balete, Aklan.

OBJECTIVES

This study was conducted to investigate and assess the different agroecological production systems of *Ananas comosus* for fiber production and determine the biomass production, fiber yield, and fiber recovery of *Ananas comosus* production systems on Balete, Aklan, Philippines.

METHODOLOGY

Research duration: This study was conducted from July to August 2016 in collaboration with the non-timber forest products (NTFP) task force Philippines.
Selection and description of study site: This study was conducted in Balete Province of Aklan, Philippines which was selected based on different cultural production practices of the growers involved in cultivating the Red Spanish pineapple. These were: a) intensive pineapple monoculture; b) traditional pineapple monoculture; c) pineapple-rambutan-gmelina; d) pineapple-rambutan-banana; e) pineapple-indigenous trees.
Collection of soil sample: The soil samples were collected on the selected sites. About 1,000 grams of composite soil samples from each site were collected for physico-chemical analysis at the Central Analytical Service Laboratory (CASL) of the Visayas State University (VSU). In identifying the soil, a soil profile characterization, and observation of the soil physical properties in the field were done.
Collection of tissue and fiber samples: The pineapple plant samples were collected randomly from the selected plantations. This was done two days before the termination of the study. There were 18 sample plants collected in each production site. These samples were placed in a sack and were brought back to VSU for further laboratory analysis. The fibers were extracted using the traditional stripper. Fibers were classified and weighed and fiber yield plant^{-1} was determined. Fiber recovery plant^{-1} (in relation to leaf fresh weight) was calculated using the formula:

$$F_{R\ (\text{leaf fresh weight})} = \frac{W_F}{W_P} \text{x } 100 \qquad \text{Eq. 1}$$

Where: $F_{R\ (leaf\ fresh\ weight)}$ = Stripped fiber recovery per plant (%)
W_F = Total weight of dried fiber per plant (g)
W_P = Total weight of harvestable leaves per plant (g)

Determination of Dry Biomass: Ten sample pineapple plants from each plantation site were carefully selected ensuring that they were in optimum growth condition. Biomass samples were partitioned into plant organs. For each plant fraction, fresh and dry weight (after over drying at an appropriate temperature and time until a constant weight was reached) were determined. The tissue samples were weighed using digital analytical balance. Then the percent moisture content and percent dry biomass were computed using the formula as cited by Bande (2013), Lambers et al. (1998) and Lahav and Turner (1985):

$$\text{Moisture Content (\%)} = \frac{\text{fresh weight (g)} - \text{dry weight (g)}}{\text{fresh weight (g)}} \text{x } 100 \qquad \text{Eq. 2}$$

$$\text{Dry weight} = \frac{\text{Fw}}{\text{Mc}} \qquad \text{Eq. 3}$$

Where: F_w = the mass of fresh matter in a tissue (g)
M_c = moisture content in a tissue

$$\text{Biomass}_{\text{Proportional Distributions}} = \frac{Mo}{Mw} x\ 100 \qquad \text{Eq. 4}$$

Where: M_o = the mass of dry matter in a tissue (g)
M_w = the mass of dry matter in the whole plant (g)

Statistical analysis: All data were tested for normality and homogeneity using PROC Univariate of Statistical Analysis System version 9.1 (SAS, 2003). PROC GLM (general linear model) procedure was initially performed to assess the significant effects of production system on pineapple's total biomass, fiber yield and fiber recovery. The final models for each response variables were analyzed but including only those significant main factors and interaction effects. Duncan multiple range test (DMRT) and least squares differences (LSD) were carried out to compare different production system means of independent variables with significant variations at probability<0.05.

RESULTS AND DISCUSSION

Agroecological Description of the Different Pineapple Production Systems

1. Intensive Pineapple Monoculture Production System

The study site is in Barangay Fulgencio, Balete, Aklan (11° 35′ 42.65″ N and 122° 22′ 25.21″ E) on an alluvial terrace with an elevation of 49 meters above mean sea level and a slope of 0-3%. The site has an average annual precipitation of 2,600 mm yr^{-1} and a mean annual temperature of 27.5°C. The site was previously planted with maize (*Zea maize*) and banana (*Musa* sp.) then left under fallow for five years. This production system was established in 2015 by the members of the Aklanon Piña Fiber Producer's Association (APFiPA) with high planting density associated with intensive application of commercial fertilizer and weeding to attain a maximum fiber yield.

The soil analysis revealed that the texture of the surface horizon on this production site was clay loam with 1.6% soil organic carbon which is suitable for pineapple production (Table 1). Ficciagroindia (2007) reported that pineapple can suitably be grown on sandy and loamy soils that is rich in humus. Otsuka, et al. (1988), and Asio (1996) reported organic C content of the A horizons of some volcanic soils in the Philippines ranged from 0.79 to 11.1%. Organic carbon in agricultural soils contributes positively to soil fertility, soil tilt, crop production and over-all soil sustainability (Bauer and Black, 1994; Lal, et al., 1997; Reaves, 1997). The soil chemical analysis results revealed that NPK contents in the soil was generally low for crop production. According to Hoffmann's (1991), the nutritional standard for phosphorus on agronomic crops, soils with values within the range between 0-22 mg kg^{-1} is classified as low (category A) for plant nutrition. On the other hand, soils having available potassium values of 67-141 mg kg^{-1} are moderate (category B) for plant nutrition (Hoffmann, 1991).

2. Traditional (less intensive) Pineapple Monoculture Production System

This production system is located in Barangay Guanko, Balete, Aklan (11° 29′ 58.20″ N and 122° 22′ 56.35″ E) about 15 km south of Balete town at an elevation of 156 masl. The site was selected since traditional way of growing Red Spanish pineapple for fiber production is still being practiced. The socio-cultural management was different from the first site since there was no application of inorganic fertilizer and less intensive weeding was observed. In this production system, available P and exchangeable K was considerably higher than the first study site. Based on the interview conducted with pineapple growers, regular burning of cogon grass (*Imperata cylindrica*) is practiced during land preparation prior to planting of pineapple suckers or crown. This was confirmed on the soil organic carbon analysis where a significant difference was observed between the SOC value in site 1. Meanwhile, the phosphorus and available potassium in this production system qualifies under category A (low) and E (very high); respectively, based on Hoffmann's

(1991) nutritional standard on agronomic crops.

3. Pineapple-Rambutan-Gmelina Production System

The site is in Barangay Guanko, Balete, Aklan (11° 28′ 38.17″ N and 122° 22′ 41.84″ E) about 15.5 km south of Balete town at an elevation of 208 masl. It is presently planted with gmelina (*Gmelina arborea*) and rambutan (*Nephellium lapaceum*). As part of the production system, Red Spanish pineapples were intentionally planted underneath the existing trees and/or fruit trees which provides shade to the pineapple plants. According to the pineapple grower, he had been practicing the production system for 5 years already which provided considerable increase in his farm income. The soil nutrient analysis results showed that the total nitrogen was 2.4 g kg^{-1} while available phosphorus was 0.05 mg kg^{-1} and exchangeable potassium 107.50 mg kg^{-1}. This means that P and K content in the soil were generally low and moderate; respectively, for plant nutrition on agronomic crops (Hoffmann, 1991).

Table 1 Soil chemical characteristics of the different Red Spanish pineapple production systems

Study Site	Agroecological Production System	OC (%)	Total N (%)	Avail P (mg/kg)	Exch K (mg/kg)	pH (1:2.5)	Exch Al (mg/kg)
1	Intensive Pineapple Monoculture Production System	1.60	0.23	0.56	64.48	4.95	12.18
2	Traditional Pineapple Monoculture Production System	3.51	0.34	2.39	661.25	4.64	7.81
3	Pineapple-Rambutan-Gmelina Production System	2.81	0.24	0.05	107.50	4.87	17.74
4	Pineapple-Rambutan-Banana Production System	2.46	0.23	0.46	247.50	4.94	18.15
5	Pineapple-indigenous trees Production System	3.61	0.36	3.54	308.75	4.56	12.05

4. Pineapple-Rambutan-Banana Production System

This production system is in Barangay Guanko, Balete, Aklan (11° 27′ 27.07″ N and 122° 22′ 17.0″ E) about 15.8 km south of Balete town at an elevation of 243amsl. It is presently planted with rambutan (*Nephellium lapaceum*) and banana (*Musa spp.*). As part of the multi-strata agroecological production system, Red Spanish pineapples were intentionally planted underneath the existing fruit tree and bananas which provide shade to the pineapple plants. The soil nutrient analysis results revealed that soil texture was clay loam and SOC was 2.46%. Like in study sites 1 and 3, both available P and exchangeable K in the soil were generally low for plant nutrition in agronomic crop (Hoffmann, 1991).

5. Pineapple-Indigenous Trees Production System

This production system is practiced in Barangay Guanko, Balete, Aklan (11° 26′ 48.73″ N and 122° 22′ 17.15″ E) about 16 km south of Balete town at an elevation of 246 masl. The site was selected since it is different from the other production systems where the early succession native trees were intentionally allowed to regenerate which provides shade to the pineapple plants. Generally, this production system has a higher NPK contents compared to those in the other study sites.

Biomass Production and Proportional Allocation of Dry Biomass

Total dry matter accumulation differed significantly ($p \leq 0.05$) among harvested Red Spanish pineapple sample plants from different agroecological production systems. Results showed that those Red Spanish pineapple planted in the intensive monoculture system has significantly

($p \leq 0.05$) higher total biomass production than the other four production systems being studied (Figure 1). This was followed by plants harvested from the traditional monoculture system which has comparable dry matter accumulation with plants grown in the pineapple-rambutan-gmelina and pineapple-rambutan-banana production systems. The higher biomass production in the intensive monoculture was because of the exhaustive application of inorganic fertilizer compared to the other production systems.

Furthermore, farmers who are engaged in the production of Red Spanish pineapple are concerned on the quality and quantity of leaves produced per plant since the fibers are extracted from the leaf. Based on the results of the study, pineapple grown under the intensive monoculture production system significantly ($p \leq 0.05$) produced more leaves than those grown using the pineapple-indigenous trees but had comparable leaf production with plants grown in traditional monoculture, pineapple-rambutan-gmelina and pineapple-rambutan-banana production system.

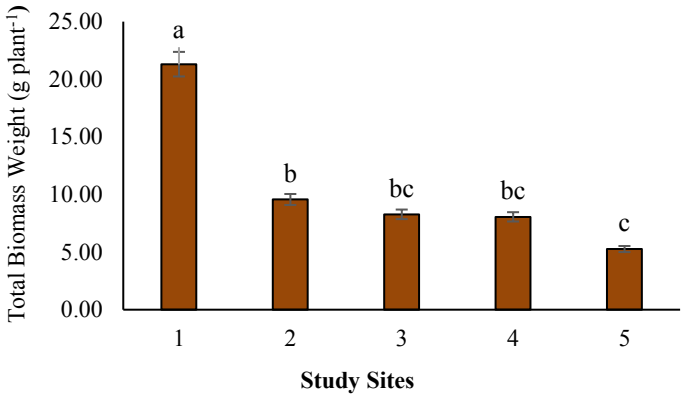

Fig. 1 Dry biomasss production (g plant^{-1}) of Red Spanish pineapple planted in different agroecological production systems
(*Note: LSD values with letter supersript (a-c) between study sites are significantly different ($p \leq 0.05$); N = 14; **1** = Intensive Pineapple Monoculture, **2** = Traditional Pineapple Monoculture, **3** = Pineapple-Rambutan-Gmelina, **4** = Pineapple-Rambutan-Banana, **5** = Pineapple-Indigenous Trees*)

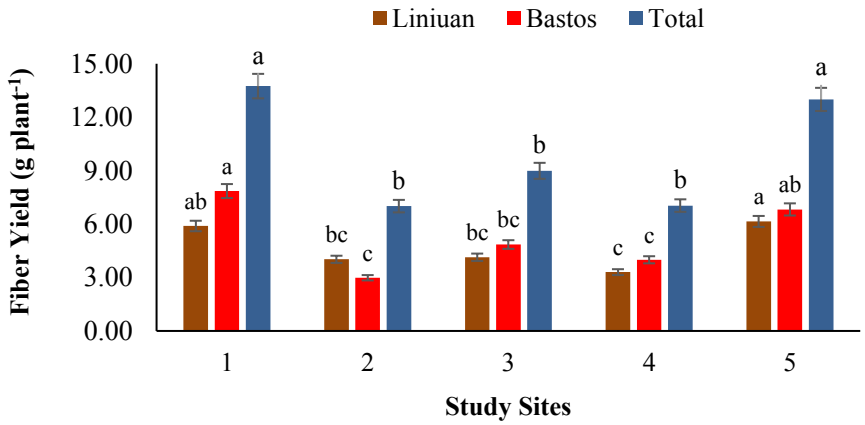

Fig. 2 Primary (bastos), secondary (liniuan) and total dry fiber yield (g plant^{-1}) of Red Spanish pineapple planted in different agroecological production systems
(*Note: LSD values with letter supersript (a-c) between study sites are significantly different ($p \leq 0.05$); N = 14; **1** = Intensive Pineapple Monoculture, **2** = Traditional Pineapple Monoculture, **3** = Pineapple-Rambutan-Gmelina, **4** = Pineapple-Rambutan-Banana, **5** = Pineapple-Indigenous Trees*)

Fiber Yield and Fiber Recovery

According to FIDA (2010), the pineapple fiber is usually composed of coarse or primary "bastos" and fine or secondary "liniuan" fibers which are manually extracted from its leaves. The results of the study revealed (Fig. 2), there was a significant difference ($p \leq 0.05$) on total, primary (bastos) and secondary (liniuan) fibers yield between intensive pineapple monoculture and pineapple-indigenous trees production systems to traditional monoculture, pineapple-rambutan-gmelina, and pineapple-rambutan-banana production systems. Furthermore, FIDA (2010) reported that fiber yield depends on the number of harvestable leaves and the physical characters of the leaves at harvest. It was found out that there was a significant correlation between leaf weight, length, and fiber yield. This was consistent with the result in this study where there were highly significant correlations ($r=0.93$) between fiber yield and leaf weight.

On the other hand, the results on fiber recovery calculation showed no significant difference among different agroecological production systems (Table 2). However, the pineapple grown under indigenous trees has higher fiber recovery than the other four production systems. The data on fiber recovery also revealed lower secondary (Fine) fiber recovery than primary (Coarse) fiber. The low fiber recovery of the "Fine" fiber was probably due to the developed parenchyma cells attached to the fibers and to presence of stigmata. In contrast the rough surface of primary fiber resulted to easier extraction time and higher recovery during stripping.

Table 2 Recovery (%) of bastos (primary), liniuan (secondary) and total fiber extracted from the leaves of the Red Spanish pineapple in different agroecological production systems

Agroecological Production System	Fiber Recovery (%)		
	Fine	Coarse	Total
Intensive Pineapple Monoculture	0.42 ± 0.11^a	0.55 ± 0.14^a	0.97 ± 0.22^a
Traditional Pineapple Monoculture	0.48 ± 0.11^a	0.32 ± 0.14^a	0.80 ± 0.22^a
Pineapple -Rambutan-Gmelina	0.33 ± 0.11^a	0.46 ± 0.14^a	0.79 ± 0.22^a
Pineapple-Rambutan-Banana	0.33 ± 0.09^a	0.35 ± 0.11^a	0.67 ± 0.18^a
Pineapple-Indigenous Trees	0.48 ± 0.09^a	0.59 ± 0.11^a	1.08 ± 0.18^a

Note: LSD values with letter superscript (a) within columns of liniuan and bastos fiber have no significant differences; N = 18

CONCLUSION

The pineapple grown underneath the indigenous trees significantly ($p \leq 0.05$) produced lower dry biomass but higher fiber yield ($p \leq 0.05$) as compared to the other four production systems. However, no significant difference on fiber recovery was observed between study sites. On the other hand, pineapple-indigenous trees agroecological system had higher NPK contents compared to those in the other four production systems studied. Therefore, it is concluded that the pineapple–indigenous trees production was found out to be highly favorable and sustainable system for pineapple fiber production in Balete, Aklan, Philippines since this will lead to better soil fertility and provide optimum fiber yield.

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Research article

Effective Utilization of Ceramic Powders for Concrete Pavement

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Abstract The effective utilization of industrial wastes has been becoming the urgent problem for the establishment of the recycling society. Especially, there are many kinds of the powders-formed industrial wastes, and studies on the utilization of them have been conducted individually and widely. The powders which do not have activity are often used as a filler of asphalt pavement, but its supply has been already saturated in Japan. Therefore, the methods to use them as the aggregate of concrete pavement is also studied. When the approach method is established, it will help the reduction of the environmental load in the infrastructure development of the field of agriculture. In this study, authors focused on the powder exhausted in the manufacturing process of the ceramic product. This ceramic powder (CP for short) is one of the powders-formed industrial wastes which don't have activity. A process of the abrasion is necessary in the production of the ceramic product. On this occasion, ceramic fines are produced as sludge-formed drainage. Under the present condition, the drainage is dried by the sun and solidified by the addition of cement. It is disposed as the industrial waste in the state, and effective utilization has been expected. In this paper, CP was investigated to be used effectively as the substitute of fine aggregate. A part of JIS standard sand was replaced to CP by volume, being based on the mix proportion in the strength test of cements. The maximum replacing ratio was established experimentally from the viewpoint of fresh properties such as mortar flow test and setting time test and strength properties. The shrinkage properties was also obtained by the test of length change of mortar with dial gauge.

Keywords ceramic powder, concrete pavement, workability, strength, drying shrinkage

INTRODUCTION

The effective utilization of the industrial waste becomes the urgent problem in the establishment of the recycling society (Sogo et al., 2013). Especially, the powders-formed industrial waste exist for having many kinds, and a study on utilization is conducted individually and widely (Malhotra et al., 2005; Matsuo et al., 2007; Hosokawa et al., 2014). The powders which do not have activity are often used as a filler of asphalt pavement, but its supply is already saturated in Japan. Then, the methods to use them for aggregate of the concrete pavement is also studied. When the approach method is established, it helps the reduction of the environmental load in the infrastructure development of the field of agriculture. In this paper, authors focused on the powders exhausted in the manufacturing process of the ceramic product (CP). CP is one of the powders-formed industrial waste which does not have activity. A process of the abrasion is necessary in the production of the ceramic product. On this occasion, ceramic fines are produced as sludge-formed drainage. Under the present condition, the drainage is dried by the sun and solidified by the addition of the cement. It is disposed as the industrial waste in the state, and effective utilization is expected.

Giving attention to studies on CP, Sakagami clarified the applicability as segregation control material in the high slump concrete by replacing a part of the cement with CP (Sakagami et al., 2003). They were concerned about strength decreasing and suggested aggregate replacement not cement replacement.

In this study, CP was investigated to be used effectively as the substitute of fine aggregate. A part of JIS standard sand was replaced to CP by volume, based on the mix proportion in the strength test of cements. The maximum replacing ratio was acquired experimentally from the viewpoint of fresh properties such as mortar flow test and setting time test (JIS A 1147) and strength properties. The shrinkage properties was also obtained by the test of length change of mortar with dial gauge (JIS A 1129-3).

METHODOLOGY

1. Materials and Basic Properties

CP was dried by furnace drying to the absolute dry condition. And CP which passed 0.15mm sieve was used to unify the particle size. Table 1 shows the ingredient analysis of CP, and the Aluminum proportion is the most. The main materials were ordinary Portland cement (bulk density is 3.15 g/cm^3) as binder, the city water as mixing water and JIS standard sand (bulk density is 2.64 g/cm^3, water absorption is 0.42%) and CP (density in absolutely dry condition is 3.71 g/cm^3, non-sphere) as fine aggregate. High performance AE water reducing agent was used, and its effect was confirmed.

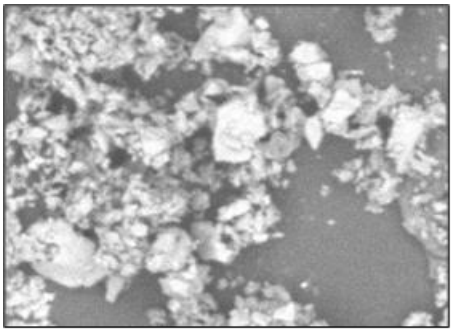

Photo. 1 Ceramic powder (3000 times)

Table 1 X-ray Diffraction Analysis of CP

Element	Al	Si	Ca	Mg	Cu
(%)	89.2	6.6	1.1	1.0	0.5
K	Ni	Mn	Na	Fe	Others
0.4	0.4	0.3	0.2	0.2	0.2

Table 2 shows the mix proportion of mortar. Unit volume water and unit volume cement was constant. Mixing was carried out following JIS R 5201, physical testing method for cement. Namely, after the mixing of water and cement for 30 seconds, the fine aggregates were added and mixed for another 30 seconds. After 90 second stop, they were mixed for 60 seconds again.

Air content was measured just after mixing, and setting test and bleeding test were conducted, each according to JIS A 1128, JIS A 1147 and JIS A 1123. In JIS A 1128, the air amount of mortar is able to be measured by the device such as Photo.2. In JIS A 1147, the increase of penetration resistance by time can be obtained by inserting of the bar into mortar as Photo.3. The time when the penetration resistance was to 3.5 N/mm^2 is determined as the initial setting, and that of 28.0 N/mm^2 is determined as the final setting. In JIS A 1123, the water floating on the surface of the mortar is absorbed in a filler directly, and the weights is measured as the bleeding (see Photo.4). The test specimens were prisms, and the dimensions were 40*40*160 mm. Strength test was conducted at the curing age of 3, 7, 28 and 91 days.

Table 2 Mix Proportion of Mortar (Base)

No.	W/C (%)	*CP (%)	**SR (%)	Unit Weight (kg/m^3)					Fresh & Strength	Shrinkage
				W	C	S	CP	SR		
S0	50	0	0	256	512	1536	0	0	○	
S5	50	5	0	256	512	1458	108	0	○	
S10	50	10	0	256	512	1381	216	0	○	
S15	50	15	0	256	512	1305	324	0	○	
S15H1	50	15	1	256	512	1305	324	10		○
S15H2	50	15	2	256	512	1305	324	20		○
S20	50	20	0	256	512	1228	431	0	○	
S25	50	25	0	256	512	1151	539	0	○	
*CP: Ceramic replacing ratio by volume **SR: Shrinkage reducing agent, 1 means the standard usage										

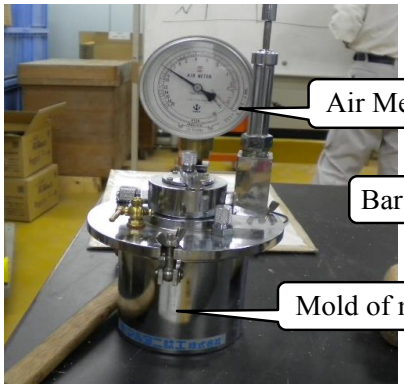

Photo. 2 Measurement of air amount **Photo. 3 Measurement of setting time**

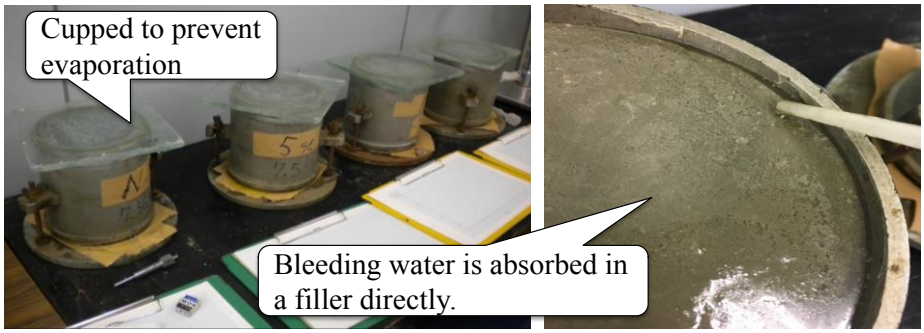

Photo. 4 Measurement of the amount of bleeding water

2. Methods of Measurement for Length Change

Table 2 also shows the mix proportions in the length change test. "S" means the replacing ratio to CP. Based on S0 which is the mix proportion of the cement strength test, a part of fine aggregate was replaced by volume to CP. "H" means the amount of shrinkage reducing agent, which main ingredient is glycol ether. "1" means the standard amount and "2" means twice as much. This agent was used and the effect was confirmed in the mix proportion of 15% of replacing ratio of CP.

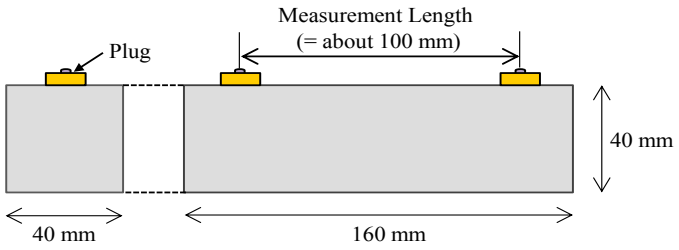

Fig. 1 Specimen size and position of the plugs for length change test

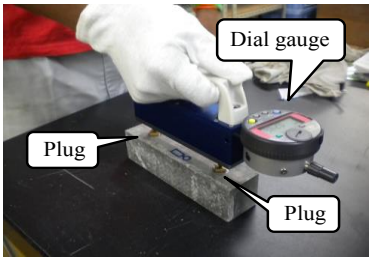

Photo. 5 Length change test

The test specimens were prisms, and the dimensions were 40*40*160 mm as same as basic tests (see Fig.1). 3 specimens were made by every mix proportion. They were demolded on the next day of casting, and had begun to be dried after 28 days standard curing. The environmental condition of drying in draft chamber was the room temperature of 20 degrees Celsius and the humidity of 60%. The length change test was conducted according to JIS B 7503 (see Photo.5).

RESULTS AND DISCUSSION

Figure 2 shows the relationship between CP replacing ratio and mortar flow. As the replacing ratio increase, the mortar flow decreases. Especially, when the replacing ratio exceeded 15%, workability decreased remarkably, which is out of practical use. Because a particle size of CP is extremely smaller than JIS standard sand, and surface area ratio is big, the adsorption water increased, which could be estimated as the factor that the workability decreased.

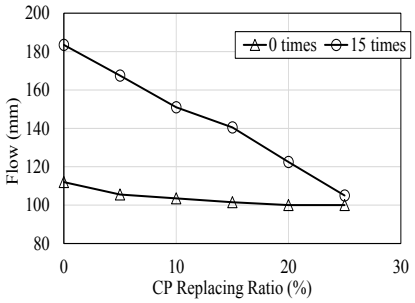

Fig. 2 Relationship between CP replacing ratio and mortar

Figure 3 shows the result of the bleeding test. When the replacing ratio exceeded 10%, almost none of bleeding occurred. Even at 5% of CP replacing ratio, bleeding became about a one-third of basic mix proportion. This would be because the surface of CP which particle size is very small absorbed water like flow test. From the above, CP decreases the bleeding, but workability extremely decreases when CP replacing ratio exceed 10%.

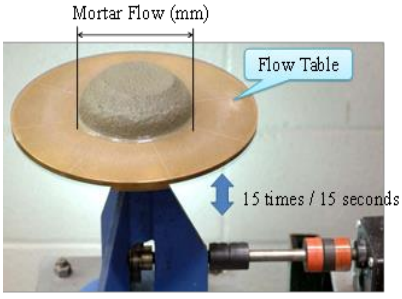

Photo. 6 Measurement of mortar flow

Figure 4 shows the result of the air content test. When CP was mixed, the air content increased obviously. The air content represented the maximum value at 5% of CP replacing ratio, and had a tendency to decrease at 10 and 15% of CP replacing ratio. Generally, when the amount of powders increases, the air content increases. In this study, there was too much quantity of particles, and the mortar was too dry condition, that caused the difficulty of air entraining.

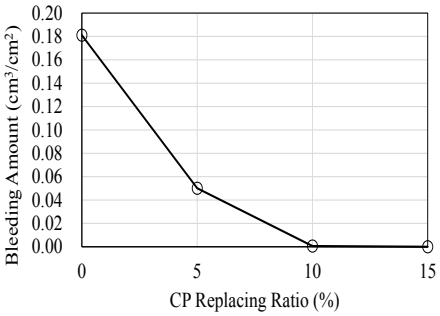

Fig. 3 Result of bleeding test

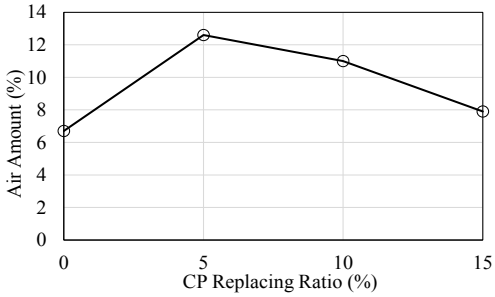

Fig. 4 Relationship between CP replacing ratio and air amount

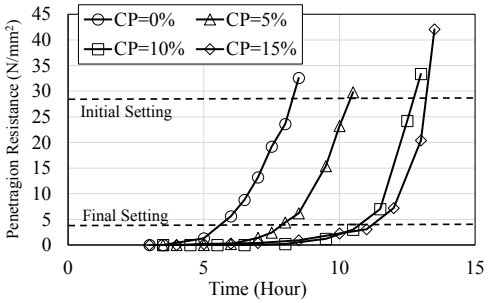

Fig. 5 Result of setting test

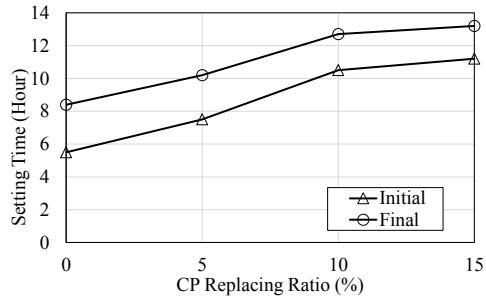

Fig. 6 Relationship between CP replacing ratio and setting time

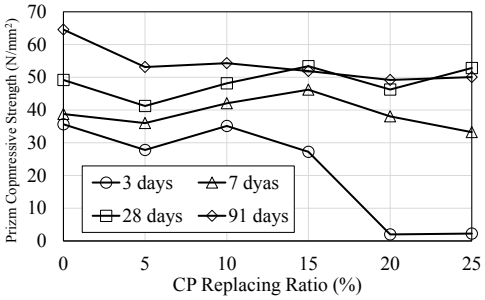

Fig. 7 Relationship between CP replacing ratio and prizm compressive strength

Figures 5 and 6 show the results of setting test. Retardation of setting of 2 hours in S5, 5 hours in S10 and 5.7 hours in S15, in comparison with the initial setting time of S0 (5.5 hours). And retardation of setting of 1.8 hours in S5, 4.3 hours in S10 and 4.8 hours in S15, in comparison with the final setting time of S0 (8.4 hours). In addition, time from initial setting time to final setting time decreased with the increase of replacing ratio, and the difference between S0 and S15 was approximately 0.9 hours. From the above, it was confirmed that CP delays the setting time of concrete.

Figure 7 shows the results of cubic compressive strength test. At 3 day material age, although the strength did not decrease with until 15% of CP replacing ratio, strength decreased remarkably with after 20% of CP replacing ratio. After 7 day material age, regardless of CP replacing ratio, it was confirmed that the strength development was approximately equal to plain mortar.

Figure 8 shows the results of bending strength test. It was able to be confirmed that the strength development was low in the case of high replacing ratio of CP in 3 day material age, and the strength development could be obtained in every replacing ratio after 7 days material age as same as compressive strength. Figure 9 shows the change of shrinkage strain with time. In all specimens in which fine aggregate was replaced with CP, the shrinkage strain increased in comparison with plain specimen. And as CP replacing ratio increased, the shrinkage strain also had a tendency to increase. In S15H2 which used shrinkage reducing agent, it could be improved to the same degree as S0, and in S15H2 it was improved to degree more than S5.

Figure 10 shows the change rate of weight with time. The change rate of weight among S10 to S25 did not have the evident difference. The performance was improved in all the specimen using the shrinkage reducing agent in comparison with plain specimen. However, CP replacing ratio and the change rate of weight did not have the proportion relations. It is a future problem to elucidate the reason. Fig.11 shows the change rate of specific strain with time. Here, the specific strain is the value that divided the shrinkage strain by the amount of evaporated water, which could be considered to be a resistant index for drying shrinkage. It is confirmed that the hardness has an influence on the length change also from this figure.

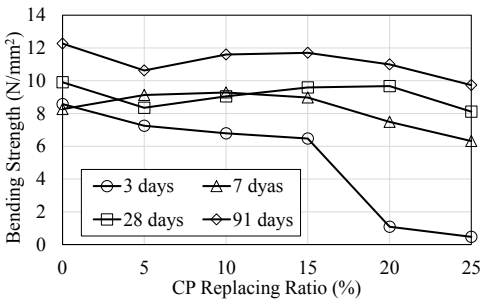

Fig. 8 Relationship between CP replacing ratio and bending strength

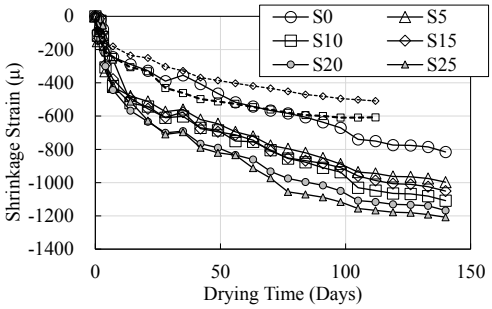

Fig. 9 Change of shrinkage strain with time

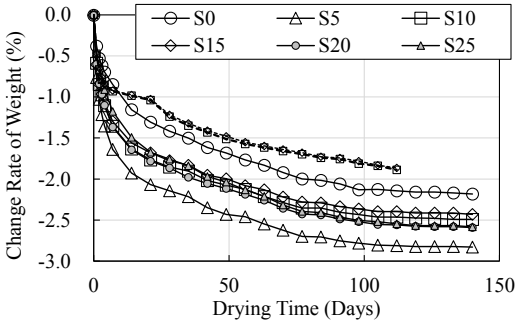

Fig. 10 Change rate of weight with time

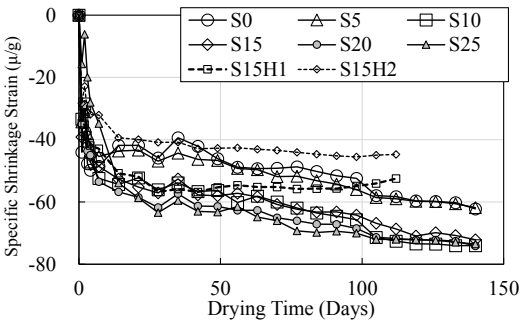

Fig. 11 Change rate of unit strain with time

CONCLUSION

1. When CP was mixed, the air content increased obviously and the bleeding decreased and the setting time delayed.
2. When CP replacing ratio is high, the strength in early age is small, but the strength does not decrease within 25% of CP replacing ratio after 7 days of curing age.
3. Without water reducing agent and so on, most adequate CP replacing ratio is 15%, considering workability altogether.
4. Shrinkage strain have a tendency to increase with CP replacing ratio, but shrinkage reducing agent is effective as measures, and the improvement effect is proportional to its mixing amount.

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Research article

Productivity and Sustainability of Coconut Production and Husk Utilization in the Philippines: Coconut Husk Availability and Utilization

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Abstract The technical possibility to manufacture fibreboards based on coconut husk and bonded with tannin adhesive formulation was shown. However, there were limited information on the husk production in different coconut producing provinces in the Philippines. Surveys and interviews were conducted to assess husk productivity and utilization by the smallholder coconut farmers. In 2014 and 2015, a total of 13 top coconut producing provinces in the Philippines were surveyed. A total of 1,200 coconut farmers were interviewed. A total of 200 nuts were sampled from the six provinces in the Philippines to characterize husk of coconut. Statistical analysis results showed that the weight of husks are significantly different ($p \leq 0.05$) between the provinces across the islands. The heaviest husks (dry weight) were in the province of Northern Samar (463 ± 11 grams). The mean density (ton ha^{-1} yr^{-1}) of husk production in the 13 provinces was analyzed using the Geographic Information System (GIS) spatial analyst tool. Among the 13 provinces surveyed, Davao Oriental in Mindanao had the highest density (0.70 – 1.43), followed by Camarines Sur (0.66 – 1.29) in Luzon. In the Visayas, Northern Samar (0.55 – 1.17) has the highest density.

Keywords coconut, sustainability, husk production, husk utilization

INTRODUCTION

Husk production in the Philippines is 14.69 billion nuts per year and farmers use more than 5 billion of them for firewood during copra drying (PCA, 2015). The remaining husks become farm waste and large volumes are left in the field together or without the shell. The Department of Agriculture (DA) of the Philippines estimated 9 billion husks are left or burnt in the field (DA, 2014). This massive amount of husks might represent an important natural resource (Greer, 2008). Fibres are extracted from the husk of the coconut and are made into geotextile and a variety of manufactured articles such as ropes, bags, mats, rugs, carpets and many other products (Kavitha, 2016). Meanwhile, the coconut peat –the non-fibrous part of the husk– is also utilized as

component of organic plant media fertilizer (Nazari et al., 2011). In spite of all the current applications of husk mentioned, the estimated husk utilization in the Philippines amounts to 334 tons/day (about 120,000 tons/year) which is a negligible fraction of the total husk production (PCA, 2015).

Niro et al., (2016) showed the technical feasibility to produce fibreboards made of milled coconut husk and bounded with natural adhesives, specifically tannin-based adhesive formulations. To ensure the sustainability of the board production, the husk availability and current utilization should be fully assessed. However, there was limited information on how much volume is actually produced, utilized and therefore potentially available in certain provinces in the Philippines.

This study was conducted to assess husk availability, density and utilization in the major coconut producing provinces in the Philippines. The data were collected with the main aim to provide baseline information for the identification of most suitable locations for the setting up of new coconut husk processing plants, e.g. coconut husk fibreboard manufacturing.

OBJECTIVE

1. To characterize the husks in selected provinces in the Philippines;
2. To assess the husk production and utilization in major coconut producing provinces in the Philippines; and
3. To conduct spatial analysis on husk production and utilization using Geographic Information System (GIS).

METHODOLOGY

Site Selection and Secondary Data Collection

Official visits to the regional and provincial offices of Philippine Coconut Authority (PCA) and Office of the Municipal and Provincial Agriculturist was conducted to collect secondary data (i.e., coconut farm in hectare and production per province and municipality) on coconut production and farming related activities in the locality. In addition, secondary data on coconut production was also obtained from the Philippine Statistics Authority (PSA).

A total of four (4) provinces in Luzon, five (5) provinces in Visayas and four (4) provinces in Mindanao were selected during the 2014 and 2015 survey period. These provinces were pre-determined as the top coconut producers in the major island based on the official data from PCA.

Field Survey and Interview

Using the pretested survey questionnaire, primary data on farming profile which include husk production and utilization from coconut smallholder farmers were collected. Prior to the interview to the coconut farmers, official visits to the regional and provincial offices of PCA as well as from the local government units (i.e., provincial, municipal and barangay/village) were done. The visit was conducted to coordinate the survey with local officials and PCA personnel who are knowledgeable in the area.

The survey was conducted in 2014 and 2015 constituting a total of 900 and 300 respondents (coconut farmers), respectively. During the 2014 survey period, two provinces in Luzon and Mindanao while three provinces in the Visayas were surveyed. Whereas in 2015, two provinces in each major island were surveyed. On the other hand, the respondents were randomly selected based on their availability and willingness to provide information.

Husk Sampling

Aside from the coconut farmer and husk processor survey, 200 samples of husk were collected in the provinces of Laguna, Sorsogon, Northern Samar, Bohol, Surigao del Norte and Agusan del

Norte. The husks from the provinces of Laguna, Sorsogon, Northern Samar, Surigao del Norte and Agusan del Norte were collected from the newly (fresh) harvested whole coconuts. While in Bohol, the husks were collected from already harvested stock nuts in the field. All nuts were individually weighed using a 25 grams mark off top loading balance right after harvesting except on the samples from Bohol. Coconut harvesting and weighing last out an average of 4 hours.

After weighing the nuts, these were manually dehusked using a sharp and pointed tool. Right after dehusking, the husks were then individually weighed to obtain the fresh weight ratio of the husk to the whole nut. After weighing, approximately 100 grams samples (fresh weight) from the whole husk were placed and sealed in a plastic bag brought to laboratory for analysis. These husk samples were oven dried at 70°C for 24 hours (PCARR, 1980) for moisture content determination. The moisture content (%MC) was calculated using Equation 1:

$$\%MC = (\text{Fresh husk weight} - \text{Husk oven dry weight}) / (\text{Fresh husk weight}) \times 100 \quad (1)$$

Gross and Net Husk Density Determination

The gross and net husk density (dry weight) was determined using the harvest yield data collected during the field survey. These was calculated based on the following formulae:

$$\text{Husk density (gross)} = (\text{Total dry husk weight}) / (\text{Coconut farm area}) \quad (2)$$

$$\text{Husk density (net)} = \text{Husk density (gross)} \times (1 - (\text{Percent annual husk utilization}) / 100) \quad (3)$$

Data Encoding and Statistical Analysis

All figures gathered during the survey were collated, encoded and summarized using an electronic spreadsheet editor (Microsoft Excel 2013). A numerical code was provided for each variable of the recorded data.

The data were analyzed using the Statistical Packages for Social Studies (SPSS Version 20). The variabilities of the means on husk fresh and dry weight, moisture content (wet basis), and husk production were analyzed using the one-way analysis of variance (ANOVA). In case significant variations at $p \leq 0.05$ were identified, Duncan multiple range test (DMRT) and least squares differences (LSD) were carried out to compare means of independent variables between different provinces for each major island and between islands. Data with no significant relationship (e.g. husk utilization) were qualitatively analyzed by SPSS.

Mapping of the Spatial Gross and Net Husk Production

The Global Positioning System geographical coordinates of each interviewed farmer was used in mapping the spatial distribution of husk production and utilization. Secondary geo-data of polygon vector at municipal and/or barangay level was obtained from PhilGIS. Using the vector polygon, basic maps on the spatial husk availability were generated using ArcGIS (version 10.2) program through the *Spatial Analyst* and *Network Analyst* tools. The mean value on gross and net availability of husks density (ton ha-1 yr-1) were spatially presented using the PhilGIS vector polygon at the barangay/village level. In addition, the ArcGIS feature to point data management tool was used to generate representative point locations on the husks density data in a barangay level. Using the *kriging spatial analyst* tool, interpolation of the husk data was performed following the ordinary linear semivariogram model in a 100 meters raster cell size.

RESULTS AND DISCUSSION

Coconut Husk Biomass Production

The weights of the fresh husk were significantly different ($p \leq 0.05$) within the provinces and across the major islands (Fig. 1). The heaviest husks were in the province of Northern Samar (1,183 ± 29 grams) while Bohol fresh husk weight was the lowest. The weight of fresh husks from Laguna and Bohol does not differ significantly. The observed differences in the weight of fresh husks between some provinces could be the effect of variety and maturity of nuts during harvest.

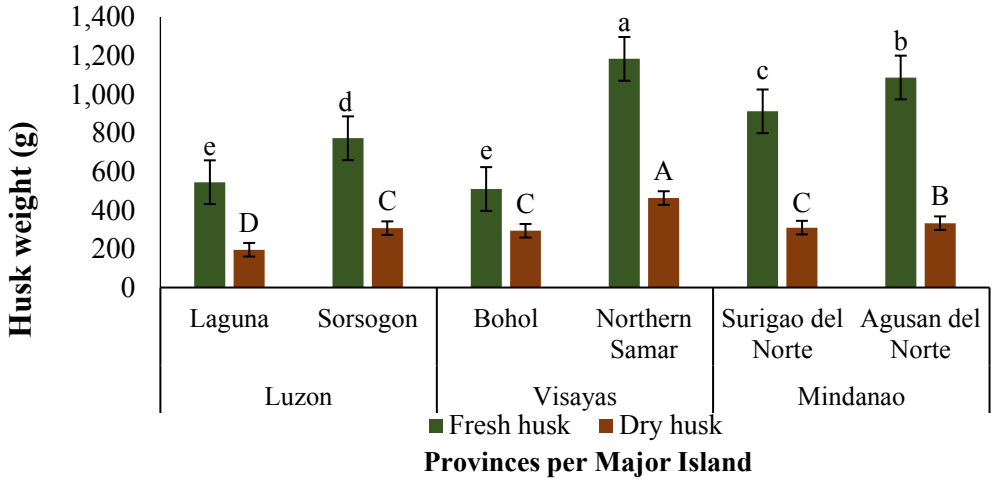

Fig. 1 Fresh and dry husk weight (grams) from the selected provinces the Philippines

Average and standard deviation bars are reported. Values with different superscript letter across province are significant at $p \leq 0.05$; n=200

The dry weight of husks showed as well significant differences ($p \leq 0.05$) and followed similar trend with the fresh husk weights (Fig. 1). Significant difference ($p \leq 0.05$) were observed between the provinces of Northern Samar, Agusan del Norte and Laguna. No significant differences were instead detected between the dry husk weight from the provinces of Sorsogon, Bohol and Surigao del Norte.

Coconut Husk Utilization

The husk utilization by farmers in the three major islands is presented in Fig. 2. The highest percentage of husk use was firewood. Only a small portion of the husks were utilized for handicraft and cococoir (fibres + peat) related productions.

In the three major islands, Visayas has the highest uses of husks for firewood. This is likely related to different copra processing methods in the islands. It was in fact recorded during the interview that in Visayas the copra are dried by the farmers in the field prior to selling to the local buyers. In Luzon and Mindanao island instead, most of the farmers delivers the fresh copra or the whole nut to the buyers. Cococoir processing is mostly concentrated in Luzon and Mindanao.

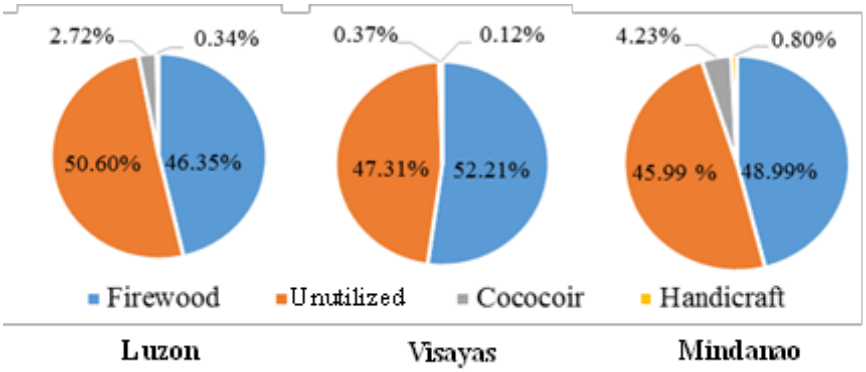

Fig. 2 Percentage of husk utilization by farmers in the provinces from three major islands

Husk Availability in the Different Provinces

Among the top coconut producing provinces in the Philippines, Quezon in Luzon has the largest area of coconut farm of 338,723 ha (Table 1). This was followed by Davao Oriental in Mindanao and Leyte in Visayas with a total coconut area of 143,584 and 126,873 ha, respectively.

Table 1 Gross and net husk density (ton ha^{-1} yr^{-1}) and production from the selected provinces the Philippines

Major Island	Province	Total area cultivated with coconut (ha)*	Husk density (tons ha^{-1} yr^{-1})		Husk production (tons yr^{-1})	
			Gross	Net	Gross	Net
Luzon	Laguna	62,200	1.03	0.52	63,755	32,033
	Quezon	338,723	0.93	0.48	315,012	160,893
	Camarines Sur	119,045	1.29	0.66	153,568	77,974
	Sorsogon	97,153	1.18	0.60	114,641	57,806
Visayas	Northern Samar	85,661	1.17	0.55	99,795	47,114
	Western Samar	49,000	0.99	0.47	48,510	22,785
	Biliran	20,245	0.84	0.40	17,006	7,997
	Leyte	126,873	1.06	0.50	133,851	62,802
	Negros Oriental	45,525	0.80	0.38	36,420	17,072
Mindanao	Surigao del Norte	60,729	0.63	0.32	38,259	19,433
	Agusan del Norte	33,486	0.71	0.35	23,775	11,720
	Misamis Oriental	103,244	0.54	0.27	55,236	27,360
	Davao Oriental	143,584	1.43	0.70	204,607	100,509

**Source: Philippine Coconut Authority (2015)*

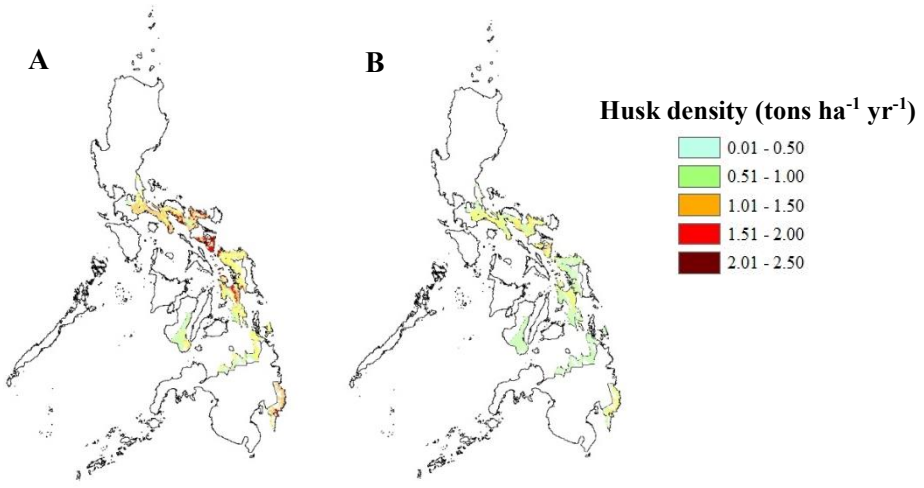

Fig. 3 Gross (A) and net (B) coconut husk production in selected provinces in the Philippines

On the other hand, the highest husk density (Fig. 3) is located in Davao Oriental with a value ranges from 0.70 – 1.43 tons ha^{-1} yr^{-1}. This was followed by Camarines Sur and Sorsogon with densities ranges from 0.66 – 1.29 and 0.60 – 1.18 tons ha^{-1} yr^{-1}, respectively. However, the highest gross and net production of husk is still found in Quezon province. Then again, Davao Oriental ranked second followed by Camarines Sur. The highest husk production is primarily attributed to the total land area planted to coconut. Looking into the husk density between provinces within major islands, Camarines Sur in Luzon, Northern Samar in Visayas, and Davao Oriental in Mindanao were the provinces with the highest husk densities compared to the other provinces.

CONCLUSION

The statistical analysis results showed that the fresh and dry weight of husks are significantly different ($p \leq 0.05$) between the provinces across the islands. The heaviest husks were located in the province of Northern Samar.

The gross and net husk density (ton ha^{-1} yr^{-1}) was highest in the province of Davao Oriental in Mindanao compared to the other provinces surveyed. The highest total husk production was recorded in the province of Quezon.

The gross and net husk density are the major parameters in selecting the site for fibreboards made of milled coconut husk processing plant. Based, on the result of GIS spatial analysis Davao Oriental province with the highest density of husk is the most suitable site of a husk processing plant.

ACKNOWLEDGEMENTS

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Research article

New Science Tools for Spatial Distribution of Yield and Management Practices of Major Pulse in Selected Area in Myanmar

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Abstract Pulses are one of the major agricultural exports in Myanmar. About 70 percent of all pulses are normally grown immediately after monsoon rice in middle and lower region. Farmers are not achieving the optimum yield due to inappropriate crop management and insufficient technological solutions although modern varieties are cultivated extensively. The introduction of applying new science tools such as GPS, GIS and drone image can develop timely and accurate estimation of crop areas and forecasting its production. It may also provide governments, planners, and decision makers with essential information to make a successful plan of appropriate technologies in regard to import/export. The study was conducted at Kyee Inn Village, Pyinmana Township, middle Myanmar from December 2016 to May 2017 to expose mapping for spatial distribution of yield and management practices. Drone flying had done by using DJI Phantom 4 drone and Litchi software. Drone photos were consolidated and prepared for digitizing and analyzing with pix 4D software and ArcGIS. Seventy farmers were selected as sample respondents for collecting ground truth information of yield and management practices based on pulses cultivated area. The study revealed that the major pulse grown in target area was black gram with yields ranging from 0.16 to 2.29 MT/hectare. The majority of respondents were found to have low level adoption of Good Agriculture Practices (GAP) of black gram recommended by Agricultural Department. It is urgently needed to upgrade full adoption of improved recommended package of practices by supporting training institutions to train the farmers and recommend technological solutions for the increase of productivity. Thus, new science tools such as GPS, GIS and drone image must be applied in agricultural system for increasing crop productivity as well as improving livelihood of the farmers.

Keywordsp pulses, new science tools, mapping, yield, management practices

INTRODUCTION

Pulses are one of the major agricultural exports in Myanmar. The major pulses exported are black gram, green gram, pigeon pea, kidney bean and cow pea. Pulses are grown on 4.20 - 4.30 million hectares of area with an annual production of 5.04 -5.16 million tons (GAIN, 2017). About 70 percent of all pulses are normally grown immediately after the harvest of monsoon rice in middle

and lower region. Farmers are not achieving the optimum yield due to inappropriate crop management and insufficient technological solutions although modern varieties are cultivated extensively (Phway Su Aye et al., 2013).

Spatial data incorporating with socioeconomic information relating to pulses cultivation is possible to perform appropriate technological solutions for constraints of their cultivation. Currently, nationwide pulses production area has been obtained with statistically-based ground surveys but there has been seldom precise information on spatial distribution of yield, management practices and constraints of major pulses. Indeed statistical data are costly, time-consuming and do not provide sufficient detailed information to determine either the extent or the geographical distribution of major crops.

The introduction of applying new science tools such as Global Positioning System (GPS), Geographical information systems (GIS) and drone image can develop timely and accurate estimation of crop areas and forecasting its production (Wyland, 2009). Geographical information systems (GIS) technology in combination with ground surveys can relate spatial distribution of crop yield and management practices that would determine the extent of major crop production and constraints to their cultivation (Sreedevi et al., 2009). Moreover, it may provide governments, planners, and decision makers with essential information to successfully plan and deploy appropriate technologies in the most effective manner in regard to import/export.

OBJECTIVES

The objective of this research was to expose mapping for spatial distribution of yield and management practices of major pulse in selected area using new science tools.

METHODOLOGY

Study area: The research was conducted at Kyee Inn Village, Pyinmana Township, middle region of Myanmar, which lies between north latitudes 19°42'30" and 19°43'40" and east longitudes 96°13'30" and 19°15'30" from December 2016 to May 2017 (Fig 1.). Total study area is 483ha and pulses are grown just after the harvest of monsoon rice as double cropping (Table 1).

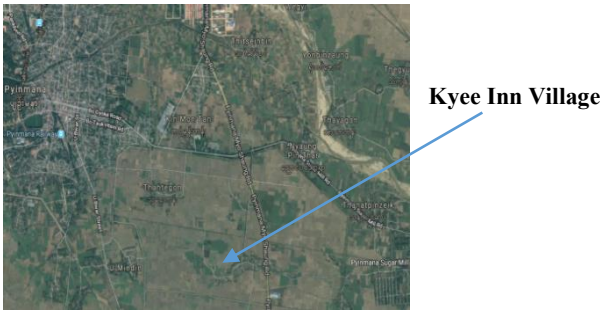


Fig. 1 Study area at Kyee Inn Village, Pyinmana Township, Myanmar

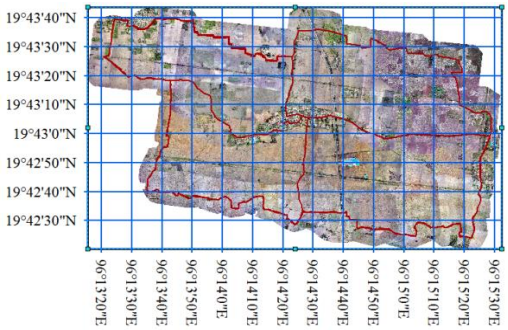


Fig. 2 Sample plots taken in study area using grid sampling system

Table 1 Total cultivable area and major pulses growing area in study area, 2016

Block No.	Cultivable area (ha)	Major pulse Area (ha)	Percent (%)
1698	120	107	89.17
1699	100	84	84.00
1708	114	100	87.72
1709	149	137	91.95
Total	**483**	**428**	**88.61**

Source: DoALMS Pyinmana Township

Data collection: Using 300m × 300m grid sampling system, total numbers of 104 grid squares were taken in the study area (Fig 2.). Grid squares located outside of the study area were removed and left 78 grid squares which had been cultivated with pulses. One plot from each grid squares was randomly selected as a sample plot and surveyed in the field for ground truth data. Seventy farmers occupied in sample plots were selected as sample respondents and interviewed with the help of well-structured questionnaire. The data collected were demographic characteristics of the respondents, yield and cultivation of major pulses practiced by the respondents, source of seed availability and constraints of management practices related to major pulses cultivation in the study area.

Field basemap hardcopy used as the base layer for digitizing and required secondary data were gathered from Department of Agricultural Land Management and Statistics (DoALMS), Pyinmana Township, Union of Myanmar.

Drone Flying: Drone flying had done by using DJI Phantom 4 drone and Litchi software at an altitude of 120 meters above the ground. Drone photos were consolidated and prepared for digitizing and analyzing with pix 4D software to provide digital base map of the study area. Thematic mapping for spatial distribution of yield and management practices were provided using ArcGIS Desktop [software] from Environmental Systems Research Institute (ESRI).

RESULTS AND DISCUSSION

Cultivation Conditions of Major Pulses in the Study Area

Major pulse grown in the study area was black gram (*Vigna mungo* (L.). Figure 3 shows total sown area possessed by sample respondents ranging from 0.2 to 11.0ha. Most of sample respondents (72%) were experienced with pulses cultivation in 4-10 years, 26% in 11-20 years and only 2% in 21-30 years respectively (Fig 4.).

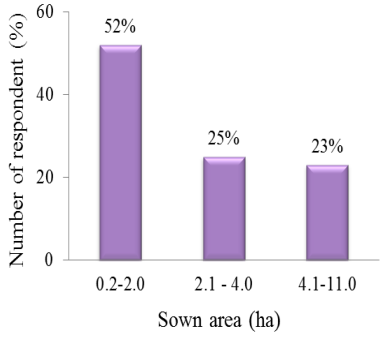


Fig. 3 Sown area possessed by sample respondents in study area

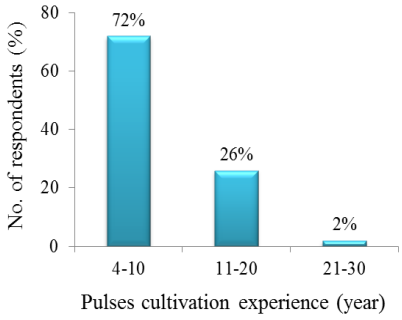


Fig. 4 Pulses cultivation experience of sample respondents in study area

Cultivation Practiced by Sample Respondents in the Study Area

Seed source and variety used: Figure 5 reveals that most of the sample respondents in study area applied their own seed or dealer seed for sowing. Only 5% of them applied quality seed from research station. They usually practiced by storing their own seed or exchanging with dealer seed at the time of crop harvest. This clearly indicates that the necessity of quality seed multiplication program should be undertaken with cooperative farmers by Department of Agriculture (DOA).

The black gram varieties commonly sown by sample respondents were Yezin-6 (Sepae), Yezin-5 (Paenat) and Yezin-2 (Matpae Yoeyoe) (Fig 6.). Among them, Yezin-5 is more longer duration (100-110 days) than Yezin-6 (90-95 days) and Yezin-2 (70-75 days).

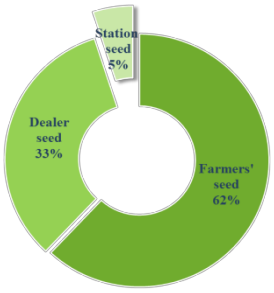


Fig. 5 Seed source of sample respondents in study area

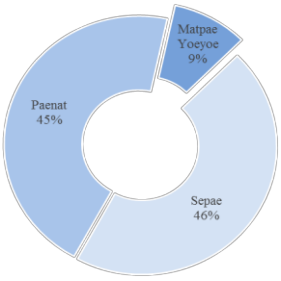


Fig. 6 Black gram varieties sown by sample respondents in study area

Time of sowing and method of sowing: In the study area, 4%, 59% and 37% of sample respondents sowed black gram in October, November and December, respectively. The optimum time of sowing for black gram recommended by Department of Agricultural Research (DAR) is during mid-October to end of November. It was found that some of the farmers in study area could not sow black gram timely. The reason given by the farmers was late harvest of monsoon rice possibly relating with late onset of monsoon or irregular rain during harvesting of monsoon rice in that area.

All of the sample respondents in study area used broadcasting practice in seed sowing. Although Department of Agriculture (DOA) endorses line sowing method for pulses cultivation, all of the farmers in study area did not adopt that practice. The constraints for adoption of practice as expressed by a majority of farmers were labor shortage and insufficient mechanical implements for line sowing.

Applying basal fertilizer and seed treatment: The majority of sample respondents (94%) did not apply fertilizer as basal application during land preparation. Because of the high cost of fertilizers, they usually apply basal fertilizer for monsoon rice and rarely for black gram. Moreover 96% of them did not treat the seed with pesticide and fungicide at the time of sowing. Perhaps they may not familiarized with the practice of seed treatment.

Seeding rate and plant population at vegetative growth stage: It was noticed that 59% of sample respondents practiced the optimum seeding rate (60kg/ha) recommended by DOA whereas less seeding rate by 10% and 31% applied more than the optimum rate. Furthermore, it was observed that 59% of sample respondents achieved normal plant population while 4%, sparse and 37%, dense at vegetative growth stage. Probably normal plant population may be concerning not only with seeding rate but also adequate amount of residual soil moisture at sowing time.

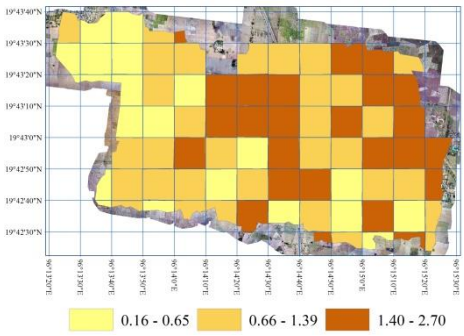
Spatial Distribution of Yield and Management Practices

According to spatial distribution of grid squares, it was found that black gram variety applied in most of the sample plots was Yezin-5 in western part and Yezin-6 in eastern part of study area. Moreover the trend in spatial distribution of yield also revealed that yield per hectare in western part was lower than that in eastern part of study area (Fig 7.). It may be in agreement with the potential yield of black gram variety, 1.6-2.0 ton/ha for Yezin-5 and 2.5-3.3 ton/ha for Yezin-6, reported by Department of Agricultural Research (DAR, 2016).

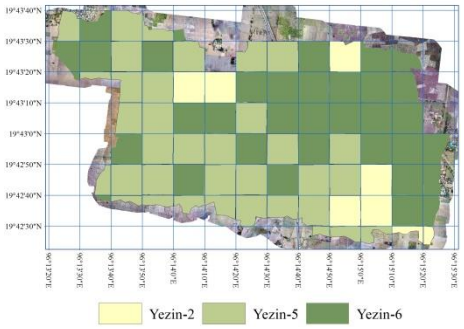
Generally, it was clear in Fig 7 that the yield of Yezin-2 and Yezin-6 variety in most of the sample plots were not considerably affected by time of sowing although a few days later than recommended sowing time. In contrary, the yield was diminished by late sowing time in the sample plots applied with Yezin-5. It indicates that crop duration of the variety should be considered if the sowing time will be late because of the dependence on residual soil moisture for crop's success.

Spatial distribution of management practices such as weed management, spraying frequency of foliar fertilizer and pesticide were shown in Fig 7. It was found that weed management practices are not applied in sample plots at the middle of study area. About 2-12 spraying frequency for the whole season was applied in half of the sample plots (54%) and the rest applied till to 15.

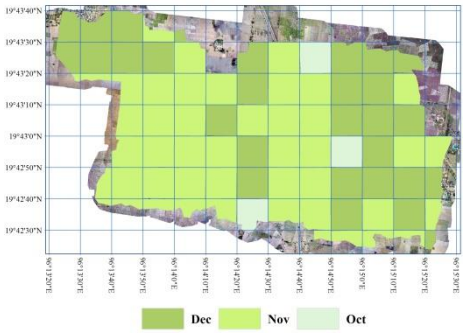
(a) Yield (ton/ha)



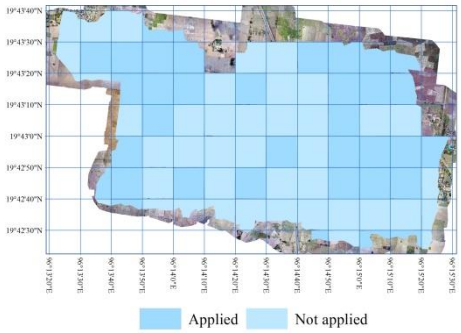
(b) Variety



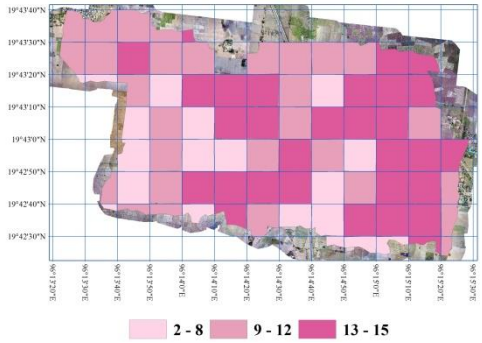
(c) Time of sowing



(d) Weed management



(e) Foliar fertilizer spraying frequency for the whole season



(f) Pesticide spraying frequency for the whole season

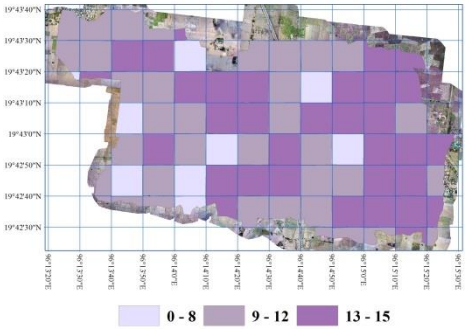


Fig. 7 Spatial distribution of yield and management practices based on sample plots randomly in each grid squares in study area

Regarding to foliar fertilizer and pesticide spraying frequency mapping, it was noticed that higher spraying frequency were applied in the sample plots at the middle and eastern part of the study area. The reason said by the sample respondents was that higher spraying frequency was required to increase black gram yield starting from 15 days after emergence to 15 days before harvest.

Constraints for Good Agriculture Practices of Black Gram

The data regarding the constraints for Good Agriculture Practices (GAP) of black gram perceived by sample respondents were stated in Table 2.

Table 2 Constraints for good agriculture practices of black gram

Good Agriculture Practices (GAP)	Constraints
- To apply good quality seed for sowing	- Insufficient supply of quality seed
- To sow timely with recommended sowing time	- Late harvest of monsoon rice
- To apply line sowing method	- Labor shortage and insufficient mechanical implements for line sowing
- To apply fertilizer as basal	- High cost of fertilizers
- To apply seed treatment with pesticide and fungicide	- Not familiarized with the practice

CONCLUSIONS

Use of drone image along with GIS helps quick and accurate analysis on huge data. According to the results, mapping allows to identify easily the correlation between spatial distribution of yield and management practices of black gram in the study area. Since a thematic map has a table of contents that allows adding layers of information to a basemap of the study area. The majority of respondents were found to have low level adoption of Good Agriculture Practices (GAP) of black gram recommended by Agricultural Departments. It is urgently needed to upgrade full adoption of improved recommended package of practices by supporting training institutions for training of the farmers and advising technological solutions for the increase of pulses productivity. It was clear that another study can be extended across the country as the present study. The use of new science tools are cost effective and time saving, thus it must be applied in agricultural system for increasing crop productivity as well as improving livelihood of the farmers.

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Research article

Application of TOPMODELs for Assessment of Ecosystem Services: Regulating Service in Agricultural and Forest Watershed

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Abstract According to Millennium Ecosystem Assessment, ecosystem services are divided into four services. Among them, regulating services include water regulation and natural hazard regulation which regulate water-discharge to rivers and mitigate flood risk by forest ecosystem. This research investigated characteristics of river flow changes at the time of rainfall runoff in two different land-use types, i.e.,1) watershed forest in Soebethu river watershed in Hokkaido and 2) intermixed watershed forest and pastureland in Igarashi river watershed in Hokkaido. A semi-distributed hydrological model, TOPMODEL was applied to simulate the amount of water discharge to the rivers. The conventional TOPMODEL was applied to the watershed forest, and the developed version of TOPMODEL to the intermixed watershed and pastureland. Monte Carlo simulation was used to identify unknown parameters required for the simulation. By comparing the identified parameters in the two different watersheds, flood control effect was evaluated in both land-use watersheds and each watershed and pastureland separately in the intermixed land-use. As the results of comparing the unknown parameters between the different land-use in the intermixed watershed and pastureland, the model showed that watershed forest has higher regulating service than pastureland. In addition, the research found that the difference of the type of surface soil influenced the amount of water discharge, that is, flood control effect. As the consequence, TOPMODEL was applicable for quantitative assessment of water regulation: the regulating service of the forest ecosystems.

Keywords TOPMODEL, ecosystem services, hydrological model, watershed, land-use

INTRODUCTION

Ecosystem services that prosper by the coexistence with agriculture provide various benefits to human life. According to Millennium Ecosystem Assessment (MEA) initiated by the United Nations, ecosystem services are categorized into four services, 'Provisioning', 'Regulating', 'Cultural' and 'Supporting' services. Regulating services that this paper focuses on, contain the flood risk alleviation by water storing function of forests such as riparian forest, and risk reduction of flood and sediment disasters by vegetation cover. In general, valuing ecosystem services can be done by monetary valuation such as hedonic approach and travel cost (Smith, 1993). However,

such monetary valuation is considered an incomplete method to evaluate ecosystem services (Kate et al., 2007). Although there is also qualitative method to evaluate environmental value except for monetary valuation, there is no previous study which evaluated the regulating service in Japan.

This research applied a hydrological model, TOPMODEL to evaluate the flood control effect of forestland and pastureland. The target areas are two watersheds which differ in land-use from one another. One is a simplex land-use formed by only forestland, and another is the complex land-use by forestland and pastureland. TOPMODEL is a semi-distributed model, to predict water-runoff within a watershed scale (Beyen et al., 1979), and a conceptual model where has been confirmed its applicability in many parts of the world (David, 1993; Tada et al., 2002; Ali et al., 2015; Gao et al., 2015). TOPMODEL is a distribution model that divides a watershed into grids and calculates the surface flow generated in each grid. However, it regards the groundwater flow as a lumped model by considering the flow as one group in a watershed. Therefore, TOPMODEL is called a semi-distributed model. For this reason, the conventional TOPMODEL was applied to a simplex land-use watershed, and a developed TOPMODEL was developed to enable the prediction in a complex land-use (Mukae et al., 2017). TOPMODEL is mainly applied to a watershed consisted of a simple land-use, for example a watershed only consisting of forest (Tada et al., 2002). On the other hand, there are few studies which applied to an agricultural watershed which both of forest and agriculture lands are mixed.

OBJECTIVE

This research applied the conventional TOPMODEL to a simplex land-use watershed and a developed TOPMODEL to a complex land-use watershed. It aimed to evaluate the applicability of both models for the prediction of water-runoff and the flood control effect in the different land-use types of the watersheds. Unknown parameters between the conventional and the developed models were compared to evaluate them.

METHODOLOGY

Research Site

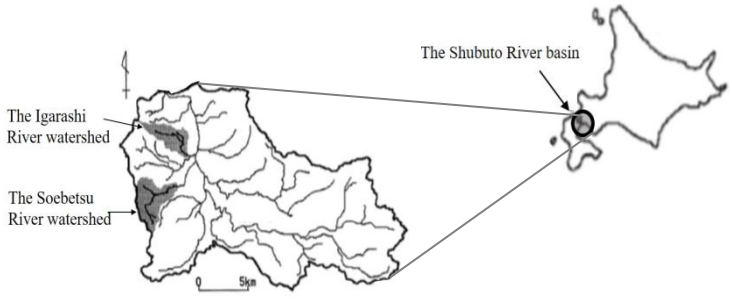

Fig. 1 The Shubuto River Basin, Hokkaido, Japan

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

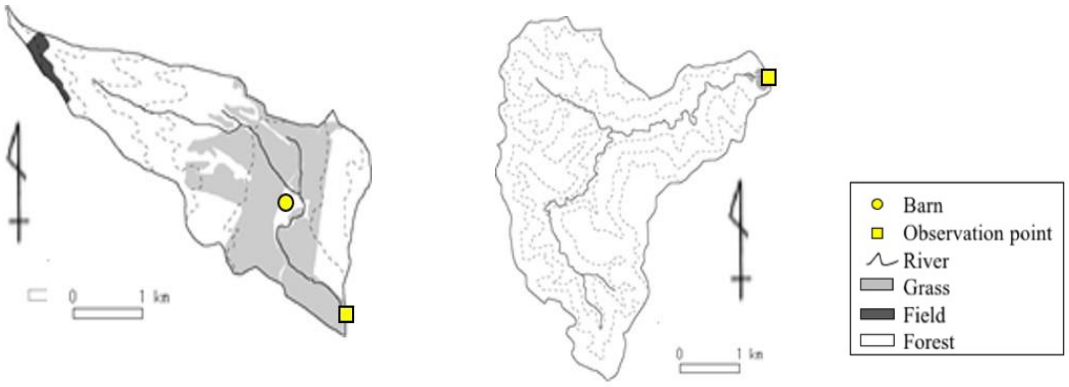

Fig. 2 Land-use of Igarashi River Watershed (Left) and Soebetsu River Watershed (Right)

This research used data of the daily record of river discharge and precipitation from June 1, 1998 to October 31, 1998 observed by Okazawa, et al. (2002). With these data, the applicability of the developed version of TOPMODEL is analyzed. Penman-monteith method (Allen, 1998) is applied for calculation of daily evapotranspiration. The daily data of temperature, wind speed and hours of sunshine which are required to calculate daily evapotranspiration, are obtained from AMeDAS in Kuromatsunai Town managed by Japan Meteorological Agency.

TOPMODEL

TOPMODEL is a semi-distributed model suggested by Beven et al. (1979). This model divides soil layer into root zone, unsaturated zone and saturated zone. The semi-distributed model calculates the upper layer which contains root and unsaturated zones by each grid as a distribution type. For the lower layer, which is saturated zone, it is calculated as concentration type, thus every grid has the same value. TOPMODEL has a character that calculates the status of drying state of surface layer of basin from the topographical index (TI) induced from digital elevation model (DEM) and spatially evaluates the amount of the surface-flow. TI is calculated from flow accumulation area and slope of each grid. If TI's value is large, the grid can be storage more water. But, If TI's value is small, the grid can be storage little water. So, Unsaturated zone is distribution model because it is calculated using Topographic Index. So, Soebethu river watershed can be storage little water than Igarashi river watershed.

Computational Procedure of TOPMODEL

TOPMODEL considers three storage parts, root zone, saturated zone and unsaturated zone as seen in Fig. 3, and calculates in each grid in the watershed as described below.

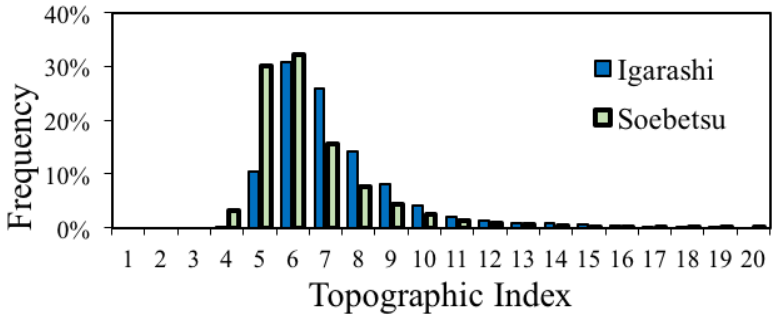

Fig. 3 Histogram of Topographic Index

a) Water balance equation of root zone: In root zone, the amount of water that can be stored within the root zone is calculated from the water balance of rainfall (R) [L], actual evapotranspiration amount (ET_a) [L], water available amount within root zone (SR_{max}) [L] and storage deficit in root zone (SRZ) [L]. When redundant water, (EX_i) [L] is caused in root zone (SRZ<0), the redundant water is supplied to unsaturated zone and added to storage water (SUZ_i) [L]in that zone. Potential evapotranspiration (ET_0) is calculated by Penman-Monteith (PM) method, and ET_a is treated as the function of ET_0, SR_{max} and SRZ.

$$ET_a = ET_0\left(1-\frac{SRZ_t}{SR_{MAX}}\right) \tag{1}$$

b) Water balance equation of saturated zone: The base-flow Q_{sub} [LT^{-1}] from the whole watershed is treated as the concentrated amount per watershed. Base-flow is calculated by the following equation using the mean value of downslope transmissivity when the soil is just saturated (T_e) [L^2T^{-1}], the mean topographic index of watershed (λ) [-], the mean storage deficit in watershed, ($\overline{S_t}$) [L] and model parameter (m):

$$Q_{sub} = T_e \exp(-\lambda)\exp\left(-\frac{\overline{S_i}}{m}\right) \tag{2}$$

c) Water balance equation of unsaturated zone: Unsaturated zone is a temporary water storage zone that connects between root zone and saturated zone. It is calculated as a distribution model. The mean storage deficit amount in the watershed at the starting point of calculation, $\overline{S_t}$ is obtained from Eq. (3), assuming that the initial discharge at the start is Q_0 [LT^{-1}].

$$\overline{S_i} = -m \cdot \ln\frac{Q_0}{T_e \exp(-\lambda)} \tag{3}$$

S_i in Fig. 4 expresses the storage deficit of each grid [L] and obtained from Mukae et al. (2017). UZ_i is the amount of water supply from unsaturated zone to saturated zone [L], i is the number of grid. However, because a grid which has the same value as TI is regarded as hydrological similarity, a grid is calculated in each status class of TI rather than that the water amount is calculated in each grid (Fig. 4).

If S_i is 0 or negative, that class is regarded as saturation. Therefore, the excessive water inflow from root zone is return surface-flow (EX_i). If S_i is positive, the excessive water inflow is temporarily added to SUZ_i. UZ_i is

$$UZ_i = \frac{SUZ_i}{S_i \cdot t_d} \tag{4}$$

where t_d is a parameter that expresses the period of retention.

These [LT^{-1}] are the concept of TOPMODEL. Operation of the model requires to determine five unknown parameters,"m", "T_e", "t_d", "SR_{max}", and "SRZ_0". This research determined the optimal value of five parameters by Monte Carlo method. Monte Carlo method is the generic term of a numerical simulation that uses random numbers.

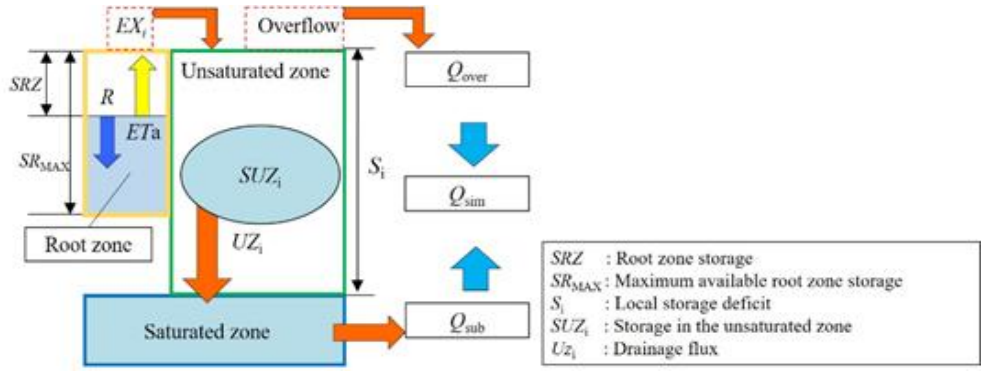

Fig. 4 Concept of TOPMODEL

TOPMODEL for Combined Forestland and Pastureland

In general, TOPMODEL is applied to a simple land-use at forest watershed. However, this study discusses the applicability of the developed TOPMODEL which considers the difference of land-use between forestland and pastureland, that is, a watershed with a complex land-use (see Fig. 5). The followings explain how this research calculated the complex land-use.

1) Land-Use Division

The area of forestland and pastureland in the Igarashi's watershed is obtained from the 100 m mesh data of Land classification in National Land Numerical Information provided by the Ministry of Land, Infrastructure, Transport and Tourism of Japan. The ratio of land-use for each forestland and pastureland was 61% and 39 % respectively. From this, the mean topographic index of forestland, (λ_1) and pastureland (λ_2) is calculated.

2) Computational Procedure

a) Water balance equation of saturated zone: From Eq. (5), the base-flow of the whole forestland, $Q_{sub1}[LT^{-1}]$ and the base-flow of the whole pastureland, $Q_{sub2}[LT^{-1}]$ are calculated. Then, the summation of the both values is regarded as the base-flow from the whole watershed.

$$Q_{sub} = Q_{sub1} + Q_{sub2} \tag{5}$$

b) Water balance equation of unsaturated zone: It is necessary to gain the initial river discharge (Q_{01}, Q_{02})$[LT^{-1}]$ from forestland and pastureland to gain the storage shortage (S_{i1}, S_{i2}) of each grid of forestland and pastureland. Here it assumed that the ratio of flow amount from the both of forestland and pastureland is always constant, and obtained the initial value of the river discharge in the following equation.

$$Q_0 = KQ_0 + (1 - K)Q_0 \tag{6}$$

Here, it assumed that the ratio of water outflow from the forestland to the whole watershed is $K(0<K<1)$, the ratio of pastureland is $(1-K)$, and K is an unknown parameter.

c) Other calculation: When it calculates root zone, UZ_i, it divides the watershed into forestland and pastureland. From this, it determines the eleven unknown parameters "m_1", "T_{e1}", "t_{d1}", "SR_{max1}", "SRZ_{01}", "m_2", "T_{e2}", "t_{d2}", "SR_{max2}", "SRZ_{02}" and "K" for the developed TOPMODEL.

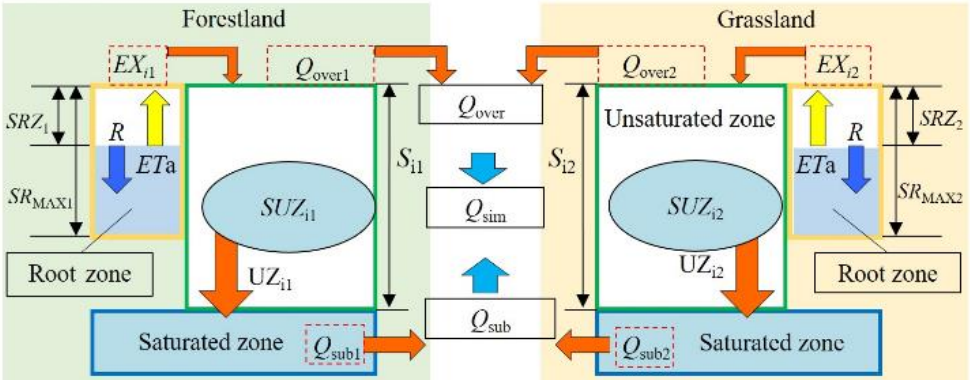

Fig. 5 Concept of Developed Version of TOPMODEL

Method of Identification and Comparison of Unknown Parameter

This research determined the optimal values of the 11 unknown parameters for the developed TOPMODEL by using Monte Carlo method. Through the method, generating random numbers for

each 11 unknown parameter, "m_1", "T_{e1}", "t_{d1}", "SR_{max1}", "SRZ_{01}", "m_2", "T_{e2}", "t_{d2}", "SR_{max2}", "SRZ_{02}" and "K", 100,000 sets of combination were created. As the result of 100,000 times of calculation, it obtained the combination that accords the closest between the actual value of flow amount and the estimated value.

RESULTS AND DISCUSSION

The actual value of rainfall and river discharge and the predicted values generated by both conventional TOPMODEL and developed TOPMODEL are shown in Fig. 6 for the Igarashi and Fig. 7 for the Soebetsu. Both models estimated changes of river discharge according to the changes of rainfall accurately. In addition, the developed TOPMODEL showed the closer value to the actual value than the conventional one when the river discharge decreases after it reached the peak point.

The compatibility of the actual value of river discharge and the estimated value is evaluated by Nash-Sutcliffe coefficient (NS value) and Root Mean Squared Error (RMSE). Regarding the accuracy of prediction in the function value, the conventional TOPMODEL showed 0.823 for NS and 1.069 for RMSE. On the other hand, the developed TOPMODEL showed 0.853 for NS and 0.973 for RMSE. From these values, it confirms that the developed TOPMODEL has the higher accuracy of prediction of river flow changes by rainfall than the conventional one throughout the target period.

The optimal value of unknown parameters of the conventional TOPMODEL and the developed TOPMODEL were determined by the Monte Carlo method as seen in Table 1. The developed model showed the higher value in T_e and t_d than the conventional one. Besides that, the developed model showed that these two values are higher in forestland than those in pastureland. As T_e expresses the downslope transmissivity when the soil is just saturated, forestland has better transmissivity than pastureland. According to Ohte et al. (1989) and Ohta et al. (1989), transmissivity of forestland is generally high in Japan. This is because the transmissivity in pastureland is lowered due to soils compressed by tiller machine or tractor. For this reason, it is valid that T_e is higher in forestland than pastureland.

A parameter, t_d expresses the delayed time caused by when water moves from unsaturated to saturated zone. That is, it shows that water flows more slowly from unsaturated to saturated zone in the developed model than the conventional one.

Comparting the unknown parameters between the forest watersheds in the Igarashi and the Soebetsu, the values except coefficient of saturated hydraulic conductivity showed the almost same values. The reason for the same value is that forest watersheds in the Igarashi and the Soebetsu are adjacent to the watershed, both of which are considered to have forestland. On the other hand, the cause of the gap in the coefficient of saturated hydraulic conductivity is probably attributed to the surface soil. The surface soil is composed by conglomerate and sandstone in the Igarashi watershed, and by mudstone in the Soebetsu watershed. Since transmissivity is lower in mudstone than conglomerate and sandstone (Ogata et al., 1992), it is considered that coefficient of saturated hydraulic conductivity in the Soebetsu watershed is lower. From these, it confirms that in case that watersheds have the same water system and land-use, the unknown parameters except coefficient of saturated hydraulic conductivity can be the same values and the difference of the coefficient is caused by the surface soil.

Table 1 Comparison of Unknown Parameters

unknown parameter		m (mm)	Te (mm/d)	td (mm/d)	SRZ_0 (mm)	SR max (mm)	K
Sobetsu (Conventional)		26.1	1.0×10^{4}	0.0218	0.13	0.88	
Igarashi (Conventional)		46.0	2.5×10^{4}	0.0104	0.52	0.62	
Igarashi (developed)	forestland	24.5	9.0×10^{4}	0.0206	0.42	0.85	0.43
	grassland	81.6	6.5×10^{4}	0.0198	0.43	0.49	

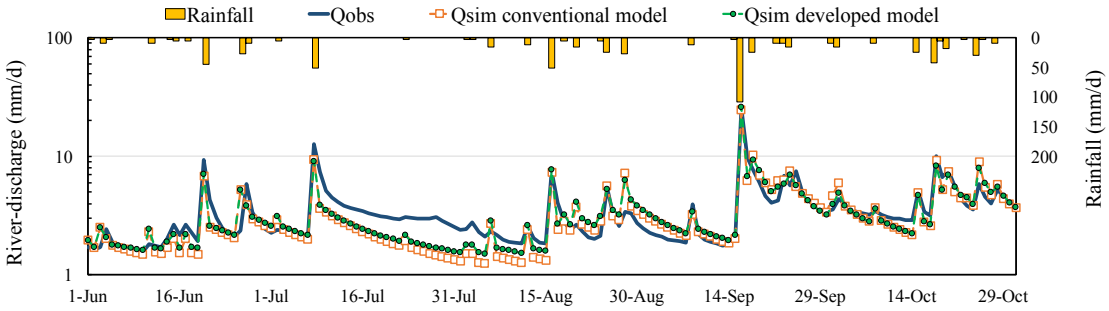

Fig. 6 Comparison between the conventional and the developed TOPMODEL

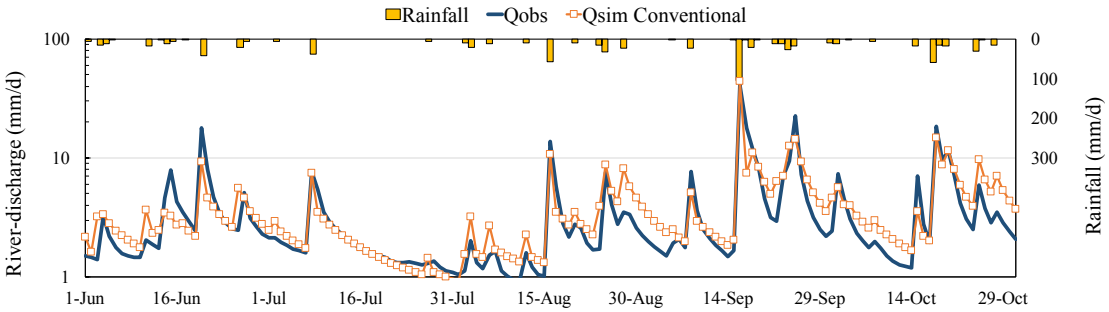

Fig. 7 Comparison between the conventional TOPMODEL

CONCLUSION

By comparing the unknown parameters between a simplex land-use and a complex land-use with application of the conventional TOPMODEL and developed TOPMODEL, it showed the result that forest watershed has higher flood control effect than pasture watershed. Besides that, it is expected that the value of coefficient of saturated hydraulic conductivity is related to the type of surface soil. For these reasons, this research clarified if the water system and land-use are the same, the unknown parameters except coefficient of saturated hydraulic conductivity in TOPMODEL gain the close values, and coefficient of saturated hydraulic conductivity is influenced by surface soil. Therefore, flood control effect as a regulation service which one of the ecosystem services is evaluated by the application of the conventional TOPMODEL and developed one.

For future study, this research result should apply to other agricultural and forest watersheds and different water system by using the same method to evaluate the ecosystem service more accurately.

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Research article

Enhancing Fermentation of Farmyard Manure Using *Bacillus* sp. in the Mid-hills of Nepal

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Abstract Farmers in the mid-hills of Nepal have been using farmyard manure for maintaining soil fertility for their lands. However, there has been a decrease in production of farmyard manure. Less application of farmyard manure has led to declined soil fertility and reduced nutrient balance. Soil degradation through nutrient depletion is a serious issue. Soils in mid hills have very low nutrients, particularly nitrogen and phosphorus concentration. Sustainability of hill agriculture depends on how farmers use the available resources. Application of incompletely fermented and decomposed farmyard manure could have low nutrient contents, cause health risks as plants can uptake pathogenic bacteria through soil. Also, imbalances in nutrient content of manure mainly nitrogen and phosphorus can pollute water sources through leaching and runoff. An experiment was conducted to determine the action of *Bacillus* sp. as an inoculant for composting. Three different concentrations of *Bacillus* sp. liquid were extracted from locally available rice husk, which were 6.0×10^{10}, 6.0×10^{12}, 6.0×10^{14} cfu mL^{-1}. An experiment was conducted for 60 days comparing samples with and without *Bacillus* sp. liquid. Results showed that *Bacillus* sp. helped in enhancing the fermentation process and better decomposition of organic matter, mineralization and the heat generated during the process helped in the elimination of pathogenic bacteria. Further, a growth experiment was conducted where *Brasicca rapa* was grown on the compost prepared. The results of growth experiment showed application of *Bacillus* sp. is good for development of plants.

Keywords Nepal, mid-hills, farmyard manure, *Bacillus* sp., soil fertility

INTRODUCTION

Farmers in the mid hills of Nepal (Fig. 1) have been using farmyard manure for maintaining soil fertility for their lands. However, there has been decreasing production of farmyard manure. Less application of farmyard manure has led to decline soil fertility and reduce nutrient balance (Regmi et al., 2005). Soil degradation through nutrient depletion is also a serious issue (Lal, 2000). Soils in mid-hills have very low nutrients, especially nitrogen and phosphorus concentration (Shah and Schreier 1991; Brown 1997; Westarp et al., 2004).

Application of farmyard manure, which is not completely fermented, raises health risks as plants can uptake pathogenic bacteria. Also, imbalance in nutrient contents of manure mainly from nitrogen and phosphorus can pollute water sources through leaching and runoff.

Adding of microbial inoculants often referred as effective microorganisms (EM) have been used in composting process. Li et al., (2013) suggested improvement of crop residue composting using *Bacillus* sp. Also, Kuroda et al., (2009) stated better quality compost using the same. Studies have been conducted addressing the use of microbial inoculants with the purpose of accelerating composting and improving the final product (Zeng et al., 2009; Figueiredo et al., 2013). García et al., (2006) observed in their studies that the use of bacterial inoculants (*Bacillus* and actinobacteria) in the composting of vegetable products increased the final humification of the compost and

consequentially improved the agricultural quality of the product. Nevertheless, further information about the composting system is necessary.

Therefore, the aim of this study was to assess the effect of *Bacillus* sp. in composting process by evaluating the mineralization and its effect in eliminating pathogenic bacteria.

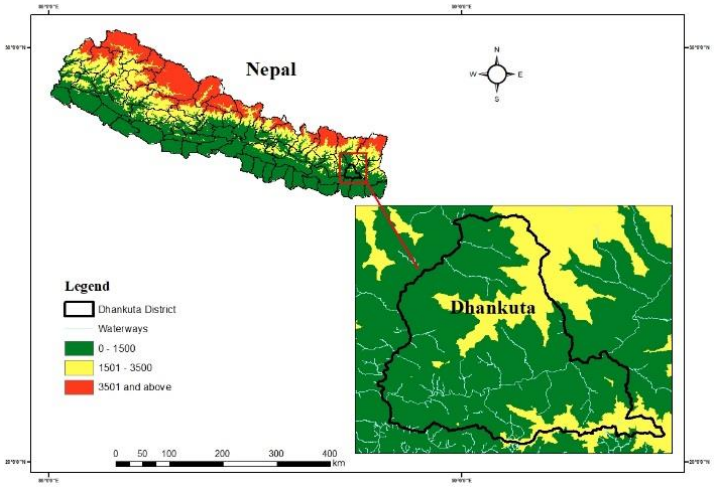

Fig. 1 Digital elevation model map of Nepal and study site

METHODOLOGY

Isolation of *Bacillus* sp.

In this study, *Bacillus* sp. solution was extracted from rice straw and husk. Ten grams of rice husk and straw was added in 90 mL of sterile water and kept overnight in shaker. Serial dilutions were made and inoculated in nutrient agar plates which was incubated for 24 h at 30°C. Serial plate count method was used to determine the number of colonies on nutrient agar. Three different *Bacillus* sp. solutions were made which were 6.0×10^{10}, 6.0×10^{12} and 6.0×10^{14} cfu mL^{-1} was made in nutrient broth. The *Bacillus* sp. solution was made 200 mL for each cfu mL^{-1}.

Sample Preparation

Cow manure and leaves were used in this composting experiment, where 1 kg of cow manure was mixed with 1 kg of leaves to make a total mass of 2 kg. Physical, chemical and microbial experiments were conducted to analyze the initial condition of materials used. Four treatments were made which were Control, Treatment 1, Treatment 2 and Treatment 3 (Table 1). In treatments other than Control, 200 mL of *Bacillus* sp. liquid was added and mixed thoroughly.

Table 1 Preparation of samples for composting experiment

Control	Treatment 1	Treatment 2	Treatment 3
Cow manure 1kg	Cow manure 1kg	Cow manure 1kg	Cow manure 1kg
Leaves 1 kg	Leaves 1 kg	Leaves 1 kg	Leaves 1 kg
No *Bacillus* sp. added	200 mL of 6.0×10^{10} cfu mL^{-1} *Bacillus* sp. added	200 mL of 6.0×10^{10} cfu mL^{-1} *Bacillus* sp. added	200 mL of 6.0×10^{14} cfu mL^{-1} *Bacillus* sp. added

Composting Setup and Experiment

An apparatus was designed where composting treatments were kept in glass containers. These containers were kept in a tank containing water and temperature was maintained at a range of 30-35°C (Fig. 2) by heating water with an electric rod. Composting was performed for 60 days and samples were taken for 0, 15, 30, 45 and 60 days. Moisture content was maintained at 50-55% with frequent checking and testing. According to Gajalakshmi and Abbasi (2008), the ideal moisture content for an efficient composting lies between 50-60%, which is ideal for microbial metabolism. Carbon content, pH, nitrogen concentration, phosphorus concentration, C/N ratio, temperature and *E. coli* colony formed units were measured.

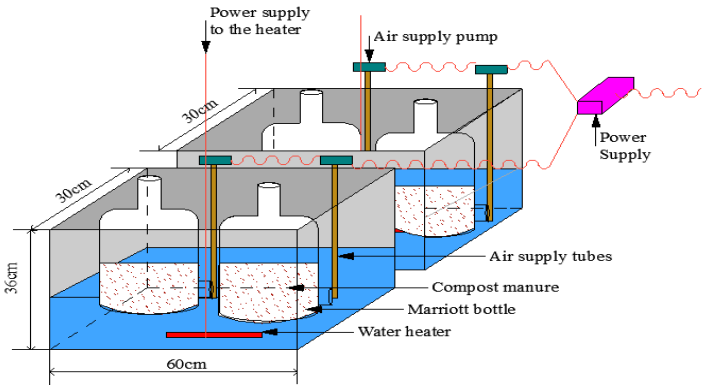

Fig. 2 Apparatus designed for composting

RESULTS AND DISCUSSION

Evaluating Fermentation with *Bacillus* sp.

The result of temperature (Fig. 3) shows that there is difference in highest temperature obtained compared with control and *Bacillus* sp. added treatments. The highest temperature obtained by Control, Treatment 1, Treatment 2 and Treatment 3 were 55 °C, 59 °C, 58 °C, 60 °C respectively. The high temperature can be corresponded to heat generated by microbial activity of added *Bacillus* sp. compared to control. The temperature did not reach a very high level (above 65 °C), which is considered harmful for microbial growth (Valente et al., 2009). Also, very low temperature is unfavorable for composting as it delays decomposition (Bernal, Alburquerque and Moral, 2009).

Maintaining an appropriate pH in a compost pile is vital for the survival of beneficial microbes. The pH of all the treatments was in between the range of 6.8 to 7.5 (Fig. 4), which indicated that a favorable condition existed for growth and metabolism of microorganisms.

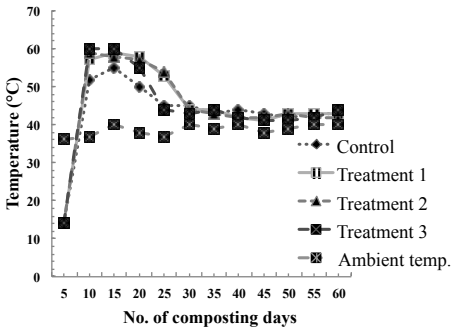

Fig. 3 Changes in temperature with time

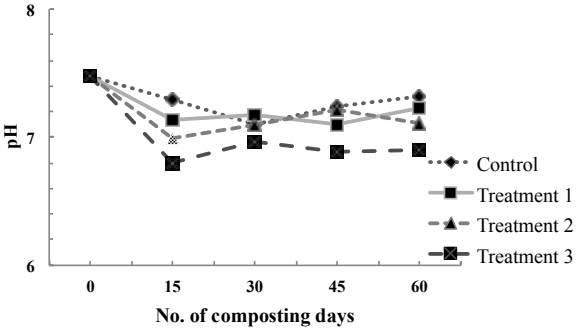

Fig.4 Changes of pH with time

Table 2 shows the total numbers of colonies formed of *E. coli* for different treatments. After 15 days of composting, there were no colonies formed with *Bacillus* sp. added treatments. This can be attributed to the heat generated during metabolism and competition of nutrients by microbes. According to Haug et al., (1980) pathogenic microbes die if there is temperature above 55°C for 3 or more days. On the other hand, there were 5.1×10^3cfu g^{-1} of *E. coli* colonies in control during the first 15 days. At 30 days of sampling colonies of *E. coli* were not found in control as well.

Table 2 *E. coli* (cfu g^{-1}) in different treatments

	0 days	15 days	30 days	45 days	60 days
Control	9.3×10^3	5.1×10^3	0	0	0
Treatment 1	9.3×10^3	0	0	0	0
Treatment 2	9.3×10^3	0	0	0	0
Treatment 3	9.3×10^3	0	0	0	0

Of the many elements required for microbial decomposition, carbon and nitrogen are the most important. Carbon provides both an energy source and the basic building block making up about 50 percent of the mass of microbial cells. As seen in Fig. 5 the carbon percent decreases with increase in composting days. After 60 days, carbon percent of Control was 40.2, Treatment 1 was 38.45, 2 Treatment 2 was 38.45 and Treatment 3 was 36.18 percent. This result can be explained as number of colonies of added *Bacillus* sp. increased there was higher decomposition of organic carbon. Similarly C/N ratio (Fig. 6) observed, had significant difference in decrease between control and *Bacillus* sp. added treatments.

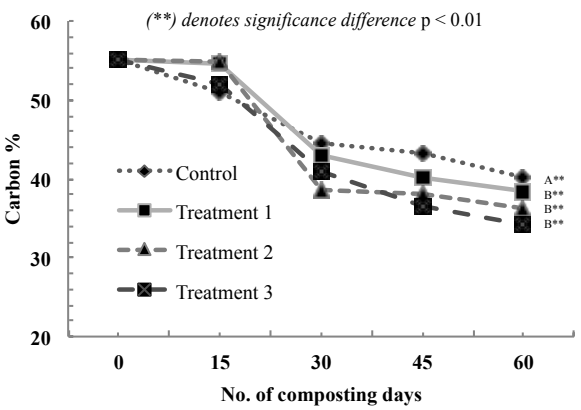

Fig. 5 Decrease in carbon percent with time

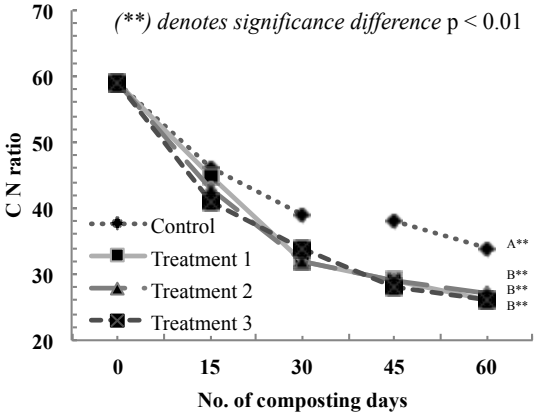

Fig. 6 Decrease in C/N ratio with time

According to Tumihairwe et al., (2009) large organic loss suggests pronounced microbial activity. This supports the obtained result where added *Bacillus* sp. had resulted in increased decomposition rate of carbon decreasing the carbon percentage and C/N ratio.

The nitrogen (Fig.7) and phosphorus concentration (Fig.8) of all the treatments showed increase with increase in composting days. The final concentration of total nitrogen at 60 days for control, treatment 1, treatment 2 and treatment 3 were 6825.07, 7728.02, 7835.02 and 8457.71 mg^{-kg} respectively. According to Viel et al., (2007) increase in total nitrogen value might increase due to nitrogen fixing bacteria that commonly occurs at the end of composting. The results obtained contradict to Tognetti et al., (2007) who showed that total nitrogen decreased during composting. Decrease in nitrogen content may occur due to leaching and volatilization, but this experiment was conducted in a closed container nullifying the effects of leaching.

Likewise, After 60 days of composting the total concentration of phosphorus for Control, Treatment 1, Treatment 2, and Treatment 3 were 2728.1, 3178.29, 3168.52, 2920.52 mg kg^{-1}

respectively. The result obtained matches with those of Felton et al., (2004) and Chandna et al., (2013) where they found increase in total phosphorus.

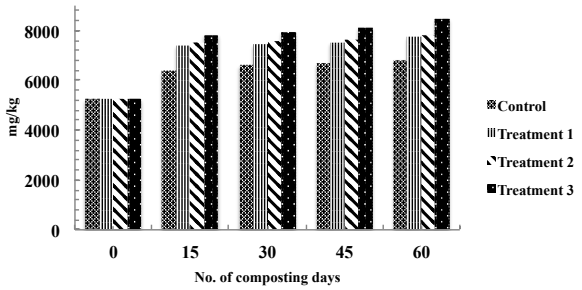

Fig. 7 Change of nitrogen concentration with time

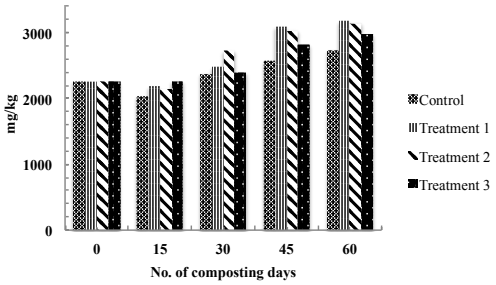

Fig. 8 Change of phosphorus concentration with time

Plant Growth Experiment

A plant growth experiment was conducted to analyze the effects on growth of plants using the compost that was made. The plant used was *Brassica rapa* (Komatsuna). Twelve pots were used; three each for Control, Treatment 1, Treatment 2 and Treatment 3 (unit area is 1/10000 a, and a height of 150 mm). Six hundred grams of soil was used in each pot with 350 grams of compost applied. 100 ml of water was put in the pots after three days interval. Environmental conditions like temperature, light were made constant for all the pots. The height of the plants was measured after 3 days. The experiment was conducted for the period of 30 days from July 2017 to August 2017.

Table 3 Physical and chemical properties of soil used

Water content (%)	10.7±0.10
Organic content (%)	14.87±0.17
EC (mS/cm)	1.33±0.03
pH	5.22±0.04
Total nitrogen Mg Kg^{-1}	1590.36±0.72
Total phosphorus Mg Kg^{-1}	907.65±0.03

Note: Values are mean ± SD (n=3).

In the result (Fig. 9) of plant growth experiment, the treatments with added *Bacillus* sp. had higher crop height compared to control with significant difference at 99%. There was no significant difference in height of plants with *Bacillus* sp. added treatments. The heights of plants for Treatment 1, Treatment 2 and Treatment 3 were 14.97, 14.56 and 14.3 cm respectively. With the obtained results it can be said that plants grown in compost made with added *Bacillus* sp. can help in growth of plants which coincides with results obtained by Toyota and Watanabe (2013) who found that *Bacillus* sp. helps in development of plant by suppressing disease and enhancing plant growth.

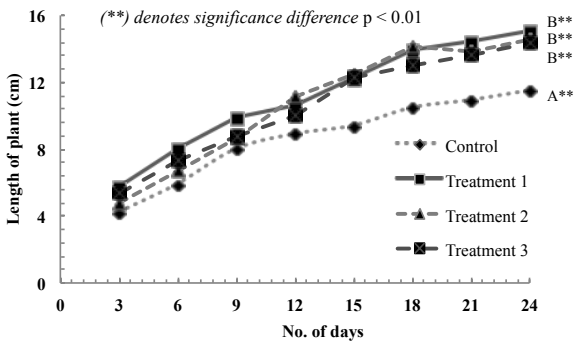

Fig. 9 Increase in plant growth with time

Fig. 10 Plant grown for two treatments

CONCLUSION

This research was conducted to examine if adding of *Bacillus* sp. is beneficial for enhancing fermentation, better decomposition of farmyard manure and also elimination of pathogenic microbes from it. The results showed that adding of *Bacillus* sp. was effective in increasing the temperature, thus eliminating of pathogenic microbes. Additionally, increased microbial activity helped in better decomposition of carbon matter and better C/N ratio. Further, there was increase in nitrogen and phosphorus concentration in *Bacillus* sp. added treatments compared to control. The plant growth experiment proved that compost prepared with added *Bacillus* sp. can help in development of plants.

Thus, with the observed results we can conclude that adding *Bacillus* sp. is beneficial for better farmyard manure. Further research is required to identify specific species of microorganisms involved during composting. Also, field experiments should be conducted to determine the loss of nutrients through leaching, runoff and volatilization.

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Research article

Effects of Legume Residues with and without Allelochemicals on Biodiversity of Plant Growth Promoting Bacteria in Long-Term Organic Residues Amendment Systems

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Abstract Application of organic residues into infertile soil is one way to restore the fertility and productivity of arable soils. However, organic residues have different qualities (especially chemical compositions including allelochemicals) that may influence the activity and type of microorganisms present in the soil. Therefore, this study aims to investigate the effect of allelochemicals on plant growth promoting bacteria (PGPB) biodiversity in 17 years long-term field experiment continuous application of different quality residues, groundnut stover (*Arachis hypogaea*) (high quality organic residue; with allelochemicals) and tamarind (*Tamarindus indica* L.) (intermediate quality organic residue; without allelochemicals), compare to control (no organic residue applied). PGPB isolates were screened for their plant growth promoting factors such as production of indole-3-acetic acid (IAA), phosphate solubilizing activity and their ability to grow in nitrogen-free medium. In addition, the biocontrol activities which are protease production and antagonistic activity against *Fusarium* sp. were investigated. PGPB biodiversity was determined on a basis of amplified rDNA restriction analysis (ARDRA). The majority of bacteria were found to belong to the genera of *Bacillus*, *Staphylococcus*, and *Brevibacterium*. In addition, at 52 weeks after residue application, PGPB richness of tamarind treatment was higher than groundnut treatment. The findings of this study also indicated that long-term legume residues amendment with and without allelochemicals can affect PGPB richness and biodiversity.

Keywords plant growth promoting bacteria (PGPB), groundnut stover, tamarind residue, allelopathy

INTRODUCTION

Application of organic residues into infertile soil is one way to restore the fertility and productivity of arable soils. In addition, incorporating organic matter into soil affects on the biological, chemical and physical properties of the soil and its overall health. However, organic residues have different qualities (especially chemical compositions including allelochemicals) that influence the number

and type of microorganisms present in the soil (Aciego Pietri and Brooks, 2009; Marschner et al., 2003). Among allelopathic plants, tamarind is well known for its allelopathic potential. There are several allelochemicals playing role as allelopathic substances were found in tamarind leaves such as tannins, phenolic compounds, flavoniod and alkaloids (Bhadoriya et al., 2011; Lewis and Neelakantan, 1964). Total phenols such as gallic acid, Caffeic acid were observed in tamarind leaves for 14 g/kg and tannic acid for 8 g/kg. These chemicals also showed antimicrobial activities (Lawongsa et al., 2016a) and leaf extract of tamarind which showed decreasing bacterial population in sandy soil (Somboon et al., 2017). Moreover, applications of different quality of organic residue also have a tendency to induce plant growth promoting bacteria (PGPB) in soil (Rungthong et al., 2013). The PGPB represent numerous species of soil bacteria which, when grown in association with a host plant, result in stimulation of growth of their host. PGPB are used as inoculants for biofertilization, phytostimulation and biocontrol (Bloemberg and Lugtenberg, 2001). PGPB can directly benefit plant growth by fixing nitrogen, which can subsequently be used by the plant, thereby improving plant growth when the amount of nitrogen in the soil is limiting (Vessey and Buss, 2002), produce phytohormone such as indole-3-acetic acid (IAA) (Ahemad and Khan, 2012; Sachdev et al., 2009) and phosphorus uptake (Rodriguez et al., 1999). Indirectly, by increase resistance to pathogen and stimulate activation of induced systemic resistance (ISR) and systemic acquired resistance (SAR) pathways (Duffy and Défago, 1999). The accumulation of legume residue with allelochemicals into soils beyond certain threshold levels to overcome soil degradation is may affect PGPB diversity.

OBJECTIVE

The purpose of this study was to investigate the effect of allelochemicals on plant growth promoting bacteria (PGPB) biodiversity in 17 years long-term field experiment continuous application of different quality of legume residues, groundnut stover (*Arachis hypogaea*) (high quality organic residue; without allelochemicals) and tamarind (*Tamarindus indica* L.) (intermediate quality organic residue; with allelochemicals), compare to control (no organic residue applied).

METHODOLOGY

Study Sites and Soil Sampling

The long-term field experiments were established at the research station of the Agriculture and Co-operatives of Northeast at Tha Phra subdistrict, Khon Kaen province, Thailand (16°20′ N; 102°49′ E) since 1995. This experiment has been designed as the randomized complete block design (RCBD). Three treatments apart from control soil (C; soil with no organic residues applied), there were two legume residue treatments applied in early May every year including:, groundnut stover (*Arachis hypogaea*) as high quality organic residue (GN; C/N ratio: 17.1, Lignin: 67.6 g/kg; Polyphenols: 12.9 g/kg) and tamarind (*Tamarindus indica* L.) leaves + petiole litter as intermediate quality organic residue (TM; C/N ratio: 31.5, Lignin: 87.7 g/kg; Polyphenols: 31.5 g/kg) at the rate of 10 Mg/ha/year to bare soil plots. The organic materials were incorporated to a depth of 20 cm in a 4 x 4 m^2 plot. The average of soil moisture content in the control field, GN field and TM field all year were 6.24%, 6.26% and 6.6%, respectively. Weeds were controlled at approximately monthly intervals. For the present study, soil samples were obtained in April 2012, 17 years after the field experiment had started. Three random soil samples from each of three replicate plots of each treatment were collected at 0-15 cm depth for PGPB analysis at 0, 26, 52 weeks after residue application. The soil in this study was characterized as a Khorat sandy loam (fine loamy siliceous isohyperthermic Typic (Oxyaquic) Kandiustults (USDA, 2014). Soil texture of all plot sites were sand. The proportion of sand in the topsoil (0–15 cm depth) was between 93.86 - 94.93 %. The pH of all soil samples were found to vary from 5.1 to 6.62 which indicated the slight acidity of soils. The soil pH values of 5.10, 6.37 and 6.62 were obtained from C, GN and TM, respectively. The

electrical conductivity (EC) values of all soil samples were found in the range of 33.66 to 64.66 µS/cm indicated that all soil treatments were low in salinity. The soil samples were placed in plastic bags and stored at 4°C for further microbial analysis.

Isolation of PGPB from Soil Samples

Bacterial strains were isolated from soil samples by serial dilution plate technique on nutrient agar medium (NAM). The bacterial colonies were isolated and maintained on NAM slants at 4°C. One hundred isolates obtained from serial dilution plate technique of each treatment were screened for their plant growth promoting factors like production of indole-3-acetic acid (IAA), phosphate solubilizing activity and their ability to grow in N-free medium. In addition, their biocontrol activity like protease enzyme production as well as antagonistic activity against *Fusarium* sp. was investigated.

Total Genomic DNA Isolation

PGPB isolates were grown in a nutrient broth at 28°C overnight and then were harvested by centrifugation at 5,000xg for 5 min and washed twice in 500 µl of TEN buffer (50 mM Tris, 20 mM disodium EDTA, and 50 mM NaCl, pH 8.0). Cell lysates were prepared by mixing the cell pellet with 200 µl of 20% (w/v) sucrose in TEN buffer to this 20 µl of 2 mg/ml of lysozyme and 20 µl of 10 mg/ml of RNase was added. Cell mixtures were incubated at 37°C for 60 min. Then 75 µl of 5 M NaCl and 100 µl of 10% SDS were added before gentle mixing. The solution was purified twice by using phenol:chloroform:isoamyl-alcohol (25:24:1, by volume). The upper phase was collected and precipitated by using isopropanol and 3 M sodium acetate. The DNA pellet was resuspended in sterilized deionized-water and total genomic DNA was kept at -20°C before use (Sambrook and Russell, 2001).

Amplified rDNA Restriction Analysis (ARDRA)

The selected promising plant growth promoting traits were continued analyzed for biodiversity analysis using ARDRA. The 16S rDNA universal primers fD1 (5'-AGA GTT TGA TCC TGG CTC AG-3') and rP2 (5'-AAG GAG GTG ATC CAG CC-3') (Weisburg et al. 1991) were used to amplify a 1.5-kb internal region of the 16S rRNA gene. An initial denaturation at 95°C for 5 min was followed by 35 cycles with denaturation at of 95°C (30 s), annealing at 58°C (1 min) and extension at 72°C (2 min), and a final extension at 72°C for 7min. Restriction analysis was performed with 5 µl of amplified product and 10 µl of restriction buffer containing 2 U of either the restriction enzymes *Alu*I. After a 4 h digestion at the appropriate temperature, the enzyme was inactivated by heating the preparations at 65°C for 20 min. For each isolate, PCR amplification and restriction analysis were performed at least three times. Calculation of the pair-wise coefficients of similarity was based on the presence or absence of bands. A cluster analysis with the UPGMA algorithm was performed with the NTSYS-pc numerical taxonomy and multivariate analysis system. Then, Representatives of each group were selected for cloning and partial 16S rRNA gene sequencing to retrieve sequence similarity and bacterial identity from sequence databases.

Diversity Index Analysis

Based on these clusters, PGPB community richness and diversity index (Shannon) was calculated. The formula is as follows:

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

where H' is the species diversity index, s is the number of species, and pi is the proportion of individuals of each species belonging to the species of the total number of individuals (Nolan and Callahan, 2006).

RESULTS AND DISCUSSION

PGPB Richness

The PGPB diversity was estimated by Shannon's index. Shannon value can reflect the species diversity of the community, affected by both species richness and species evenness, that is the two values also consider the abundance of each species. The greatest PGPB richness was observed in GN (0.14) and TM (0.14) at 26 weeks after residue application (Table 1). At 52 weeks after residue application, PGPB richness of tamarind treatment was higher than groundnut treatment. This study indicated that application of legume residue with allelochemicals like tamarind induced PGPB richness overtime. In a relatively study showed that a large number of bacteria and fungi have their ability to degrade allelochemicals (Zhang et al., 2010; Chen et al., 2011). These microorganisms could mineralize the allelochemicals as its sole source of carbon and energy. This could be certified to the fact that the PGPB richness can increase eventually.

Table 1 PGPB richness from the three treatments

Treatments*	Shannon's index (weeks after residue application)		
	0	26	52
C	0.02	0.10	0.07
GN	0.02	0.14	0.10
TM	0.02	0.14	0.12

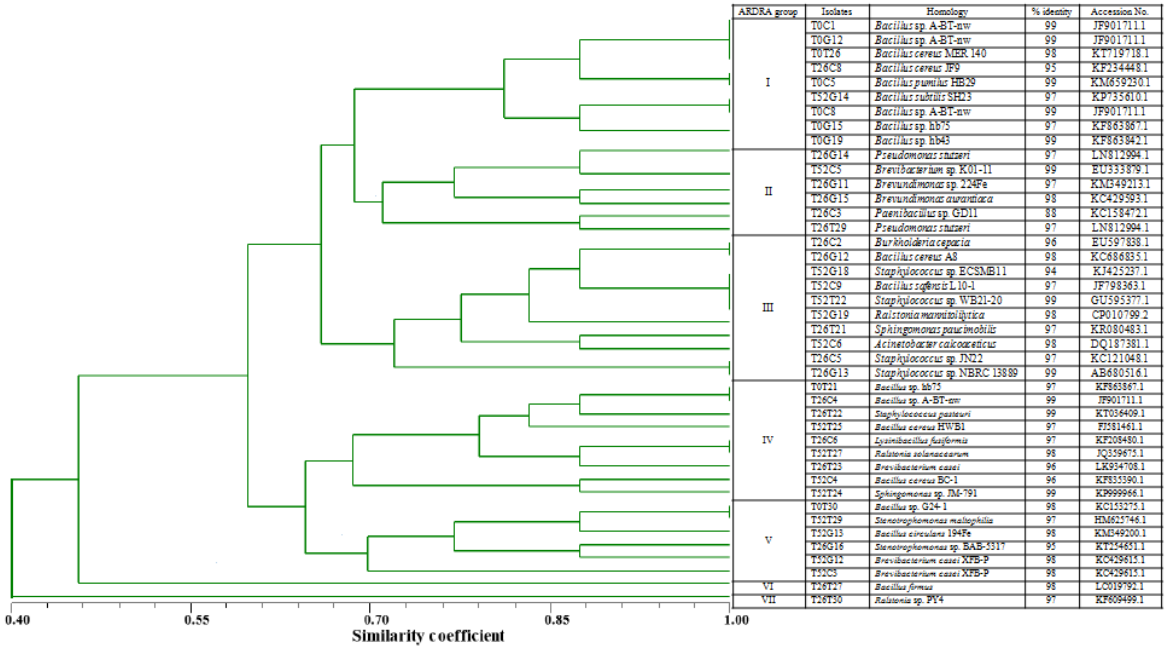
**Treatments (C; no long-term application of organic residue in tropical sandy soil, GN; long-term application of groundnut strover in tropical sandy soil, TM; long-term application of tamarind in tropical sandy soil)*

ARDRA Analysis and 16S rRNA Gene Partial Sequencing on PGPB Isolates

The cluster dendrogram of ARDRA analysis of PGPB isolates obtained from soil samples of 17 years long-term field experiment is illustrated in Fig. 1. Digestion of amplified 16S rDNA with *Alu*I revealed seven main clusters of ARDRA dendrogram. Cluster I, II, III and V of ARDRA dendrogram showed representative of genera/species from all treatment. Cluster IV contained representative of PGPB genera/species only from groundnut treatment while, cluster VI and VII showed representative of PGPB genera/species only from tamarind treatment. Remarkably, Cluster I, IV and V of ARDRA dendrogram showed representative of genera/species from all weeks after residue application. No representative of PGPB genera/species isolated at 0 week after residue application was observed in cluster II, III, VI and VII of ARDRA dendrogram. In addition, no representative of PGPB genera/species isolated from 0 and 52 weeks after residue application was observed in cluster VI and VII of ARDRA dendrogram.

On the basis of the 16S rRNA gene sequence analysis, in excess of 1 kb fragments were sequenced for most of isolates, with similarities ranging between 88 and 99%. Thirteen isolates were identified as *Bacillus* spp., *Staphylococcus* spp., *Brevibacterium* spp., *Ralstonia* spp., *Pseudomonas* spp., *Brevundimonas* spp., *Sphingomonas* spp., *Stenotrophomonas* spp., *Paenibacillus* sp., *Burkholderia* sp., *Acinetobacter* sp. and *Lysinibacillus* sp.
Further, *Bacillus* spp., *Staphylococcus* spp. and *Brevibacterium* spp. were observed in all treatments. The PGPB in the genus of *Brevundimonas* was only found in groundnut treatment. In addition, the *Sphingomonas* spp. was only found in tamarind treatment.

The previous study reported that long-term application of organic residues strongly affected bacterial and fungal community structure and diversity (Lawongsa et al., 2016b; Kamolmanit et al., 2013). This study suggested that not only application of legume residue with or without allelochemicals can alter bacterial and fungal diversity, but also PGPB diversity.



ARDRA group	Isolates	Homology	% identity	Accession No.
I	T0C1	*Bacillus* sp. A-BT-nw	99	JF901711.1
	T0G12	*Bacillus* sp. A-BT-nw	99	JF901711.1
	T0T26	*Bacillus cereus* MER 140	98	KT719718.1
	T26C8	*Bacillus cereus* JF9	95	KP234448.1
	T0C5	*Bacillus pumilus* HB29	99	KM659230.1
	T52G14	*Bacillus subtilis* SH23	97	KP735610.1
	T0C8	*Bacillus* sp. A-BT-nw	99	JF901711.1
	T0G15	*Bacillus* sp. hb75	97	KF863867.1
	T0G19	*Bacillus* sp. hb43	99	KF863842.1
II	T26G14	*Pseudomonas stutzeri*	97	LN812994.1
	T52C5	*Brevibacterium* sp. K01-11	99	EU333879.1
	T26G11	*Brevundimonas* sp. 224Fe	97	KM349213.1
	T26G15	*Brevundimonas aurantiaca*	98	KC429593.1
	T26C3	*Paenibacillus* sp. GD11	88	KC158472.1
	T26T29	*Pseudomonas stutzeri*	97	LN812994.1
III	T26C2	*Burkholderia cepacia*	96	EU597838.1
	T26G12	*Bacillus cereus* A8	98	KC686835.1
	T52G18	*Staphylococcus* sp. ECSMB11	94	KJ425237.1
	T52C9	*Bacillus safensis* L10-1	97	JF798363.1
	T52T22	*Staphylococcus* sp. WB21-20	99	GU595377.1
	T52G19	*Ralstonia mannitolilytica*	98	CP010799.2
	T26T21	*Sphingomonas paucimobilis*	97	KR080483.1
	T52C6	*Acinetobacter calcoaceticus*	98	DQ187381.1
	T26C5	*Staphylococcus* sp. JN22	97	KC121048.1
	T26G13	*Staphylococcus* sp. NBRC 13889	99	AB680516.1
IV	T0T21	*Bacillus* sp. hb75	97	KF863867.1
	T26C4	*Bacillus* sp. A-BT-nw	99	JF901711.1
	T26T22	*Staphylococcus pasteuri*	99	KT036409.1
	T52T25	*Bacillus cereus* HWB1	97	FJ581461.1
	T26C6	*Lysinibacillus fusiformis*	97	KP208480.1
	T52T27	*Ralstonia solanacearum*	98	JQ359675.1
	T26T23	*Brevibacterium casei*	96	LK934708.1
	T52C4	*Bacillus cereus* BC-1	96	KF855390.1
	T52T24	*Sphingomonas* sp. JM-791	99	KP999966.1
V	T0T30	*Bacillus* sp. G24-1	98	KC153275.1
	T52T29	*Stenotrophomonas maltophilia*	97	HM625746.1
	T52G13	*Bacillus circulans* 194Fe	98	KM349200.1
	T26G16	*Stenotrophomonas* sp. SAS-3317	95	KT254851.1
	T52G12	*Brevibacterium casei* XPB-P	98	KC429615.1
	T52C5	*Brevibacterium casei* XPB-P	98	KC429615.1
VI	T26T27	*Bacillus firmus*	98	LC019792.1
VII	T26T30	*Ralstonia* sp. PY4	97	KF609499.1

** The different isolates were designated T followed by the weeks after residue application (0, 26, or 52), treatment name (G;groundnut or T; tamarind) and by progressive numbers of PGPB isolation.*

Fig. 1 Dendrogram of PGPB isolates representing each ARDRA group

CONCLUSION

In this study, thirteen bacterial strains isolated from 17 years long-term field experiment continuous application of different quality residues, groundnut stover (*Arachis hypogaea*) (high quality organic residue) and tamarind (*Tamarindus indica* L.) (intermediate quality organic residue), compare to control (no organic residue applied) were characterized. Most of the bacteria were member in the genera of *Bacillus* spp., *Staphylococcus* spp., *Brevibacterium* spp., *Ralstonia* spp., *Pseudomonas* spp., *Brevundimonas* spp., *Sphingomonas* spp., *Stenotrophomonas* spp., *Paenibacillus* sp., *Burkholderia* sp., *Acinetobacter* sp. and *Lysinibacillus* sp. The bacterial communities were dominated by *Bacillus* spp. (42.86%), *Staphylococcus* spp. (11.90%) and *Brevibacterium* spp. (9.52%). Interestingly, the richness of PGPB strains showed no different between groundnut treatment and tamarind treatment at 0 and 26 weeks after residue application. However, the richness of PGPB strains of tamarind residue had increased at 52 weeks after residue application. Notably, only the *Brevundimonas* spp. was only found in groundnut treatment. In addition, the *Sphingomonas* spp. was only found in tamarind treatment. These findings suggested that application of legume residue with allelochemicals like tamarind can alter PGPB richness and diversity. The direction of the future research should thus consider, apart from studying PGPB, also decomposing fungi and archaea in long term field experiment. This may include phylogenetic studies and functional genes to identify microbial community directly involved in the degradation of organic materials in soils.

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Research article

Local Government Support for the Development of Nutmeg Industry in Fakfak Regency, West Papua, Indonesia

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Abstract This study aims to evaluate the impact of the local government support in farmers' level and to analyze the potential of rural development through the improvement of nutmeg production system in Fakfak Regency. The results can be concluded as follows: (1) Nutmeg industry in Fakfak Regency has been developed intensively by the support of local government; (2) The nutmeg industry is deeply connected with traditional culture. Meanwhile, the recent development efforts including local government support seem to meet many obstacles when confronted with tradition; (3) However, there are farmers who showed positive attitudes towards development, especially those who realize the importance of sustaining production for their future generations; (4) Farmers will be highly motivated to improve their skills and production when they can personally prove that their efforts can directly lead to the increase of their family income.

Keywords nutmeg production, local government, local culture, rural development

INTRODUCTION

Papuan nutmeg (*Myristica argentea* Warb) is one of nutmeg varieties indigenous to Fakfak Regency (Musaad et al., 2016) and has been traditionally grown in the wild forests by the indigenous people of Fakfak (INOBU, 2017). Development of nutmeg cultivation in Fakfak Regency has been carried throughout generations. With a total cultivated area of 16,733 hectares (UNIPA, 2013), nutmeg is a major commodity of Fakfak Regency and plays a key role to the local economy as an important source of income.

On the other hand, nutmeg industry in Fakfak Regency faces two major problems, namely low productivity and low-quality products. Low productivity occurred due to inappropriate management practices in cultivated lands. In farmers' level, nutmegs are planted naturally in high density, narrow planting spaces (about 3x3m) and random distribution of male-female ratio, while the ideal planting space is 10x10m (Gardner et. al., 1991; Deptan, 1986) and recommended composition of male-female ratio is 1:10 (Hadad and Syakir, 1992). It has been identified that the current planting condition may have caused the low productivity and emergence of disease infection (Musaad et al., 2016). Meanwhile, low-quality products were caused by lack of awareness during harvesting, processing and distribution, such as early-harvest, incomplete drying process and high-humidity storage. To solve these problems and enhance the development of nutmeg industry in Fakfak Regency, the local government has been conducting support programs since 2011. However, the impact of the support programs and the actual condition of nutmeg production in farmers' level are still unclarified.

OBJECTIVES

This study aims to evaluate the impact of the local government support in farmers' level and to analyze the potential of rural development through the improvement of nutmeg production system in Fakfak Regency.

METHODOLOGY

Data Collection and Selection

This study is conducted through interview and questionnaire surveys of nutmeg farmers and government officials in Fakfak Regency, West Papua Province, Indonesia. The first interview survey of the government officials of Regional Estates Crops Office of Fakfak Regency (the representative of the local government) was carried out in October 2016. Through the assistance of this office, a total of 39 nutmeg farmers from 10 districts were selected using convenience sampling method due to distance and time constraints during data collection. The 39 respondents were interviewed to clarify the characteristics of nutmeg industry in the regency and to identify the form of local government support in farmers' level. In order to evaluate the impact of the current local government support, the second survey was carried out in September 2017 through structured questionnaires and in-depth interviews with 9 farmers who showed important characteristics in terms of production and sales among the 39 nutmeg farmers.

Data Analysis

Based on primary data of 39 farmers, the average values and component ratios were calculated to clarify the general condition and the characteristics of nutmeg industry in Fakfak Regency (i.e. cultivating areas, cropping and harvesting patterns, and yield). Cost and profit analysis was conducted to estimate the economic values of nutmeg industry in farmers' level. Moreover, questionnaire was also structured using Likert Scale scoring method to grasp quantitative values on farmers' evaluation of the local government support. Lastly, through the case study of selected farmers, descriptive analysis was used to describe the actual condition of nutmeg production and sales in farmers' level.

RESULTS AND DISCUSSION

Characteristics of Nutmeg Industry in Fakfak Regency

Nutmeg production is distributed widely in 14 districts out of the 17 districts across Fakfak Regency and has been an indispensable part of Fakfak society (Disbun Fakfak, 2017). Based on the local culture, lands and nutmeg trees are inherited by the family members. The ownership of lands is divided equally among the male members of the family. However, the female members also have the rights to collect nutmeg fruits during harvest seasons.

Nutmeg cultivations spread from seacoast to semi-mountainous and mountainous areas at latitude between 0 and 700 meters above sea level with different patterns and productivity (Musaad et al., 2016). Survey of 39 farmers revealed seven (7) main results, namely (1) Generally, farmers in Fakfak Regency own lands in 3 different areas with an average cultivated area of 4.8 hectares per farmer; (2) Nutmeg fruits in Fakfak Regency can be harvested twice a year. The first harvest season called as "The Big Harvest" usually starts from around October to February. Meanwhile, the second harvest usually starts around April to June with the quantity of nearly half of the first season; (3) Farmers usually start the harvest from lands in seacoast area and continue up to the mountain area; (4) On the average, nutmeg farmers can produce around 30,000 fruits per hectare during "The Big Harvest"; (5) Nutmeg fruits in Fakfak Regency are processed into nutmeg spices. Farmers usually count harvested fruits while separating seeds and mace to be used for nutmeg spices and leave out flesh on the ground as natural fertilizer for the trees; (6) Nutmeg seeds and

mace will be dried separately before sold to the buyers; (7) Depends on the cultivation areas, weight of dried seeds and dried mace per 1,000 fruits vary from 8-15 kg and 1-1.5 kg, respectively.

Local Government Support for Nutmeg Industry

Indonesian central government under the 5-Year Strategic Plan of Ministry of Agriculture 2015-2019 aimed to realize sustainable agriculture and bioindustry system that produces varieties of healthy foods and high added value products from regional resources (Secretariat General of Indonesian Ministry of Agriculture, 2014). Through the support of this strategic plan, the local government has been conducting the various support programs based on two main objectives, namely, to preserve the sustainability of the Papuan nutmeg and to increase their local production. In relation to the former objective, the local government conducted three programs, such as Certification of Geographic Indication Commodity for Papuan nutmeg, Issuance of the Local Regulation, and Distribution of Papuan nutmeg varieties. On the other hand, in relation to the latter objective, farm rehabilitation and extensification of nutmeg cultivating lands have been intensively conducted with the assistance of Regional Estate Crops Office of Fakfak Regency. Specifically, these support programs can be categorized into three different stages: cultivation, processing, and sales.

In the cultivation stage, farm rehabilitation and extensification are the main programs. Local government started the programs by spreading information through radio broadcasting. Then, local extension workers from Regional Estate Crops Office will do on-site counseling and training by conducting one-day seminar and making sample plot in selected villages. Due to budget limitation, on-site activities are conducted in 10-13 selected villages annually. Leaders of the selected villages will propose several farmers as participants of the programs. Selected farmers will receive support of seedlings and fertilizer to be used in their own lands. Pesticides were also distributed to farmers whose lands have been infected by diseases. In the farm rehabilitation, farmers are encouraged to reduce numbers of trees, replace old trees with young seedlings, and clean up their cultivated lands. Meanwhile, in the extensification program farmers are obligated to implement proper cultivation method in newly opened lands.

In the processing stage, the local government put efforts to preserve the quality of nutmeg spices. As nutmeg spices from Fakfak Regency are mostly exported to international market, price of nutmeg spices highly depends on its quality. Recently, the local government has set the quality standard of Fakfak's nutmeg spices, which mainly includes appropriate harvesting period and drying method, determination of moisture content, and grading classification for nutmeg seeds and mace. Under the supervision of Industrial and Trade Office of Fakfak Regency, wholesaler companies are required to undergo quality control before shipping nutmeg spices.

In the sales stage, through the Certification of Geographic Indication Commodity program managed by the central government, the local government has been working to certify nutmegs produce in Fakfak Regency. During the certification, 300 farmers were randomly selected to check the whole production processes, from seedlings selection to cultivation, harvest, and processing methods. Through these processes, the local government was able to clarify and legally issue the Local Regulation (*PERDA*) regarding the quality standard of their nutmeg products.

Implementation of Local Government Support in Farmers' Level

To analyze the implementation of the support programs in farmers' level, the second survey was conducted through structured questionnaires and in-depth interviews with 9 farmers from 2 different areas. Selected farmers were asked to evaluate their own condition in each stage using specified scoring methods. Table 1 shows results of farmers' evaluation towards their personal condition.

Farmers in central Fakfak own 9.8 hectares of cultivated areas which are 5 times bigger than in eastern Fakfak (1.8 hectares). The interview also confirmed that farmers in central Fakfak generally have cultivated lands in three different areas, seacoast, semi-mountainous, and mountainous areas. Meanwhile, farmers in eastern Fakfak mostly own lands in seacoast area only.

Table 1 Farmers's evaluation towards personal condition

Nutmeg cultivation areas	**Central Fakfak**	**Eastern Fakfak**
Average distances from city center (km)	12	40
Number of surveyed farmers (persons)	4	5
Average cultivated land areas (ha)	9.8	1.8
Average harvested land areas (ha)	3.0	1.4
Personal evaluation on nutmeg cultivation		
Satisfaction towards own cultivation [1)]	3.5	4.6
Percentage of nutmeg trees infected by diseases [2)]	1.8	1.0
Knowledge and skills of nutmeg cultivation method [3)]		
a. Adjusting planting spaces	2.0	1.2
b. Adjusting distribution of male/female ratio	2.0	0.8
c. Preventing disease infection	1.0	1.6
Personal evaluation on nutmeg harvesting		
Importance during harvesting process (%) [4)]		
Time effectiveness	25	100
Quality of harvested fruits	75	0
Personal evaluation on nutmeg processing		
Knowledge and skills of nutmeg spices processing method [3) 5)]	2.0	1.2
Knowledge and skills of nutmeg flesh processing method [3)]	1.8	1.6
Personal evaluation on nutmeg sales		
Satisfaction towards own sales condition [1) 6)]	2.0	1.9

Source: Author's calculation based on survey data in 2016 and 2017.

1) Questions were answered using 5-level scoring system (1-very bad, 2-bad, 3-average, 4-good, 5-very good).

2) Question was answered using 5-level scoring system (1-0%, 2-25%, 3-50%, 4-75%, 5-100%).

3) Questions were answered using 3-level scoring system (0-not understand, 1-understood, 2-understood & implemented).

4) Numbers showed are percentage of respondents.

5) Knowledge and skills about nutmeg spices processing method consist of the following items: a) Conducting post-harvest treatment, b) Drying processes of nutmeg seeds, c) Drying processes of nutmeg mace, d) Separating seeds skin, and e) Classifying grade of nutmeg spices. Respondents were asked to answer each item using 3-level scoring system, and numbers showed are the average score of all items from all respondents.

6) Satisfaction towards own sales condition consists of satisfaction towards the following items: a) Sales quantity, b) Current price, and c) Current buyers. Respondents were asked to answer each item using 5-level scoring system, and numbers showed are the average score of all items from all respondents.

In the cultivation stage, farmers in central Fakfak felt less satisfied on their own cultivation (3.5/5.0 points). This is because some of them realized that they spent less time to manage their lands, especially in mountainous areas. It is also confirmed that there has been disease infection found in central Fakfak (around 25%), while there is none in eastern Fakfak (0%). However, the interview revealed that farmers in central Fakfak have not received any support on disease infection. Although some farmers have personally tried to prevent further infection by burning infected trees, collective actions are necessary before diseases infections spread to other areas.

Moreover, to evaluate farmers' understanding and awareness in proper cultivation method, farmers were asked whether they know and apply ideal spacing and male-female ratio in planting nutmeg trees. The survey clarified that farmers in Fakfak Regency face difficult barriers in applying the proper method. There are beliefs in society that cutting nutmeg trees means cutting the hands of their ancestors since trees were inherited throughout generations, hence farmers have hesitated to apply the proper method when cutting trees is required. However, despite of this condition, the survey also showed that farmers in central Fakfak have understood and been trying hard to implement the method in their lands (2.0 points). Although it is still difficult to cut old trees, some farmers have felt that applying proper method (e.g. at least cleaning their lands) has increased their production. The assistance of local extension worker who lives in same village also helps

farmers to get information. Despite of no formal program from the local government, farmers felt that there is a person available for consulting their problems. Hence farmers' awareness and motivation increase when they fully understand the importance of conducting the proper method.

On the other hand, farmers in eastern Fakfak still have resistance to apply the proper method. One of the reasons is because they have not actually seen the results of applying proper method in nearby areas. Moreover, farmers refused to use seedlings distributed in the programs because they could not trust and guarantee that those seedlings would properly bear fruit. They also did not use the fertilizer and pesticide because they were afraid that trees would depend on those chemical materials once it was given. Thus, it can be highlighted that besides dealing with traditional custom, it is important for the local government to gain trust from farmers and provide proof of benefits of the programs.

In the processing stage, there are clear differences in both areas in relation to harvesting process. Seventy-five percent of farmers in central Fakfak pay attention to quality when harvesting fruits, while 100% of eastern Fakfak farmers consider more on time efficiency. The survey also confirmed that farmers in central Fakfak have properly applied processing method (2.0 points). Although there is barely significant support on processing method from local government, farmers in central Fakfak have closer access to the market and local government offices. Thus, once information is received, farmers regularly share it with their fellow farmers during village gathering, which helped them to get updated to the current condition. Moreover, farmers in central and eastern Fakfak mentioned that they have received training on nutmeg flesh processing method (1.8 and 1.6 points, respectively). In Fakfak Regency, farmers only use seeds and mace to produce nutmeg spices. Every year there are about 2.4 million kilograms of nutmeg flesh being wasted and left to the ground. To maximize the use of fresh fruits into more value-added products, the local government has conducted training on nutmeg juice and syrup processing to housewives of nutmeg farmers. However, interview revealed that producers still find it difficult to sell the processed products to the market, hence some of them conduct order-based processing or only produced by orders and some were not really motivated to continue their productions.

On the other hand, all farmers gave same responses towards sales condition. Farmers were unsatisfied with their current sales, including quantity, price, and buyers (2.0/5.0 and 1.9/5.0 points). Farmers had no bargaining power on sales and no access to information on where and how their nutmeg spices were distributed once sold to buyers. Although the local government has legally issued the Local Regulation for quality standard of nutmeg spices and conduct quality control in wholesalers' level, it seems that it has not been implemented in farmers' level. Currently, there is also no regulation for standard selling prices in local market.

Impact of Local Government Support in Farmers' Level

To evaluate further the impact of local government support in farmers' level, Table 2 shows the actual condition of nutmeg production of 4 farmers in central Fakfak. Farmers were asked to record their production between October 2016 to September 2017 to calculate their actual cost and income.

Farmers O and P live in the same village. Farmer O was known for his hard work in managing his land. Before formally participated in the farm rehabilitation program, he has been implementing approximately 5x5m planting spaces in his own land. Aside from nutmeg cultivation, farmer O also plants other crops such as taro and coconut trees. He learned that by giving enough spaces, plants grow bigger and less diseases. Hence, with high motivation to sustain his nutmeg production, he implemented the same method to his nutmegs and was able to maximize his production and reach 30,000 fruits per hectare regardless of relatively small cultivated area than other farmers in central Fakfak. Meanwhile, farmer P started implementing proper method after receiving support programs. The interview revealed that before implementing proper method, he barely cleaned his lands, hence his production was rather small. Despite of owning 3 hectares of cultivated areas, his production only reached around 20 to 30 thousand fruits per year. However, in 2016 he was able to produce 50,000 fruits. Thus, among all farmers, farmer P gave a very positive response to the support programs. He stated that he was able to get more knowledge and improve his production through the programs and have felt the benefits of the programs himself.

Table 2 Profile of selected farmers in Central Fakfak (Production Year 2016)

Nutmeg Farmers (age years old)	O (41)	P (47)	Y (41)	A (46)
Number of household members (persons)	5	5	6	7
Total areas of nutmeg cultivated lands (ha)	1	4	10	24
Targeted buyers of nutmeg products	Middlemen	Middlemen	Middlemen	Wholesaler
Selling price of fresh fruits (IDR/piece)	350	350	350	500
Selling price of dried seeds (IDR/kg) [1)]	40,000	45,000	60,000	65,000
Selling price of dried mace (IDR/kg)	110,000	110,000	90,000	108,000
Support programs received from local government	Farm rehabilitation	Extensification; Farm rehabilitation	Selected high-producing farmer; Extensification	-
Nutmeg fruits yield (pieces)	30,000	50,000	164,850	390,000
Harvested land areas (ha)	1	3	5	12
Yield per hectare (pieces/ha)	30,000	16,667	32,970	32,500
Total sales (IDR/year)	13,350,000	24,000,000	91,491,750	240,630,000
Total production cost (IDR/year)	1,419,750	4,523,750	35,950,000	100,498,750
Hired labor cost (IDR/year)	-	-	28,848,750	97,500,000
Firewood cost (IDR/year) [2)]	960,000	3,360,000	5,120,000	-
Tools and machinery (IDR/year)	333,750	883,750	1,901,250	2,868,750
Transportation cost (IDR/year)	126,000	240,000	-	-
Taxes (IDR/year)	-	40,000	80,000	130,000
Net profit (IDR/year)	11,930,250	19,476,250	55,541,750	140,131,250
Net profit per hectare (IDR/year)	11,930,250	6,492,083	11,108,350	11,677,604
Net profit per family member (IDR/year)	2,386,050	3,895,250	9,256,958	20,018,750

Source: Author's calculation based on survey data in 2016 and 2017.

1) Selling price of dried seeds shown on the table is price of SS grade dried seeds. SS grade is the classification of mixed dried seeds with skin, the most common type of dried seeds sold in the local market.

2) Firewood cost was calculated from the time spent by farmers to gather firewood for drying nutmeg seeds. Firewood cost for farmer A was included in hired labor cost.

Farmer Y was categorized as one of high producing farmers (a total yield of 164,850 fruits), who reached more than an average yield of 30,000 fruits per hectare. Thus, during the certification program he was selected as one of *High-producing Farmers* (i.e. farmers whose lands produce good quality of nutmegs and chosen as seedlings resources) for his good production. Hence, the government has issued instructions to use seedlings from *high-producing farmers* to be distributed in the support programs. However, interview revealed that before being chosen as *high-producing farmer*, farmer Y has never actually received any program. He has been personally implementing proper method (i.e. 5x5m planting spaces) by learning from experience and sharing knowledge with other farmers who have participated in the program. Unlike other farmers who mostly conduct all activities by family members, farmer Y hires laborers during harvest season to maximize his production, while tries to manage lands on his own by conducting weekly cleaning with his family. On the other hand, farmer Y seems to be unsatisfied with the program. He stated that regardless of being selected as high-producing farmer, he cannot get higher price when selling his nutmeg products. Thus, at this moment farmer Y has not personally felt any benefit of the program.

Farmer A was the only surveyed farmer who has not participated in any program. However, he was one of the biggest land-owners in Fakfak Regency and his family was known as the early generation of Fakfak's nutmeg farmers. He owns 12 hectares of cultivated lands and currently is expanding his cultivation by opening new lands in privately owned wild forest. Despite of not participating in any program, farmer A manages to conduct proper method by himself. His father used to travel outside Fakfak Regency to learn about agriculture and try new method in his lands. Thus, farmer A took after his father and continued implementing the methods. Because of their

hard work and high production, his family was able to connect with local wholesaler and gain trust to regularly supply nutmeg spices to this buyer. Farmer A stated that he is satisfied with his current production and sales, since he has been able to sell all his products in higher price than average. His good relationship with the buyer also helps him to get the latest information of nutmegs' market regardless of no support from the local government.

Based on cost and profit calculation, it is clarified that farmers earn significant incomes from nutmeg production. The bigger the lands are cultivated; the more incomes can be earned. For farmer O and P, nutmeg production has become an important source of household income, combined with incomes from other on-farm activities (i.e. vegetables, fruits, and livestock). As for farmer Y, with his good production, he was able to earn stable incomes and reach the same level of Indonesia's middle-class households with incomes between IDR 36-120 million per year (Deloitte, 2016). Moreover, with large cultivation areas, farmer A can be categorized as the high-income farmer. Hence, by conducting proper methods, there is a high potential for nutmeg farmers in Fakfak Regency especially those who have more than 5 hectares cultivating areas to earn as much as incomes of the middle-class households in Indonesia.

CONCLUSION

This study has clarified that nutmeg industry in Fakfak Regency has been intensively developed by the support of the local government. Although there are difficulties to instantly shift from a long-standing tradition to proper cultivation methods, there are farmers who showed positive attitude towards development and willing to improve their productions. It has also been confirmed that access to information and proofs of the benefits are very important to increase farmers' understanding and awareness to implement proper methods themselves. In the future, the following actions are essential to enhance the development of nutmeg industry in Fakfak Regency. First, it is important for the local government to ensure farmers receive necessary information. Increasing support through assistance of local extension worker and providing opportunities to exchange knowledge with other farmers can be effective ways to provide information. Second, farmers will be highly motivated to improve their production when they can personally prove that their efforts in production can also benefit their sales. Not only in cultivation stage, through cooperation with other related offices, the local government should intensively expand their support to processing and sales stages. Third, setting a legal sales regulation is highly necessary to ensure that proper quality standard and fair price in sales activities are applied from farmers to wholesalers' level. Lastly, due to the small number of respondents in this study, it is necessary to broaden the scope of this research and conduct further analysis. Comparison study with other areas where the local government support has also been implemented should be conducted to analyze necessary improvements on the current support programs.

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Research article

A Study on Cambodian Rice Farming: Comparative Analysis on Aromatic and Non-Aromatic Rice Farming in Voatkor Commune, Battambang Province

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Abstract Cambodian agriculture is now in midst of transition from the traditional subsistent to modern commercial one. With respect to rice farming, more farmers are shifting from non-aromatic to aromatic rice production. Currently, aromatic rice accounts for about 10% of total rice cultivated area, and 30% of total rice production. Furthermore, the competitiveness of non-aromatic rice has worsened recently. By observing this trend, this study aims to grasp the differences in characteristics and profitability between non-aromatic and aromatic rice production, and to discuss the factors affecting the variety selection from farmers' viewpoint. This study is based on the survey conducted in Voatkor commune, Battambang province in 2017, one of the biggest rice producing areas in Cambodia. In the survey, random sampling method was applied, and 82 rice farmers were interviewed. Among the sample, 59 farmers adopted non-aromatic rice, and 61 farmers adopted aromatic rice, including farmers adopted both aromatic and non-aromatic. Study farmers generally cultivated only once a year, mainly in wet season. The result of the study showed that aromatic rice was not commonly used for home consumption, and that more than 80% of the production was for sale, considering greater demand from international market. On the other hand, the non-aromatic rice was mainly used for home consumption and domestic market. The costs of aromatic rice production were higher on material and labor costs, but farmers were able obtain higher yield in comparison with the non-aromatic rice. Despite higher production costs, aromatic rice was found to be more profitable in gross value added, gross margin and net profit, thanks to higher yield and favorable paddy price. In addition, this study also identified non-economic factors affecting the farmers' decision-making on varieties. Finally, some recommendations are offered.

Keywords aromatic rice, non-aromatic rice, production costs, profitability, Cambodia

INTRODUCTION

Rice is a staple food in Cambodia, cultivated all over the country. It contributes more than 10% to the national GDP with more than 50% of employment. After 30-years hiatus caused by civil war, Cambodia has been slowly recovering its status as a major rice producer and exporter. Currently, Cambodia stands as the World 6th rice exporter and second largest exporter of Premium Jasmine Rice (USDA, 2013).

With the achievement of rice self-sufficiency in 1990s, the Cambodian government has set a goal to export one million tons of milled rice by 2015. For this goal, aromatic rice was strategically important, since it has a great potential for exportation pulled by the increasing demand from international market. As World Bank (2015) pointed out, many farmers were shifting from non-

aromatic to aromatic rice production. Currently it is estimated that aromatic rice accounts for about 10 percent of cultivated area, and 30% of total production. However, most farmers still stick to non-aromatic rice farming partly due to the constraints of socio-economic factors, land condition, and partly due to the farmers' preference. It is important to clarify the obstacles from field data, which hinder the shift of rice production to more rational direction.

This study aims to grasp the differences in characteristics of production as well as differences in cost and return, among several types of rice farming. Also, it aims to point out the factors affecting the variety selection, based on interviews with rice farmers.

METHODOLOGY

This survey was conducted in Voatkor commune, Battambang province. It is one of the biggest rice producing areas in Cambodia, also known as "Cambodian Rice Basket". The total number of farm household is around 82 households in 2017, and the total agriculture land is around 164.53 ha, which consists of 159.44ha of rice field. The water resource of this commune is provided by Kampingpouy reservoir, and Kahout irrigation. The irrigation situation in this study area is considerably poor. Rice field located inside the village, cannot access to the irrigation system fully throughout the year, and rice farming there is heavily dependent on rainfall.

This study is based mostly on primary data, collected through direct interviewing with rice farmers in the commune. Interviewed farmers were selected by random sampling method. The survey was conducted two times in March and September 2017. Totally 82 rice farmers were interviewed and they categorized into three groups: group A (21 non-aromatic rice adopter), group B (22 aromatic rice adopter), and group C (38 farmers adopted both).

The method of analysis of this paper is mainly descriptive, but considering the wide differences in the characteristics and economic performance of rice production among various rice cultivating systems, this paper tries to compare the above-mentioned differences not only between aromatic and non-aromatic rice production but also among rice cultivating systems.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Aromatic and Non-Aromatic Rice Producers

Table 1 Socio-economic characteristics of aromatic and mon-aromatic rice producers

	Non-aromatic farmers	Aromatic farmers	Farmers adopted both[1]	T-test (p value)		
				NA & A	NA & Both	
Number of household (HH)	21	22	38			
Number of male head of HH	20	21	38			
Average family size (person)	5.05	4.91	5.37	0.78	0.45	
Average age (years old)	54.71	51.52	51.89	0.41	0.44	
Year of education (years)	5.57	7.48	7.89	0.08	0.01	*
Average owned land per HH (ha)	1.13	1.54	3.01	0.24	0.04	*
Average planted area per HH (ha)	1.48	1.93	4.05	0.17	0.07	

Source: Field survey, 2017
1: Farmers adopted both means farmers who produced both aromatic and non-aromatic rice varieties.
**Indicates statistical significance at 0.05 level*

Basic features of interviewed farmers are presented in Table 1. Table 1 shows that farmers of group C had longer career of education in comparison to farmers in group A and B. In addition, farmers in group C had bigger size of owned and as well as planted rice area. The difference between owned and planted land can be regarded as rented land and this was around one hectare (one third of total planted area) for farmers in group C. On the other hand, rented land of group A and B farmers was not so much, suggesting they were mostly using their owned land. With respect to family size and age of respondents there was no significant difference among these 3 group farmers.

Rice Farming System in the Study Area

In Cambodia, there are many types of rice farming in accordance to seasons, land type, and water condition. The main crop is rain-fed rice farming in rainy season, primarily harvested in November to January, using local varieties. It should be noted that the performance of rice faming, such as yield, cost of production, profitability and so on, are ranging widely depending on land condition, availability of water, and variety use. Thus, before discussing the difference in production cost and return of rice farming, it is needed to examine the existing rice cultivation system in the study area.

Four different types of rice farming system were observed in the study area (Table 2): medium non-aromatic rice, late non-aromatic rice, medium aromatic rice, and early aromatic rice.

Table 2 Typology of rice farming systems in the study area

Rice cultivating system by length of maturity	Local variety		Modern variety	
	Non-aromatic	Aromatic	Non-aromatic	Aromatic
Early	**X**	**X**	**X**	**O**
Medium	**O**	**O**	**X**	**X**
Late	**O**	**X**	**X**	**X**

Source; field survey 2017 by the first author
Note 1). o: Observed in studied area
x: Not observed in studied area

Medium non-aromatic rice farming: 29 respondents adopted this farming system. Using local varieties, farmers started in May to June and harvest in November to December (around 6 months). This rice system is extensive with a bag of fertilizer (50kg/bag) and only a limited insecticide and weedicide were applied. This farming is fully dependent on rainfalls, so irregular rainfalls might damage or delay the process of farming, resulting the decreasing in the paddy yield. The average yield per hectare is around 2.74 ton, and the purpose of this production is mainly for home consumption.

Medium aromatic rice faming: 45 farmers were found to adopt this farming system. The varieties that farmers used are local ones with 2.82 tons of average yield per hectare. The cropping period is the same as medium non-aromatic rice. This rice system is also an extensive type with a limited use of weedicide, insecticide, and fertilizer (commonly 1 bag). It fully depends on rainfalls, and only shallow depth-rice field is suitable to this system. The purpose of this rice production is partially for home consumption and for sale.

Late non-aromatic rice farming: 30 farmers revealed to adopt this farming system. Same as the earlier farming system, the varieties of this farming system consist of local varieties. The average yield of adopted farmers is around 2.78 ton per hectare. The cropping period is 8 months, starting from May to June, and finishing in December to January. This rice system is an extensive one as medium rice farming, and faces the same risk. The main purpose of this production is for home consumption as well as for sale.

Early aromatic rice farming: 34 farmers adopted this farming system. This farming system is the main practice when the irrigated water can reach to the rice field during dry season and short dry in wet season. Early aromatic rice farming is an intensive farming with high use of fertilizer (3 to 4 bags) and of weedicide and insecticide. The varieties for this farming system are the modern ones, and the yield per hectare (around 3.56 tons) is higher than the local varieties. The cropping period for this farming system is only 3 to 4 months (around 105 to 115 days). The purpose of this type of rice production is mainly for sale, and finally export to international market.

Total Production Cost of Rice Farming

From above analysis, it was found that in the study areas, there were four types of rice farming, and that the system differed much in variety selection, production purpose, and input use among them. Thus, in the analysis of cost and returns of rice farming, it is necessary that diversified aspects of rice farming among farming systems should be fully took into the account.

In this study two different comparison are adopted. First, comparison between medium non-aromatic and medium aromatic rice farming was compared, since those two shared the same cropping period. Second, late non-aromatic rice farming and early aromatic rice farming was compared. Those two types are currently the most common rice farming system in the study area.

Concerning the cost analysis, this study followed the method of World Bank (2015). Additionally, the analysis calculated the cost not only of cash payment, but also imputed cost such as cost of organic fertilizer, family labor costs, cost of owned land, and depreciation of farm assets. To check the significance of difference in cost items between farming systems, T-test with two-sampled assuming unequaled variances is applied in this study as well.

Table 3: Total production cost of aromatic and non-aromatic rice production

Item	Non-aromatic rice		Aromatic rice		T statistic			
	Medium (a)	Late (b)	Medium (c)	Early (d)	(a) & (c)		(b) & (d)	
Number of HH (HH)	29	30	45	34				
Paid seed	9.90	7.08	23.58	22.17	-1.72	*	-1.25	
Imputed cost of keeping seed	27.76	28.71	18.08	37.14	-13.91	*	-2.14	*
Chemical fertilizer	73.35	77.49	82.85	117.41	-1.88		-6.99	
Paid organic fertilizer	2.07	0.00	0.00	0.00	1.00		-	
Imputed cost of organic fertilizer	3.36	0.00	0.00	0.00	2.29	*	-	
Pesticide	4.60	0.08	3.39	28.86	0.52		-12.53	*
Weedicide	21.08	14.23	17.55	24.13	0.85		-3.38	*
BC Cost	**142.12**	**127.59**	**145.45**	**229.71**	**-11.91**	*	**-9.41**	*
Fuel	8.97	16.00	14.78	52.48	-1.60		-7.80	*
Water charge	0.00	0.78	1.60	2.70	-2.52	*	-1.20	
Material cost	**151.09**	**144.37**	**161.83**	**284.89**	**-12.36**	*	**-11.87**	*
Paid land preparation service	33.91	23.93	30.78	27.79	0.86		-0.64	
Imputed cost of land preparation	40.95	50.89	42.85	32.21	-0.44		2.11	*
Total land preparation cost	**74.86**	**74.82**	**73.63**	**60.00**	**0.95**		**2.69**	*
Paid harvesting service	87.69	93.27	87.00	68.38	0.56		2.34	*
Imputed cost of harvesting service	21.72	29.17	18.00	6.62	-1.77		1.33	
Total harvesting cost	**109.41**	**122.44**	**105.00**	**75.00**	**-13.15**	*	**41.48**	
Total service cost	**184.27**	**197.26**	**178.63**	**135.00**	**-0.76**		**10.19**	*
Hired labor	34.40	36.78	44.77	51.29	-2.06	*	-2.07	*
Family labor	89.35	73.50	75.36	55.48	4.12	*	3.08	*
Total labor cost	**123.75**	**110.28**	**120.13**	**106.77**	**1.12**		**0.71**	
Rented land	17.67	51.25	37.06	74.17	-1.28		-0.86	
Total variable cost	**266.07**	**262.56**	**282.72**	**373.04**	**-1.97**	*	**-7.20**	*
Total production cost	**476.78**	**503.16**	**497.65**	**600.83**	**-6.09**	*	**-3.38**	*

Source: Field Survey, 2017 *Unit: USD/ha*

**Indicates statistical significance at 0.05 level*

Table 3 shows production costs (cost per ha) of four types of rice faming. The result revealed that the total production cost of medium non-aromatic rice was 476.78 USD/ha, while the total production cost of medium aromatic rice was 497.65 USD/ha, suggesting that production cost of medium aromatic rice was significantly higher than that of medium non-aromatic rice due to higher costs of seed, fertilizer, fuel, and water cost. The result also showed the total production cost of early aromatic rice (600.83 USD/ha) was significantly higher than total production cost of late non-aromatic rice (503.16USD/ha), resulted from higher spending in seed, fertilizer, pesticide, weedicide, fuel, service cost, and family labor. The production cost of both aromatic rice farming systems was reported to be much higher in comparison to the non-aromatic rice farming systems.

Economic Returns of Rice Farming

Regarding economic returns, this study examined several indicators, like gross value added, gross margin, total cash income, and net profit of rice farming in each category. Gross value added was the deduction from gross revenue and intermediate inputs. Gross margin was obtained by deducting gross revenue deducting intermediate inputs and hired labor. Total cash income was calculated by deducting total cash expense from gross revenue, and finally net profit was calculated by deducting costs of family labor, costs of owned land, and depreciation cost from gross margin. In addition, T-test analysis with two-sampled assuming unequal variances was applied in this study as well.

Table 4 shows the comparison of cost and returns per hectare among four rice faming system in the study in each category. The production of aromatic rice was more profitable in whatever model used. As the extensive farming system, both medium non-aromatic and medium aromatic

rice had similarity of input used and yield. But, the result revealed that net profit of medium aromatic rice is 90% higher and more profitable than medium non-aromatic rice in every indicator. However, it is important to note that the net profit of medium aromatic rice was not significantly higher than medium non-aromatic rice.

Table 4 Net profit of aromatic and non-aromatic rice production

Item	Non-aromatic rice		Aromatic rice		T statistic			
	Medium (a)	Late (b)	Medium (c)	Early (d)	(a) & (c)		(b) & (d)	
Number of HH (HH)	29	30	45	34				
Paddy yield (ton/ha)	2.74	2.78	2.82	3.56	-0.06		7.00	*
Paddy price per ton (USD)	236.77	239.06	253.54	267.42	-5.76	*	-4.75	*
Paid material Cost	119.97	115.66	143.75	247.75	-1.93		-9.64	*
Total material Cost	151.09	144.37	161.83	284.49	-12.36	*	-11.87	*
Hired labor cost	34.40	36.78	44.77	51.29	-2.06	*	-2.07	*
Family labor cost	89.35	73.50	75.36	55.48	4.12	*	3.08	*
Total labor cost	123.75	110.28	120.13	106.77	1.12		0.71	
Total job commission	121.60	117.20	117.80	96.17	-0.35		1.48	
Cash land rent	17.67	51.25	37.06	74.17	-1.28		-0.86	
Owned land Rent	170.83	170.83	178.63	280.2	0.00	*	0.00	*
Depreciation	44.04	28.50	20.06	6.94	-0.32		1.57	
Total cash expenses	293.64	320.89	343.38	469.38	-2.26	*	-4.67	*
Total expenses	611.31	571.18	598.45	774.57	-2.22	*	-4.57	*
Gross revenue	**648.75**	**664.59**	**714.98**	**952.02**	**-2.02**	*	**-8.01**	*
Gross value added	**528.78**	**548.93**	**571.23**	**704.27**	**-0.22**		**-4.30**	*
Gross margin	**372.78**	**394.95**	**408.66**	**556.81**	**-1.24**		**-4.10**	*
Total cash income	**355.11**	**343.70**	**371.60**	**482.64**	**0.92**		**-2.69**	*
Net profit	**50.89**	**70.87**	**97.55**	**140.02**	**0.04**		**-1.62**	

Source: Field Survey, 2017 *Unit: USD/ha*

**Indicates statistical significance at 0.05 level*

Concerning the comparison of cost and returns between late non-aromatic and early aromatic rice, this analysis confirmed the significant difference in terms of production cost and yield between two categories. It was found that early aromatic rice was significantly more profitable than late non-aromatic rice. Higher yield and higher paddy price resulted the higher economic performance of aromatic rice than late non-aromatic rice. This implied that farmers who adopted aromatic rice both medium and early rice farming system made greater profit than farmers who adopted only non-aromatic rice. This result also realized the reasons behind the occurrence in diversities in rice farming in the study area as well.

Factors Affecting Farmers' Decision-making

Understanding the differences in cost and returns between aromatic and non-aromatic rice farming, it is needed to examine farmers' socio-economic characteristics factors, affecting their decision-making on varieties selection.

The result of estimated probit model of factors influencing group A and B farmers on varieties selection is presented in Table 5, which value 1 represented aromatic rice and 0 was non-aromatic rice. This study was examined farmers by farmers, and some of the variables had significant effects on the probability of adopting aromatic rice and some for non-aromatic rice. As result showed, the adoption of rice varieties was likely to be influenced by some factors. For instance, land condition appeared to be the most crucial factor in adopting decision of group A and B farmers. The significant of land condition indicated that well condition factor was likely important in increasing aromatic rice adoption. Similar studies suggested that the endowment of land field was critical for farmers' decision-making on varieties adoption. Farming experiences also appeared to be another important factor affecting on farmers' decision. The study pointed that the more experienced the farmers is, the more likely farmers will adopt aromatic rice. Eating preference was added in the model in order to capture the farmers' preference on home consumption rice varieties, and the result, on the other hand, indicated that eating preference and age of interviewed farmers showed

negative significant effect on adoption of aromatic rice. This suggested that eating preference and age of respondents were more likely to influence on adoption of non-aromatic rice.

Table 5 also shows the result of estimation of probit model of factors impacting group C farmers' decision-making. This analysis was examined plot by plot, and it also proved that land condition and farming experience factor showed the propensity toward adopting aromatic rice. The result indicated that the better land condition is and the more farming experiences farmers have, group C farmers were likely to produce more aromatic rice. It was possibly explained that group C farmers were mostly consisted of big size or farm oriented farmers, which proved that this farmers group was more responsive toward varieties with better yield and market.

Table 5 Estimated probit model for factors affecting farmers' varieties selection of aromatic, farmers adopted non-aromatic, and farmers adopted both aromatic and non-aromatic rice

Variable	Farmers adopted aromatic and farmers adopted non-aromatic rice only				Farmers adopted both aromatic and non-aromatic rice			
	Coefficient	Z-statistic		Average marginal effect	Coefficient	Z-statistic		Average marginal effect
Age	-0.08	0.07	.	-0.02	0.02	0.41		0.01
Family size	-0.09	0.63		-0.02	-0.07	0.53		-0.02
Level of education	0.09	0.26		-0.02	-0.04	0.48		-0.01
Farming experience	0.07	0.05	.	0.02	0.04	0.06	.	-0.01
Land size	0.04	0.89		0.01	3.81e-03	0.90		1.05e-03
Land condition	1.47	0.01	*	0.32	1.98	1.05e06	***	0.55
Eating preference	-0.98	0.09	.	-0.22	0.46	0.20		0.13
Constant	1.70	0.37		0.37	-0.11	0.93		-0.03
Percent of right predictions	83.33				64.78			

Source: Field survey, 2017
*Significant codes: 0'***' 0.001'**' 0.01'*' 0.05'.'*

CONCLUSION

The result of the analysis of production cost and returns revealed that all indicators including gross value added, gross margin, total cash income, and net profit of medium and early aromatic rice varieties received higher income and more profitable from economic view point in comparison to medium and late non-aromatic rice. The result also revealed that land condition was the most crucial factor in determining farmers' decision, specially toward producing aromatic rice because suitable land condition was needed in producing aromatic rice. It is indicated that in the future, the non-aromatic rice might lose its status as the major rice production in Cambodia, and more farmers will shift to grow more aromatic rice in the study. This study also suggested that in order to improve the production of aromatic and non-aromatic rice, two majoring issues are needed to address such as reduction domestics production cost and minimizing the marketing and trade related costs and barriers.

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Research article

Evaluation of Rates and Forms of Urea Fertilizer for Improved Nitrogen Use Efficiency in Hybrid Maize Cultivation

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Abstract By using different rates and forms of urea fertilizer, the field experiments were carried out at Department of Agricultural Research, Head Quarters, Yezin and Tatkon Agricultural Research Farm, during the monsoon season of 2017. For improving nitrogen use efficiency of Yezin Hybrid Maize-10 variety, four nitrogen fertilizer rates (0, 71.27, 118.78 and 166.29 kg N ha^{-1}) were applied with two forms of nitrogen fertilizer (Briquette urea and Prilled urea). The 4 x 2 factorial arrangements were assigned in the Randomized Complete Block Design with 3 replications in both experimental sites. Mean effects of applied nitrogen rates on seed yield of maize were highly significant in this study. The highest mean values of seed yield resulted with the rate of 166.29 kg N ha^{-1} in Yezin (8.14 t ha^{-1}) and Tatkon (11.69 t ha^{-1}). Although, there was no significant effect from forms of urea fertilizer on seed yield, mean seed yields of Briquette urea were generally higher than those of Prilled urea at the same level of applied N rate in both sites. Non-significant interaction was observed between rate and form of urea fertilizer factors in the variation of hybrid maize seed yield. The similar trend was also observed in comparison of agronomic nitrogen use efficiency (AE) of hybrid maize. The AE mean values of 166.29 kg N ha^{-1} (8.14 and 11.69 t increased seed kg^{-1} N applied) were significantly higher than those of other two rates of applied nitrogen in Yezin and Tatkon, respectively. The significant effect was observed from forms of urea fertilizer on nitrogen recovery efficiency (RE) in both trials. The RE means of Briquette gave 208.58 in Yezin and 631.43 in Tatkon.

Keywords hybrid maize, AE, RE, briquette, prilled, urea fertilizer

INTRODUCTION

Maize is the second most important cereal crop after rice and it is the main feed crop grown in Myanmar. One of the major nutrients limiting maize production is nitrogen. In tropical soil, the potential for loss of fertilizer N is substantial. Poss and Saragoni (1992) found that 36-153 kg N ha^{-1} had leached below the root zone (150 cm) during the growing season. Myers (1988) reported that maize takes up only 20 to 40% of available N during the main 3 to 5 months of the growing season. Nitrogen (N) management studies have been conducted for many years, mainly with the aim of reducing N losses and increasing nitrogen use efficiency (NUE). Improving efficient use of applied nutrients in crop production is a desirable agronomic, economic, and environmental goal. Improving the NUE and increasing agricultural productivity have been the major focus of research

for the last one to two decades. Some of the N management practices are the use of slow- and controlled release fertilizers and improved placement methods, which reduce the emissions of GHG gases from agricultural fields.

Urea deep placement (UDP) is a proven technology in Bangladesh, sub-Saharan African countries, and more recently in Myanmar that can increase the yield of transplanted lowland rice by 15-20 percent with less use of urea (up to 40 percent) compared to broadcast application of urea (IFDC, 2016). In Bangladesh, 15-20 percent increases in maize yields have been achieved with fertilizer deep placement (FDP), while farmers use 15-20 percent less N (IFDC, 2013). Fertilizer deep placement with briquette form is a technology that is now being promoted in Myanmar by Fertilizer Sector Improvement (FSI) Project of International Fertilizer Development Center (IFDC).

OBJECTIVES

The present study aims to investigate the efficient nitrogen fertilizer rate for maize production and to determine the appropriate fertilizer placement method to get high yield.

MATERIALS AND METHODS

The experiments were conducted during monsoon season 2017 at the Department of Agricultural Research, Head Quarters, Yezin (19˚57'N, 96˚16'E, elevation 130.85 m), Tatkon Agricultural Research Station (20˚ 07'N, 96˚ 12'E, elevation 155.25 m). The 4 x 2 factorial arrangements were assigned in the Randomized Complete Block Design with 3 replications in both experimental sites. Used cultivar in the experiment was single-crossed Yezin Hybrid Maize-10. Selected soil chemical and physical characteristics for the two research stations soil are presented in Table 1. The experimental materials were included four nitrogen fertilizer rates (0, 71.27, 118.78 and 166.29 kg N ha^{-1}) were applied with two forms of nitrogen fertilizer (Briquette urea and Prilled urea). The Prilled Urea (PU) is the most common form of urea available in the market and contains 46% nitrogen (N). The Briquette Urea (BU) is manufactured from a physical modification of ordinary urea fertilizer. The International Fertilizer Development Center (IFDC) has developed it. Its nature and properties are similar to that of PU, but its granule size is bigger and condensed in shape containing 46%N. The weight of Briquette used in this study was 1.8 g and 2.7 g. The ordinary triple super phosphate (TSP) 123.5 kg ha^{-1} and Muriate of Potash (MOP) 123.5 kg ha^{-1} were used for source of nutrient at basal for BU treatments (T2, T3 & T4) and N control treatments (T1 & T5). TSP 123.5 kg $ha^{-1}$was applied at basal and three equal split amounts of MOP (123.5 kg ha^{-1}) was used at basal, 21 days and 35 days after sowing for PU treatments (T6, T7 & T8). BU was applied at sowing time inserted into 7-10 cm deep.

Table 1 Physico-chemical properties of experimental soils

Properties	Analytical method	Tatkon	Yezin
Soil texture	Pipette method	Loamy sand	Loamy sand
Sand %		87.85	85.40
Silt %		2.10	6.33
Clay %		10.05	8.26
Soil pH	4A1-1:5 soil: water suspension	6.60	5.90
Available N (mg/kg)	Alkaline permanganate method	73.00	63.00
Available P (mg/kg)	9C-Olsen's P-Malachite green	6.40	15.00
Available K (mg/kg)	1N Ammonium acetate extraction	210.00	183.00
Organic matter (%)	Tyurin's method	2.50	2.20

Each plot comprised of 8 rows with 5 m long and spacing was 0.76 m between row and 0.23 m within plants. The standard procedure for maize was carried out during the crop stand.

Agronomic characteristics and grain yield were recorded. As N fertilizer were applied in different plots at different forms and doses, the use efficiency N was calculated by the formula NUE = (G_{y+N}-Gy_{0N})/FN, where G_{y+N}= grain yield in treatment with N application; Gy_{0N}= grain yield in treatment without N application; FN= amount of fertilizer N applied in kg ha^{-1} (Afroz, 2013). The N uptake by grain and stover was determined from N content and yield data. The recovery efficiency of applied N was calculated by the formula RE= ‰N uptake at N_x - N uptake at N_0/ applied N at N_x. Data analysis was done by using SAS program version 9.1 (SAS Institute 2001) for analysis of variance and mean comparisons.

RESULTS AND DISCUSSION

Nitrogen rates significantly affected yield in Yezin and Tatkon (Table 2). Yield increased with increasing N rates. The highest rate N4 (166.29 kg N ha^{-1}) provided maximum yield (8.14 t ha^{-1} in Yezin and 11.69 t ha^{-1}in Tatkon) which was statistically significant from lower N rates. The lowest value of yield 2.96 t ha^{-1} in Yezin and 9.37 t ha^{-1} in Tatkon was found in the no nitrogen N1 (0 kg N ha^{-1}). It was cleared that nitrogen fertilizer is needed to get better yield in hybrid maize.

Table 2 Mean effect of rate and form of urea fertilizer on seed yield and agronomic efficiency (AE) and recovery efficiency (RE) of hybrid maize during monsoon season of 2017

	Seed yield (t ha^{-1})		AE (N) (t increased seed kg^{-1} N applied)		Recovery efficiency(N)	
N rate (kg ha^{-1})	Yezin	Tatkon	Yezin	Tatkon	Yezin	Tatkon
0	2.96 ^{c}	9.37 ^{c}	-	-	-	-
71.27	6.09 ^{b}	10.68 ^{b}	6.05 ^{b}	10.55 ^{b}	154.73^{c}	579.85^{b}
118.78	6.36 ^{b}	10.46 ^{b}	6.33 ^{b}	10.39 ^{b}	194.87^{b}	627.32^{a}
166.29	8.14 ^{a}	11.69 ^{a}	8.12 ^{a}	11.63 ^{a}	234.29^{a}	540.95^{c}
$LSD_{0.05}$	0.61	0.7 9	0.53	0.81	7.23	36.58
Form of Urea (F)						
Briquette	5.99 ^{a}	10.75 ^{a}	6.98 ^{a}	11.14 ^{a}	208.58^{a}	631.43^{a}
Prilled	5.78 ^{a}	10.35 ^{a}	6.69 ^{a}	10.57 ^{a}	180.68^{b}	533.98^{b}
$LSD_{0.05}$	0.43	0.79	0.44	0.66	5.90	29.87
Pr>F						
N	< 0.0001	0.0002	< 0.0001	0.0133	< 0.0001	0.0013
F	0.3230	0.1481	0.1766	0.0832	< 0.0001	< 0.0001
N x F	0.7025	0.4264	0.5194	0.4700	0.0014	0.0240
CV (%)	8.39	6.02	6.07	5.81	2.89	4.87

Means having similar letter(s) do not differ significantly whereas means having dissimilar letter(s) differ significantly as per DMRT at 5% level, LSD: Least Significant Different, CV: Coefficient of variation

Form of nitrogen fertilizer application (Briquette urea and Prilled urea) on yield was not statistically significant in both trials (Table 2). The briquette urea treated plots were gained more value in yield than Prilled urea treated plots in both locations. Nair and Singh, 1974 and Misra et al., 1994 pointed that split N of Prilled urea provided yield and its components especially when the last split was scheduled near the phase with high N demand could have more likelihood of being deposited in sink than in other vegetative organs helping development of sink and ultimately the yield parameters. The results pointed that briquette form of urea application at once in basal could also behave as split prilled N application.

The effect of interaction between nitrogen fertilizer rate and form of nitrogen fertilizer application was not significantly on yield in both trials. The interaction of N4 (166.29 kg N ha^{-1}) with briquette form of urea gave the highest yield (8.28 t/ha) in Yezin (Fig. 1) and 12.03 t ha^{-1} in Tatkon (Fig. 2). At the same fertilizer rates, briquette form of application intended to increase yield in both locations.

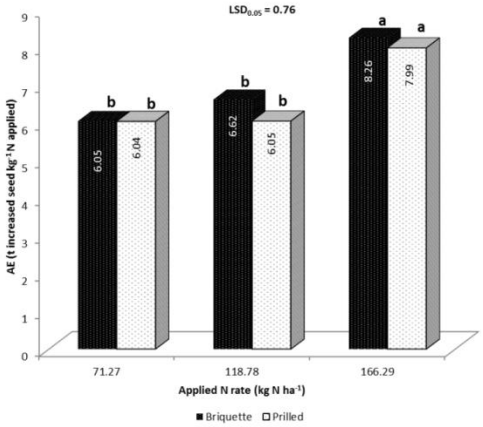

Fig. 1 Mean seed yields as affected by the different rates and forms of nitrogen fertilizer at Yezin Agricultural Research Farm during monsoon season 2017

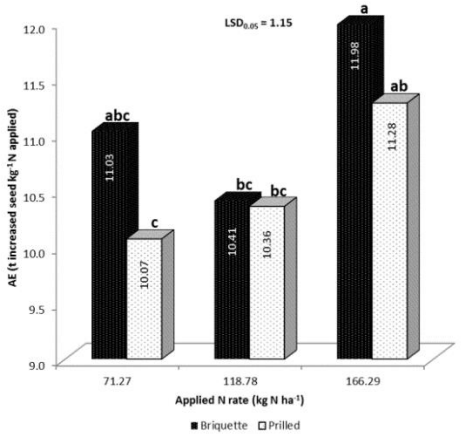

Fig. 2 Mean seed yields as affected by the different rates and forms of nitrogen fertilizer at Tatkon Agricultural Research Farm during monsoon season 2017

The nitrogen fertilizer rate significantly affected agronomic nitrogen use efficiency (AE), and nitrogen recovery efficiency (RE) in both trials. With increasing N rates AE and RE also increased in Yezin Trial (Table 2). The AE consistently increased with increase in nitrogen rates. The highest N rates (N4, 166.29 kg N ha^{-1}) provided the maximum amount of AE (8.12 t increased seed kg^{-1} N) and RE (234.29) in Yezin. Increase in nitrogen rates from N1 to N3 significantly enhanced RE in Tatkon (627.32). Further increase in nitrogen rates could not bring increase rather curved the recovery efficiency of N (Table 2).

No significant effect was given by the form of nitrogen application in AE for both trials. The mean value of AE with briquette urea treated plots gave higher values than using Prilled urea in both locations. The RE was statistically increased by using briquette urea in both trials. More RE was obtained from the briquette urea treated plots (Table 2). The nitrogen recovery efficiency is an index which determines the quantity of plant N uptake per unit of N fertilization. Dobermann (2005) and Aita and Giacomini (2008) argued that nitrogen recovery efficiency depends on the timing of the plant demand with nutrient availability. This synchronism is affected by several factors, the method of N fertilizer application, fertilizer source, fertilizer rate, quantity of residue, type of residue, and weather conditions (Wendling et al., 2007; Amado et al., 2009). The present investigation highlighted that Briquette urea with deep placement method could be effective method to maximize the recovery efficiency of N in maize production.

The effect of interaction between different rates of nitrogen fertilizer and form of nitrogen fertilizer application was not highly significant in AE of both trials (Table 2). The highest result on AE (8.26 t seed kg^{-1} N and 11.98 t seed kg^{-1} N) was found in N4 (166.29 kg N ha^{-1}) treated with briquette form of urea as well in Yezin (Fig. 3) and Tatkon (Fig. 4). The lowest AE (6.05 t seed kg^{-1} N, 10.07 t seed kg^{-1} N) was resulted from Prilled urea application with the rate of 71.27 kgN/ha (N2) in Yezin and Tatkon, respectively. The results pointed that, at the same N rate, the efficiency of briquette urea could be attributed to increase the AE in both locations (Figs. 3 and 4). Higher AE of rice due to deep placement of N fertilizer was reported by Wang (2004), Jena *et al.* (2003) and Niznin *et al.* (2013).

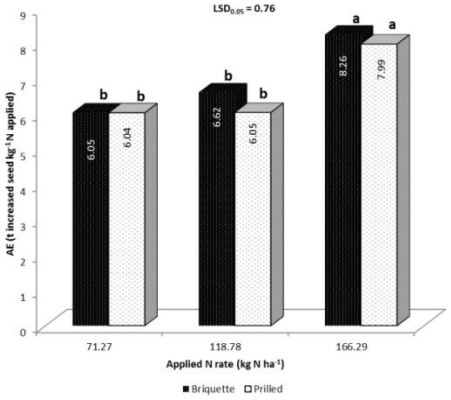

Fig. 3 Mean values of agronomic efficiency as affected by the different rates and forms of nitrogen fertilizer at Yezin Agricultural Research Farm during monsoon season 2017

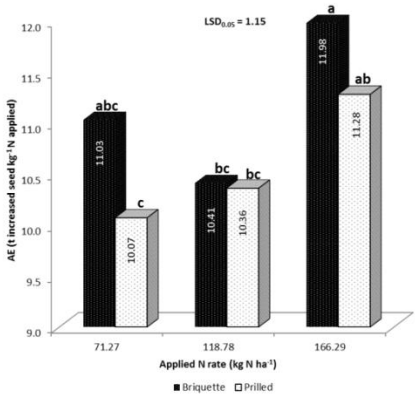

Fig. 4 Mean values of agronomic efficiency as affected by the different rates and forms of nitrogen fertilizer at Tatkon Agricultural Research Farm during monsoon season 2017

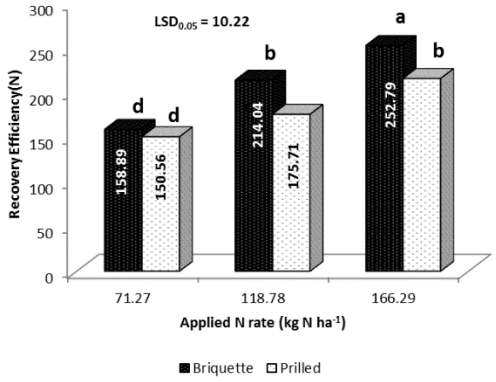

Fig. 5 Mean values of recovery efficiency as affected by the different rates and forms of nitrogen fertilizer at Yezin Agricultural Research Farm during monsoon season 2017

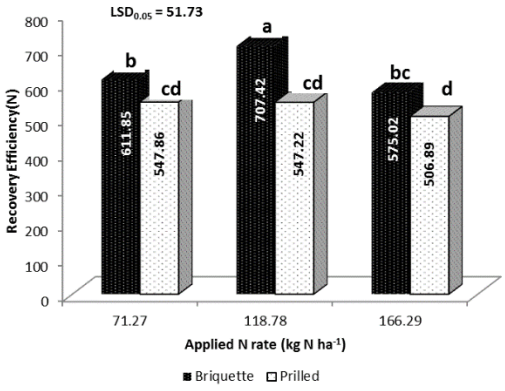

Fig. 6 Mean values of recovery efficiency as affected by the different rates and forms of nitrogen fertilizer at Tatkon Agricultural Research Farm during monsoon season 2017

The significant response in RE to the interaction of N rates and forms of urea was detected in both trials (Table 2). Improvement of RE with increasing N rate was found and it was ranged from 150.56 to 252.79 in Yezin (Fig. 5). The least RE was found at the rate of 71.27 kg N ha^{-1} using Prilled form of urea. The highest RE was obtained from briquette urea with N rate of 166.29 kg N ha^{-1}, N4 (Fig. 5). For the Tatkon trial, the RE was differed significantly and it was varied from 506.89 to 707.42 (Fig. 6). The maximum value of RE was obtained from the N rate (118.78 kg N ha^{-1}, N3) with briquette form of urea. The lowest RE was accompanied with the highest N rate 166.29 kg N ha^{-1}, N4 with Prilled urea treated plots. At the same level of applied N rates, Briquette urea using plots gave more RE values than Prilled urea using plots (Fig. 6).

CONCLUSION

Finally, results could be summed up that hybrid maize production could be favored by higher nitrogen rates. Application of the entire N in the form of briquette at basal with the rate of 166.29 kg N ha^{-1} showed better performance with respect to yield, AE of Yezin Hybrid Maize-10 compared to band placement of split N Prilled urea. Some interaction is existed in the nitrogen recovery efficiency and RE point out that even recommended fertilizer rate 118.78 kg N ha^{-1} could gain the

high yield. The results of this experiment provided valuable information about urea deep placement method which is environmental friendly and will not decrease the normal fertility of land. This study suggests that briquette urea with deep placement method can be used by farmers to improve nitrogen use efficiency and increase grain yields in hybrid maize production.

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Research article

The Opinion Study of Pedestrian User to Footpath Characteristics in Rajamangala University of Technology Thanyaburi Rangsit Center

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Abstract The purposes of this research are 1) to investigate the pedestrian behavior; 2) to analyze the footpath physical characteristics and opinion of user in Rajamangala University of Technology Thanyaburi (RMUTT) Rangsit center; 3) to present footpath model that encourage to use footpath in RMUTT Rangsit center. The samples used in this research were analyzed by 340 sampling sets from instructor, student and officer in RMUTT Rangsit center. The main questions focused on pedestrian behavior, satisfaction and attitudes of pedestrian towards physical obstacles in sidewalk. The answers were analyzed by statistical methods. The results found that the factor affecting the choice to walk at RMUTT Rangsit center was based on cover way. Factors considered were pedestrian satisfaction of footpath physical characteristics such as parallel footpath with road, shade tree and good surrounding environment.

Keywords opinion, pedestrian, footpath, characteristics

INTRODUCTION

At present, universities around the world have begun to focus on green university concepts that are especially environmental protection, climate change, global warming and greenhouse conditions. The green university approach that is used to UI green metric world university ranking will measure campus sustainability efforts. The criteria of UI green metric word university ranking in 2016 are 1) setting and infrastructure; 2) energy and climate change; 3) waste; 4) water; 5) transportation; 6) education (UI green metric world university ranking, 2016). All of the above about green university shows that the transportation system is important in reducing carbon emissions and polluting in area and it is related to encourage pedestrian to use footpath in the university. It also affects the relationship with pattern of pedestrian to use area (Frank and kavage, 2009). Thus, Rajamangala University of Technology Thanyaburi (RMUTT) Rangsit center has started to develop the area in accordance with the green university guidelines by lay-out planning and creating space and activities area according to the UI green metric world university ranking. Therefore, the pedestrian policy on campus is part of develop to green university. At present, RMUTT Rangsit center is no pedestrian walkway in the campus and there is a lack of proper routing and lay-out to accommodate the behavior and needs of users within the university. Therefore, a major goal of this research is to analyze pedestrian satisfaction of footpath physical characteristics. In addition, the footpath model that encourages pedestrian to use footpath in RMUTT Rangsit Center was also investigated.

OBJECTIVE

The research was conducted for the following three main objectives:
1) To investigate the pedestrian behavior,
2) To analyze the footpath physical characteristics and opinion of user in RMUTT Rangsit Center,

3) To present footpath model that encourage to use footpath in RMUTT Rangsit center.

METHODOLOGY

The proposed study site is located within Rajamangala University of Technology Thanyaburi (RMUTT) Rangsit Center, Pathum Thani, Thailand (Fig. 1).

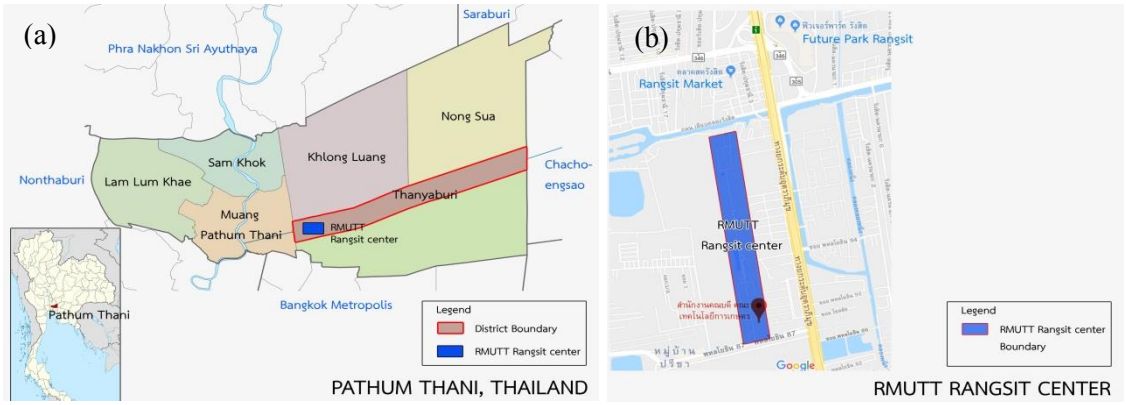


Fig. 1 Location (a) and study site (b)

The sample of this research is calculated by using Taro Yamane (Yamane, 1967) formula with 95% confidence level. (according 2,267 persons from the data of RMUTT Rangsit center report 2017.) The calculation formula of Taro Yamane is presented as follow.

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

Where: n=sample size required, N=number of people in the population, e=allowable error (%)

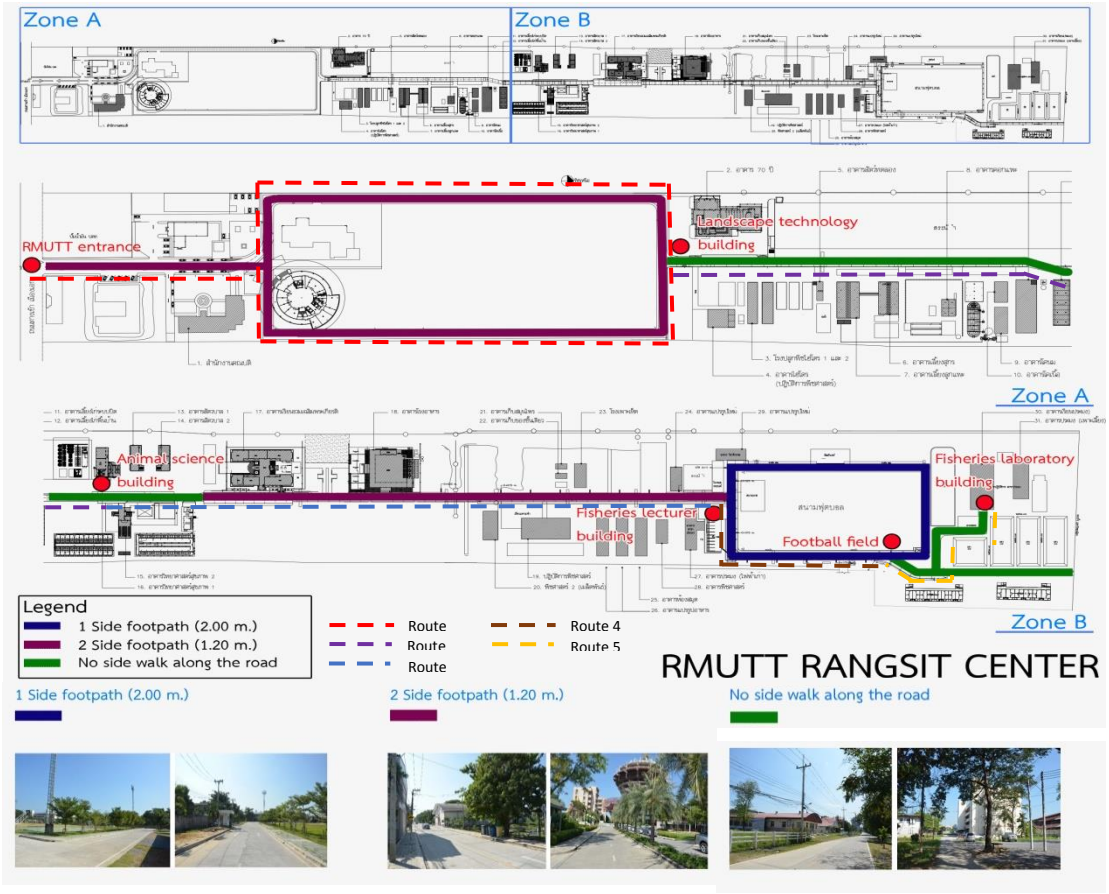
$$n = \frac{2{,}267}{1+2{,}267(0.05)^2}$$ Substitute number in formula: $n = 340$

Data collection is divided into two parts such as physical survey in the study area and behavior survey including comments and requirements of pedestrian. Questionnaire used to collect behavior data, comments and requirements are divided into four parts such as personal information, pedestrian behavior, opinions and obstacles in the study area and formats, and suggestions for pedestrian walkways within the study area. Data collection was conducted in April 2017 and all the collected data was analyzed by statistic package for social science (SPSS and Excel).

RESULTS AND DISCUSSION

The physical of pedestrians within the study area are divided into 3 types are 1) one pedestrian walkway (width 2.00 meter.) is parallel to the road on one side of the road. Found around football field; 2) two pedestrian walkway (width 1.20 meters) is parallel to the road. Both sides of the road will meet RMUTT entrance to landscape technology building, and from the animal science building to the fisheries lecturer building; 3) no pedestrian walkway along the road will be a range of landscape technology building to the animal science building, and the football field to the fisheries laboratory building. Problems and obstacles within the area are pedestrian walkway is not divide space between footpath and car, no shade for pedestrian walkway footpath, the pedestrian is deteriorating, no ramp for the disabled, and obstructions on the pedestrian walkway, for example, bench, road symbol sign, electric pole, garbage can (Fig. 2).

(a)



(b)

Fig. 2 Physical of study area (a), problems and obstacles of study area (b)

The statistics from observed data show that the proportion of female pedestrians is higher than male pedestrians during peak hour and proportion of range 18-25 years of pedestrians is the largest comparing to range 26-32 years and range 33-40 years. The data indicates that pedestrians are student rather than officer with 96% of pedestrian and lecturer with 98% of pedestrian. The average pedestrian time observation 6.00-12.00 rather than 12.00-18.00. The data collection showed that pedestrian behavior use route 1 (RMUTT entrance to landscape technology building) is higher than route 2 (landscape technology building to animal science building), route 3 (animal science building to fisheries building), route 4 (fisheries lecturer building to football field), and route 5 (football field to fisheries laboratory building) (Table 1). In additions, Marisamynathan (2014) indicated that pedestrian crossing speed of a male is faster than that of a female. Pedestrian age and departure signal phase have more significant impact on crossing speed variations. Gender and group size of pedestrians are significant factors affecting the pedestrian compliance behavior. Approaching and the vehicle are identified as the influencing parameters in pedestrian – vehicular interactions.

From the previous study by physical of pedestrians within the study area, statistics from observed data, and questionnaire (characteristic, behavior, and model of pedestrian) found that footpath which encourage to use footpath in RMUTT Rangsit center were footpath model (type 2) consisted of parallel footpath containing shade tree and good surrounding environment (Fig. 3). Leopairojana (2016) reported that problems in travelling to the station include: the unsafe atmosphere prevailing along routes to the station and at the station itself; inconvenient and long access routes, and high travel expenses. The concepts of sustainable transportation that promote walking, cycling and public transportation was then used to develop recommendations as to how improve the station's environment and access. In addition, Tanarinya et al. (2007) indicated that improving condition of footpaths, creating good environments, promoting walking and connecting footpath to BTS stations will encourage people to change their modes from cars to walking and riding public transports.

Table 1 Pedestrians classified by their characteristics and behavior

Observed parameter			No. of observed pedestrians	Percent (%)
Characteristic	Gender	Male	143	42.06
		Female	196	57.94
	Age	18 – 25 years	332	97.65
		26 – 32 years	7	2.06
		33 – 40 years	1	0.29
	User type	Student	328	96.47
		instructor	4	1.18
		Officer	8	2.35
Behavior	Time observation	6.00 – 12.00	185	54.41
		12.00 – 18.00	182	45.59
	Pedestrian	Route 1	126	37.06
		Route 2	122	35.88
		Route 3	62	18.24
		Route 4	24	7.06
		Route 5	6	1.76

Route 1 (RMUTT entrance to landscape technology building), route 2 (landscape technology building to animal science building), route 3 (animal science building to fisheries lecturer building), route 4 (fisheries lecturer building to football field), route 5 (football field to fisheries laboratory building)

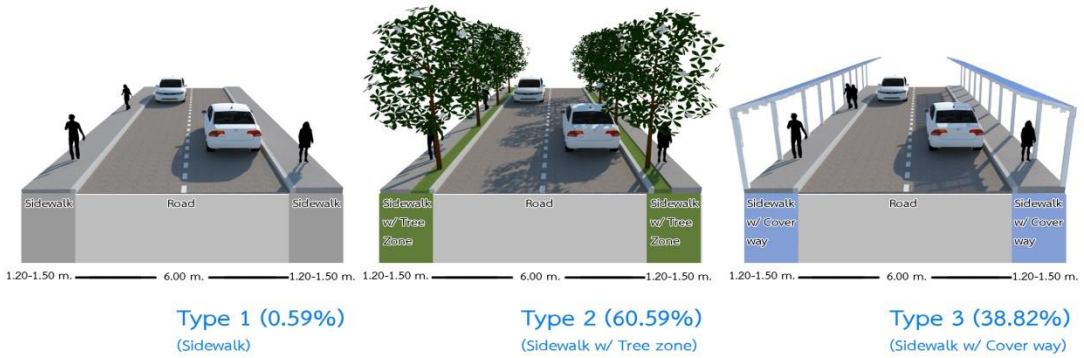


Fig. 3 Pedestrian model type 1 (a), type 2 (b) and type 3 (c)

CONCLUSION

This study revealed the perception of pedestrians on the use of footpath in RMUTT Rangsit center. It is found that 37.06% of the pedestrians use route 1 (RMUTT entrance to landscape technology building), and also identified that no shade for pedestrian walkway is the problem of pedestrian to use footpath. Footpath model has been proposed and selected based on pedestrian behavior in order

to encourage to use footpath is model type 2 (side walk with tree zone).

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Research article

Evaluation of Dust Generation from Animal Farm Activities

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Abstract Dust generated in feedlots from roads, animal activity in pens, and equipment can have detrimental effects on air quality for animals, workers and surrounding communities. Controlling dust in cattle feedlots requires an understand of the key sources and processes needed to better manage dust generation and associated activities. There is growing recognition internationally that dust sources from the agricultural sector may contribute to regional sources with both local and area wide effects on the population, animals and other biota in the environment. Monitoring of fine 10 micron-sized particulate matter (PM_{10} air particulate matter) over the last decade shows that agricultural activities can contribute to regional dust generation from diffuse sources such as from farms and feedlots. The basic features and processes of manure generation at feedlots and storage with water are dried to become a source of dust but other subtle phenomena associated with interaction of conditions and constituents are being identified. In the Central Plains of the United States antibiotic residues and antibiotic-resistant bacteria absorbed on particles have been observed. By understanding the processes of dust generation from feedlots as diffuse sources, it should be possible to identify risks to the population, animals and other biota in the environment. Sustainable production systems rely on keeping soil in place and in good health, efficient use of water, minimizing nutrient loss and maintaining or enhancing biodiversity. This is primarily achieved through management of the pasture base (native, naturalized and sown) in a highly variable and changing climate. This review provides a summary of the significant advances in dust suppression technologies and strategies to suppress dust generated from farms. It also identifies that emerging issues including the dispersion of antibiotics, antibiotic-resistant genes and human-pathogenic bacteria on dust particles from feedlots require managing.

Keywords dust generation, animal feedlots, sustainable, management

INTRODUCTION

Dust generated in feedlots from roads, animal activity in pens, and equipment is recognised as having detrimental effects on air quality for animals, workers and surrounding communities (Galvin et al., 2005). For satisfactory suppression and control of dust in cattle feedlots it is necessary to understand the key sources and processes to give better management of dust generation and associated activities. In Australia, National guidelines were adopted in 1992 for beef cattle feedlots but the regulations vary from state to state (ARMCANZ, 2003).

The scale of feedlot dust generation is related to their number; for example, in Australia there are over 400, with a nominal estimate of over 1,000,000 cattle fluctuating with drought conditions (Jones et al., 2017). The cost of feedlot dust generation was estimated to be more than AUD5 billion nationally per annum (Jones et al., 2017). Management techniques typically centre on regular pen cleaning, watering of roads, and use of in-pen sprinklers during peak times of dust-generating behaviour. Whilst National guidelines identify basic requirements for managing feedlots, they don't indicate all interactive factors that are associated with feedlot management (Galvin et al., 2005). In addition, there is growing recognition of dust sources from the agricultural sector which may contribute to regional sources with both local and area wide effects on the population, animals and other biota in the environment.

Particulate matter (PM) is categorized according to various diameters or sizes based on the physical property of airborne material (NEPC, 2002). The measurement of ambient 24-hr average air concentrations of air particulates may cover the following categories: (i) Total suspended particulates (TSP, <50 μm in diameter); (ii) PM_{10} suspended particulates (<10 μm in diameter); (iii) $PM_{2.5}$ suspended particulates (<2.5 μm in diameter, "respirable"); and (iv) Particle identification in the TSP fraction of the dust. No data on typical dust fall levels for Australian beef cattle feedlots was confirmed (Jones et al. 2017) and no guidelines exist for dust fallout. However, the Queensland recommended guideline for fallout dust is 120 $mg/m^2/day$ for nuisance soiling of property and is adopted from the NSW guideline (DEHP, 2013).

Monitoring of fine air particulate matter (<10 μm in diameter or PM_{10} suspended particulates) over the last decade shows that agricultural activities can contribute to regional dust generation from diffuse sources such as from farms and feedlots (NPI, 2001). Whilst manure needs to be dried to become a source, there are subtle phenomena associated with interaction of conditions and constituents that are being identified (Wilson et al., 2002). In the Central Plains of the United States, antibiotic residues and antibiotic-resistant bacteria absorbed on particles are identified as hazardous and may be dispersed by wind (McEachran et al., 2015).

By understanding the processes of dust generation from feedlots as diffuse sources, it should be possible to identify if uncontrolled processes are risks to the population, animals and other biota in the environment that may be causing undescribed effects. The significance of this step is in being able to properly describe any risks associated with dust generation that may be shown to be detrimental to the population, animals and other biota in the environment. Sustainable production systems rely on keeping soil in place and in good health, efficient use of water, minimising nutrient loss and maintaining or enhancing biodiversity. This is primarily achieved through management of the pasture base (native, naturalised and sown) in a highly variable and changing climate.

This review provides a summary of the significant advances in dust suppression technologies incorporating strategies to detect when dust-load is problematic, available technologies and strategies to suppress pen and road dust, animal health impacts, occupational health and safety impacts, air quality impacts on surrounding neighbours, recommendations to limit exposure of dust to animals, workers and neighbours. The review also identifies emerging issues including the dispersion of antibiotics and related compounds on dust particles from feedlots.

OBJECTIVE

The objectives of this paper are: (i) to review and summarize advances in control of dust from animal feedlot activities that can impact on air quality impacts on surrounding areas; and (ii) identify emerging issues including the dispersion of antibiotics on dust particles from feedlots.

METHODOLOGY

Published papers, reports and other sources including internet and suppliers of dust collection equipment were collated, reviewed and summarized.

Monitoring data for PM_{10} air particulates (covering the period 2003 – 2012 at 8 sites) and for fall out dust (covering the period 2009 – 2011 at 24 sites), were collected on the Darling Downs, the main grain-growing area in Australia, 30-50 km west of Toowoomba, Queensland (Noller and Zheng, 2013). Collection of PM_{10} (Standards Australia 2003a) followed the National Environment Protection (Ambient Air Quality) Measure (Air NEPM) standards, the uniform standards for ambient air quality in Australia (NEPC, 2002). Fall out dust monitoring was undertaken using dust deposition gauges described by the Australian dust sampling method (Standards Australia, 2003b). The extracted data was placed in EXCEL spread sheets. The PM_{10} and dust deposition data was set out in a statistical format giving the mean, seventy-five and ninety-five percentile values.

Monitoring data for fall out dust from a large cattle feedlot study site located on the Darling Downs (Galvin et al., 2005) was examined to compare with the data described above. The fall out dust data were converted from units of $g/m^2/month$ to $mg/m^2/day$.

RESULTS AND DISCUSSION

The dusty conditions of feedlots have been found to result from fine dry material being dispersed by wind and mechanical action (Galvin et al., 2005). Studies on feedlot dust sources have shown that the largest contributor of dust was manure (Huang et al., 2013). Apart from its physical nature manure is a valuable agricultural resource. This value is even though it contains high numbers of microorganisms, that include a large variety of organisms capable of causing disease in animals and farm workers (Milinovich and Klieve, 2011). Dust from road traffic could also be a major source of dust at drier locations like Texas (Wanjura et al., 2004). Dust from roads can be finer than that generated by material handling due to the repeated pulverizing of road materials into smaller fragments and the resultant creation of fine particles which can easily become airborne (Cox and Isley, 2012). The production of fine particles at feedlots has been shown to arise from cattle hooves causing dry manure to be pulverized (Jones et al., 2017). In general, dust emitted from an emission source consists of a range of particle sizes that is dependent on the source characteristics.

The introduction of the National Pollutant Inventory (NPI) handbook for beef cattle feedlots in Australia in 1999 resulted in some feedlots reporting emissions of particulate matter <PM_{10} (NPI, 2001). Emission rates for feedlots based on US data for feedlots were demonstrated to overestimate the actual emissions from US feedlots (Galvin et al., 2005). However limited dust monitoring data has been available in Australia and elsewhere to the current time.

Dust generation is a recognized issue for many Australian and other feedlots because it has the potential to impact on the health and safety of livestock, employees and the surrounding community. Significant advances are required in dust suppression technologies incorporating strategies (Jones et al., 2017): (i) To detect when dust-load is problematic, (ii) To improve available technologies and strategies to suppress pen and road dust, (iii) Deal with animal health impacts, occupational health and safety impacts, (iv) Air quality impacts on surrounding neighbours and (v) Make recommendations to limit exposure of dust to animals, workers and neighbours feedlots. The review of the issues regarding dust generation by Meat and Livestock Australia (Jones et al., 2017) gave the following key findings: (i) There is growing recognition of dust sources from the agricultural sector which may contribute to regional sources with both local and area wide effects on the population, animals and other biota in the environment; (ii) Monitoring of fine dust (PM_{10} suspended particulates) over the last decade shows that agricultural activities can contribute to regional dust generation from diffuse sources such as from farms and feedlots; and (iii) Whilst manure needs to be dried to become a source, there are subtle phenomena associated with interaction of conditions and constituents that are being identified.

A hierarchy of hazard control was recommended to minimize or eliminate exposure to hazards from feedlot dusts (Jones et al., 2017). The hazard controls in the hierarchy, in order of decreasing effectiveness described by Jones et al. (2017), are: Elimination, the most effective means of hazard control such as sealing of feedlot roads to eliminate dust generation by traffic; Substitution that may involve replacement with something that does not produce a hazard, e.g preparing feed rations offsite to eliminate feed-related dust; Engineering and other physical controls that do not eliminate hazards but isolate workers and livestock from hazards by using barriers placed between personnel and hazards; Administrative controls that change the way people work; and Personal protective equipment for farm workers such as gloves, respirators, hard hats, safety glasses, high visibility clothing and safety footwear.

Plots of Darling Downs monitoring data for air particulates (PM_{10}) and dust fall are shown in Figs. 1 and 2 and the summary data is given in Table 1. Comparison of the Australian National Environment Protection (Ambient Air Quality) Measure (Air NEPM) standard (NEPC, 2002) for PM_{10} (50 $\mu g/m^3$ for an averaging period of 1 month) with the data in Table 1 shows there were no exceedances of PM_{10} with the guideline (Fig. 1), excepting for one site (6) during 3-4 November 2011 that had the maximum value (71 $\mu g/m^3$) out of PM_{10} monitoring data for all 8 sites. The fallout monitoring data (Fig. 2) is compared against the level of 120 $\mu g/m^2$/day for soiling that is adopted in Queensland (DEHP, 2013); the exceedances of this level were historical and not the most recent for the monitoring period up to 2012.

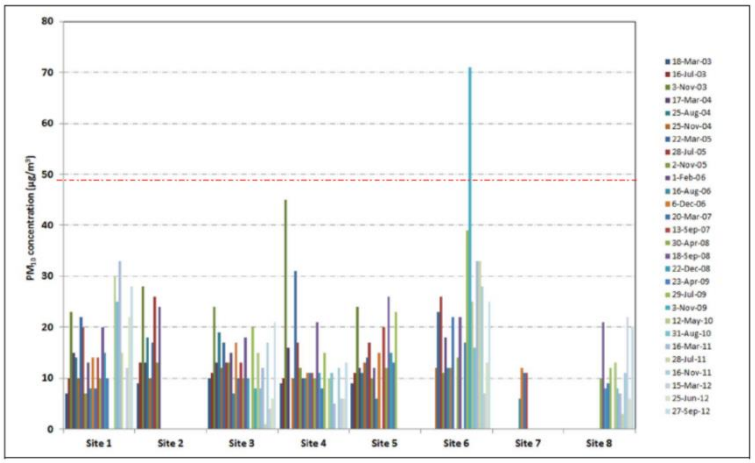

Fig. 1 PM_{10} (μg/m^3) monitoring record during 2003 – 2012 at Darling Downs

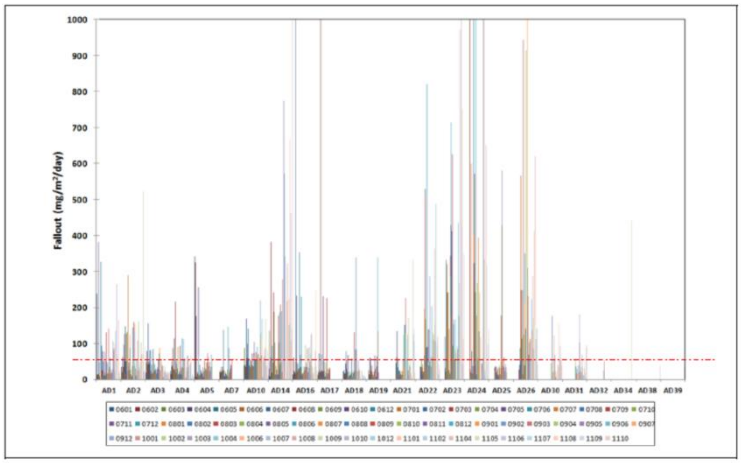

Fig. 2 Dust fallout (mg/m^2/day) monitoring record during 2006 – 2011 at Darling Downs

Fig. 2 gives the overall picture of historical exceedances of fall dust; however, some of the large exceedances for fall out monitoring data were related to bird and frog activity and a long dry dusty period associated with drought (Noller and Zheng, 2013). The data set for all fall out dust monitoring (Table 1) shows that the mean and 75th percentile did not exceed the level of 120 mg/m^2/day, while the 95th percentile did. When the data set for fall out dust monitoring values <120 mg/m^2/day (Table 1) were examined, the mean of 38 mg/m^2/day was a representative background level for the farming activity on the Darling Downs during 2006-2011.

Table 1 Background levels of PM_{10} air particulates and dust deposition at Darling Downs

Category	Time frame	Mean	75th Percentile	95th Percentile
PM_{10} air particulate (μg/m^3)	2003-2012	14	17	26
Dust deposition all monitoring (mg/m^2/day)	2006-2011	103	89	365
Dust deposition <120mg/m^2/day only (mg/m^2/day)		38	52	93

Source and explanation: Data from Noller and Zheng (2013)

Table 2 shows the range of fall out dust was 107 - 923 mg/m^2/day for the beef cattle feedlot study at the Darling Downs (2003-2004) with the highest dust deposition being near roads in and around the feedlot (Galvin et al. 2005). Comparison of the dust deposition monitoring data in Tables 1 and 2 shows that the dust deposition for all monitoring mean was 103 mg/m^2/day (Table 1) and was almost the same as 107 mg/m^2/day at the dust deposition at intermediate sites located on edges of feedlot pen (Table 2). In addition, dust deposition near roads in and around feedlot (923 mg/m^2/day) and dust deposition at background sites (417 mg/m^2/day) (Table 2) exceeded the 95th percentile for dust deposition all monitoring (365 mg/m^2/day) given in Table 1. Dust deposition within a feedlot (320 mg/m^2/day) in Table 2 was marginally lower than 365 mg/m^2/day (Table 1), but indicated that the cattle feed lot data (Table 2) was collectively very dusty.

Table 2 Dust deposition at beef cattle feedlot Darling Downs (2003-2004)

Category	Mean
Dust deposition near roads in and around feedlot (mg/m^2/day)	923
Dust deposition at background sites (mg/m^2/day)	417
Dust deposition within a feedlot (mg/m^2/day)	320
Dust deposition at intermediate sites located on edges of feedlot pen areas (mg/m^2/day)	107

Source and explanation: Data from Galvin et al. (2005) converted from g/m^2/month to mg/m^2/day

Table 2 does not include air PM_{10} data for the beef cattle feedlot study at the Darling Downs (2003-2004). The concentration of PM_{10} was measured at the feedlot and ranged from 29 μg/m^3 to 204 μg/m^3 with a mean of 100 μg/m^3 (Galvin et al., 2005) and far exceeded the air NEPM guideline of 50 μg/m^3 (NEPC, 2002) and the mean background levels of PM_{10} air particulates given in Table 1. Thus, the feedlot was demonstrated as emitting PM_{10} particulates. Although total concentrations of dust and PM_{10} can be measured and compared against guidelines, the manure-derived dust could not be distinguished from manure-derived dust (Galvin et al., 2005).

In addition to the organic matter in manure is the management of zoonotic diseases and means to treat and eliminate them remains a critical issue (Milinovich and Klieve, 2011). McEachran et al. (2015) identify that the reported half-lives of tetracycline antibiotics in soil and soil-slurry mixes are sufficiently long for these antibiotics to remain active during aerial transport and after deposition onto soil, water or other surfaces for days to weeks. The measured concentrations antibiotics found in airborne PM and in cattle manure by McEachran et al. (2015) were also similar to those inside large-scale swine production facilities. The use of antibiotics and other related substances for maintaining animal health and growth require further understanding. Dust issues are relevant to other species of domestic animal production apart from beef cattle.

CONCLUSION

This review has provided a summary of the significant advances in dust suppression technologies. The review also identifies emerging issues including the management of manure and dispersion of antibiotics and related compounds on dust particles. Thus, by understanding the processes of dust generation from feedlots as diffuse sources, it should be possible to identify if uncontrolled processes are risks to the population, animals and other biota in the environment that may be causing undescribed effects.

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Research article

Effects of Gypsum and Rice Husk Biochar on Surface Discharge and Nutrient Loss from Farmlands in Budalangi, Kenya

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Abstract Loose soils from recent cultivation, especially before the crops well cover the surface are highly vulnerable to erosion. The effects of gypsum and rice husk biochar on runoff, loss of soil and nutrients from farmlands in most parts of Kenya are rarely documented. This study aims to discuss effects of surface application of gypsum and rice husk biochar on discharge of sediments and nutrient loss from farmlands in Budalangi, Kenya. Gypsum and rice husk biochar were incorporated into the soil and erosion experiments conducted in the laboratory. Two soil types, loam and silt loam were used in this experiment involving four treatments: control (C), gypsum (G), rice husk biochar (RHB) and a combination of rice husk biochar and gypsum (G+RHB). The effects of G application at a rate of 5 t ha-1 and RHB on runoff volumes, sediment yield and level of nutrient losses were evaluated. The results showed that treatment of G induced a significant reduction in runoff and sediment yield followed by RHB+G and RHB. By plotting the data obtained, it was observed that average runoff decreased by 52.7%, whereas sediment yield decreased by 88% in G treatment. RHB+G treatment showed a reduction in average runoff of 42.3%, whereas sediment yield by 75%. RHB treatment showed 30.7% average reduction in runoff with 71% in sediment yield for loam soil. Similar trends were observed for silt loam soil. Addition of G increased levels of magnesium in both loam and silt loam soils to about five times the initial levels. Total nitrogen loss was minimized by between 15% and 27%, with total phosphorous loss minimized by 50% to 70% between the different treatments. Based on these findings, it can be suggested that amending soil with G and RHB can be effective in controlling soil and nutrient loss from farmlands.

Keywords gypsum, rice husk biochar, soil loss, nutrient loss, farmlands

INTRODUCTION

Land degradation is a threat to both low and high agricultural potential areas in Kenya. Loose soils especially from recent cultivation before the crops well cover the surface is highly vulnerable to erosion, thus there is need to protect soil during this stage as soil surface is in bare condition (Carroll et al., 2000).

Nutrient loss from farmlands especially small-scale farms has been mainly through crop harvest and soil erosion due to use of insufficient quantities of both organic and inorganic fertilizer to replenish soil fertility. According to Smaling et al., (1993), the average annual nutrient depletion rates of -22 kg of N, -2.5 kg of P and -15 kg of K estimates per hectare of cultivated land have been reported in sub-Saharan Africa. For example in Kenya, depletion rates of -112 kg N ha^{-1}, -2.5 kg P ha^{-1} and -70 kg K ha^{-1} were reported on small-scale farmers' fields in western Kisii highlands.

Complementary to conventional strategies like mulching and changing slope gradients, soil and water conservation can be achieved by amending the soil properties responsible for

deterioration of the stability of soil structure. An option given for improving soil structural stability is surface application of soil amendments such as gypsiferous materials and anionic polymers (Cochrane et al., 2005). Gypsum minimizes dispersion of clay particles hence boosting soil permeability and subsequently stabilizing soil aggregates. It has been widely used especially in reclamation of sodic soils since it is calcium-rich and dissolves at high pH (Horneck et al., 2007). The Ca^{2+} ions in gypsum ($CaSO_4.2H_2O$) replace the exchangeable Na^+ ions on soil surface. This property together with its electrolyte concentration makes it effective to be used as a soil amendment especially for reclamation of sodic soils (Korcak, 2001). Its relative solubility in water makes it applicable in agricultural fields. In cultivated arid and semi-arid lands (ASALs), application of gypsum and its contribution to soil solution ionic concentration is necessary as it limits instability in soil structure which would otherwise lead to surface sealing and commencement of runoff with subsequent erosion (Ellen et al., 2006). On the other hand, over application of gypsum would lead to its accumulation on the soil surface, hence need of scraping and this would otherwise require a lot of labor to break it up.

Biochar is a product of slow thermo-chemical pyrolysis of biomass materials. Organic materials such as crop residues, sewage sludge and livestock excreta can be converted to biochar and used as soil amendments (Jien and Wang, 2013). Biochar is essential due to its richness in carbon content thus it is useful in amending soil and boosting soil organic matter content. The objective of this study is to discuss the effectiveness of gypsum and rice husk biochar in minimizing the discharge of sediments and nutrient loss from farmlands in Budalangi, Kenya.

METHODOLOGY

Soil and Rice Husk Biochar Collection and Preparation

Soil was sampled from the surface at a depth of about 0-25 cm in the study area located within coordinates N 0° 7′ 0″ to N 0° 9′ 0″ and E 34° 1′ 30″ to E 34° 3′ 30″. This area forms part of the lower catchment of river Nzoia watershed. The soils were classified as loam and silt loam based on the IUSS (International Union of Soil Scientists) taxonomy from the results of soil particle size distribution analyses conducted in the laboratory. Some of the common crops grown in this area include maize (*Zea mays*), beans (*Phaseolus vulgaris*) and groundnuts (*Arachis hypogaea*).

The biochar used in this study was produced from rice husks at a pyrolysis temperature of about 450 ^oC. This was done at the Institute of Environmental Rehabilitation and Conservation, Japan. After pyrolysis, the rice husk biochar used was then ground to pass through a 2 mm sieve. This was to ensure that all the biochar used in the experiment had similar particle size.

Experimental Design

Runoff experiment was conducted in the laboratory of Land and Water Use Engineering, Tokyo University of Agriculture, Japan using erosion plots measuring 0.91 m long by 0.03 m wide by 0.025 m deep and water supplied by a Marriott bottle to attain constant flow rate of 0.83 cm^3s^{-1} at constant pressure, for a concentrated surface flow scenario. The experiments involved four treatments; control, C, gypsum, G, (5 t ha^{-1}, an optimum rate from former studies); rice husk biochar, RHB, (5 t ha^{-1}) and combination of gypsum and rice husk biochar, G+RHB, (1:1 w/w) in three replications. G and RHB amendments were broadcasted on the soil surface and subsequently mixed for each treatment. For G+RHB treatment, soil samples were mixed with amendments at gypsum/rice husk biochar mix ratio of 1:1 w/w for both loam and silt loam textured soil. The soils were compacted in the erosion plots based on the dry densities of 1.25 gcm^{-3} and 1.39 gcm^{-3} for loam and silt loam soils respectively. Erosion plots were then pre-wetted for 24 h at 0% inclination prior to commencement of the experiments. This pre-wetting was to attain field capacity.

RESULTS AND DISCUSSION

Soil and Rice Husk Biochar Properties

Table 1 shows some of the basic properties of soil and rice husk biochar used in this study. The soils were acidic (pH 6.4 and 6.2) with low electrical conductivity (0.17 $mScm^{-1}$ and 0.2 $mScm^{-1}$).

Table 1 Physical and chemical properties of soil (0-25 cm) and rice husk biochar used

Item	Particle-size distribution			P (*10^{-5})	pH	EC	Ca	Na	Mg	TN	TP
	Sand	Silt	Clay	cms^{-1}		$mScm^{-1}$			$mgkg^{-1}$		
		%									
LS	38.2	45.7	16.1	28.3	6.4	0.17	2.7	0.4	0.2	855	736
SLS	23.4	53.2	23.4	9.3	6.2	0.2	2.4	1.3	0.2	579	421
RHB	-	-	-		8.1	0.1	6.0	0.3	0.4	915	355

LS=Loam soil; SLS= Silt loam soil; RHB= Rice husk biochar; P=Permeability

Surface Runoff

The amounts of surface runoff generated under different treatments compared to control are as shown in Table 2. From the results, there was a trend of an increase in cumulative amount of surface runoff produced with time in each treatment with a decrease between the treatments when compared to control.

Table 2 Surface runoff under different treatments

Soil texture	Treatment	Discharge (Lm^{-2})	Percentage reduction from control
Loam	G	14.73d	52.7
	RHB	21.58b	30.7
	G+RHB	17.95c	42.3
	Control	31.12a*	
Silt loam	G	22.97d	27.2
	RHB	17.91b	43.2
	G+RHB	21.43c	32.1
	Control	31.54a*	

G=Gypsum; RHB= Rice husk biochar; G+RHB= Gypsum + rice husk biochar

**Values followed by the same letter within the column are not significantly different at p=0.05 confidence level.*

G treatment showed a significant reduction in surface runoff of 52.7% in loam soil and 27.2% in silty loam soil, whereas, RHB treatment showed a reduction of 30.7% in loam soil and 43.2% in silty loam soil. In the case G+RHB treatment, the surface runoff was reduced by 42.3% and 32.1% in loam and silty loam soils respectively.

Infiltration

Table 3 Infiltration under different treatments

Soil texture	Treatment	Specific infiltration (Lm^{-2})	Percentage change from control
Loam	G	37.99d	98.3
	RHB	32.60c	70.1
	G+RHB	33.55b	75.1
	Control	19.16a*	
Silt loam	G	35.09b	59.4
	RHB	30.88b	40.3
	G+RHB	33.15b	50.6
	Control	22.01a*	

G=Gypsum; RHB= Rice husk biochar; G+RHB= Gypsum + rice husk biochar

**Values followed by the same letter within the column are not significantly different at p=0.05 confidence level.*

Surface application of G followed by its incorporation into the soil increased specific infiltration amount by almost double. On addition of RHB, specific infiltration amount was increased by about 70%. Concurrent application of G+RHB increased specific infiltration amount by 75.1% in loam soil. For silt loam soil, an increase of 59.4%, 40.3% and 50.6% were observed on treatment with G, RHB and a concurrent application of G+RHB, respectively. Gypsum at the surface dissolves during pre-wetting and releases electrolytes into the soil solution. This leads to reduction in soil dispersion and surface seal formation encouraging infiltration.

Addition of biochar significantly increased infiltration amount probably due to increased soil bulk density. Increase in bulk density results in an increase in total porosity (Abrol et al., 2016).

Soil Loss

Specific load generated from the experimental plots under different treatments are as shown in Table 4. With a constant discharge of water at a rate of 0.83 cm^3s^{-1}, specific load generated was 0.94, 0.109, 0.273 and 0.24 t ha^{-1} for control, G, RHB and G+RHB, respectively on loam soil. On silt loam soil, 1.708, 0.095, 0.208 and 0.143 t ha^{-1} specific load was yielded for control, G, RHB and G+RHB, respectively. On average, reductions in specific load generated per treatment compared to control was found to be 88%, 71% and 75% for G, RHB and G+RHB treatments, respectively on loam soil and 94%, 88% and 92% for G, RHB and G+RHB treatments, respectively on silt loam soil.

When data was subjected to mean separation analysis using 1-way analysis of variance (ANOVA) statistical test at 95% level of confidence (p=0.05), there were significant differences in reduction of specific loads generated under all the treatments when compared to control in both soil textures. The results showed a steady increase in specific soil loss in the first 5 minutes followed by a slow decrease with time. The increase in specific soil loss in the first 5 minutes for control treatment could be attributed to the high occurrence of fine particles in the surface runoff. The fine particles are as result of breakdown of aggregates from pre-wetting before the experiment commenced. Also, the subsequent decrease can be attributed to the development of deposited layer that was formed by deposition which is size-selective.

Table 4 Specific load of surface runoff under different treatments

Soil texture	Treatment	Specific load (*10^{-3} t ha^{-1})	Percentage reduction from control
Loam	G	109.07c	88
	RHB	273.27b	71
	G+RHB	240.41b	75
	Control	940.03a*	
Silt loam	G	95.47b	94
	RHB	208.28b	88
	G+RHB	143.28b	92
	Control	1708.82a*	

G=Gypsum; RHB= Rice husk biochar; G+RHB= Gypsum + rice husk biochar

**Values followed by the same letter within the column are not significantly different at p=0.05 confidence level.*

During the experiments, it was observed that on the soil surface of control plot, there was formation of rills which began as very small channels on the soil surface and widened and deepened as the experiment progressed. Sediment transfer was mainly dominated by these rill flows. Conversely, on addition of amendments, there was minimal rills formation throughout the experiments. Since rill formation is generally associated with higher sediment concentration in runoff, this could be one of the explanations for the high sediment concentration in control plot compared to treated plots.

On addition of G, there was a significant reduction in soil loss probably because the soil surface was well aggregated which minimized breakdown of these aggregates by runoff. Application of gypsum is able to maintain surface roughness of the soil as well as increase electrolyte concentration in both runoff and the infiltrating water. According to Shainberg et al., 1989, an increase in electrolyte concentration prevents aggregate dispersion; bigger particles are

less eroded. RHB treatment showed a reduction in amount of soil loss compared to control. This could be as a result of redistribution of relative proportions of soil aggregate sizes. Also, it can be attributed to an increase in roughness of soil surface due to accumulation of relatively large particles of RHB as surface runoff occurs. The surface roughness may have interfered with the lateral movement of detached soil particles in the runoff as the accumulated particles of RHB acted as traps, with finer soil particles accumulating behind them.

The reduction in cumulative soil loss as a result of application of soil amendments could be attributed also to a decrease in shearing action by flowing water or in a reduced soil erodibility as a result of aggregate stability (Peterson et al., 2002). Under no treatment, soil aggregates may disintegrate quickly in water leading to an accumulation of these dispersed particle in the surface runoff and thus resulting in a higher concentration of particles in the surface runoff as in control plots.

Concentration of Cation in Surface Runoff

The transfer of chemicals to surface runoff is mainly through three processes: (1) adsorption and desorption of chemically reactive components by soil constituents, (2) transportation of the dissolved portions of these reactive chemicals to soil surface by convection and diffusion, and/or (3) through chemical dissolution into runoff and through release by return flow. Zhang et al., (1997) observed chemical loss under free drainage conditions; an indication that there is possibility of loss of chemicals from farmlands as was observed in this study.

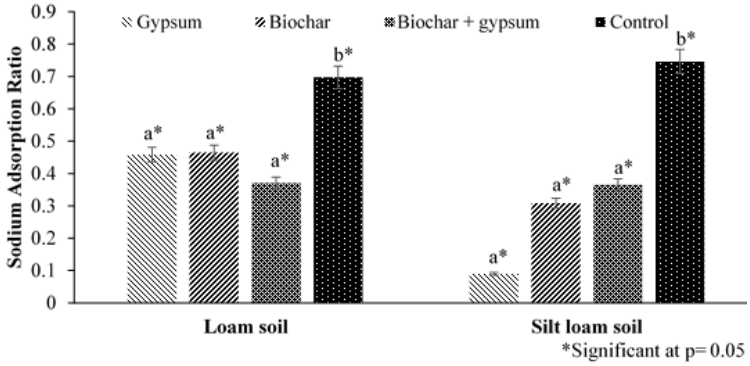

Fig. 1 SAR under different treatments for loam and silt loam soils

Nutrient Loss

The concentration of soil nutrients (nitrogen and phosphorous) in surface runoff was determined by absorption photo-spectroscopy procedure and results showed in Table 5. The average concentrations of total nitrogen in surface runoff from plots treated with G were found to be 0.59 mgL^{-1} for loam soil and 1.67 mgL^{-1} for silt loam soil plots. TN concentration of treatment with RHB was 0.69 mgL^{-1} and 1.57 mgL^{-1} for loam and silt loam soils, respectively. These were higher compared to the respective plots treated with a combination of G+RHB. The results also indicated a reduction in total phosphorous in surface runoff on application of the amendments compared to control.

A study by Pamela et al., (2010) on selected Kenyan acid soils indicated low levels of essential plant nutrients especially phosphorous and exchangeable bases with high levels of exchangeable aluminium. The study noted that for increased and sustainable crop production, there is need for soil management practices that will increase nutrient availability and enhance uptake of the nutrients. Helen et al., (2005) measured equilibrium phosphorous concentration (EPC_O) of riverbed materials to check whether the materials are acting as source or/and sink of soluble reactive phosphorous under low flows and during periods of high eutrophication risks. This was done especially by estimating differences in SRP (soluble reactive phosphorous) flux transfers, an

indication that the catchment area could be one of the sources of phosphorous in the riverbed materials.

Table 5 Total nitrogen and total phosphorous concentration in surface runoff under different treatments

Soil texture	Treatment	Total nitrogen (mgL^{-1})	Total phosphorous (mgL^{-1})
Loam	G	0.59	0.066
	RHB	0.69	0.100
	G+RHB	0.61	0.063
	Control	0.81	0.210
Silt loam	G	1.67	0.170
	RHB	1.57	0.273
	G+RHB	1.70	0.130
	Control	1.79	0.360

G=Gypsum; RHB= Rice husk biochar; G+RHB= Gypsum + rice husk biochar

Pesticide residues of long half-life such as dichlorodiphenyltrichloroethane (DDT) and hexachlorocyclohexane (HCH) and their isomers have been estimated and found to be available in the tissues of the sampled vegetables from riverbed agriculture (Hans et al., 1999). This is a probable indication that farm inputs such as pesticides and other soil nutrients could be finding their way into water systems from farmlands within water catchment areas.

CONCLUSION

The application of gypsum at 5 t ha^{-1} was found to be more effective in reducing surface runoff, sediment transfer and loss of nutrients such as N and P from farmlands. It was closely followed by the concurrent application of a combination of gypsum and rice husk biochar and then application of rice husk biochar alone. Rice husk biochar helps in improving soil stability as it cannot decompose due to its complete carbonization hence, its structure do not collapse for a long period of time. It also improves soil moisture retention capacity. Since rice husk biochar is basically carbon, its burying into the soil assists in carbon sequestration thus, important in reducing carbon concentration in the atmosphere.

All soil amendments used in this study were effective in maintaining a good and well aggregated soil surface that resulted in a minimized detachment of soil particles and probably a surface that was resistant to surface sealing (seal formation) as infiltration was also improved on application of these soil amendments. Due to increased infiltration, there could be an increase in soil moisture hence, important for establishment of vegetation cover. Therefore, it was concluded that surface application of soil amendments on farmlands especially before vegetation is established during which the soil surface is bare and vulnerable to erosion, may be effective on minimizing erosion and subsequent transfer of sediments and nutrient losses from farmlands prior to establishment of vegetation cover.

Considering the cost of gypsum especially on large scale, application of rice husk biochar is recommended for the study area.

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Research article

Influence of Percolation Patterns on Copper Uptake, and Growth and Yield with Copper-polluted Stratified Paddy Fields

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Abstract Copper(Cu), arsenic, and cadmium are designated as specific substances of the Agricultural Land Soil Pollution Prevention Act in Japan. It has been known that high Cu concentrations in soil layers reduce rice crop production and therefore agricultural practices such as soil dressing have been applied to minimize damage to crops by Cu pollution. In this study, we investigated the effects of percolation patterns of the plowsole and the subsoil on growth and yield, and Cu uptake of paddy rice. Four stratified paddy field models were constructed to conduct growth tests under the condition that the percolation patterns of plowsole and subsoil were in an open or closed system. These models had a plow layer and an upper plowsole made with 12.5cm-thickness of non-polluted soil dressing (3.7 mg/kg) and underlying 15cm-thickness of a polluted lower plowsole and a subsoil layer whose Cu concentrations were either higher (approximately 250 mg/kg) or lower (approximately 70 mg/kg) than Japanese safety standards (125 mg/kg). During the tests, a constant water-ponding system was adopted, and mid-summer drainage was not done. As a result, Cu concentrations in the rice grains were 5% significantly higher in the open system percolation models regardless of the original amount of Cu in the plowsole and subsoil. On the other hand, we did not recognize the significant difference in growth and yield of rice plants among the models. We concluded that the Cu concentrations in rice plants were affected by percolation patterns of the polluted plowsole and subsoil even though they were covered with non-polluted soil dressing layers.

Keywords copper, rice, percolation patterns, soil dressing

INTRODUCTION

Copper (Cu), Cadmium (Cd) and Arsenic are recognized as the specific contaminant heavy metals for agricultural lands and thus a variety of techniques for minimizing the heavy metals uptake of crops have been developed, for example, soil dressing, chemical measurement, phytoremediation, and breed improvement of rice plants. It has also been recommended to keep the soil in reduction condition by flooding during the whole growing period in order to reduce Cd and Cu uptake (Yamane et al., 1997; Asami, 2005; Inahara et al., 2007; Akahane et al., 2013).

The studies of Cu pollution in agricultural lands have mainly been focused on damage to crops such as growth inhibition, while Cd concentrations in brown rice itself have been another significant issue of soil pollution. The problem of soil Cu pollution has been of relatively small interest compared to Cd pollution. It is probably because Cu pollution rarely directly affects human health (Kobayashi, 1978, Takaishi et al., 2015) and the area affected by Cu pollution is not as large as that of Cd contamination in Japan. It is reported that in apple orchards, Bordeaux mixtures, mixture of copper sulphate and calcium carbonate have been used for a long time and thus soil Cu concentrations in some orchards are as high as several hundred mg/kg (dry soil) (Aoyama, 2009) while the safety standard of soil Cu concentrations in Japan is 125 mg/kg. Since apple farming is really hard work, elderly farmers, especially, tend to abandon their orchards. Some of the apple orchards in lowland had once been converted from paddy fields and there is a possibility that they will be restored to paddy fields, which require less labor. Therefore, it should be necessary and important to develop the technique of minimizing Cu uptake of paddy rice plants.

In Japan, soil dressing has mainly been applied for remediation of Cu polluted soil (Asami, 2010). Recently, Paul et al. (2011a, b) and Sasaki et al. (2016a, b) clarified that variations of percolation patterns of the plowsole and the subsoil using stratified paddy field models with soil dressing layers resulted in significant differences in Cd concentrations in the brown rice. Paul et al. (2011b) also showed that the percolation patterns affected the amount of Cu accumulation in rice plants even though they used non-polluted soil (12.2 mg/kg). Since the solubility of Cu increases under the oxidation condition and decreases in the reduction condition as in the case of Cd (Dong et al., 2007), the percolation patterns in stratified paddy fields may affect the Cu uptake and growth and yields of rice plants.

It has been reported that Cu polluted soil is likely to induce a Cu accumulation in the roots of paddy rice and a decrease in the number of panicles and the ratio of ripening (Chino et al., 1966; Shibuya, 1979). Shibuya (1979) also mentioned that the yields of brown rice had decreased by approximately 10% under the condition that Cu concentrations in the subsoil layer were higher than 200 mg/kg with a 15cm-thick soil dressing. These studies, however, did not consider utilizing the percolation patterns.

From the above, the objective of this study is to clarify whether percolation patterns affect the growth, the yields, and the Cu uptake of rice plants under the conditions that Cu concentrations are either under or above the Japanese safety standard (125 mg/kg). We prepared stratified paddy field models with approximately 70 mg/kg- and 250 mg/kg- Cu contaminated soil. The results were that the percolation patterns significantly changed Cu concentrations in the brown rice but neither the growth nor the yields.

METHODOLOGY

Table 1 shows the physical and chemical properties of the soils used in this study. Kanagi soil (Loam), 3.7 mg/kg Cu concentration, was sampled from a plow layer of the paddy field in Kanagi farm of Hirosaki University, Aomori prefecture. Bunkyou soil (Clay Loam) was made by adding a solution of $CuCl_2 \cdot 2H_2O$ to the soil which had been sampled from a plow layer of the paddy field on Bunkyo campus of Hirosaki University, Aomori prefecture, and both were mixed well. Cu concentrations in the soil of Bunkyo campus were originally 10.5 mg/kg. We produced two levels of Cu contaminated soil, Cu concentrations in which were either lower (71 mg/kg) or higher (247 mg/kg) than Japanese safety standard (125 mg/kg). These values are 15 and 50 times, respectively,

as large as the average Cu concentration of non-contaminated paddy fields in Japan (4.47 mg/kg) (Asami, 2010). The organic matter content (OM) of the Kanagi soil and Bunkyou soil was 4.7% and 6.6%, respectively. The gravel, which contained 0.8 mg/kg, was used for the lower layer of the models since they were designed after the fashion of paddy fields near a river.

Table 1 Physical and chemical properties of soil samples and gravel

	Density (g/cm^3)	Soil Texture	MgO	CaO	K_2O	Cu	T-C	T-N	C/N	OM
				(mg/kg)			(%)	(%)		(%)
Kanagi Soil	2.58	L	229	531	306	3.7	2.74	0.18	15.40	4.7
Bunkyou Soil	2.61	CL	219	1848	373	10.5	3.84	0.26	14.50	6.6
Gravel	2.68	-	-	-	-	0.8	0.04	0.01	4.00	0.1

Experimental Design

According to the previous report (Sasaki et al., 2016a), two types of stratified paddy field models were used for the experiment: the open-system percolation model and the closed-system percolation model. The percolation patterns were determined by Sasaki et al. (1992). Each stratified paddy field model was constructed in an iron box (30 cm×50 cm×70 cm) filled with three layers of soil. The plow layer was from 0cm to 10cm deep with non-polluted Kanagi soil (dry density in puddling condition was 1.04 g/cm^3). The plowsole was from 10cm to 20cm deep with non-polluted and polluted soil (dry density at the depth from 10cm to 12.5cm [non-polluted Kanagi soil] and from 12.5cm to 20cm [Cu mixed Bunkyou soil] were 1.23 g/cm^3 and 0.75 g/cm^3, respectively). The subsoil was from 20cm to 55cm deep with polluted Bunkyou soil and non-polluted gravel (dry density at the depth from 20cm to 27.5cm [polluted Bunkyou soil] and from 27.5cm to 55cm [the gravel] was 0.75 g/cm^3 and 1.40 g/cm^3, respectively). Those layers were formed by compaction. The authors defined O-70 and C-70 as the setting value of 71 mg/kg of the stratified paddy field modes. Similarly, O-250 and C-250 were defined as the setting value of 247 mg/kg of Cu concentrations ('O' and 'C' stand for 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 57.5cm and 12.5-20cm depth, 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 plowsole and the upper part of the subsoil in order to aerate those layers.

After the two types of models were prepared, fifteen paddy seedlings (the plant length and the leaf stage were from 12.5 to 17.5 cm and from 4.4 to 5.0 leaves, respectively) named '*Oryza sativa* L., Tsugaru Roman' were transplanted. The paddy seedlings were transplanted by 10cm intervals. As for fertilizer, 2g of N, 2g of P_2O_5 and 2g of K_2O were administered per model and mixed with the whole plow layer before transplanting. During the cultivation period, the water ponding condition was constantly adopted but 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. The experiment with the stratified paddy field models was conducted in a greenhouse on the university campus.

Measuring Method

The examination of rice plants such as plant length, leaf stage, the number of stems and panicles, the weight of straw, the number of grains of brown rice and the weight of brown rice was done by the standard method of Iwate Agricultural Experimental Station (1981). The quantitative analysis of Cu concentrations in leaves, root, brown rice and soils extracted by HCl solution was carried out with atomic absorption spectroscopy (MAFF, 1979). Other measurements were also conducted in

standard methods used in Japan. The Oxidation-Reduction Potential (ORP) meter (Central Kagaku Co., Ltd., model UC-203) was used for measuring oxidation-reduction potential (Eh). The ORP sensors were installed at depths of 5, 15, 20, 27.5, 37.5 and 47.5 cm of each model.

RESULTS AND DISCUSSION

Oxidation-reduction Potential (Eh)

The temporal changes of Eh are shown in Figs. 1~4. The plow layer of O-70 and O-250 became reduction layers (under -100 mV) while the plowsole and the subsoil became oxidation layers (over 400 mV). On the other hand, Eh values measured at the depths of C-70 and C-250 were gradually decreased after transplanting, and in due time all the layers became reduction layers as Eh values showed under 0 mV. This means that, in this study, the polluted soil layers in O-70 and -250 were under oxidation condition while those layers in C-70 and C-250 were under reduction condition. It has been pointed out that the Cu uptake in rice is affected by the oxidation-reduction environment (Matsunaka, 2014) and, therefore, in this study, Cu solubility was probably high in the models of O-70 and O-250 (Takaishi et al., 2015). We decided on the oxidation and reduction condition on the basis of Yamane (1982), who had defined the oxidation layer as Eh value as 300 mV or more and reduction layer as < 300 mV.

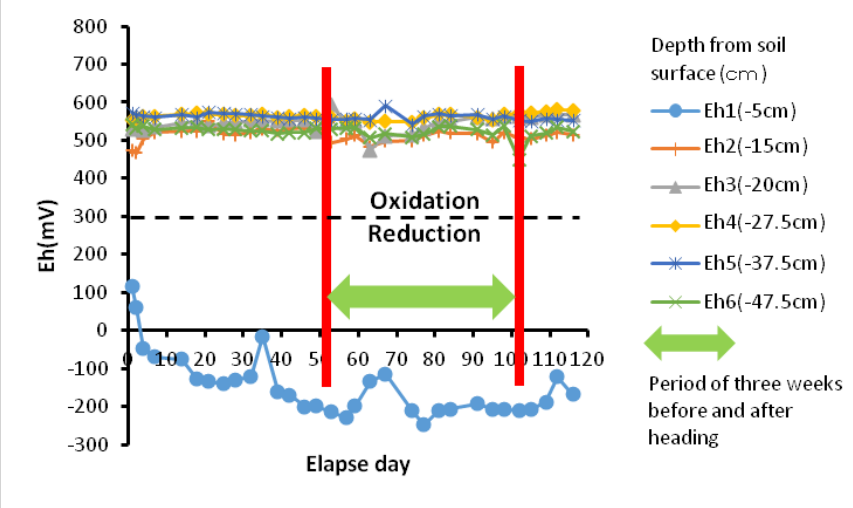

Fig.1 The temporal changes of Eh in the stratified paddy field model (O-70)

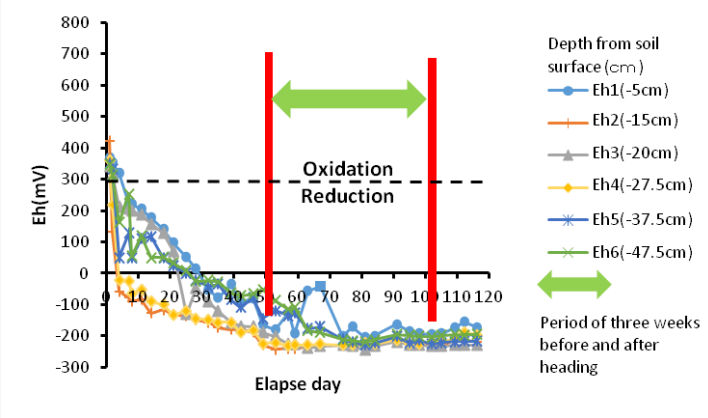

Fig.2 The temporal changes of Eh in the stratified paddy field model (C-70)

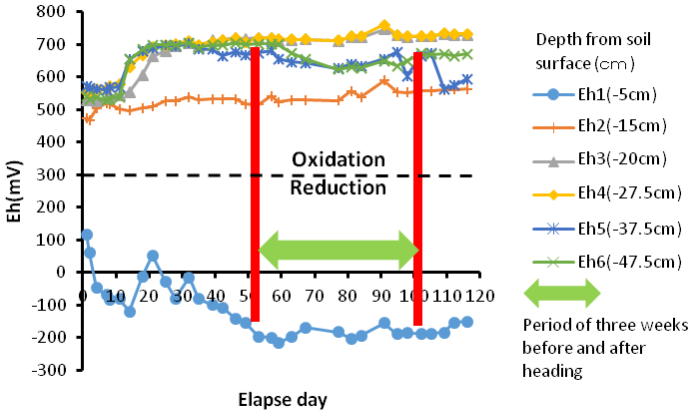

Fig.3 The temporal changes of Eh in the stratified paddy field model (O-250)

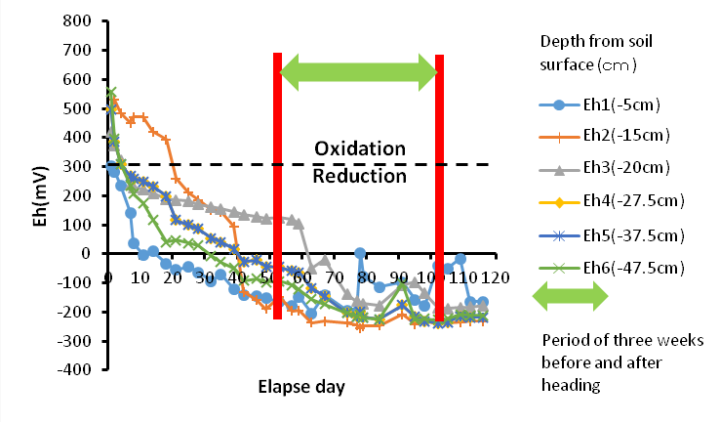

Fig.4 The temporal changes of Eh in the stratified paddy field model (C-250)

Copper Concentrations in Rice Plants

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

Rice grains: Cu concentrations in brown rice ranged from 2.8 to 4.3 mg/kg which were similar to the values reported by Asami (2010). Their studies, however, did not make a distinction between open and close percolation patterns. Paul et al. (2011b) reported that the significant difference was observed in Cu concentrations in brown rice due to differences in percolation patterns. In addition, in their study, despite the low soil Cu concentrations, Cu concentrations in brown rice ranged from 2.5 to 4.2 mg/kg, similar to the results of our experiment. Thus the Cu concentrations in the lower layer did not make much difference in Cu concentrations in brown rice. From these results, it was revealed that the differences in Cu concentrations in brown rice due to differences in percolation patterns were confirmed as those in Cd concentrations found in the experiments conducted by Sasaki et al. (2016a, b).

Stems and leaves: It confirmed that statistically significant differences in the Cu concentrations in stems and leaves were between O-250 (1.6 mg/kg) and C-250 (0.8 mg/kg). However, there was no significant difference between O-70 and C-70. This discrepancy might be caused by the soil Cu concentrations, but this requires further elucidation.

Roots: In Cu concentrations in roots, significant differences in the high concentration models of O-250 (20.3 mg/kg) and C-250 (13.7 mg/kg) were recognized. However, significant differences in the low Cu concentration models due to the percolation patterns were not confirmed. Here, further discussion is needed to clarify its mechanism as in the case of stems and leaves.

Cu concentrations in the rice plants were in the order of roots > brown rice > stems and leaves. This order was similar to those of Shibuya (1979) and Paul et al. (2011b) who used rice plants, and to those of Li et al. (2017) who used soybeans. This result is probably due to the transport characteristics of Cu and Cd in the rice plants.

Table 2 Cu concentrations in rice grains, stems and leaves and roots in plow layer (mg/kg)

Model	Rice grains n=10	Stem and leaves n=5	Root of plow layer n=8
O-70	4.3±0.3[a]	1.5±0.4[a]	16.0±2.3[a]
C-70	3.4±0.4[b]	1.2±0.4[ab]	17.8±2.7[a]
O-250	4.1±0.4[a]	1.6±0.2[a]	20.3±1.4[b]
C-250	2.8±0.2[c]	0.8±0.1[b]	13.7±0.5[a]

Growth and Yield of Rice Plants

Experimental results for the growth and yield of rice plants are shown in Tables 3 and 4, respectively.

Growth of rice plants: The average plant height (n = 10) of each model was almost equal, at 90 cm level (Table 3). Leaf age of each model was about 14, showing a small difference between them. Total straw weight was 12.3～15.0 g/hill. No significant difference was observed in the plant height, leaf age and total straw weight regardless of the percolation patterns. Previous research (Shibuya, 1979) reported that Cu concentrations in the Cu polluted soil layer had an influence on the growth of rice plants. In this study, however, influence of the Cu concentrations on the growth of rice plants was not noticeable, which may well to have resulted from the application of soil dressing.

Yield of rice plants: An average number of panicles per unit hill in each model was 8.6～9.6 /hill (Table 4). Likewise, averages of the weight of one panicle and the number of grains of brown rice per unit hill were 1.9～2.2 g / panicle and 616～680 grains /hill, respectively. In addition, averages of the percentage of ripening and the 1,000 grain weight of brown rice were 86.5～93.7% and 19.1～19.9 g, respectively. No significant differences were found in any of the items of the models with different percolation types. Paul et al. (2011a) reported that yield components of the closed-system percolation model were significantly higher than those of the open-system percolation model though their experiment was conducted by using a different soil type for Cd polluted soil layers. Sasaki et al. (2016a) conducted an experiment using stratified paddy field models with a Cd polluted soil layer and reported that there was no significant difference between the models with different percolation patterns. Soil dressing was presumed to be one of the reasons why no significant difference was observed in that study. In a previous study (Shibuya, 1979), it was reported that Cu concentrations had an influence on the number of panicles and the percentage of ripening. In this study, however, the influence of the Cu concentrations on the growth of rice plants was not remarkable, which may be attributed to the soil dressing.

Table 3 Parameters of rice plant growth

Model	Plant length (cm)	Leaf age (leaf)	Weight of dry straw (g/hill)
O-70	99.6±5.1[a]	14.3±0.5[a]	13.3±2.4[a]
C-70	99.6±3.8[a]	14.3±0.5[a]	15.0±2.2[a]
O-250	95.6±4.4[a]	14.0±0.0[a]	13.3±3.0[a]
C-250	99.7±5.5[a]	14.3±0.5[a]	12.3±1.8[a]

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

Table 4 Parameters of rice plant yield

Model	Weight of one panicle (g)	No. of Panicles (Panicles/hill)	Percentage of ripening (%)	Number of brown rice per unit hill (grains/hill)	1000 grain weight of brown rice (g)
O-70	1.9±0.3[a]	9.4±1.1[a]	92.3±2.2[a]	644.3±116.0[a]	19.1±0.9[a]
C-70	2.0±0.2[a]	9.6±1.2[a]	86.5±4.1[b]	616.9±118.8[a]	19.7±0.5[a]
O-250	2.2±0.3[a]	8.6±1.3[a]	93.1±1.5[a]	680.5±163.9[a]	19.9±0.8[a]
C-250	2.0±0.2[a]	9.6±1.8[a]	93.7±1.5[a]	627.9±65.0[a]	19.4±0.8[a]

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

CONCLUSION

Using four types of Cu polluted stratified paddy field models, we conducted an experiment to clarify the effects of percolation patterns in the sub-layer (both plowsole and subsoil) on the Cu concentrations in the rice plants and their growth and yield. The models had a 15-cm thick Cu polluted soil layer and a 12.5-cm thick non-polluted soil dressing. For the Cu polluted soil layer, two different Cu concentrations of 71 mg/kg and 247 mg/kg were prepared.

The results of our experiment showed that in the open system percolation models the sub-layers became oxidation layers and those in the closed system percolation models the sub-layers became reduction layers. Cu concentrations in the brown rice of the open system percolation models were significantly larger by 5% than those of the closed system percolation models. In the models with concentrations of Cu (247 mg/kg), the Cu concentrations in stems and leaves and roots showed significantly different values between the percolation patterns. However, there was no statistically significant difference in the growth and yield of rice plants between the percolation patterns.

Under the above conditions, difference in percolation patterns of the stratified paddy field models did not affect the growth and yield of rice plants, while it had an influence on the Cu concentration in the rice plants.

ACKNOWLEDGEMENTS

The authors appreciate the cooperation of Toikawa Yoshito, Okada Hiroaki, and Fujita Masayoshi who cooperated in carrying out this research. In addition, this research was conducted under the support of Grant-in-Aid for Scientific Research (No. 26660188). We would like to thank everyone concerned.

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Research article

Nonpoint Source Water Pollution in Rural Areas in the Upper Ayase River Basin of Saitama Prefecture in Japan

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Abstract Nonpoint source pollution of water is an important environmental issue in Japan. In this study, water samples were collected from 12 selected sites and 4 different periods at the upper stretch of the Ayase River Basin located in Saitatma prefecture, and analyzed. The results revealed that the water in the study area was in eutrophic condition and the extent of pollution varied in different ranges depending on the sites' ambient conditions. Moreover, the growing to harvesting period of crops (mainly mid-September to late-October) showed peak-values for nitrogen/phosphorus levels in water samples. The study recommends that either a strict policy needs to be incorporated or much more care should be taken to control pollution from agricultural runoffs.

Keywords water quality, nonpoint source pollution, agricultural water, Ayase River Basin

INTRODUCTION

While agriculture is the single largest user of global freshwater resources, surface water quality detriment in agricultural watersheds is a major environmental concern in many parts of the world. In Japan, efforts over the recent decades to address point source pollution from industrial and municipal sources have greatly improved the water quality. However, problems related to nonpoint sources of pollution, e.g. agricultural sources still remain to be solved (Inoue, 2003; Roy, 2007, Takeda et al., 2009). Depending on the land uses and management practices, different types of nutrients, pesticides, fecal coliforms and sediments from agricultural activities are acknowledged to be among the main causes of these problems (Kawashima, 1996; Takeuchi et at., 2005; Matsuno et al., 2007; Kawamura and Ebise, 2014).

The Ayase River, which flows through the Saitama prefecture and Tokyo's metropolitan city, has been ranked as one of the country's most polluted rivers while domestic and industrial effluences were detected as the prime causes for its pollution. The central government (Ministry of Land, Infrastructure and Transport; MLIT) with the cooperation of local authorities/communities adopted different measures to stop the inflows of domestic and industrial wastewater into the rivers which resulted in the satisfactory recovery of the water quality in the Ayase River (MLIT, 2015). Also the government policy (adopted in 1987) facilitated to control such point source pollution activities. However, for nonpoint sources, although some monitoring guidelines and activities have been launched in recent years by the central government and local authorities, there is no established national regulation/act or policy to stop the pollution caused mainly from agricultural effluents. Therefore, individual consciousness and activities of farmers remain as the most dominating factors to maintain the water quality in the public water bodies such as lakes, ponds, and rivers of a locality in Japan. It is noted here that the amount of nitrogen/phosphorus input and pesticides per hectare of agricultural lands in Japan is remarkably high compared to other developed countries in the world (Parris, 2011). Therefore, even the central government and the local authorities maintain the water quality of the public waterbodies, such as sampling and monitoring works in the Ayase River are carried out periodically by the respective bureaus; it could be difficult to determine the short-periodic (daily and weekly) load from every individual farmland and settlement to the river. However, to reduce the non-point source pollution, it is important to regular monitor the water quality at a micro level in public waterbodies that reside next to agricultural settlements.

This study focuses on the upper reach of the Ayase River Basin, which lies in the Saitama prefecture and is a highly-dense and famous agricultural suburb. Along with other tributaries of the Ayase River in the upper basin, the Minumadai irrigation canal, excavated in 1728, functions as the trunk waterway to irrigate more than 12,000 hectares of farmland (Shibata, 1985). In short, the upper Ayase River Basin is a rural suburb characterized by a dense intermixtures of farmlands and farmers' residences, and this study analyzed the spatial (site-specific) and temporal (seasonal) status of water quality linked to agricultural activities in the area. Accordingly, water samples from the mainstream and tributaries of the Ayase River as well as primary, secondary, and tertiary canals of the Minumadai irrigation canal were collected periodically as the water passed through different agricultural settlements, and analyzed.

The objective of this study is to evaluate the spatial and temporal variations in the water quality of the streams and canals in the upper Ayase River Basin as well as to identify different variation patterns associated with either seasonal variations or pollution sources in the area.

METHODOLOGY

Study Area and Sampling

The length of the Ayase River is 47.6 km with a total basin area of 176 km^2. In fact, agricultural effluent is the main water source of the Ayase River, and the basin is characterized by a level to undulating topography. Average annual precipitation in the vicinity swings from 1100 to 1800 mm. While most of the lands in the upper basin (present study area) are occupied mainly with paddy fields, uplands, and farmers' residences, the middle and the lower basins are full of residences, office-buildings and small- to medium-sized factories. The sampling sites were selected based on preliminary surveys and information collected from the local government authorities. As seen in Fig. 1, the study area (in the upper Ayase River Basin) overlaps the borders of three neighbor wards, namely the Minuma ward, Midori ward, and Iwaki ward, all of which incorporate agricultural fields with numerous surface inlets and outlets of the Ayase River and its tributaries as well as the Minumadai irrigation canal and its diversions. Also in the study area, the lower reach of the Fukasaku River joins the upstream of the Ayase River from the north (Fig. 1). Sampling of surface water from these waterways was carried out from July 2014 to December 2014. The average monthly precipitation was 143 mm in July, 100.5 mm in August, 71 mm in September, 300.5 mm in October, 74 mm in November and 45.5 mm in December (Japan Meteorological Agency). Within this period, water samples were collected in daytime from 12 locations (waterways) at 4 different intervals: July 23 (1st sampling); September 19 (2nd sampling); October 26 (3rd sampling): and December 3 (4th sampling) in 2014. While the 1st sampling covered seeding, sowing, and transplanting activities of paddy and upland crops and was labeled the "summer-irrigation" period, the 2nd sampling represented the peak-time of growing and fertilizer use and was labeled the "fall-growth" period. Also, the 3rd sampling time was labeled the "fall-harvest" period, and the 4th sampling time was labeled the "winter-fallow" period.

Samples of surface water were collected in polyethylene bottles, brought back to the laboratory, and preserved and processed for major physico-chemical analyses while *in-situ* measurements were carried out for several parameters. Specifically, the position of each sampling site was recorded with a Global Positioning System receiver (Poke-Navi Map 21EX; Empex Instruments Inc., Japan), the Dissolved Oxygen (DO: mg L-1) was measured at each site by using a portable DO meter (YK-22DO; Lutron Co. Ltd.), and air and water temperatures (°C) were measured by using a mercury thermometer (0-100°C). Table 1 summarizes the sampling details of the survey.

Measurement and Analysis

The pH and Electrical Conductivity (EC: mS cm^{-1}) of the water samples were measured with a pH meter (Twin pH B-212; Horiba, Japan) and an EC meter (B-173; Horiba, Japan), respectively. The

Chemical Oxygen Demand (COD) of the water samples was measured by using a compact COD analyzer (TNP-10 coupled with a TNP-HT heater; TOA-DKK Co., Japan). Moreover, the concentrations of the major water-polluting ions (NO_3^- , NO_2^- , NH_4^+, PO_4^- , SO_4^{2-} , Cl^- , Na^+, K^+, Mg^{2+}, and Ca^{2+}) were measured with the ion-chromatography method (833 Basic IC plus ion-chromatograph, 863 Compact Autosampler; Metrohm).

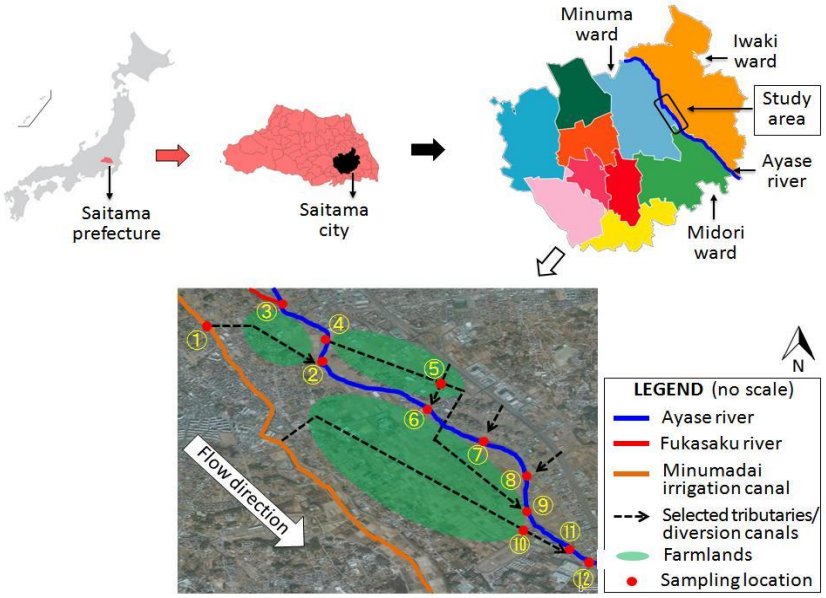

Fig. 1 Study area (the upper Ayase River Basin) showing the sampling sites of agricultural water

Table 1 Detail of survey showing sampling period and positions in different sites of the study area, 2014

Sampling location	Characteristics of the sampling site	Sampling position	
		Latitude	Longitude
1	Water intake point of the MIC*	35° 41' 18.78" N	139° 45' 24.37" E
2	MIC* water discharge outlet to the Ayase River	35° 56' 5.27" N	139° 40' 55.62" E
3	Joining point of the Fukasaku River	35° 56' 23.03" N	139° 40' 47.49" E
4	Upper reach of the Ayase River/OSG* irrigation canal	35° 56' 30.89" N	139° 40' 56.13" E
5	OSG* drainage canal outlet	35° 56' 57.20" N	139° 41' 34.15" E
6	Drainage outlet of OSG and others to the Ayase River **	35° 55' 47.20" N	139° 41' 31.44" E
7	Drainage outlet to the Ayase River (mainly uplands)	35° 55' 32.24" N	139° 41' 57.06" E
8	Drainage outlet to the Ayase River (near a factory)	35° 55' 11.7" N	139° 42' 1.42" E
9	OSG* drainage canal final outlet	35° 55' 10.4" N	139° 41' 58.89" E
10	Drainage outlet to the Ayase River (paddy fields)	35° 54' 55.5" N	139° 42' 8.15" E
11	Lower reach of the Ayase River	35° 54' 59.42" N	139° 42' 6.75" E
12	Discharges mixed from locations (sampling sites) 10 and 11	35° 54' 42.89" N	139° 42' 22.54" E

Notes: ** MIC indicates the Minumadai Irrigation Canal, and OSG the Ohashi Sluice Gate.*
*** In this sampling site, discharges from other outlets mixed with the discharges from the Ohashi Sluice Gate drainage canal.*

RESULTS AND DISCUSSION

Spatio-temporal Variation in Water Quality

The average values of the parameters measured at the 12 selected sampling sites in the upper Ayase River Basin are summarized in Fig. 2 (2.1 to 2.15). The temperature of water samples in all the measured periods showed no extreme variation from the average value at the time of collection, which decreased with the seasonal ambient temperature. However, the pH value at sites 1, 4, and 9 (Fig. 2.2 and Table 1) showed little variation (alkaline) in the fall-growth and fall-harvest periods. For EC, sampling site 7 (upland outlet; Fig. 2.3) particularly showed larger values (26 to 81 mS cm^{-1}) in all sampling periods while sampling site 1 (Minumadai Irrigation Canal: MIC intake) showed extreme temporal fluctuation compared to the other sites (0.18 to 73 mS cm^{-1}). Fig. 2.4 shows that the DO values in the sites increased gradually from the summer-irrigation to winter-fallow period. Since DO is inversely dependent on temperature, the tendency is natural. With different ranges of spatio-temporal fluctuations, the water in most of the sampled sites showed increased DO levels. The samplings were carried out in daytime and under eutrophic conditions; DO greatly increases during the day, but is greatly reduced after dark. The tendency of elevated COD (above 10 mg L^{-1}) at several sites, particularly at site 7 (upland outlet) and site 8 (factory outlet) in the fall-harvest period, site 10 (paddy field outlet) and site 11 (lower reach of the Ayase) in the summer- irrigation period indicated the water bodies had suffered some kind of deterioration due to the discharges of effluents (see Fig. 2.5). Figs. 2.6, 2.7 and 2.8 show the forms of nitrogen (NO_3^- , NO_2^- , and NH_4^+)-effects to the water quality, all of which were caused by runoffs from fertilized lands.

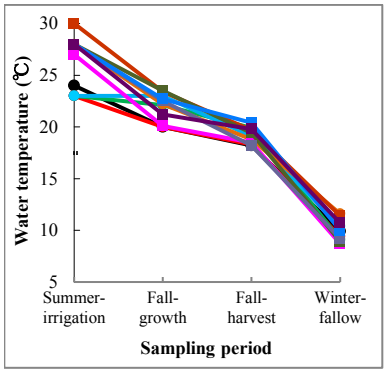

Fig. 2.1 Periodic variation in temperature

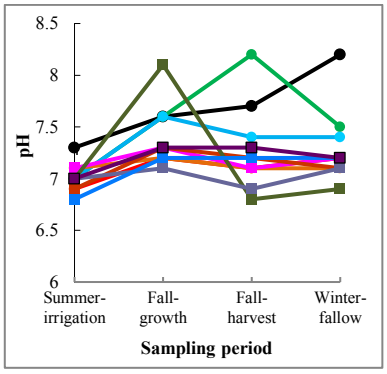

Fig. 2.2 Periodic variation in pH

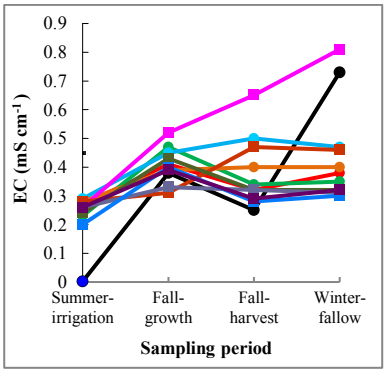

Fig. 2.3 Periodic variation in EC

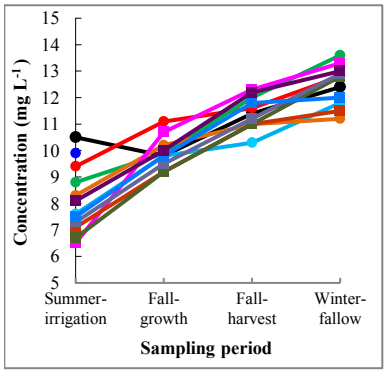

Fig. 2.4 Periodic variation in DO

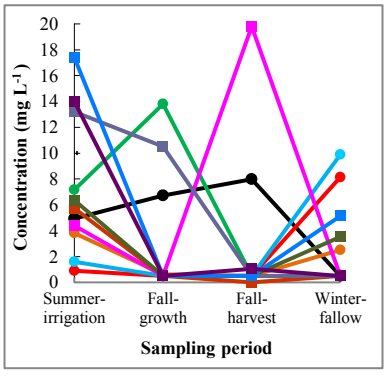

Fig. 2.5 Periodic variation in COD

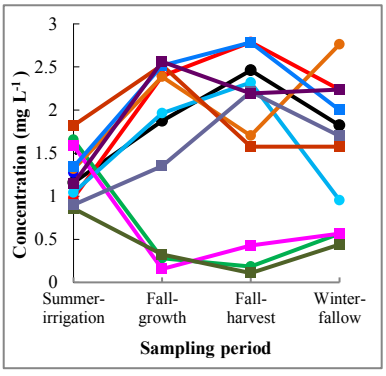

Fig. 2.6 Periodic variation in NO_3^-

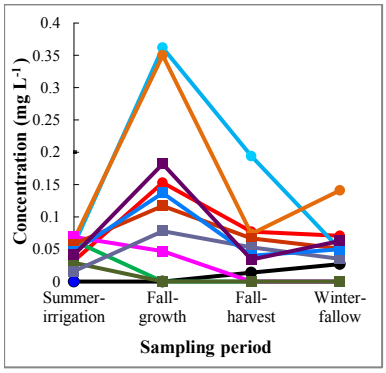

Fig. 2.7 Periodic variation in NO_2^-

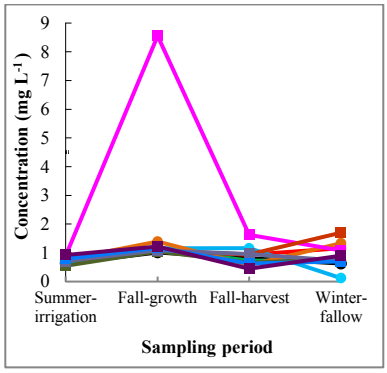

Fig. 2.8 Periodic variation in NH_4^+

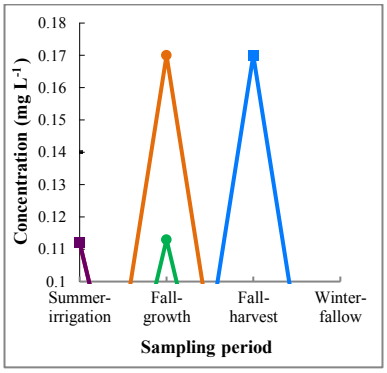

Fig. 2.9 Periodic variation in PO_4^-

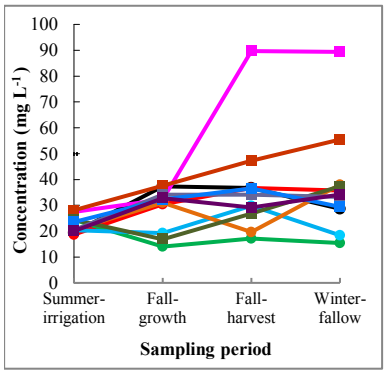

Fig. 2.10 Periodic variation in SO_4^{2-}

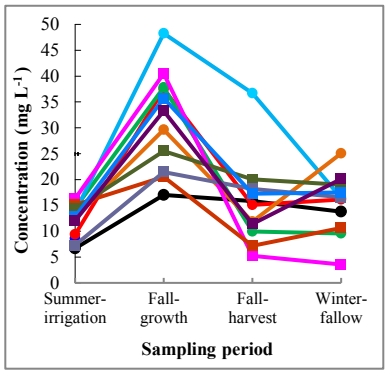

Fig. 2.11 Periodic variation in Cl^-

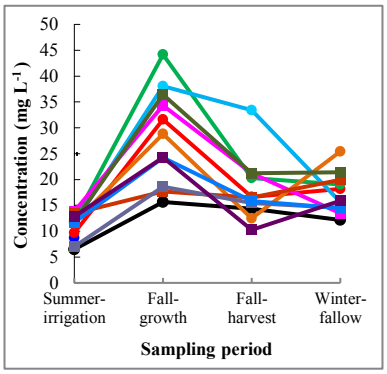

Fig. 2.12 Periodic variation in Na^+

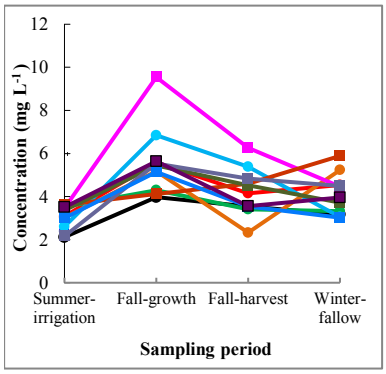

Fig. 2.13 Periodic variation in K^+

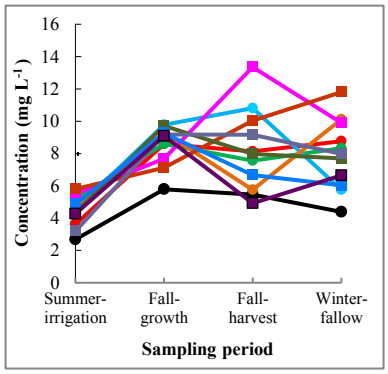

Fig. 2.14 Periodic variation in Mg^{2+}

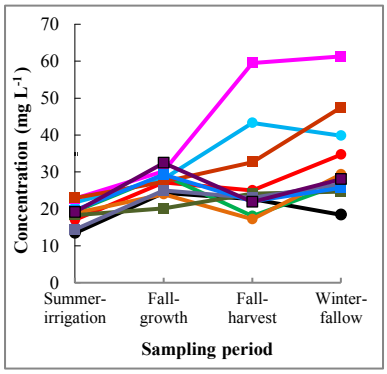

Fig. 2.15 Periodic variation in Ca^{2+}

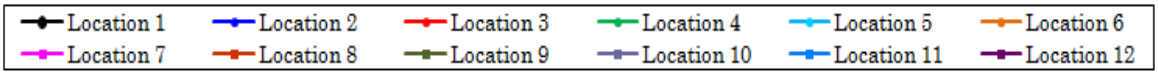

Fig. 2 (2.1 to 2.15) Periodic variation in physico-chemical parameters of water at 12 selected sampling locations(sites) in the upper reach of the Ayase River Basin in Saitama prefecture, Japan (2014)

Among these items, nitrates (NO_3^-), which have an attraction for soil particles, dissolve in water more readily than phosphates (PO_4^-) and are a better indicator of possible non-point pollution of water while the oxidized/temporary ammonium (NH_4^+) and nitrite (NO_2^-) forms are considerably more toxic. All sites except 4, 7, and 9 showed elevated amounts of nitrates in water throughout the samplings (Fig. 2.6). In addition, the fall-growth season showed elevated amounts of nitrites in water samples at site 5 (Ohashi Sluice Gate: OSG outlet) and site 6 (outlet of OSG and others) while site 7 (upland outlet) showed elevated amounts of ammonium. Fig. 2.9 shows the traceable amount of orthophosphate (the detection limit of phosphate is 0.1 mg L^{-1} of the ion-chromatograph used in the measurement) produced by runoffs at sites 3, 4, 6, 11 and 12 from the summer-irrigation to fall-harvest period. Fig. 2.10 presents the distribution of sulfate (SO_4^{2-}) at different sites where site 7 (upland outlet) and site 8 (factory outlet) showed elevated amounts in the fall-harvest and winter-fallow periods. Sulfate is an inorganic anionic substance that forms salts with sodium, potassium, magnesium and other cations. Both sites 7 and 9 along with site 5 (OSG outlet) showed elevated amounts of cations (Na^+, K^+, Mg^{2+}, and Ca^{2+}) between the fall-growth and winter-fallow periods (see Fig. 2.12 to 2.15). Increases in chloride (Cl^-) loads from the summer-irrigation period to the fall growth period (Fig. 2.11) might be related to variety of factors such as fertilizers and agricultural chemicals in irrigation water used in different fields. In particular, site 5 (OSG outlet) showed elevated amount of chloride during the fall-growth period.

Analysis from the Existing Water Quality Standard Perspective

The sampling sites included multiple inflows and outflows of the Ayase River, and some of these inflows and outflows were used as irrigation water sources. Lately, the irrigated water has been discharged to the mainstream directly or through other diversion canals. In Japan, since there is no regulatory act such as the Total Maximum Daily Load (TMDL) in USA, the status of agricultural water quality in the studied area can only be judged from the country's existing standards for irrigation water quality in paddy fields (MAFF, 2009). On that basis, pH values at sites 1, 4 and 9 in different sampling periods exceeded the recommended limit (6.0 to 7.5). Regarding EC, the values in most of the sites exceeded the limit (below 0.3 mS cm^{-1}) from the fall-growth to winter-fallow period. DO with a spatio-temporal average value of 10.4 mg L^{-1} was much higher than the prescribed limit (above 5 mg L^{-1}), and COD values in several sites and periods exceeded the recommended value (below 6 m L^{-1}). For paddy field water, the recommended amount for total nitrogen (T-N) is less than 1 mg L^{-1}; however, only the nitrate-part in most of the samples exceeded the limit. The measured values clearly indicated that the water flowing through the canals and streams in the study area were oversupplied with nutrients, which is called eutrophication.

At the same time, the country has a strict regulation for the environmental water quality in a river, and therefore, the water quality in a river is usually judged based on the country's environmental standard (MOE, 2015). Both standards share some common items such as pH, EC, DO, COD, T-N and several heavy metal constituents (As, Zn and Cu). However, the latter standard is stricter and is similar to other global standards of developed countries. For example, in Japan, public waterbodies such as lakes, ponds, and rivers are classified into several groups, and the health-hazard parameters (Cd, Pb, As, PCBs, Hg etc.) are monitored regularly by responsible authorities. However, the status of agricultural water is dependent completely upon the farmers' personal attitudes and practices. Since many agricultural canals are directly or indirectly connected with public rivers, keeping the agricultural waterbodies healthy is a prerequisite of maintaining the environmental health of rivers and seas.

CONCLUSION

The upper reach of the Ayase River Basin is a typical agriculture-dominated suburb and the Ayase River itself is an agricultural effluent-based stream. In this study, multiple sites were selected on major waterways for more complete characterization and to allow examination of possible impacts related to various land use practices. Results of this study reveal that, in general, mainstream water

quality (the Ayase River) as well as the discharge canals (upper stretch of the Ayase basin) is linked to the ambient land-use practices, and agricultural land flushes more water-polluting agents into the canals and streams between the growing and harvesting seasons, which is early September to late October in the study area.

The control of water pollution from agriculture clearly needs to occur within broader integrated water resource management frameworks that ensure linked land water use together with re-use management. In addition, sustained regulation and water quality monitoring activities at all scales are essential. The findings of this paper provides baseline information and existing status of a rural suburb with agriculture-derived water-pollution, which could be valuable to the design of future participatory (individual and community-based) and policy-making strategies to stop nonpoint source pollution in waterbodies.

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Research article

Soil Health Assessment of Soil under *Miscanthus* × *giganteus* Cultivation

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Abstract Soil health is the capacity of soil to function as a living ecosystem that sustains plants, animals, and humans. Healthy soils support the optimal crop yields and also plays a crucial role in protecting water quality and other aspects of environmental stewardship. Meanwhile, the agricultural damage by the earthquake causes serious crop productivity degradation in Japan. Thus, there is a need for research on crop productivity, especially land under the earthquake disaster. In addition, the global demand for renewable energy resources such as *Miscanthus* spp., mainly the triploid interspecific hybrid *Miscanthus* × *giganteus* (M × g), has increased substantially. Because it has the potential to have a high yield, sequester the carbon into the soils, and improve the soil health. Therefore, the objective of this study was to demonstrate soil health index assessment at *Miscanthus* spp. fields. We investigated (1) to quantify the impact on land use changes including Miscanthus, pasture, and arable land on soil health index. T soil under *M* × *g* increases the over-all SHI value to compare another land use. Therefore, it can be concluded that *M* × *g* is the better land use management option in the cool climate regions such as Northern Japan.

Keywords soil health, soil management assessment framework, *Miscanthus* × *giganteus*

INTRODUCTION

What is a good soil or a bad soil? That is the ultimate question for soil scientists. The soil scientists have been trying to answer that question as well as to find out the way to ensure the soil health. Soil health is defined as the capacity of soil to function to sustain plant and animal productivities, to maintain or improve water and air qualities and to support human health and habitation (Karlen et al., 1997). Soil health index (SHI) assessment involves an evaluation of soil physical, chemical, and biological attributes to know how well the resource is functioning. Therefore, SHI assessment seeks to characterize the overall agro-ecological functions of soil by selecting soil physical, chemical, and biological properties as indicators, measuring them, and calculating a score or index for both the individual properties and overall soil health (Nakajima et al., 2015). Miscanthus spp., as source of biomass energy crop mainly the triploid interspecific hybrid Miscanthus × giganteus (*M* × *g*), has increased drastically. The *M* × *g* has the potential to mitigate greenhouse gas emissions by replacing fossil fuels, sequestering carbon into the soils, and improve soil health (Clifton-brown et al., 2004, Guzman and Lal, 2014). In addition, the *M* × *g* requires low annual energy net and financial inputs, including tillage, planting, and practical management such as fertilizer, herbicide, and pesticide application. Yet, the effects of SHI on soil under *M* × *g* cultivation vary by climate, soil type, management practices, and former land use history. Thus, there is a need for site-specific research on *M* × *g* of SHI.

OBJECTIVES

The objective of this study was to demonstrate SHI assessment at *M* × *g* fields. We specifically investigated to quantify the impact on land use changes including *M* × *g*, *M. sinensis*, pasture, and arable land on SHI. The hypothesis tested in this study was that soil under *M* × *g* increases the overall SHI value to compare another land use.

METHODOLOGY

Study Site and Soil Sampling

The study site was established in 2009 at the Experiment Farm of the Field Science Center for Northern Biosphere, Hokkaido University, Sapporo, Japan (43°04′22″N, 141°20′16″E). According to the Japan Meteorological Agency, the annual average temperature and annual precipitation were 9.48 °C and 1209 mm, respectively from 2009 to 2015. The soil at the study site is classified as Humic Andosols. The undisturbed soil core samples were collected with 100 cm^3 steel soil core sampler (height = 5.0 cm, diameter = 4.8 cm) using a cylindrical hammer-driven core sampler for soil depths of 0-5 cm, with three replicates. In addition, disturbed soil samples were obtained for soil layers at depths of 0-5 cm, with three replicates per plot, using a hydraulic soil sampling device (FV-477, Fujiwara Scientific Company Co., Ltd., Okayama, Japan). The soil samples were homogenized by replicate and sieved through 2 mm sieve and air-dried before the analysis.

Photo. 1 *Miscanthus* × *giganteus* and soil sampling at arable land

Soil Health Assessment

The SHI assessment was conducted by: (1) identifying a minimum data set of indicators, (2) selecting indicator interpretation criteria, and (3) integrating all indicator scores into an overall SHI value (Andrews, et al., 2004, Nakajima, et al., 2015).

The SHI was basically computed by using the Soil Management Assessment Framework (SMAF) (Andrews et al., 2004, Karlen et al., 2001). The details for each step of the SHI assessment is summarized as follows.

1. First, the minimum data set of soil physical, chemical, and biological indicators was selected for evaluating for the management goal. The indicators were selected based on literature review (Andrews et al., 2004, Nakajima et al., 2015).
2. For the second step, the minimum data set indicators were converted into unit less scores ranging from 1 to 5 using the criteria presented in Table. 1. In general, there are three shapes of scoring functions (Karlen and Stott, 1994, Wymore, 1993). If soil quality is improving as level of an indicator increases, a “the more is better” curve is used. Conversely, a “less is better” curve is suitable if soil quality is decreasing as the indicator value rises. Finally, a “optimum” curve is used for those indicators that have an increasingly positive association with soil quality up to an optimal level, but beyond which, soil quality decreases.
3. Finally, after selecting the appropriate curve type and scoring individual indicators, the unit less values can be incorporated in a single. Overall SHI value with appropriate weighting of individual indicators if needed.

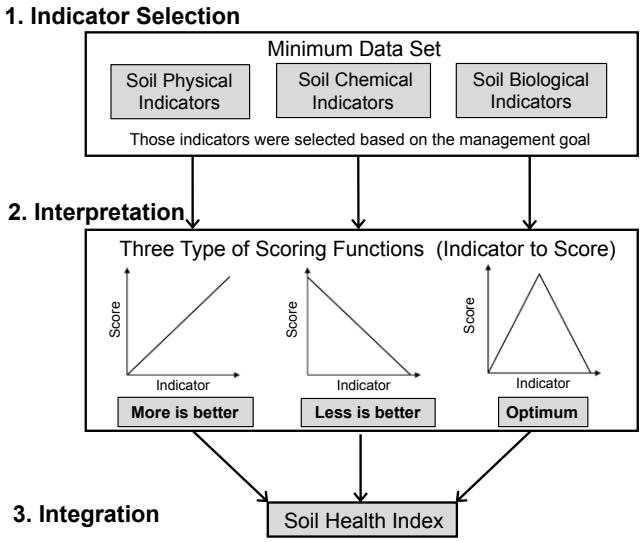

Fig. 1 Conceptual framework for soil health index scoring function analysis adapted from Andrews et al., 2004

Table 1 Scoring function chart for interpretations soil health index with source references

Indicator	Unit	5	4	3	2	1	Reference
BD	Mg m^{-3}	<1.2	1.2-1.3	1.3-1.4	1.4-1.5	>1.5	Lal (1994)
Texture	-	Loam	Silt loam, Silt, Silty clay loam	Clay loam, Sandy loam	Silty clay, Loamy sand	Clay Sand	Lal (1994)
pH	-	6.0-7.0	5.8-6.0, 7.0-7.4	5.4-5.8, 7.4-7.8	5.0-5.4, 7.8-8.2	<5.2, >8.2	Andrews et al. (2004)
EC	µS m^{-1}	<300	300-500	500-700	700-1000	>1000	Lal (1994)
SOC	g kg^{-1}	>50	30-50	10-30	5-10	<5	Gregorich et al. (1994) Lal (1994)
MWD	mm	>2.5	2.0-2.5	1.0-2.0	0.5-1.0	<0.5	Lal (1994)

Statistical Analysis

Analysis of variance (ANOVA) was conducted, and comparisons between the *M* × *g*, *M. sinensis*, pasture, and arable land were performed R Studio (Studio, 2012). Statistical significance was determined when $P \leq 0.05$, unless otherwise stated.

RESULTS AND DISCUSSION

Implementation of SHI Analysis

Among all sites, the SHI ranged from 0.59 to 0.72, and the SHI under *M* × *g* (0.72) was slightly higher than that under arable land (0.59), but with no statistical differences. The SHI were significantly affected among the sites. However, *M* × *g* cultivation could improve the SHI from results SHI assessment. It implies that under the *M* × *g* in Northern Japan influence soil health due to their nutrient cycling between the rhizome and aboveground biomass, and recycling of nutrients from leaf litter and the soil. In addition, this has several possible explanations after the establishment of *M* × *g*, there was no major loss in SOC due to the minimal soil disturbance caused by the introduction of the perennial rhizomatous grass (Zimmermann et al., 2012).

Table 2 Correlation coefficients for each soil physical and chemical properties

	BD	SOC	pH	EC	Texture	MWD
BD	1.000					
SOC	0.202	1.000				
pH	0.089	0.466	1.000			
EC	0.289	0.177	0.336	1.000		
Texture	0.013	0.286	0.772*	0.024	1.000	
MWD	0.144	0.808*	0.650*	0.222	0.396	1.000

** Significant at the 0.05 level.*
BD: bulk density (Mg m^{-3})
SOC: soil organic carbon (g kg^{-1})
EC: electric conductivity (mS m^{-1})
MWD: mean weight diameter from soil aggregation analysis (mm)

The SOC, pH, MWD, Texture were the important key indicators for SHI assessment in this study sites. For soil chemical function, the pH had the highest correlation coefficient. Other important measured attributes were SOC and MWD. However, BD and EC were less responsive to the management practices in comparison to other indicators.

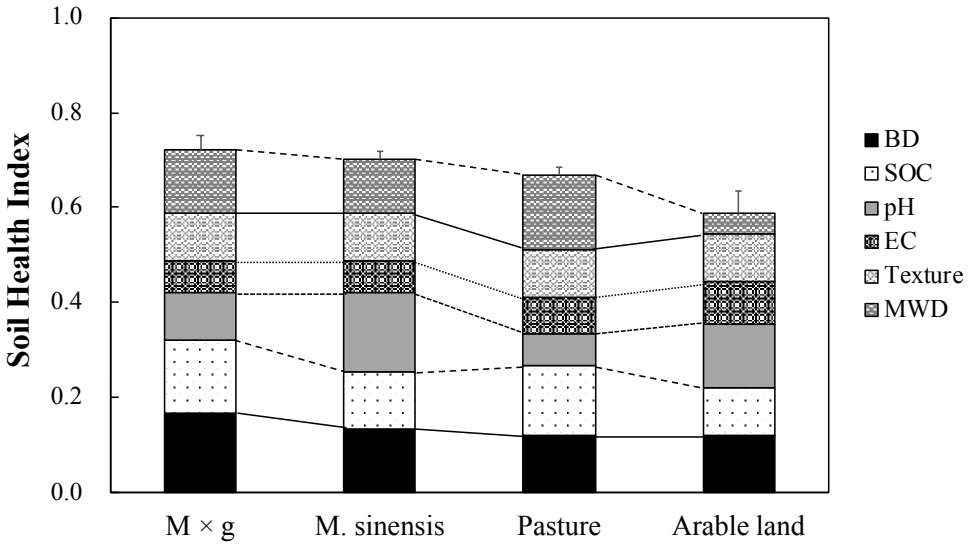

Fig. 2 The soil health index (SHI) at *M* × *g*, *M. sinensis*, pasture, and arable land Error bars indicate standard error

CONCLUSION

This study demonstrates SHI assessment using scoring function analysis for different sites. The hypothesis tested in this study was that soil under *M* × *g* increases the over-all SHI value to compare another land use was supported by the results. Therefore, it can be concluded that *M* × *g* is the better land use management option in the cool climate regions such as Northern Japan. Quantitative assessments of soil health may be useful for optimizing land use plans. However, valid, reliable, sensitive, repeatable, and accessible indicators must be identified and framework for overall evaluation of soil quality must be developed (Nakajima et al., 2015).

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Research article

A Model in Promoting Highland Terrace Paddy Cultivation Technology in Northern Thailand

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Abstract This study aimed to investigate the adoption of Highland Terrace Paddy Cultivation Technology (HTPCT) in Northern Thailand. HTPCT was promoted by the Rice Department in 2003 in four provinces of Northern Thailand under the Royal Development Project. Previous studies showed increased yields using HTPCT while cost of converting sloping lands into terrace paddy can be recouped in a few years. However, despite the promotion of the technology, adoption had not been widespread. To understand the limitations in the adoption process, quantitative and qualitative research was conducted in 5 villages of Chiang Mai and Mae Hong Son provinces located in Doi Ompai Mountain. Results show that overall the respondents had high level of adoption but for two practices, namely, soil fertilizer management and sequential cropping system and livestock production, the respondents had moderate level of adoption. Further, the two production practices were only partially practiced by the farmers. This means that even if the adopters converted their upland rice areas to terrace paddy, they still used some traditional technologies and did not follow all recommended HTPCT practices. The common problems mentioned by the respondents in practicing HTPCT were water and labor shortage, difficulty of land preparation, lack of bio-pesticides and green manure seeds, familiarity with traditional cultivation and their superstition which worked against widespread adoption. Thus, a model in promoting HTPCT in Northern Thailand is proposed. The model takes into consideration the necessary policies, roles of various stakeholders and joint learning among farmers, extension workers and researchers in each step of HTPCT promotion.

Keywords adoption, agricultural extension model, highland, innovation, rice terraces

INTRODUCTION

The mountainous regions distinguish themselves from other regions by complex ecological interactions that result to a high variability of land use and production processes (CGIAR Science Council, 2006). Mountain people are typically independent, innovative, resourceful and adaptive; but also identified as poorest, most remote and disadvantaged people in the world (Ives, 1997; Huddleston et al., 2003). In Thailand, mountainous landscape is found in the northern part of the country which share borders with Myanmar and Lao PDR. Northern Thailand covers an area of 17 million hectares comprising 33 percent of the Kingdom's total land area of 51 million hectares. Agricultural practices in the highland are rainfed, characterized by shifting cultivation and subsistence production of specific crops such as rice, maize, and sesame (Mikled et al., 2001). Agricultural production in hilly areas is low and unstable due to erratic rainfall and poor natural resource endowment. Land degradation is one of the key problems causing decline in crop productivity. One potential strategy to address those problems is to promote terraced paddy fields in the hilly areas. Terraced paddy yields have been found to be almost double those of upland rice, and the cost of converting sloping lands into terrace paddy can be recouped in a few years (Linquist

et al., 2007). While terrace paddy cultivation in upland areas had been in existence for centuries, this system was introduced and promoted in Northern Thailand only in 2003 under the Royal Development Project (Naruebal, 2011). The Highland Terrace Paddy Cultivation Technology (HTPCT) was promoted by the Rice Department in Doi Ompai mountain areas since 2003. Currently, there are 48 farmers adopting this technology but there are many more who have not adopted the technology. Because of this, there is a need to investigate why there is low adoption and subsequently, propose a model in promoting HTPCT to farmers in the highlands.

OBJECTIVES

This study aimed to investigate the practices of Highland Terrace Paddy Cultivation Technology (HTPCT) that were adopted, the problems related to the adoption, and propose a model in promoting HTPCT.

METHODOLOGY

Study Sites

The researchers chose Doi-Ompai mountain areas as the site of the study because this is the first place in Thailand that Highland Terrace Paddy Cultivation Technology (HTPCT) was promoted to farmers by the Rice Department. Four villages of Huai Hom sub-district, Mae La Noi district, Mae Hong Son province and one village of Pang Hin Fon sub-districts, Mae Cham district, Chiang Mai province, which are the working area of Doi-Ompai Highland Agricultural Development Station (DOHAD station) were chosen as shown in Table 1. The farm lots and residences of the respondents are situated within the elevation range of 728 meters asl and of 1,465 meters asl. The site has a semi-humid tropical climate with a mean annual rainfall of 1,217.25 millimeters and a mean temperature of 27.18 degree Celsius. Figure 1 shows the study sites.

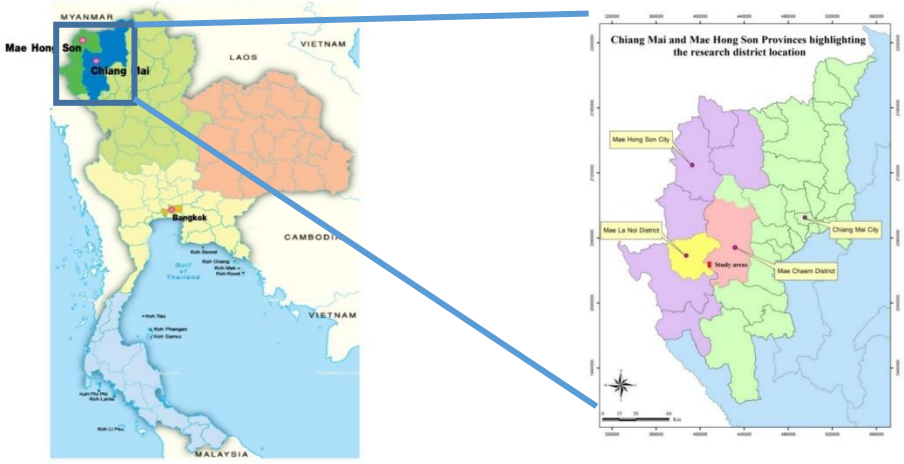

Fig. 1 Chiang Mai and Mae Hong Son Provinces highlighting the research district location
Source: LDD (2014)

Research Design

Survey research was employed to determine the respondent's adopted practices and level of adoption of HTPCT while secondary data review, key informant interviews (KIIs) and Focus Group Discussion (FGDs) were used to gather data about the agencies involved in HTPCT.

Population and Sampling

Stratified random sampling was employed to determine the sample size used for this study. There were 181 households form the 5 villages which are the working areas of the Doi-Ompai highland agricultural development station project, Mae Chaem district, Chiang Mai province, Thailand . All farmers from the 5 villages were separated into adopters and non-adopters groups based on the information from the Rice Department. To determine the number of samples for adopters from each village, a stratified sampling technique was used according to the formula given by Sukhatme (1954) as in Eq. (1) with 10 percent margin of error. Table 1 shows the sample size of the study.

$$N = \frac{NQ}{PC^2 (N-1) + Q} \quad (1)$$

Where: n = sample size
N = population size
P = population of farmers who adopted terrace paddy cultivation technology
C = 10%
Q = 1-P

Table 1 Sample size of adopters

Name of village	Name of sub-district	Number of households	Number of adopters	Sample size of adopters
Baan Sadosa	Pang Hin Fon	60	12	8
Baan Sam	Huai Hom	38	10	7
Baan La-Ang Tai	Huai Hom	7	3	2
Baan Pak Pai	Huai Hom	29	6	4
Baan Mae-Lae	Huai Hom	47	17	12
		181	48	33

Source: DNP (2013) and RD (2013)

Highland Terrace Paddy Cultivation Technology (HTPCT) represents the recommended technologies rice paddy cultivation. It combines indigenous and research based knowledge. Based on survey results, on the basis of the weighted mean ratings of each of the seven recommended HTPTC practices, the respondents had high levels of adoption of five practices, namely, land preparation, seeding and transplanting, pest management, water management, and pre-production practices, while the respondents had moderate level of adoption for two practices, namely, soil fertilizer management and sequential cropping system and livestock. This shows that these two agricultural practices were only partially practiced by the farmers (Table 2).

For the overall adoption or use of recommended HTPCT practices, the weighted mean scores were computed and categorized into three levels which are high, moderate and low levels of adoption. The results showed that the overall adoption of recommended HTPCT practices of the adopters had a mean of 2.37 described as high level of adoption which ranged from 1.94-2.75 (Table 2). Majority of the adopters (60.6%) were described as practicing high level of adoption while the rest (39.4%) were described as practicing moderate level of adoption which means that even if the adopters converted their upland rice areas to terrace paddy, they still used some traditional technologies and did not follow all recommended HTPCT practices. The fact is that most farmers are unable to adopt the whole package of HTPCT at once but, rather, they adopt some of the technology components in a sequential or step-wise manner depending on the agro-ecological characteristics of their terrace paddy field, their knowledge and understanding on the technology and their cultural beliefs. The common problems mentioned by the adopters in adopting HTPCT were water and labor shortage, difficulty in paddy preparation, lack of bio-pesticides and green manure, familiarity with traditional cultivation and their superstition.

Table 2 Rank based on the mean weight of the respondents' adoption level of seven issues of recommended HTPTC practices

HTPTC Practices	Mean	Rank	S.D.
Land preparation	2.48 (HA)	1	0.26
Seeding and transplanting	2.45 (HA)	2	0.51
Pest management	2.42 (HA)	3	0.51
Water management	2.42 (HA)	3	0.60
Pre-production	2.40 (HA)	5	0.29
Soil fertility management	2.15 (MA)	6	1.00
Sequential cropping system and livestock	1.73 (MA)	7	0.98
Overall Mean		2.37 (HA)	
S.D.		0.22	
Range		1.94 - 2.75	

Legend: *Scale Limits* *Descriptive Rating*
2.34 – 3.00 *High level of adoption (HA)*
1.67 – 2.33 *Moderate level of adoption (MA)*
1.00 - 1.66 *Low level of adoption (LA)*

A model to improve adoption of HTPCT is proposed (Fig. 2). The model takes inspiration from Rivera et al (2006).

Policies affecting HTPCT and relevant agencies: Based on KIIs, policies affecting HTPCT are those that promote food security, conserve the forests and promote tourism. These policies promote and facilitate the creation, sharing, and use of HTPCT. These policies have to be in place and should be enforced. The model shows relevant agencies who are working together under the royal project to promote HTPCT. The model outlines the key roles that each of the agencies have to perform in the promotion of HTPCT.

Step 1: Community analysis: The conduct of the community analysis is necessary to understand the biophysical characteristics, resource endowments, farmer characteristics, practices and networks. These are necessary to determine the support that will be given to farmers.

Step 2: HTPCT development and promotion: The royal project stations would serve as learning hubs for farmers, extension workers and researchers. Farmers who volunteer to conduct experiments in their own field will introduce HTPCT to other farmers.

Step 3: Provision of extension and knowledge support: Even though terrace paddy is located in the upstream areas, farmers often encounter water scarcity because they depend mainly on rainfall and do not have good irrigation systems or water storage systems. It is thus important to include technology on constructing small reservoirs or setting gravity irrigation system by providing pipes and other necessary equipment. The government might consider wage subsidies to pay labor wages in converting terraces as the task is very labor intensive and is one of the deterrents in the adoption process. Given moderate adoption, it is important to enhance knowledge in seed selection, transplanting method and pest management. Agricultural extension workers could use the handbook of HTPCT as a guideline and adapt the topics based on farmer's needs.

Step 4: Participation in environmental conservation: Based on KIIs, farmers should have better quality, security of life conditions and ability to protect the environment. People in the highlands must first meet their basic needs through increased yield. The next goal is the enhancement of the security of life by ensuring enough income. The last step of development is creating ideology in environmental conservation. When people have better quality and security of life, they are ready to protect their environment and work for community voluntarily.

Outputs and outcomes: The expected outputs from promoting HTPCT are increased terrace paddy areas and increased reforestation areas. The expansion of new terrace paddy areas which is the first expected output offers opportunities to improve rice security in Northern Thailand. When farmers have enough rice for their household consumption, they tend to reduce shifting cultivation areas and lead to increased reforestation areas. Both expected outputs would contribute to sustainability of highlands development in terms of rice security, environmental sustainability and sufficiency income which are the outcomes of promoting HTPCT.

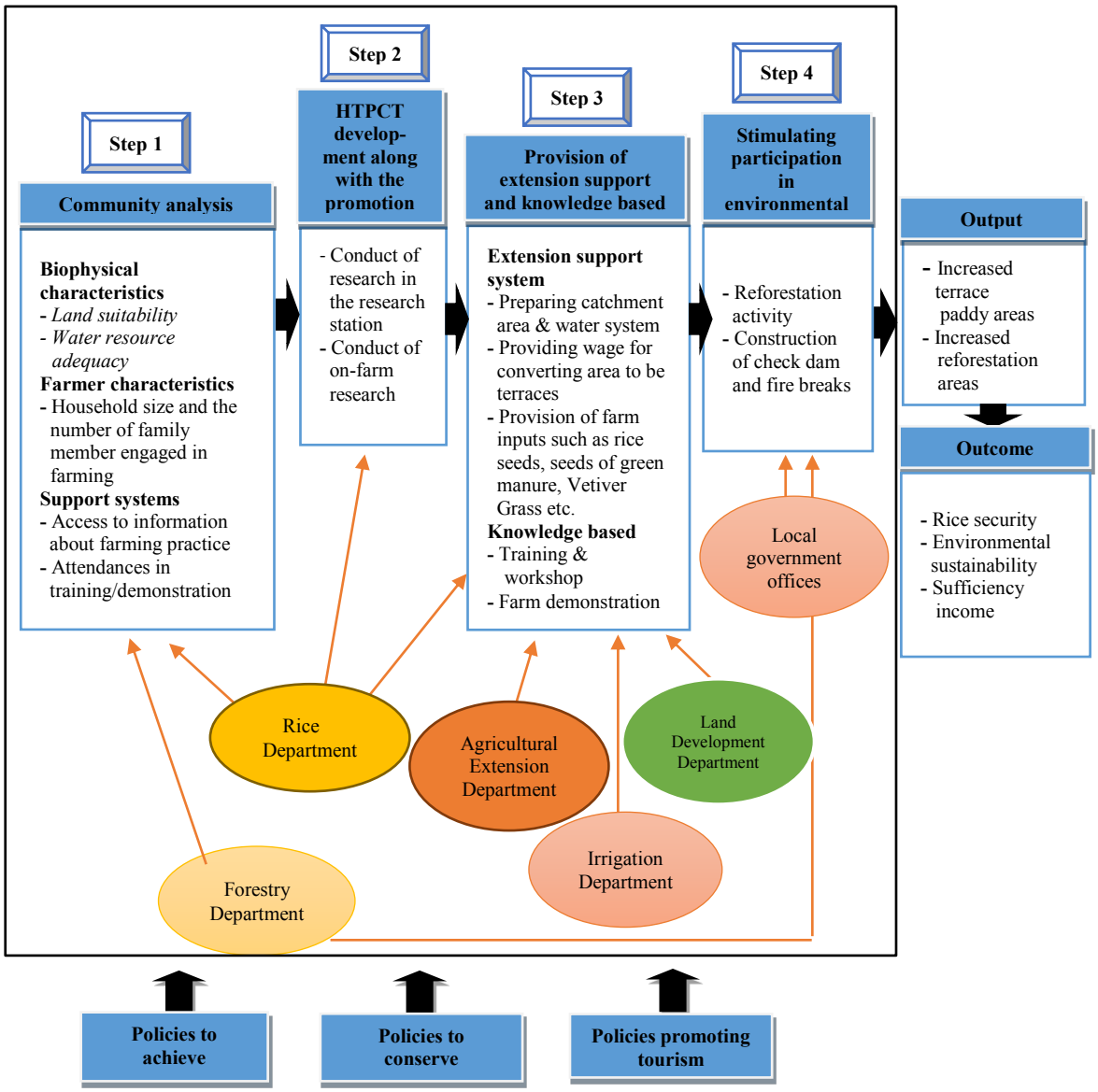

Fig. 2 Proposed model in promoting HTPCT

CONCLUSION

Based on the results of the study, there are very few adopters of HTPCT and those that adopted HTPCT do not fully adopt the recommended practices. The common reasons given by the adopters are water shortage, labor shortage, the difficulty of soil preparation, lack of the source of the bio-pesticides and green manure seeds, familiarity with traditional cultivation and their superstitions. The study presupposes that improvements in the adoption and diffusion of HTPCT can still be improved through the model that had been proposed.

RECOMMENTDATIONS

To the Agricultural Institutions Involved in Promoting HTPCT.

1. Maintain a close link with all involved agencies: In the process of promoting HTPCT, integrated work is needed. The Doi-Ompai Highland Agricultural Development Station can be used as the center of assembly. The meeting among all involved agencies should be held regularly to set

the plan for promoting HTPCT and also to discuss the solutions when the problem or constants have been found in field works.

2. Co-generate knowledge among farmers and researchers: Based on the results, the ethnic groups have their own rice farming wisdom. For example, they have the way to maintain traditional rice variety production for their consumption. The technology that corresponds with their traditional wisdom can be studied and may be useful in the context of highland production. Thus, in the process of research and development on HTPCT, researchers should study and collect the traditional rice farming wisdom from farmers in the fields and combine it with scientific knowledge to improve HTPCT.

3. Providing catchment areas for irrigation purposes: Water shortage may limit the adoption of HTPCT. Thus, the Royal Irrigation Department should provide catchment areas to farmers by constructing small reservoirs such as ponds or tanks for water storage.

4. Providing training course regarding specific areas of technology: Researchers of the Rice Department should provide a training course emphasizing specific topics to enhance skills of farmers in applying HTPCT; for example, System of Rice Intensification (SRI), Alternate Wetting and Drying (AWD) technique, Integrated Pest Management (IPM) etc.

ACKNOWLEDGEMENTS

The authors acknowledge the research grant provided by the German Academic Exchange Service (DAAD) and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) that sponsored the conduct of this research. Special thanks to Mr. Ketsada Bunart, the Director of the Doi-Ompai Highland Agricultural Development Station and Mr. Niphon Boonmee, a researcher from Rice Department for their support to the authors. Last but not the least, the authors also acknowledge the cooperation of all farmers.

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Research article

Significant Contribution of Farmer First in Farmer-Trainer for Environmentally-Friendly Agriculture and Rural Development

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Abstract With the huge number of mouths to feed, problems and challenges on food safety and sufficiency in terms of the decreasing number of new farmers and increasing number of aging farmers arises in Japan and the Philippines. Young generations do not see farming as a lucrative career. In order to attract the youth to engage into farming, one of the potential solutions is the farmer-trainer, which is a generic term used to address farmers that provides and conducts training to farmers, and other actors in a community. As a farmer-trainer, farmer also serves as an innovator and educator and promoter of indigenous knowledge that are environmentally-friendly and safe. Prior to conducting research on farmer-trainer, this paper initially aims to identify the stakeholders and their respective roles, and to review the development and contribution of farmer first movement that significantly affect the farmers to invent, try, and share the new knowledge and innovations to other farmers and actors in their respective communities since 1987. Upon reviewing related literatures on farmer first and examining farmer-conducted trainings in the Philippines and Japan using case study approach, it became clearer that farmer first movement still plays a very important role in extending agricultural knowledge and technologies that are environmentally-friendly and contributes to rural development. This research highlights the importance of farmer first movement in boosting confidence of farmers to conduct their own trainings and to spread safe, environmentally-friendly agricultural systems especially for rural development through the development of "theme-community".

Keywords farmer-trainer, Farmer first, agricultural training, farmer-to-farmer

INTRODUCTION

With increasing population, demand on food and food production also increases. According to Asia Population (2017), Asia accounts for 60% of the world population, and Japan with 126.89M and the Philippines with 102.96M are respectively on the 6th and 7th place of the top 10 populated countries in Asia. With the huge number of mouths to feed, problems and challenges on food safety and food sufficiency in terms of the decreasing numbers of new farmers arise.

The shortage of farmers is one of the greatest factors limiting agricultural sustainability in Japan. This is due to lack of new farmers and aging of existing farmers, with an average age of 67 years old (Muramoto, et al., 2010 and MAFF Japan, 2016). The Philippines' food security on the other hand, is also at risk, as millions of farmers and fishermen are getting too old with an average

age of 57 years old. Younger generations are not keen on taking over the farm and do not see farming as lucrative career (Alave, 2011).

To uplift the morale of farmers and persuade younger generations to farming, proper and effective dissemination of technologies must be considered. Training for farmers has been proven to generate variety of results. The study of Murshed-E-Jahan and Pemsl (2011) on Bangladeshi small farmers concluded that building the capacity of farmers through training is more valuable than the provision of financial support in terms of raising production and income.

Extension Agents (EA), researchers, and practitioners acknowledge the important role of farmers as scientists in the creation of agricultural technology and educators to disseminate such innovations. Indigenous knowledge has been accepted as valid and useful in agriculture, while farmers have been increasingly recognized as innovators and experimenters (Chambers et al., 1989). According to Rhoades (1989), farmers and scientists had much to learn from each other, and particularly we had much to learn from farmers.

OBJECTIVE

This paper aims to identify the stakeholders and their respective roles, and to review the development and contribution of farmer first movement that significantly affect the farmers to invent, try, and share the new knowledge and innovations to other farmers and actors in their respective communities.

METHODOLOGY

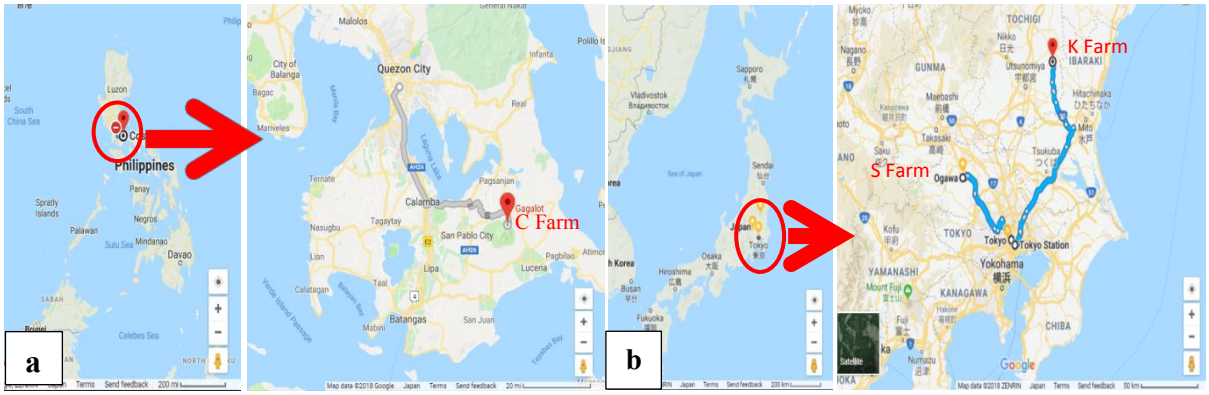

Fig. 1 Map of the Philippines (a) and Japan (b) showing the location and the distance of farms from each country's capital

This study is a type of qualitative and secondary research which utilized primary and secondary data. The researchers identified the subject domain and acquired information regarding the topic from unpublished and published reports, scientific journals, books, and articles. The research also examined interviews and farmer-conducted trainings in Japan and the Philippines. Farms in Japan were chosen as these farms are well-known to conduct trainings for decades while in the Philippines, the farm is an accredited private extension service provider for the Agriculture Training Institute (ATI) of the Department of Agriculture (DA). Through case study approach, a total of three farms were visited to understand and observe training conducted by the owner-farmer-trainer, specifically S Farm in Saitama Prefecture, Japan (located about 60km North-West from the center of Tokyo) on 13 May 2017; K Farm in Tochigi Prefecture, Japan (located about 150km North from the center of Tokyo) on 3-5 August 2017; and C Farm in Majayjay Town, Laguna Province, Philippines (located approximately 110km South of Metro Manila) on 23 August 2017. Figure 1 shows the location of the farms and its proximity to the capital in the Philippines and Japan. Data from different sources were reviewed, compared, analyzed and interpreted.

RESULTS AND DISCUSSION

Farmer First Movement

The idea of 'farmer first' was first introduced in 1987 when Chambers et al. (1989) compiled the work of several researchers that studied farmer participation in agricultural research. The concepts started by identifying farmers' problems and going back to them with alternatives. The idea proposed by social scientist in 1980s, was to involve farmers more systematically and actively in the research process to take advantage of farmer skills to experiment.

Farmer first movement was a result of gathering of small minority social and biological scientists that collaborated with farmers to further understand the reason for non-adoption of technologies in 1980s. According to Chamber et al. (1989), non-adoption of technology was more often attributed to ignorance of farmers that resulted to the prescription of extension education in 1950s to 1960s. On the other hand, non-adoption was ascribed to farm level constraints with the gaps in yield between research stations and farms that leads to a recommendation to modify and make the farm more like a research station in 1970s. In 1980s, analysis about non-adoption was interpreted as neither the farmer nor the farm is the problem, but the technology and the faults of technology can be traced to the priorities and processes which generate it.

Unlike the conventional Transfer-of-Technology (TOT) model which greatly favors the large-scale or resource-rich farmers whose conditions are the same to those research stations, the farmer first prioritized farmers' needs first. It aims to provide the appropriate technology for the needs and opportunities of resource-poor farmers.

Stakeholders and Their Roles

In Farmer first, farmers were the ones who detected and assessed their problems, needs, and priorities in their farms. Upon evaluation of the needs and problems, farmers conducted their own experiments in the farm. Successful innovations by farmers were transferred and spread to other farmers by farmer-to-farmer approach or by the "farmer-trainers" which is a generic term used to address farmers that provides and conducts research and training to farmers and other actors. Contrasting to the farmer first, the scientists were the main responsible in the assessment of problems, needs, and priorities of farmers, and key experimenters in TOT. Moreover, researches and innovations generated in research stations and laboratories were transmitted to farmers by EA. Table 1 summarizes the difference between TOT and farmer first. This clearly conveys that farmers were in the center in every activity and serve as the main actors or stakeholders in Farmer first.

Farmer-trainer does not rule out the need for scientific research, hence they open a new area of research. Chambers (1989) stated that farmers must be empowered to learn, adapt and do better on their own and on their farm field, outsiders such as scientists, EAs or NGOs should just assist and give them principles, methods and technology choices. Moreover, Franzel et al. (2015) acknowledged that farmer-trainer needs coaching and technical supervision and assistance from scientists and EAs, otherwise they may perform poorly.

Table 1 Differences between Transfer-of-Technology and Farmer First

Activity Indicators	Transfer-of-Technology	Farmer First
Problems, needs, priorities, knowledge, and analysis (are determined by)	Scientist/ Researchers	Farmers
Main location of technology or action generation (are in the)	Research Stations and Laboratories	Farm
Transfer of technology (are done by)	Extension Agents	Farmers
Central experimenters	Scientist/ Researchers	Farmers

Note: Compiled by author based on Chambers et al..(1989); Franzel et al. (2015); Hocde (1997); Rhoades (1989); and Simpson et al. (2015)

Farmer First in Farmers' Innovation and Technology Dissemination

In experimentation, farmers are more prepared to take risk and go into the unknown than conservative researchers. Chambers et al. (1989) discuss about the interest and involvement of farmers in experimentation in a holistic approach, wherein farmers seek interactions within the whole farm system, rather than redesign the whole farm at once. This approach also includes experimentation with solutions that lay within farmers' own capacity than experimenting with conventional high-input solution. Experimenting farmers are starting to believe more in themselves, and in their ability and strengths. The experiments are theirs. Farmers are participating in the construction of something new and feeling happy and proud to discover new horizons, to broadcast their work and teach their neighbors (Hocde, 1997).

The attitude of having the conviction that outsider knowledge has a universal validity and application which should override whatever the farmers know, prevent learning from farmers. Reversals of attitude are essential complements of the farmer first method. Respect for farmers, a sensitive interaction with them, a recognition of them as fellow professionals and colleagues were necessary for them to maximize their potential (Chamber et al., 1989).

Farmers are driven to satisfy their thirst for knowledge hence, salaries and allowances are not needed to motivate them to volunteer in serving as lead farmers or 'farmer-trainer' (Hocde, 1997 and Simpson, et al, 2015). Significantly, almost all traditional agriculture is a result of spontaneous spread of innovation from one farmer to another, from one village to another and even clear across continents (Bunch, 1989).

Farmers experimenting and disseminating innovations is not a new approach. According to Franzel et al., (2015), farmer-to-farmer extension programs have been used significantly in the Philippines since 1950s and in Central America since 1970s. In the Philippines, successful and outstanding farmers with knowledge on innovations are recognized as Magsasaka Siyentista (MS) or Farmer-Scientist by the Department of Agriculture (DA). According to Qamar (2012), MS play vital roles in serving as researchers and EA in their respective areas by showcasing and promoting indigenous and science and technology-based agriculture, forestry and natural resources technologies based on their own farming experiences. These farmers are not only active participants but also serves as facilitators and initiators of technology transfer process.

Table 2 shows the similarities and differences of the three farms selected in Japan and the Philippines. C Farm was established in 2006 as a hobby farm of a former IT executive with no agriculture background. The farm has been performing and conducting experiments and trainings on Organic Agriculture (OA) production management. Based on the observation of trainings and farmer interview, C Farm performs modifications and experimentations of different innovations that will suit their farm's condition and needs. Dissemination of these innovations through trainings are conducted in their own farm to their neighbors and other interested individuals and groups. As part of the interview the Farmer-trainer said that "at first we just wanted to produce safe food for family consumption, we don't want to feed our children toxic and chemicals".

The farmer-trainer added, "When we started, it was very hard for us to do OA, we even needed to go abroad to attend trainings and to adopt different technologies, and a lot of Filipino farmers does not have the capacity or means to study abroad and attend trainings". Therefore, farmer-trainers are very motivated to share the knowledge and innovations to others to promote the spread of OA for safe and healthy food and environment.

On the other hand, farmer-trainers of S Farm and K Farm were both from farming family and received formal education on agriculture in Japan. Established in 1971, S Farm conducts experiments and trainings in Ogawa Town, Saitama Prefecture. The farmer-trainer delivers his motivation and philosophy of OA, the development process and practices of his farm and how OA transformed the community through the years. Training observation showed that the farmer-trainer is really determined to encourage the community and other stakeholders; he offered the advantages and positive effects of practicing OA. He also pointed out that it must be a community adoption because it will be no effect if it is just one farm. Aside from conducting his own training in his farm, the farmer-trainer supports different activities to promote OA not just in his community but in the whole country.

Table 2 Similarities and differences between three farms evaluated

Name of Farm	C Farm	S Farm	K Farm
Ownership Type	Family-owned	Family-owned	Family-owned
Farming background of owner	From a non-farming family but attended trainings in the country and abroad	From a farming family; but in OA: develop the techniques and methods through trial and error	Family graduated from an agricultural university in Tokyo; in OA: trial and error
Location	Majayjay, Laguna, Philippines	Ogawa Town, Saitama Prefecture, Japan	Nakayama, Tochigi Prefecture, Japan
Established Since	2006	1971	1981
Farm Management	OA	OA	OA
Modified/ Innovations	Zero-waste farming, vermicomposting, farm integration	Cycle-based organic farming: plant, soil, and animal nutrients, circulating energy	Tunnel type plastic houses; rejected crops as feeds, and animal dung for composting
Training Program/ Training conducted	Lakbay aral tour, green salad tour, and trainings for days; Agri-tourism workshop	One day seminar plus farm tour and farm stay (6months-1 year)	One day seminar and tour; Farm stay, Field works, once a week meeting (2-3 years)
Trainees	Farmers, teachers, students, government workers, EA, businessmen, and hobbyist	Farmers, teachers, students, government workers, EA, businessmen, and hobbyist	Farmers, teachers, students, hobbyist and those who wants to do and establish OF

Source: Farm visits and Farmer-trainer interviews, 2017

K Farm in Tochigi Prefecture was established in 1981. Participation, observation, and interview revealed that the main objective and mission of the farm are to educate new farmers and assist them in putting up their own organic farm. The farmer-trainer delivered his short lecture about the history of their farm and some data about the diseases, and nutritional contents of their organic crops. During the interview, he said that they are doing OA because it is safe for humans and the environment, and they are involved in the *Teikei* system, wherein customers trust them to produce safe foods. "There are many people who are interested to do OA, and they just need someone to assist them", he added when asked about his motivation to conduct trainings.

Based on initial observations, successful farmers in Japan and the Philippines seem to play important role as trainers in offering and conducting trainings to further disseminate innovations and experiences regarding the success of their farms. Even if their farms are not easily accessible, trainees are willing to travel all the way to their farms just to attend their trainings. These farmer-trainers are proof that farmer and outside actors such as researchers and EA needs to work complementarily. Farmer-trainers, assisted by researchers and EA have the confidence to do their own innovation and share it to other farmers and beneficiaries. Therefore, farmer first still plays a very important role in farmer-trainers in experimenting and disseminating innovations.

Farmer First in Environmentally-Friendly Agriculture and Rural Development

As shown also in Table 2, all farmer-trainers practice OA and their agricultural innovations are more for the conservation of the environment. Innovations include the zero-waste and cycle-based farming. Based on the farm-interviews and observations, zero-waste farming can be defined by utilization of waste as the main ingredient for one of the inputs in the farm. It can be easily understood by the observation done on the farmer-trainer at the C Farm in the Philippines, where farm waste such as trimmings, weeds, and animal dung were collected and used as the main ingredient of compost for organic fertilizer in the farm. Similarly, the K Farm in Japan also utilizes rejected crops as feeds and animal dung as compost. Cycle-based farming, on the other hand is closely related to zero-waste farming, as it also follows the same concept of utilization of farm waste and other farm inputs to produce natural fertilizers and pesticides. The farmer-trainer of S

Farm in Japan believes that in nature, everything is part of the cycle, and even without the help of mankind, nature can maintain its own.

The three farmer-trainers' common goal is to have self-sufficiency in the community and spread it nationwide. Self-sufficiency in a way that they can provide the needs and demands for food of the current generation by utilizing indigenous knowledge, available resources and innovations such as zero-waste and cycle-based farming, that place back nutrients to the soil. Through this environmentally-friendly agriculture, the capability to produce of the future generation is not at risk.

To achieve their goals, these farmer-trainers also acknowledge the importance of enhancement of "theme-community" for rural development. Their aims to bring people together who shares common interest, objectives, and passion motivates them to conduct trainings. Through these trainings, their passion, motivation, and experiences are being transferred and disseminated to small-scale farmers and other actors including younger generations in the community that will eventually be persuaded to engage themselves in an environmentally-friendly agriculture that will hopefully lead to rural development.

CONCLUSION

This research concludes that farmer first movement still plays a very significant role in boosting confidence of farmer-trainers in Japan and in the Philippines to invent and modify innovations and conduct their own trainings as they are the main actor and center focus of the farm activities. In addition, farmer-trainers are more motivated and passionate to spread safe, environmentally-friendly agricultural systems using their innovations in organic agriculture.

Farmer-trainers also acknowledge the importance of enhancement of "theme-community" that brings people with common interest and passion together. Farmer-trainers' passion, motivation, and experiences are being disseminated to small-scale farmers and other actors including younger generations in the community that will eventually be persuaded to engage themselves in an environmentally-friendly agriculture that will hopefully lead to rural development.

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Research article

Comparison of Soil Properties of Farmlands Applied with Organic and Inorganic Fertilizers in Kampong Cham Province, Cambodia

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Abstract In Cambodia, soil capability for rice production in lowlands has been almost documented, but only little is known about the properties of upland soils for growing non-rice crops. Current agricultural land use practices together with severe climatic conditions and population pressure have led to soil degradation, loss of soil fertility which declining crop yield and increase the risk of malnutrition. Therefore, the objectives of this study were 1) to compare the soil properties of farmlands applied organic and inorganic fertilizers, 2) to measure the organic fertilizer dependence in Samraong and Baray Communes. The questionnaire survey was conducted and farmer representatives were interviewed. Soil samples were collected from 20 different locations. Soil samples were analyzed for its pH, Electrical conductivity (EC), organic matter, total nitrogen (T-N), total phosphorus (T-P), calcium (Ca^{2+}), potassium (K^{+}), sodium (Na^{+}), water content, and permeability, and the Pearson coefficient correlation was used for the statistical analysis. Organic fertilizer dependence was classified into 3 categories not dependent, moderately dependent and highly dependent, 40.0%, 30.0%, and 30.0%, respectively. The results of statistical analysis showed that in Samraong Commune there was no trend detected, despite in Baray Commune there was positive trend detected between organic fertilizer dependence and soil properties.

Keywords soil properties, fertilizers, organic, inorganic, dependency

INTRODUCTION

Cambodia is located in the southern portion of Indochina peninsula, and sheared its borders with Thailand, Laos and Vietnam. The total land area of Cambodia is 181,035 km^2 and current population is 16.2 million in which only 78.3% is living in rural areas. Agricultural production in Cambodia is concentrated in the northwestern districts bordering Thailand, on the central plains surrounding the Tonle Sap Lake and its river systems, along the Mekong River towards the Mekong delta. The total land use area under major agricultural crops was about 4.5 million ha (MAFF, 2012). Agricultural lands could be categorized into two distinct topographical regions lowlands and uplands. Lowland soils mainly support rice framing interspersed with field crops, vegetable gardens and fruit trees. Upland soils are mainly used for rubber (*Hevea brasiliensis*) plantations, maize (*Zea mays*), cassava (*Manihot esculenta*), soybeans (*Glycine max*), mug-beans (*Vigna radiata*), peanuts (*Arachis hypogaea*), sesame (*Sesamum indicum*), sugarcane (*Saccharum officinarum*), and fruit trees (Ministry of Agriculture, Forestry and Fisheries, Cambodia, 2012). Moreover, the farming system in Cambodia is normally based on the application of chemical

fertilizers, chemical pesticide, fungicide and herbicide (FAOSTAT, 2016). Fertilizers play a key role in agriculture production, cultivation of a major crop that rely on the use of high rates of inorganic fertilizers continuously for several years, often lead to unsustainability in production and also pose threat to the environment (Smith et al., 1990), thought chemical fertilizers are high in nutrient contents and are rapidly taken up by plants but relatively expensive. Excessive use of fertilizers results in various problems, such as nutrients loss, surface water and groundwater contamination, soil acidification, reductions in useful microbial communities, and increase in sensitivity of harmful insects (Chen J.H., 2006). Recent year, with the support from the government and non-governmental organization (NGOs), many Cambodian farmers realized and looked for a better practice which could harmonize with natural environment and human health. There were several practices carried out to move forwards from the used of inorganic fertilizers to promote on the application of organic fertilizers such as green manure, compost, and bio-liquid fertilizer in some provinces of Cambodia. With the use of organic fertilizers could eliminated and minimize the use of inorganic fertilizers as well as improved on soil, water and environmental quality. By the several practices that carried to promote the use of organic fertilizers in order to meet the requirement of nutrients in soil, so each practice may contribute to difference of positive and negative effect attributes to farmlands.

OBJECTIVES

The objectives of this study were 1) to compare soil properties of farmlands applied organic and inorganic fertilizers, and 2) to measure organic fertilizer dependence in Samraong and Baray Communes, Kampong Cham Province, Cambodia.

METHODOLOGY

Study Site

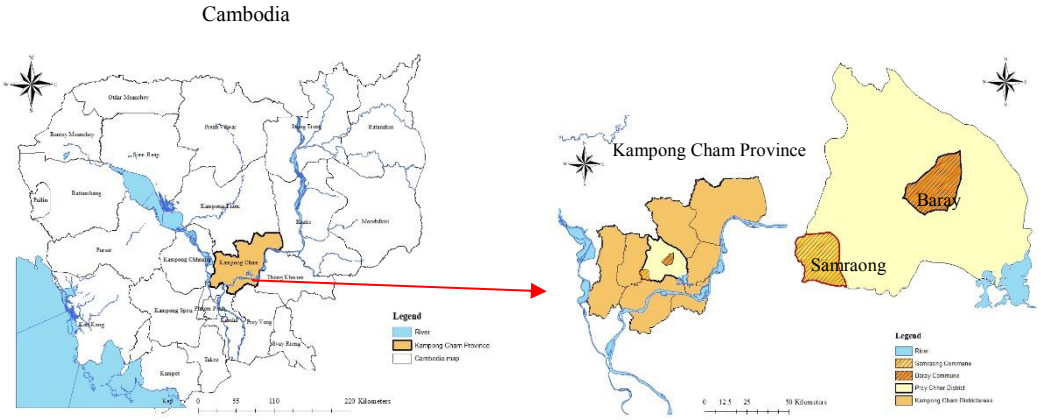

Fig. 1 Map of the study areas

Kampong Cham Province is located in the central region of Cambodia. The population is 1.6 million. Prey Chhor District is located in Kampong Cham Province and it's divided into 15 communes and 176 villages. The major soil types in this areas are brown hydromorphics, regurs and cultural hydromophics (Kampong Cham Administration, 2010). Samraong and Baray Communes were selected for this study. In Samraong and Baray Communes the population were around 8,123 and the total number of families were 1,714 and 11 villages and 10,637 and the total number of families were 2,446, and 13 villages, respetively. Farmers in both communes were mostly smallholder farmers with less than 1 ha of cultivated agricultural land (CDB, 2010). In Samraong and Baray Communes the main economic activity of farmers are rice cultivation in low land and vegetables in upland fields are also cultivated (ERECON, 2009). In order to increase the productivity of farmland local farmers tend to use high amount of chemical fertilizers. The number

of families using chemical fertilizers was around 1,587 in Samraong Commune and 1,479 in Baray Commune. There was a project implemented to promote sustainable agriculture in Samraong Commune by Japan International Cooperation Agency (JICA) from 2011 to 2016. The target group comprised of 450 households in Samraong Commune. A similer project was implemented in Baray Commune to promote organic farming through composting and liquid fertilizer by Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan from 2006 to 2009, 45 households were the target group.

Questionnaire Survey

Questionnaire survey was conducted in Samraong and Baray Communes. Farmer representatives were interviewed. The questionnaire included questions about general information, economical condition and agricultural condition as shown in Table 1.

Table 1 The contents of questionnaire survey for the field activities

Category	Details
General information	Name, Age, Gender, Level of education, Occupation
Economical condition	Working condition, Land areas, Crops cultivation, Labor use in agriculture, Cost of fertilizers
Agricultural condition	Problems in agricultural land, Kinds of agro-chemicals, Kinds of livestock

Soil Analysis

Soil samples were collected from 20 different locations. Soil sampling sites are shown in Fig. 2. There were 20 disturbed and 20 undisturbed soil samples were collected from Samraong and Baray Communes in August, 2017. Disturbed soil samples were used to analyze for its pH, EC, water content, organic carbon, total nitrogen, total phosphorus, particle size distribution, calcium, potassium and sodium. Undisturbed soil samples were analyzed for its permeability and bulk density. The experiment was conducted in September, 2017. The details of soil analysis are shown in Table 2.

Table 2 Soil indicators for the laboratory activities

Physical properties	Water content	Particle size distribution	Organic matter	Permeability
Methods	Gravimetric method	International pipette method	Ignition loss	Saturated hydraulic conductivity (Ksat) method
Chemical properties	pH	EC	T-N and T-P	Ca^{2+}, K^{+}, and Na^{+}
Methods	Dilution	Dilution	Absorption spectroscopy	Portable absorption spectrophotometer

EC: Electrical conductivity, T-N: Total nitrogen, T-P: Total phosphorus, Ksat: Saturated hydraulic conductivity, Ca^{2+}: Calcium, K^{+}: Potassium and Na^{+}: Sodium

Organic Fertilizer Dependence

Organic Fertilizer Dependence of the farmers in Samraong and Baray Communes was analyzed based on nitrogen application in organic and inorganic fertilizers during complete growing season. Total nitrogen application by farmers was calculate using equation (1) and Organic fertilizer dependence was calculated using equation (2).

$$TN = A \times N / 100 \quad (1)$$

Where, TN is total nitrogen content (kg ha^{-1} yr^{-1}), A is the amount of fertilizers applied (kg ha^{-1}), and N is the percentage of nitrogen concentration of the fertilizers (%)

$$OFD = (ON_1 + ON_2 + ON_3 + \ldots + ON_n) \div (ON_n + IN_n) \times 100 \quad (2)$$

Where, OFD is Organic Fertilizer Dependence (%), ON_1 is nitrogen content in organic fertilizer (kg ha^{-1} yr^{-1}), ON_n is total nitrogen content in all the organic fertilizers application (kg ha^{-1} yr^{-1}), NI_n is total nitrogen content in all the inorganic fertilizers application (kg ha^{-1} yr^{-1}).

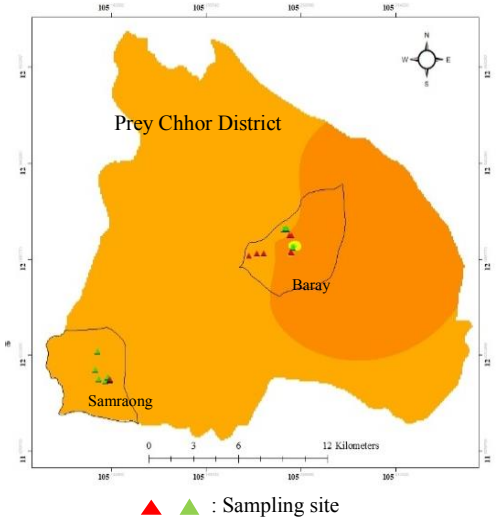

Fig. 2 Soil sampling sites

RESULTS AND DISCUSSION

Questionnaire Survey

The results from the questionnaire survey shown in Fig. 4 indicated that the representative farmers in the study areas has total cultivated agricultural lands about 0.5 to 1 ha. This cultivated land areas mostly used for the rice and vegetable cultivation activities in Samraong and Baray Communes.

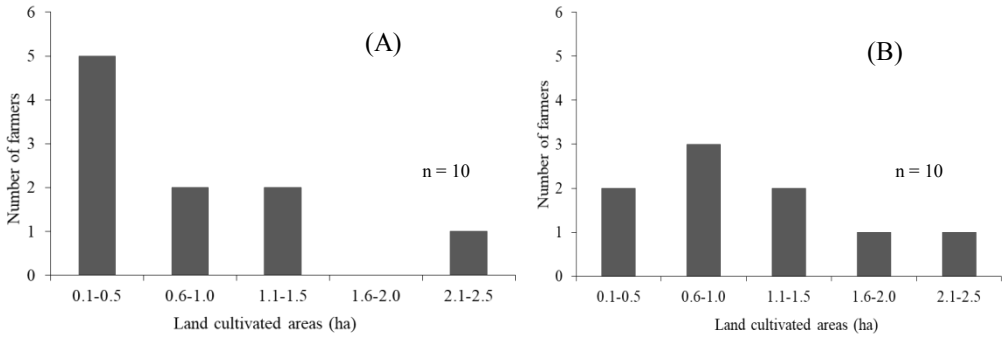

Fig. 3 Land cultivated areas from the responded farmers in (A) and (B)

Agricultural Condition

The result of agricultural condition were about the types of fertilizers used and the percentage of organic fertilizers dependence were shown in Table 3. As shown in Table 3 there were 4 types of commons fertilizers used including Urea, DAP, cow manures, and compost.

Table 3 Types of fertilizers used (kg/ha/year) from the responded farmers in Samraong and Baray Communes

Site	Urea (kg/ha/yr)	N (kg/ha/yr)	DAP (kg/ha/yr)	N (kg/ha/yr)	Cow manure (kg/ha/yr)	N (kg/ha/yr)	Compost (kg/ha/yr)	N (kg/ha/yr)	TN (kg/ha/yr)	OFD (%)
	N% (46%)		N% (18%)		N% (1.587%)		N% (1.086%)			
1	50	23	50	9	2000	31.6	1000	10.86	74.46	**57%**
2	100	46	100	18	25000	395	5000	54.3	513.3	**88%**
3	100	46	100	18	4000	63.2	4000	43.44	170.64	**62%**
4	100	46	100	18	3000	47.4	3000	32.58	143.98	**56%**
5	50	23	50	9	0	0	1500	16.29	48.29	34%
6	240	110.4	240	43.2	30	0.474	10	0.1086	154.1826	0%
7	20	9.2	100	18	100	1.58	0	0	28.78	5%
8	20	9.2	50	9	50	0.79	0	0	18.99	4%
9	500	230	250	45	0	0	0	0	275	0%
10	50	23	200	36	0	0	0	0	59	0%
11	200	92	0	0	1500	23.7	1500	16.29	131.99	30%
12	100	46	50	9	1500	23.7	1500	16.29	94.99	42%
13	40	18.4	200	36	500	7.9	500	5.43	67.73	20%
14	6	2.76	0	0	500	7.9	500	5.43	16.09	**83%**
15	0	0	16	2.88	1000	15.8	1000	10.86	29.54	**90%**
16	100	46	300	54	0	0	0	0	100	0%
17	100	46	200	36	0	0	0	0	82	0%
18	150	69	150	27	0	0	0	0	96	0%
19	30	13.8	30	5.4	0	0	0	0	19.2	0%
20	30	13.8	100	18	0	0	0	0	31.8	0%

N: Nitrogen, TN: Total nitrogen, OFD: Organic Fertilizer Dependence

Organic Fertilizer Dependence was calculated based on type of fertilizers, nitrogen concentration (N%) in fertilizers and amount applied. Average total nitrogen contents for cow manure were calculated based Maerere et al. (2001), Usman (2013), Sherrian (2016), Huang (2017) and average total nitrogen content for compost were calculated based on Obiamaka (2011), Sophark T et al. (2012), E-Sayed (2015), Sherrian (2016) and Merlyn (2017). Therefore, organic fertilizer dependence was classified into 3 categories as 'not dependent', 'moderately dependent' and 'highly dependent' at 40%, 30% and 30%, respectively as shown in Table 4.

Table 4 Organic fertilizer dependence categorized

Category	Dependence (%)	Farmer dependence (%)
No dependent	0	40.0%
Moderately dependent	0-50	30.0%
Highly dependent	50-100	30.0%

Correlation Matrix Tree Between Organic Fertilizer Dependence and Soil Properties

The correlation matric tree was used to compare the relationship between organic fertilizer dependence and soil properties. The results are shown in Figs. 4 and 5.

	Organic fertilizers dependence (%)	Inorganic fertilizers dependence (%)	pH	EC (ms/cm)	Permeability (mm/hr)	OM (%)	OC (%)	Total nitrogen (mg/kg)	Total phosphorus (mg/kg)	Potassium (mEq/L)	Calcium (mEq/L)	Sodium (mEq/L)
Organic fertilizers dependence	1											
Inorganic fertilizers dependence	-1**	1										
pH	-0.1798	0.1798	1									
EC	-0.3406	0.3406	0.4455	1								
Permeability	-0.3529	0.3529	-0.5505	0.0244	1							
OM	-0.5866	0.5866	0.7134*	0.4590	-0.3198	1						
OC	-0.5866	0.5866	0.7134*	0.4590	-0.3198	1.0000	1					
Total nitrogen	0.4307	-0.4307	-0.2028	-0.5617	-0.0128	-0.5875	-0.5875	1				
Total phosphorus	0.5645	-0.5645	0.2730	0.2698	-0.2325	0.0462	0.0462	0.0099	1			
Potassium	0.5887	-0.5887	-0.0128	0.0081	-0.1131	-0.2827	-0.2827	0.4158	0.6832*	1		
Calcium	0.3800	-0.3800	0.2849	-0.2413	-0.0974	-0.2165	-0.2165	0.4486	0.5034	0.4775	1	
Sodium	-0.4879	0.4879	0.6260	0.6138	-0.3794	0.5352	0.5352	-0.2176	-0.2347	-0.3357	-0.3041	1

*n= 10, r > 0.631897 significance level *P< 0.05, r > 0.764592 signifivance level **P< 0.01*

Fig. 4 Correlation matrix tree between Organic Fertilizer Dependence and soil properties in Samraong Commune

	Organic fertilizers dependence (%)	Inorganic fertilizers dependence (%)	pH	EC (ms/cm)	Permeability (mm/hr)	OM (%)	OC (%)	Total nitrogen (mg/kg)	Total phosphorus (mg/kg)	Potassium (mEq/L)	Calcium (mEq/L)	Sodium (mEq/L)
Organic fertilizers dependence	1											
Inorganic fertilizers dependence	-1.0000**	1										
pH	-0.4023	0.4023	1									
EC	0.7388*	-0.7388	-0.2210	1								
Permeability	-0.4161	0.4161	0.4675	-0.4296	1							
OM	0.7329*	-0.7329*	-0.1520	0.6971*	-0.5519	1						
OC	0.7329*	-0.7329*	-0.1520	0.6971*	-0.5519	1.0000**	1					
Total nitrogen	0.3524	-0.3524	0.0459	0.4819	0.3112	0.0590	0.0590	1				
Total phosphorus	-0.0221	0.0221	-0.2782	-0.2287	-0.4450	-0.2436	-0.2436	-0.5043	1			
Potassium	0.8121**	-0.8121**	-0.5656	0.6672*	-0.2313	0.5750	0.5750	0.3015	-0.2445	1		
Calcium	0.7391*	-0.7391*	0.0102	0.7182*	-0.3011	0.7398*	0.7398*	0.1167	-0.2681	0.5985	1	
Sodium	-0.1120	0.1120	0.8429**	0.1364	0.4948	0.0170	0.0170	0.2774	-0.4706	-0.1896	0.2855	1

*n= 10, r > 0.631897 significance level *P< 0.05, r > 0.764592 signifivance level **P< 0.01*

Fig. 5 Correlation matrix tree between Organic Fertilizer Dependence and soil properties in Baray Commune

The results of statistical analysis showed that there was no any trend detected between organic fertilizer dependence and soil properties in Samroang Commune, but in Baray Commune positive trend was detected between organic fertilizer dependence and soil properties. It can be disused that the trend in Samraong Commune was related to the percentage of organic fertilizer dependent, the duration of the application of organic material in farmland and the experience of farmers on farming practice. Similarly in Baray Commune, the relationship between organic fertilizer dependence and the soil properties showed a positive correlation. It can be disused that when farmer depended more on organic fertilizer input, it leads to increase in soil physical properties such organic matter and organic carbon and soil chemical properties including EC, K^+, Ca^{2+} and Na^+. It was discussed that the application of organic fertilizers can enhanced the accumulation of soil organic matter and organic carbon. According to Ebhin Masto et al., (2006), showed that increased in soil organic matter and soil organic carbon were considerably greater in soil receiving long-term used of farmyard manure, compost or straw along with inorganic fertilizers. More

importantly adding only inorganic fertilizers may results in deficiency of other nutrient and decline in soil physical and chemical properties as the trend was appeared in inorganic fertilizers dependence. Therefore, the trend become significantly when organic fertilizer has been applied for 10 years in Baray Commune.

CONCLUSION

The Organic Fertilizer Dependence was a main factor to the impact of soil properties such as soil physical and chemical properties. In Samraong Commune there was no trend appeared between Organic Fertilizer Dependence and soil properties, however in Baray Commune the trend were obvious when organic fertilizer has been applied. This change might related to the percentage of the organic fertilizers dependent, the long-term application of organic fertilizers as well as the experience and knowledge of farmers on farming practice. In addition, due to slowly decompose of organic fertilizers in the soil, it can be recommended that farmers have to apply more of organic material on their farmland. When organic fertilizers have been applied for many years the trend will show clearly on the effectiveness of organic fertilizer on soil properties.

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Research article

Development of Water Harvesting Technique in Qargha Reservoir Watershed of Paghman District, Afghanistan

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Abstract Harvesting surface runoff water from rainfall rather than allowing these waters to run into the streams and rivers and eventually lost into sea is attaining popularity due to the increasing demand for scarce water resources. In semi-arid countries such as Afghanistan crops in need regular irrigation due to low and unequally divided annual rainfall throughout the growing season. Therefore, this study aimed to develop water harvesting technique with clayey dressing application as a water harvesting strategy for surface runoff inducement to reduce water shortage problems in Qargha Reservoir Watershed of Paghman District, Afghanistan. The results of laboratory and field experiments showed that, application of clayey dressing on the soil surface was highly effective in surface runoff inducement. The application of clayey dressing with silty clay loam and clay loam textures in the laboratory and in the field and at various concentrations increased surface runoff considerably. The plug radius of both silty clay loam dressing with 37.16% or lower concentration and clay loam dressing with 46.96% or lower concentration can effectively clog pores and seal soil surface. Therefore, development of proper water harvesting strategies such as clayey dressing application is indispensable to achieve sustainable agriculture.

Keywords water harvesting, irrigation, clayey dressing, water resource management, conservation strategies

INTRODUCTION

Water is the most essential input for successful farming. Afghanistan is often characterized as a dry or arid to semi-arid country. Water utilization in Afghanistan is mostly for agricultural purposes. Majority of the population lives in rural areas and are small subsistence farmers who live on small plots of land (Qureshi, 2002). Recently, all the country is moaning from a serious drought due to climate change. Recently National Disaster Management Authority (NDMA) (2018) stated in a report that, drought has reached to an emergency level in several parts of the country. According to FAO (2018) report, drought impacted agricultural seasons of 2017 and 2018 in some part of the country of to a level in which the harvest was considered completely lost. As a semi arid region, crops in the study area need regular irrigation due to low and unequally divided annual rainfall throughout the growing season. Growing season starts in the march and ends in the month of October. Hence, from June to October, Qargha Reservoir Watershed receives hardly any precipitation. Therefore, irrigation water shortage during the latter half of the growing season is a serious problem causing crop failure and low productivity in the study area. Karezes (Karez is a tunnel system used to extract shallow groundwater) and tube wells are the main irrigation sources in the study area. Mack et al., (2010) reported that, the water table has been continually dropping. Rahmani and Mihara (2017) reported that 83% of the farmers in the Qargha Reservoir Watershed

have an irrigation water shortage, and 66% of the farmers severely face it, especially in the latter half of the growing season. Rain water management through water harvesting and inducement of surface runoff by clayey dressing application onto soil surface can help in reducing water shortage problems in the study area. Water harvesting techniques such as compaction by (Yazar et al., 2014), gravel removel by (Parvizi et al., 2015), bitumen emulsion and tall oil, (Short and Lantzke, 2006), less permeable soil (Amu-Mensah et al., 2013), wax and plastic cover by (Fink et al., 1980), Sodium dispersants such as sodium carbonate and sodium chloride (Frasier et al., 1987 and Parvizi et al., 2015) are widely used in the world for runoff inducement. In this study clayey dressing was focused as a water harvesting techinque because it is an economical and environmental friendly strategy.

OBJECTIVE

This study aimed to develop water harvesting technique with clayey dressing for runoff inducement in order to reduce water shortage problems in Qargha Reservoir Watershed.

METHODOLOGY

Study Area

Qargha Reservoir Watershed is located within semi-arid region. Water utilization in Afghanistan is mostly for agricultural purposes. The study area lies between longitudes E 68° 49' 44" and E 68° 40' 54" and latitudes N 34° 25' 14" and N 34° 40' 19.2". The research was conducted in Qargha Reservoir Watershed, Paghman District, Kabul Province, Afghanistan. The total area of Paghman District is 361 km^2, and Qargha Reservoir catchment area is 40.33 km^2. Average annual precipitation in the watershed is 280 mm and average annual temperature is 11.01 ºC. The majority of the rural population is small subsistence farmers with small plots of land.

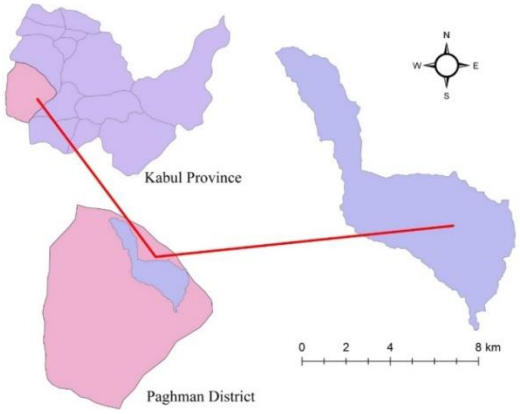

Fig. 1 Location of Qargha Reservoir Paghman District, Kabul, Afghanistan

Rheological Analysis and Pore Size Distribution

Soil from Qala e Jan Big and Qala e Khwaja area of Qargha reservoir watershed was used for clayey dressing extraction in the laboratory. Sieves of 38 µm and 75 µm were used for the clayey dressing extraction. Soil was diluted in the water and then passed it through sieves. Particles larger than 38 µm and 75 µm were removed. Water content was reduced in room temperature. Cloth sieving was used for clayey dressing extraction in the field. The extracted clayey dressing was analyzed for its soil particle size distribution. Rheological analysis of the clayey suspension was carried out using MacMicheal rotational viscometer in the laboratory.

Rotational rheometer tests have been used to determine the flow behaviors and shear strength properties of very soft clays and muds with high moisture contents (Mahajan et al., 2008; Fakher et al., 1999). Standard wire number 26, and 10, 20, 30, 40, 50 rpm (revolutions per minute) were used. Clayey suspension of silty clay loam (SiCL) and clay loam (CL) with 56.90%, 52.28%, 46.41%, 37.16% and 37.16% and 64.86%, 60.05%, 55.35%, 52.06 and 46.96% concentration were used, respectiveley. Shear stress and shear rate values of the clayey suspension were measured and were used to estimate Bingham yield values of the clayey suspension. Estimated Binghm yield values were used to calculate plug flow radius of the suspension using equation below:

$$r_o = 2L / \Delta P \quad \text{Eq. (1)}$$

Where, r_o is radius of plug flow (cm), L is pore length (cm) and ΔP is the difference in pressure (Pa).

The soil water retention curve was determined in the laboratory and was used to measure non-gravitational pore size distribution, while gravitational pores were observed using morphological method. Soil sample was prepared from local soil in a cylinder with 10 cm depth and 10 cm diameter, soil sample was adjusted at 5 cm depth and 10 cm of diameter and was compacted same as field condition. The matric potential was determined using Em50 data logger and weight changes were recorded using weight scale. Pore size distribution was calculated using Equation below:

$$r = 0.15 / h \quad \text{Eq. (2)}$$

Where, r is the pore radius (cm) and h is the matric potential (cmH_2O).

Surface Runoff Experiment

Runoff experiment was conducted in the laboratory of Land and Water Use Engineering, Tokyo University of Agriculture using runoff plots with 0.90 m long, 0.052 m wide and 0.035 m deep. Marriott bottle was used to provide constant water flow rate of 20 cm^3 s^{-1} at constant pressure for a concentrated surface scenario and 8% slope. Surface runoff experiments were also conducted in the field (Fig. 2).

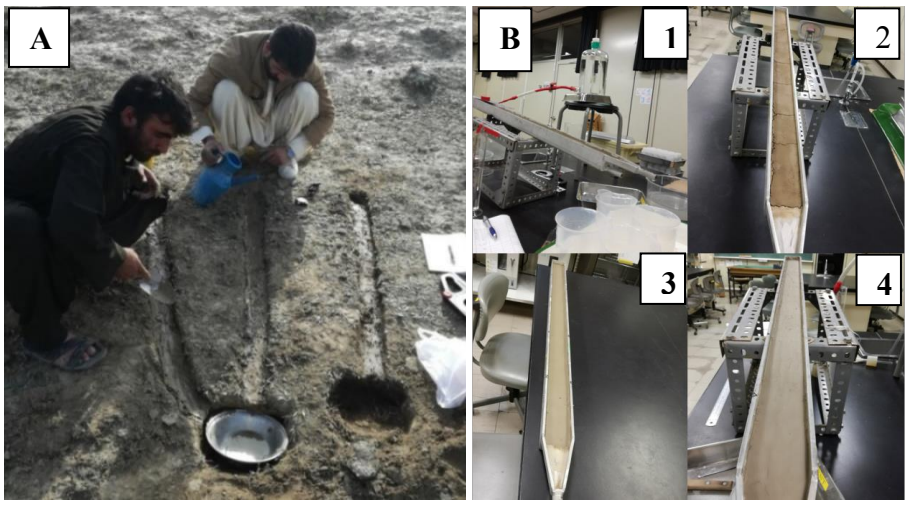

Fig. 2 Field (A) and laboratory (B) runoff experimental plots (1), cracks in the soil (2) and soil surface after clay dressing (3, 4)

RESULTS AND DISCUSSION

Two types of clayey dressing 1st silty clay loam and 2nd clay loam were extracted with 38 μm and 75 μm sieves, respectively in the laboratory and in the field using a cloth and were applied on the

soil surface. Soil properties of the two extracted clay dressing is shown in Table 1. Most water harvesting techniques are quite expensive and usually interfere with the natural environment and deprive the land for other possible uses. While, the use of less permeable soils as a top layer dressing to reduce infiltration and enhance runoff presents an interesting and viable option that could give appreciable results (Amu-Mensah et al., 2013).

Table 1 Particle size distribution of clayey dressing

Soil type	Sieve (μm)	Sand (%)	Silt%	Clay%	Total%	Sieved soil texture
Loam	38	14.3	51.8	33.9	100	Silty clay loam
Sandy loam	75	27.2	41. 7	31.1	100	Clay loam
Field	Cloth	19.6	52.7	27.7	100	Silty clay loam

Surface Runoff

The amounts of surface runoff generated under different treatments compared to control are shown in Table 2. Silty clay loam dressing with 57%, 53% and 47% concentration increased runoff by 30.07%, 28.29%, and 15.81%, respectively. While, clay loam dressing with 65%, 60% and 53% concentration increased runoff by 42.57%, 40.59%, and 27.13%, respectively. The result shows that, the clay dressing application is highly effective in increasing surface runoff, and the influence of sieve size was not obvious. Sherazi et al. (2010) stated that permeability noticeably decreasing by the increasing rate of clay in the clay-sand mixture. For instance, application of clayey dressing on the soil surface is highly recommended as a runoff maximizer. Thus, it is very economical and easy to use and extraction does not need expensive and difficult to use equipment. Availability and generation of extra rainfall runoff water can help to revive agriculture in the study area and cultivate large dry uncultivated lands.

Table 2 Surface runoff water under different treatments

Soil Texture	Dry density g cm^{-3}	Treatment	Disc. (dm^3 m^{-2})	W. used	Infil. (dm^3 m^{-2})	Coef.	Percentage increase from control
Loam	1.3	Control	9.70 a**	12.96	3.20	0.75	
		SiCLD 57%	12.62 b**	12.96	0.00	0.97	30.07
		SiCLD 53%	12.45 b**	12.96	0.99	0.96	28.29
		SiCLD 47%	11.24 b**	12.96	1.68	0.87	15.81
Loam	1.5	Control	8.68 a**	12.96	3.82	0.67	
		CLD 65%	12.38 b**	12.96	0.00	0.95	42.57
		CLD 60%	12.20 b**	12.96	0.00	0.94	40.59
		CLD 45%	11.04 c**	12.96	1.55	0.85	27.23

*CLD = Clay loam dressing, SiCLD = Silty clay loam dressing, **denotes significance difference level at P<0.01*

The amounts of surface runoff generated under different treatments in the field compared to control are shown in Table 3. Silty clay loam dressing onto Deh Ponba soil with 65% and 58% concentration increased runoff by 42.55% and 41.47%, respectively. While, clay loam dressing onto Doda Mast soil with 65%, 60% and 53% concentration increased runoff by 58.58% and 55.28%, respectively. Parvizi and Sepaskhah (2016) examined the effect of gravel removal, rill construction across to slope and applying of baking soda on surface runoff, rainfall infiltration. The most effective in the runoff enhancement were gravel removal, rill construction across to slope and baking soda 31.20, 29.30 and 22.00%. Application of less permeable soil onto soil surface to create possibility for harvesting and storing rainwater (Amu-Mensah et al., 2013). Statistical analysis showed that there was significant difference in surface runoff between control and clayey dressing treated soils both in laboratory and in the field. Sandy soils have a relatively low water-holding capacity but a high intake rate. Instead, a clay or loam soil on the other hand, hold more water than a sandy soil but will not absorb water as quickly. Hence, soils with 20% or more clay content were found to be the most sensitive to crust formation and have the lowest infiltration rate. It was concluded that the increase in surface runoff using clayey dressing was due to its low permeability.

Table 3 Surface runoff experiment in the field

Site	Treatment	Discharge ($dm^3 m^{-2}$)	W. applied	Coef.	Percentage increase from control
Deh Ponba	Control	27.73 ^{a**}	45.00	0.62	
	SiCLD 65%	39.53 ^{b**}	45.00	0.88	42.55
	SiCLD 58%	39.23 ^{b**}	45.00	0.87	41.47
Doda Mast	Control	25.27 ^{a**}	45.00	0.56	
	SiCLD 65%	40.07 ^{b**}	45.00	0.89	58.58
	SiCLD 58%	39.23 ^{b**}	45.00	0.87	55.28

*SiCLD = Silty Clay Loam Dressing, **denotes significance difference level at P<0.01*

With an increasing percentage of clay, the soil structure become more stable (Ben-Hur et al., 1985). The result showed remarkable improvements in runoff generation and the percolation reduction over the layered (dressed) soil surface as opposed to the control runoff experiments. Amu-Mensah et al., (2013), reported that, application of a clay soil layer (dressing) on the soil surface remarkably improving runoff generation. Clay is applied at the bottom of ponds alone onto porous soils or mixed with a porous soil form an impermeable layer (Keese, 2006).

Rheological Properties of Clayey Suspension

The results of rheometer tests showed that suspension Bingham yield and plastic viscosity values increased with increase in the mass concentration of clayey, and with decrease in mass concentration, Bingham yield and plastic viscosity values decreased. The results of rheometer tests as shown in Fig. 3 had a direct impact on the plug flow radius of the clayey suspension.

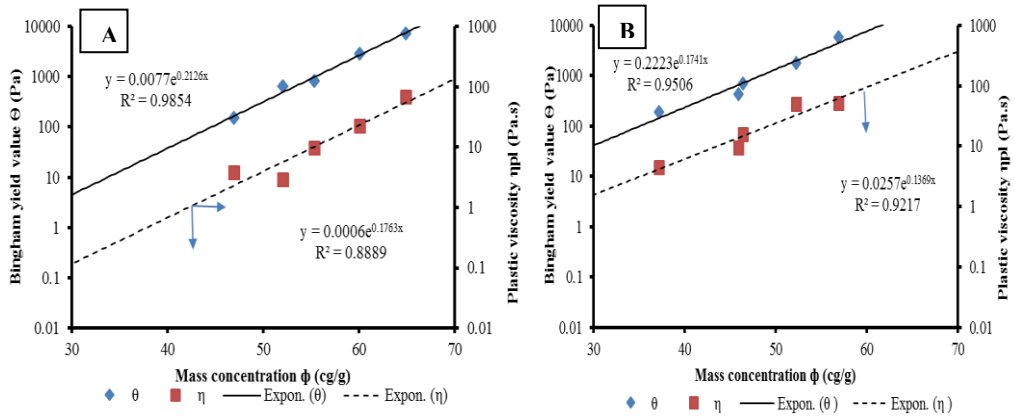

Fig. 3 Changes in Bingham yield value and plastic viscosity with mass concentration of silty clay loam (B) and clay loam (A) suspension

Relationship between Pore Size Distribution and Plug flow

The result of plug flow radius calculation showed that the radius of plug flow minimizes with a decrease in concentration of clayey suspension as shown in Table 4. Clayey suspension of silty clay loam at 56.95%, 52.28%, 46.41%, 45.88% and 37.16% concentration produce plug flow radius with 0.61 m, 0.195 m, 0.079 m, 0.048 m and 0.023 m, respectively, and clayey suspension of clay loam at 64.86%, 60.05%, 55.35%, 52.06% and 46.96% concentration produce plug flow radius with 0.725 m, 0.292 m, 0.086 m, 0.071 m and 0.017 m, respectively. Clay soils are insensitive cohesive soils that have a water content higher than the liquid limit. The behavior of clay soils and sandy soils or even clay-silt soils differ from each other and even become more complex with water content. The transformation of soil from a plastic state to a viscous liquid state is primarily caused

by a change in the water content of the soil mass. As the water content increases, the soil mass gradually starts to behave like a viscous liquid (Fakher et al., 1999).

Table 4 Plug radius of clayey dressing suspension

(Conc.) cg g^{-1}	(θ) Pa	(ρ) kg m^{-3}	(h) m	(m sec^{-2}) G	(ΔP) Pa	(r_o =2Lθ/ΔP) (m)
56.90	5888.0	1939	0.005	9.81	95.1	0.610
52.28	1815.0	1863	0.005	9.81	91.36	0.195
46.41	694.4	1766	0.005	9.81	86.61	0.079
45.88	426.5	1757	0.005	9.81	86.18	0.048
37.16	189.9	1613	0.005	9.81	79.13	0.023
(Conc.) cg g^{-1}	(θ) Pa	(ρ) kg m^{-3}	(h) m	(m sec^{-2}) G	(ΔP) Pa	(r_o =2Lθ/ΔP) (m)
64.86	7370.0	2070	0.005	9.81	101.5	0.725
60.05	2851.0	1991	0.005	9.81	97.65	0.291
55.35	814.1	1913	0.005	9.81	93.85	0.086
52.06	650.2	1859	0.005	9.81	91.18	0.071
46.96	150.9	1775	0.005	9.81	87.05	0.017

Θ=Bingham yield, h= clayey dressing depth, ρ=Bulk density

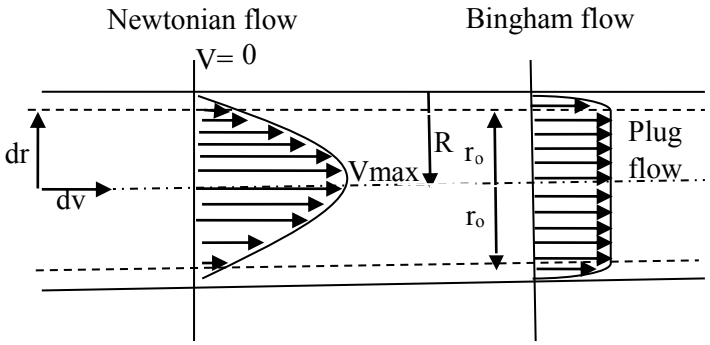

Fig. 4 Newtonian and Bingham flow

Plug flow radius of the clayey suspension also increased with an increase in Bingham yield values as it is shown in Table 4. Two type of structural clogging take place 1st immediate clogging course particles fixed in the pores and 2nd gradual clogging by adhesion and sedimentation of fine particles to the inner wall. Bingham fluids such as clayey suspension produces plug flow. Clayey suspension causes both immediate and gradual clogging (Mihara and Ysutomi, 1992).

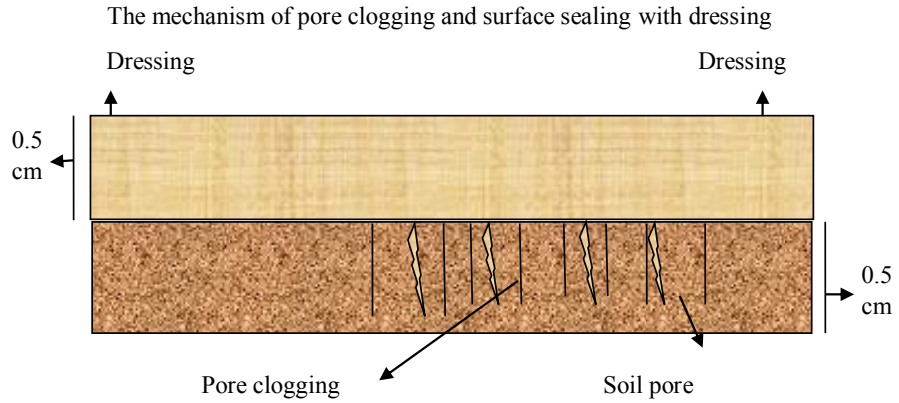

Fig. 5 Mechanism of pore clogging and surface sealing

The pore volume for each pore class was calculated from the pore size distribution curve. The pore diameter was classified into 5 categories as shown in Table 5. Pore classes of macropores, mesopores, micropores, ultramicropores and cryptopores constitute at 26.47%, 30.88%, 19.85%, 6.62% and 16.18% of the total pore volume, respectively. A pore is not simply a void in the solid structure of soil. However, various pore size categories have different characteristics and contribute different attributes to soils depending on the number and frequency of each type. A widely used classification of pore size is that of (Brewer, 1964).

Table 5 Pore size distribution of Qargha Reservoir Watershed soils

Class*	Subclass	Pore size (mm)	Volume (cm^3)	Volume (%)
Cryptopores		0.1>	47.16	26.47
Ultrmicropores		0.1 to 5	55.02	30.88
Micropores		5 to 30	35.37	19.85
Mesopores		30 to 100	11.79	6.62
Macropores	Coarse	100 to 1000	0.10	0.22
	Medium	1000 to 2000	0.91	2.00
	Fine	2000 to 5000	1.99	4.39
	Very fine	5000>	4.34	9.57

**Source: Brewer (1964)*

Changes in the pore size distribution evidently modify soil water retention. The direct relation between pore size distribution and the soil water content can be defined as macropores and mesopores control the water content at soil saturation, micropores and ultramicropores control water content at field capacity and cryptopores are very tinny pores filed by water for long time and very little amount of water of these pores are available of plant consumption. It is to be concluded that the increase observed in surface runoff by clayey dressing application compared to control was due to clogging the soil pores and sealing the surface. Pore clogging and surface sealing happens when the plug flow radius of suspension is bigger than the radius of soil pores. Mihara et al. (1993) also confirm that pore radius smaller than radius of plug flow causes structural clogging.

CONCLUSION

As a semi arid country, crops in Afghanistan need regular irrigation due to low and unequally divided annual rainfall throughout the growing season. During the growing season hardly any rainfall event takes place in the study area. Therefore, this study aimed to develop water harvesting technique with clayey dressing for runoff inducement in order to reduce water shortage problems in the study area. The results from both laboratory and in the field experiments indicated that clayey dressing application onto soil surface considerably increase surface runoff. Two types of clayey dressing 1st silty clay loam and 2nd clay loam were extracted with 38 μm and 75 μm sieves, respectively in the laboratory and in the field using a cloth and were applied on the soil surface. Silty clay loam dressing at 57%, 53% and 47% concentration increased runoff by 30.07%, 28.29% and 15.81%, respectively compared to control. While, clay loam dressing at 65%, 60% and 53% concentration increased runoff by 42.57%, 40.59%, and 27.13%, respectively. The results of field expeiments showed that, clayey dressing applied onto Deh Ponba soil at 65% and 58% concentration increased runoff by 42.55% and 41.47%, respectively. While, clayey dressing onto Doda Mast soil with 65% and 60% concentration increased runoff by 58.58% and 55.28%, respectively compared to control. Clayey suspension of silty clay loam at 56.95, 52.28%, 46.41%, 45.88% and 37.16% concentration produced plug flow radius at 0.61 m, 0.195 m, 0.079 m, 0.048 m and 0.023 m, respectively, and clayey suspension of clay loam at 64.86%, 60.05%, 55.35%, 52.06% and 46.96% concentration produce plug flow radius with 0.725 m, 0.292 m, 0.086 m, 0.071 m and 0.017 m, respectively. It is concluded that, silty clay loam dressing at 37.16% or lower concentration and clay loam dressing with 46.96% or lower concentration can effectively clog pores and seal soil surface. Therefore, development of proper strategies on water resource

development/management is needed to achieve sustainable agriculture.

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Research article

The Low-Cost Controlled Temperature Greenhouse Investigation for Marigold Seedlings in Global Warming Situation

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Abstract Global warming situation has affected many life in the world; especially its effects on agricultural industry. Greenhouse was one of many tools which was brought to help farmers in growing many plants and flowers in uncontrollable environments for long time. This work was aimed to build a low-cost controlled temperature greenhouse prototype. The greenhouse prototype was studied for temperature distributions inside the prototype to sow marigold seedlings. A water evaporative cooling system was chosen to remove heat from the greenhouse, a low-cost temperature control set was fabricated to help controlling air flow and temperature inside the greenhouse. A cooling pad system was chosen as the evaporative cooling system in this work. The greenhouse frame was built locally as a length of 2.1 m., a width of 1.8 m. and a height of 3.1 m. and was covered with clear UV reducing plastic. The cooling pad system consisted of 25-watts ventilating fans with a length of 30 cm, a width of 30 cm, a height of 16 cm and one 60-watt water pump. The low-cost temperature control set was connected with the cooling pad system to turn on and off the fan of the system automatically and to remove the humid air out of the greenhouse. Six different seedling materials; pure peat moss, pure bagasse, bagasse mixed with soil at 1:1 and at 1:0.5 by weight, bagasse mixed with soil and rice-straw biochar at 1:1:0.5 and at 1:0.5:0.5 by weight, were also investigated in the greenhouse. The experimental results showed that using one cooling pad could reduce inside temperature with an average temperature different of 2.5 Celsius while using three cooling pads could reduce inside temperature with an average temperature different of 5 Celsius. The air circulation system also affected the temperature distribution inside the greenhouse and could control the temperature inside the prototype. The seedling material which was prepared from bagasse mixed with soil; at a mixing ratio of 1:0.5 by weight, allowed marigold seedling to grow the most in the same experiment period.

Keywords geenhouse, marigold seedling, cooling pad, evaporative cooling system, heat transfer

INTRODUCTION

Global warming situations affect life on the world such as human, animals and plants. Many plants are able to grow in certain ranges of temperatures. High ambient temperatures have affected on annual plants which can grow from seeds and last for a year. Many researches paid attentions on adjusting temperatures to suit seedlings and growing of plants. One of many tools to control

suitable temperatures for seedlings and growing of plants was a greenhouse; where sunlight can go through a structure of the greenhouse, humidity and temperature inside the greenhouse can be adjusted by heating, ventilation and air conditioning systems.

Marigold is one of many flowers in Thailand which is used in many occasions such as celebrating for our beloved King Rama 9, worshipping in Buddhist traditions, etc. Varied ambient temperatures also affect seedling and growing rates of marigold because Marigold growing in Thailand prefers surrounding temperatures between 14.5 to 28.6 Celsius (Wongput 2001), quite low temperatures compared with global-warming ambient temperatures in Thailand. Taylor et al. (2013) grew 14-day-old marigold (Tagetes erecta L. 'Inca Gold') seedlings on a greenhouse bench to document the occurrence of nitrification in Pine tree substrate (PTS) and to determine if nitrification and density of nitrifying microorganisms were affected by substrate storage time and lime and peat amendments. Bridgen (2015) proposed UV-C light treatments as a plant growth regulator in seedlings of annual plants such as African marigold and French marigold. He claimed that the use of UV-C irradiation as the novel low-cost technique could provide tremendous benefits for the environment by reducing pesticide applications to plants. Randall and Lopez (2015) also studied and compared seedlings; vinca, impatiens, geranium, petunia, and French marigold, grown under low greenhouse ambient light (AL) to those grown under supplemental lighting (SL) or sole-source photosynthetic lighting (SSL) with a similar photosynthetic daily light integral (DLI). They found that height of marigold was 7% to 19% shorter, for seedlings grown under SSL compared with those under AL and SL. Pramuanjaroenkij et al. (2015) studied fluid flow in Red Oak hydroponics systems to create 4 prototypes of the hydroponics systems inside a greenhouse for a household application with initial conditions as low investment cost and easy installation. Olberg and Lopez (2016) found that all plants were delayed when grown outdoors compared with in the high tunnel, and all marigolds grown outdoors died in April of the Midwestern United States when outdoor air temperatures dropped below −4 °C, growers must be aware of the risk of crop loss due to extreme temperatures and plan for delays when growing annual bedding plant crops outdoors. Pramuanjaroenkij et al. (2017) studied the turbulent flow of the nutrient solution which affected the growth of Red Oaks in four hydroponic systems inside a greenhouse; the greenhouse was proved to help adjusting the temperatures inside the greenhouse. Owen et al. (2017) revealed that the overall trends indicated in most cases as the percent PWC increases, pH increases and electrical conductivity (EC) decreases while plant shoot growth was often as large in fresh PWC-grown plants compared to aged.

OBJECTIVE

This work was aimed to build a low-cost controlled temperature greenhouse prototype to control temperatures to sow marigold seedlings. The greenhouse prototype was constructed locally and experimentally investigated for temperature distributions inside the prototype to sow marigold seedlings. We also investigated suitable marigold for six different seedling materials in the greenhouse with high humidity air because of evaporated water from the cooling pad system.

METHODOLOGY

(1)A greenhouse structure was designed and locally built. (2) A clear UV reducing plastic sheet was cut and covered the greenhouse structure. (3) Temperatures of the greenhouse and environment were measured by an infrared temperature measurement camera to find natural temperature distributions. (4) A temperature control set was fabricated by connecting a thermocouple, a temperature controller and a relay. The relay was used to switch on and off two ventilating fan; one fan was equipped on the top part of the greenhouse to reject the heat and moisture to the environment and another fan was installed opposite to a cooling pad set. (5) Two sets of cooling pads were installed and compared. The first set contained one cooling pad and another set contained three cooling pads. (6) Twenty-three marigold seeds were put into six different seedling materials mixing ratios by weight: pure peat moss, pure bagasse, bagasse mixed with soil at of 1:1

and 1:0.5 by weight, bagasse mixed with soil and rice-straw biochar at mixing ratios of 1:1:0.5 and 1:0.5:0.5 by weight. And (7) Three seedling investigations were studied in three consecutive periods (14 days per period) to conclude the current study. Germination rates of marigold seedlings from these materials were obtained and compared while temperatures inside and outside the greenhouse were measure 3 times a day; 9am, 12.45pm and 7pm.

RESULTS AND DISCUSSION

A greenhouse was locally built as a length of 2.1 m., a width of 1.8 m. and a height of 3.1 m. and was covered with clear UV reducing plastic. The self-built greenhouse was placed in the environment, the temperatures of the greenhouse and environment were measured by an infrared temperature measurement camera to find natural temperature distributions. At the beginning, one cooling pad set was installed and the first temperature distribution was observed as shown in Fig. 1 that high temperature humid air was accumulated on the top of the greenhouse and opposite of the cooling pad. The temperature control set (Fig. 2) was linked with both fans inside the greenhouse and the thermocouple was positioned in the middle of the greenhouse to measure inside temperatures; if the measured temperatures were higher than our set value or 25 Celsius, both fans were switched on and off when the measured temperatures were lower than the set value. To reduce temperatures inside the greenhouse, one cooling pad and three cooling pads were connected with the cooling system and compared, we found that the more pads the lower temperatures, as well as, the higher humidity. High humidity could cause fungi to grow inside the greenhouse; as we avoided too high humidity, three pad were kept as the maximum number. Six different seedling materials were prepared and 23 marigold seeds were put into six seedling materials; 15 holes for each material. Three experiments were carried on consequently, 14 days for each experiment. During each experiment, temperatures and humidity of humid air both outside and inside the greenhouse were measured three times a day; minimum and maximum different temperatures and relative humidity percentage of humid air both outside and inside the greenhouse were detailed in Table 1 according to measuring times during three months in 2017. We noticed that the highest temperature and humidity were in April 2017, the middle month in Summer of Thailand.

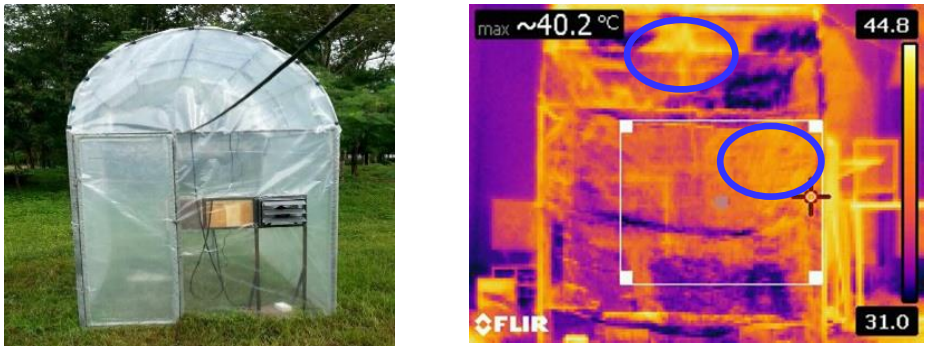

Fig. 1 The greenhouse and temperature distributions

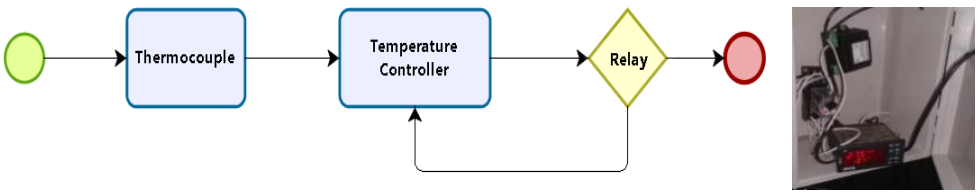

Fig. 2 The temperature control set

Table 1 Minimum and maximum different temperatures (Celsius) and relative humidity percentage (%RH) of humid air both outside and inside the greenhouse

	9 am				12.45 pm				7 pm			
	ΔT_{min}	ΔT_{max}	$\Delta\%RH_{min}$	$\Delta\%RH_{max}$	ΔT_{min}	ΔT_{max}	$\Delta\%RH_{min}$	$\Delta\%RH_{max}$	ΔT_{min}	ΔT_{max}	$\Delta\%RH_{min}$	$\Delta\%RH_{max}$
1st test	1.4°C on Mar. 11th	8.3°C on Mar. 18th	1 on Mar. 17th	14 on Mar. 12th	1.1°C on Mar. 19th	7.9°C on Mar. 16th	1 on Mar. 20th	19 on Mar. 13th	1°C on Mar. 12th	4.9°C on Mar. 22nd	1 on Mar. 12th	22 on Mar. 23th
2nd test	2.4°C on Mar. 29th	8.8°C on Apr. 4th	0 on Mar. 31th	48 on Apr. 6th	2.0°C on Mar. 29th	9.9°C on Apr. 5th	7 on Apr. 4th	56 on Apr. 5th	1.6°C on Mar. 29th	5.8°C on Apr. 9th	5 on Mar. 31th	60 on Apr. 9th
3rd test	0.5°C on May 13th	8.4°C on May 6th	4 on May 12th	28 on May 2nd	2.1°C on May 7th	7.4°C on May 5th	1 on May 13th	24 on May 6th	3.3°C on May 3rd,4th	5.3°C on May 2nd	3 on May 6th	42 on Apr. 30th

Figures 3, 4 and 5 showed average outside and inside temperatures of the greenhouse in March, April and May, respectively. We found that the average inside temperature of the greenhouse in the morning (9am) in May was the lowest inside temperature among temperatures in three experimental periods, the inside temperatures varied from 23 to 35 Celsius, the lowest and highest average different temperatures between outside and inside greenhouse was about 1.4 Celsius and 8.3 Celsius, respectively. The average inside temperature of the greenhouse at noon (12.40pm) in March was the highest inside temperature among temperatures in three experimental periods, the inside temperatures varied from 29 to 38 Celsius, the lowest and highest average different temperatures between outside and inside greenhouse was about 1.1 Celsius and 7.9 Celsius, respectively.

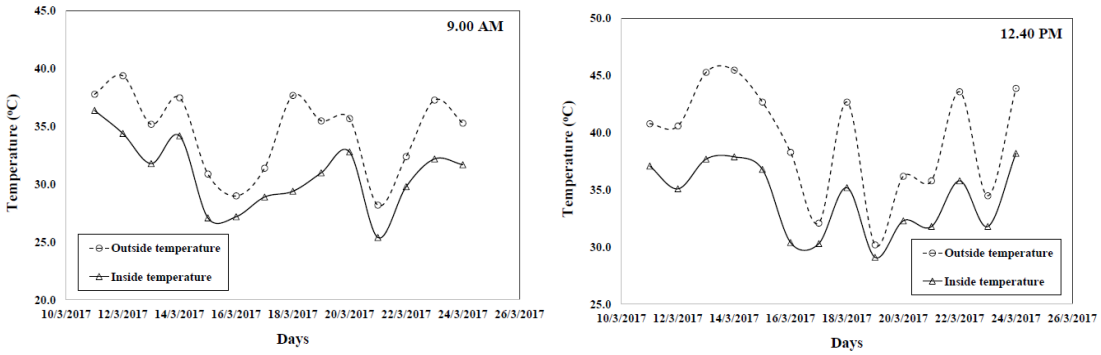

Fig. 3 The outside and inside temperature of the greenhouse in March

We noted that our greenhouse, which was cooled by evaporative refrigeration, contained high relative humidity. Seedling materials, which was suitable inside this specific greenhouse, must function well in the high humidity atmosphere. Among three different experimental periods, the first set of seedlings in any seedling materials, which were placed inside the greenhouse, could germinate out of their seedling materials in the same day on the fourth day of marigolds planting. The highest amount of seedlings germinated out from the bagasse mixed with soil at mixing ratios of 1:0.5 by weight. The bagasse mixed with soil at mixing ratios of 1:0.5 by weight showed its potential in growing marigold seedlings inside the greenhouse while the marigold seedlings in different seedling materials, which were placed outside the greenhouse, were damaged by pest animals and less seedlings could germinate out of the materials than those of the materials inside the greenhouse. Therefore, the bagasse mixed with soil at mixing ratios of 1:0.5 by weight greenhouse could be applied as the seedling material which suited to the high humidity atmosphere occurred by the evaporative refrigeration. Another greenhouse utilization found in this study was the greenhouse could protect seedlings, plants and their seedling materials from pest animal damages.

We summarized costs of the greenhouse structure, plastic cover, simple temperature control set and three cooling pad set including a water circulating pump, and we found the cost of our greenhouse at $4 per square meter. From our survey, the estimating cost of the greenhouse building in US was $55.56 per square meter (HomeAdvisor, Inc. 2017) or $19.45 per square meter as we estimated Thai construction cost at 65% lower than the American construction cost (Neal and Rawlinson 2014). The cost of the current greenhouse installed with the cooling pad and temperature control sets or $4 per square meter was lower than the estimated greenhouse cost or $19.45 per square meter about 79%.

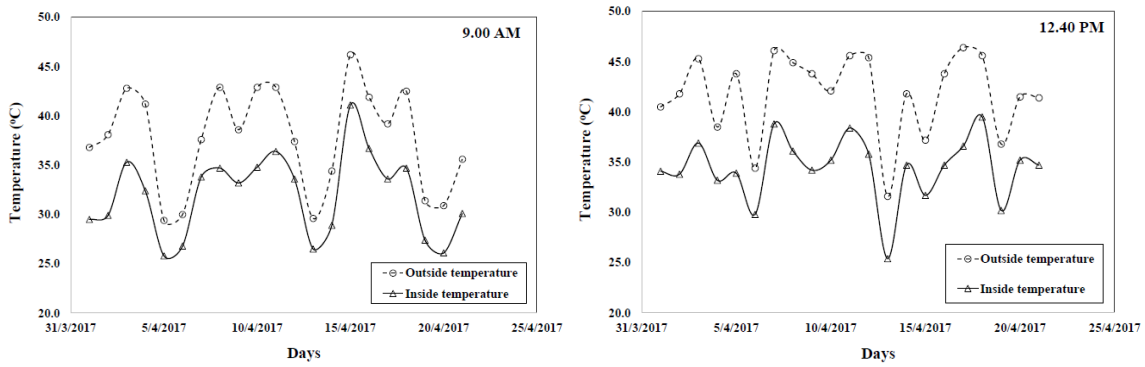

Fig. 4 The outside and inside temperature of the greenhouse in April

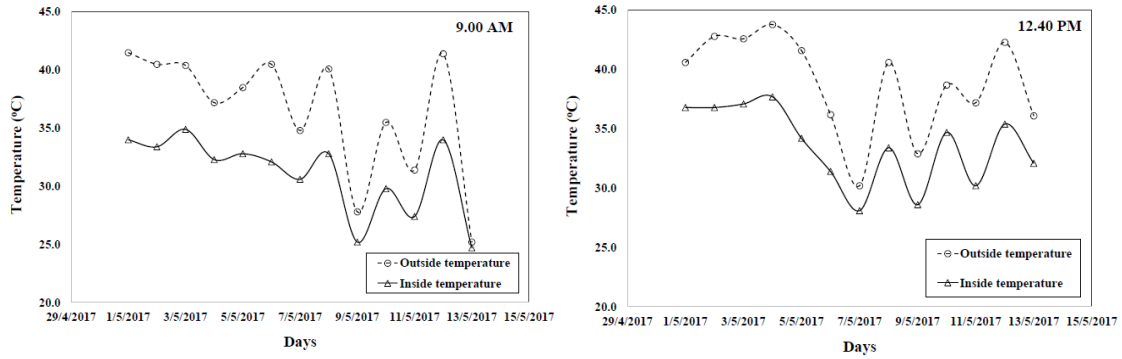

Fig. 5 The outside and inside temperature of the greenhouse in May

CONCLUSION

This study was aimed to study and develop a closed controlled greenhouse. Evaporative cooling system was chosen as the greenhouse cooling system. The evaporative cooling system consisted of cooling pads (where water was circulated and received heat from the greenhouse), water pumps (which were used to circulate the water) and ventilation fans (one fan was placed near the cooling pad to draft inside air to pass the cooling pads and another fan was placed at the top of the greenhouse roof to release hot air out of the greenhouse). The temperature control set could control operation of the evaporative cooling system and the system could reduce inside greenhouse temperatures down with an average temperature difference (between inside and outside greenhouse temperatures) of 5 Celsius. There were six different seedling materials which were investigated, 23 marigold seeds were put into these six different seedling materials in each experiment period; 15 seedling holes for each material. Six different seedling materials were prepared from 1) peat moss, 2) bagasse mixed with soil at mixing ratios of 1:1 by weight, 3) bagasse mixed with soil at mixing ratios of 1:0.5 by weight, 4) bagasse mixed with soil and rice-straw biochar at mixing ratios of 1:1:0.5 by weight, 5) bagasse mixed with soil and rice-straw biochar at mixing ratios of 1:0.5:0.5 by weight and 6) only bagasse. The air circulation system also affected the temperature distribution inside the greenhouse and could control the temperature inside the greenhouse. The seedling

material which was prepared from bagasse mixed with soil; at a mixing ratio of 1:0.5 by weight, allowed marigold seedling to grow the most in the same experiment period. Marigold seedling germinated the first set in every seedling material at the same day (the fourth day of the planting periods). The greenhouse could also protect the Marigold sprouts from pest animals because the sprouts grown outside the greenhouse were damaged by pest animals. The bagasse mixed with soil; at a mixing ratio of 1:0.5 by weight as the marigold seedling material revealed its function and potential in the high humidity atmosphere because the evaporative cooling system, which applied cooling pads, generated a lot of water vapor causing high humidity atmosphere. The construction cost of the current designed greenhouse was $4 per square meter which was an affordable cost for farmers, the current greenhouse with the temperature control set was suitable as a household greenhouse, simple in design and construction as well as easy to maintenance and develop to sustain the greenhouse application in the rural area.

ACKNOWLEDGEMENTS

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Research article

Strength Characteristics of Stabilized Soils Containing Bamboo Fiber Extracted by Steam Explosion

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Abstract Construction work and materials depend mostly on earth resources. A sustainable recycling-oriented society becomes possible only when technologies for recycling as well as for energy conservation in construction are disseminated and when untapped natural resources are effectively utilized. In this paper, applicability of natural fibers for the soil stabilization technique was examined. Especially, this paper focuses on bamboo fiber extracted by steam explosion, which technique is capable to produce thin and flexible fibers from raw bamboo. In order to understanding the mechanical properties of soil mixed with bamboo fiber produced by steam explosion, unconfined compression tests were conducted. As a result of unconfined compression tests, following findings are obtained. (1) The addition of bamboo fiber to cohesive soil helps to increase the unconfined compression strength of the soil. Moreover, the addition of bamboo fiber to soil helps to increase the toughness of the soil. (2) An increase in the mix ratio of bamboo fiber results in a change in the failure mode of test specimens. In addition, at a mix ratio by weight of 0.4% or higher, specimens did not occur shear failure, but instead broke such as to become barrel-shaped. (3) The deformation coefficient of the soil mixed with bamboo fiber is similar to the deformation coefficient of cohesive soil containing no bamboo fiber. The addition of bamboo fiber does not affect deformation properties.

Keywords bamboo fiber, steam explosion, soil stabilization, unconfined compressive test

INTRODUCTION

Construction work and materials depend mostly on earth resources. A sustainable recycling-oriented society becomes possible only when technologies for recycling as well as for energy conservation in construction are disseminated and when untapped natural resources are effectively utilized. The effective utilization of soft soil in situ and of soil generated as a byproduct of construction is realized by adding short-fiber materials to such soil in order to improve its mechanical properties (Gowthaman, 2018). This soil stabilization technique differs from those that utilize solidifying material, in that the addition of short-fiber materials has little effect on drainage and plant growth. Thus, this technique is expected to be applied to vegetation beds (Miki, 1994; Masuysms, 2012). It is known that mixing of polyester, polypropylene, polyethylene or vinylon fibers with soil helps to improve the toughness, strength and erosion resistance of the soil. Those reinforced soils have been already applied to materials that cover embankment slopes and to roadbeds on soft ground. For example, Sato et al. (1998) examined the applicability of vinylon fiber as material for subgrade soil improvement. That research found the following: Adding fiber materials to subgrade soil increased the unconfined compression strength, California Bearing Ratio and resilient modulus; the effectiveness of soil improvement varies depending on the type and moisture content of the subgrade soil as well as on the shape of fibers; and long, thin fibers are effective when fiber is added to soft subgrade soil. As mentioned above, the majority of the research on improving slope stability and bearing capacity addresses chemical fibers, and research utilizing natural fibers is limited (Dipika, 2016). For example, Otsubo et al. (2014) examined the erosion resistance of a revegetation bed on a slope to which bamboo fiber was applied. The

findings of that research included the benefits and application methods of bamboo fiber, but no mechanical assessment of bamboo fiber application was conducted.

Bamboo has been utilized as a useful natural resource in Japan. However, because bamboo has been increasingly replaced by plastic, demand for domestic bamboo has significantly declined and many bamboo forests have been left unmanaged. Bamboo grows fast and is expected to be used as a renewable resource. Techniques for the effective use of bamboo need to be developed. Bamboo is known for its high tensile strength. In the past, concrete reinforced with bamboo members was developed. Bamboo-reinforced concrete is drawing renewed attention as a material for aseismic reinforcement (Terai, 2012). The use of bamboo as a construction material has also been examined.

In this paper, applicability of natural fibers for the soil stabilization technique was examined. Especially, this paper focuses on bamboo fiber extracted by steam explosion, which technique is capable to produce thin and flexible fibers from the raw bamboo. In order to understanding the mechanical properties of soil mixed with bamboo fiber produced by steam explosion, unconfined compression tests were conducted.

METHODOLOGY

Production of Bamboo Fiber

Bamboo fiber was extracted by steam explosion. This technique is said to have been developed by Mason in the 1920s for producing pulp used for wood fiberboard. In this technique, material is steamed by using high-temperature, high-pressure saturated water vapor in a pressurized vessel for a given length of time. When the steamed material is suddenly re-exposed to air at normal atmospheric pressure, condensed moisture in the material evaporates to cause explosive volumetric expansion. As a result, the material is crushed. This fiber extraction technique has the following characteristics: The material structure can be crushed from within; the technique utilizes water vapor alone and no chemicals, so no wastewater disposal is required; and mechanical crushing and chemical treatment by steaming can be done simultaneously. The steam explosion machine used in this study is shown in Photo 1. When bamboo fibers are extracted, the properties of the fibers vary depending on the predetermined conditions of steam explosion. The length and flexibility of fibers need to be considered when bamboo fibers are extracted for mixing with soil. In this study, the steam pressure was 1.5 MPa, the steaming time was 30 minutes, and the fiber length was 25 mm. On the basis of the preliminary test results, these steam explosion conditions were determined to ensure the production of bamboo fibers flexible enough to be easily mixed with soil. The fiber length was adjusted by cutting the raw bamboo to a predetermined length. Photo 2 shows the bamboo fiber that was created by steam explosion in this study.

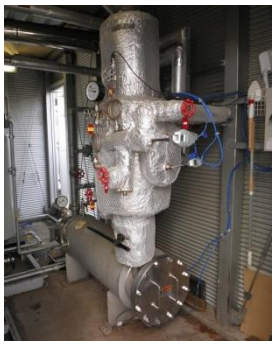


Photo 1 Steam explosion machine

Photo 2 Bamboo fiber obtained by steam explosion

Water Absorption Test for Bamboo Fiber

Soil strength properties vary according to the moisture content of soil. Because bamboo has a high

water absorption rate, the production of specimens for unconfined compression tests needs to take the water absorption rate into account. For this purpose, water absorption tests of bamboo were conducted. The water absorption rate was defined as the ratio of the absorbed moisture to the dry mass of bamboo. In a water absorption test, a specimen was immersed in water for a predetermined period of time. Then the bamboo surface was wiped with a cloth, and the bamboo mass was measured. This process was repeated until the bamboo mass reached a predetermined value. When the predetermined bamboo mass was obtained, the specimen was oven-dried and its dry mass was measured. The water absorption test was conducted six times. The test results indicate that bamboo fiber absorbs water immediately upon immersion in water and that prolonged immersion does not significantly increase the bamboo mass thereafter. The mean value of water absorption rate for the bamboo used in this study was 42.2%, and the variation coefficient was 8.00%. Based on the water absorption rate of 42.2%, the water content of the soil used in the tests described below was adjusted.

Soil Properties and Unconfined Compression Test

The soil for stabilization in the tests is a cohesive soil called "Kanto loam", which is a kind of volcanic ash soil. With the aim of understanding the physical properties of the cohesive soil, a sieve analysis test, a density test of soil particle, a compaction test, a liquid limit test, and a plastic limit test were performed. Each of these soil tests was conducted in accordance with *The Japanese Geotechnical Society: Soil Tests* (JGS, 2010). The tests found the fine fraction content to be 46.0%, the soil particle density to be 2.70 g/cm^3, the liquid limit to be 68.5 %, and the plastic limit to be 56.7%. Fig.1 shows a moisture density curve. The maximum dry density of the cohesive soil ρ_{dmax} is 1.35 g/cm^3, and the optimum water content w_{opt} is 34.6%.

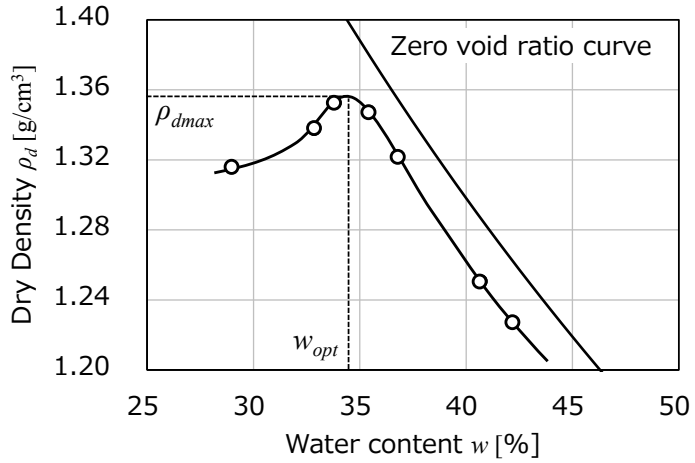


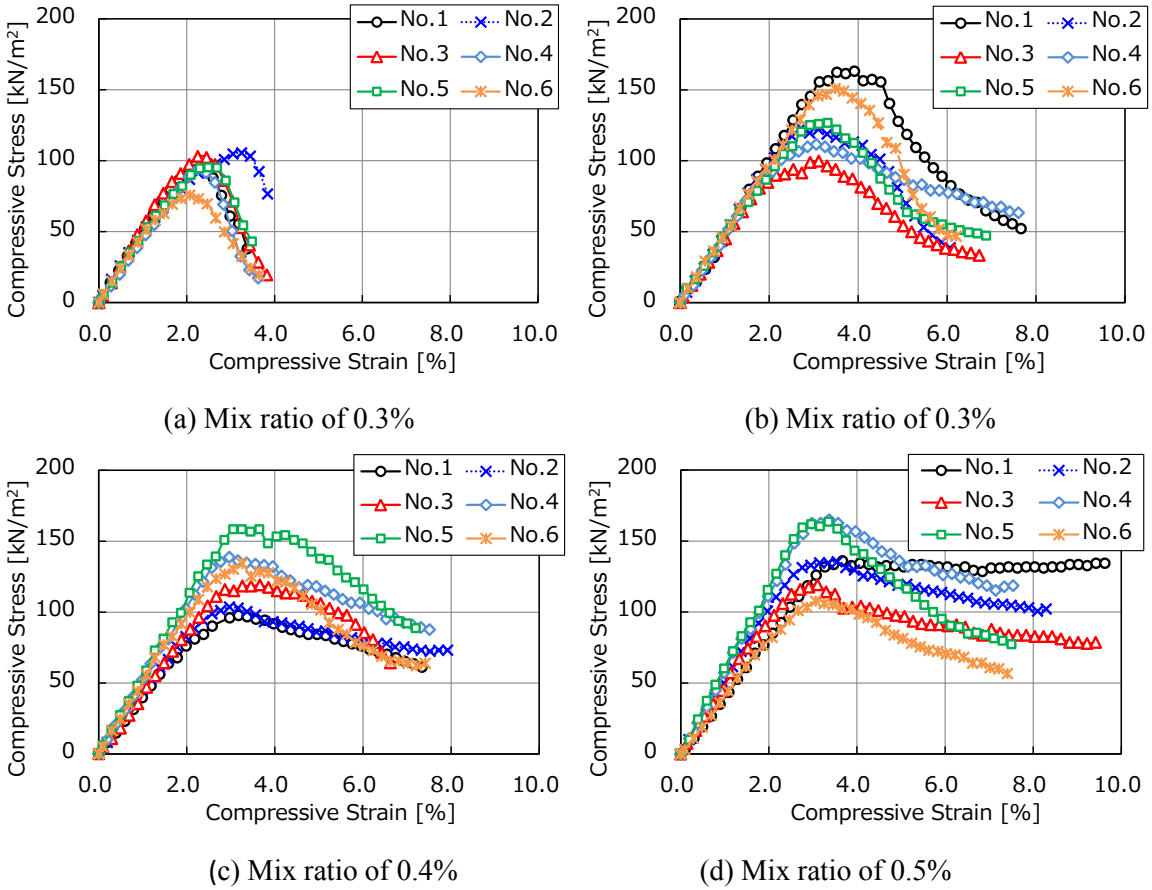
Fig. 1 Moisture density curve

The unconfined compression test was conducted by using specimens whose moisture content was adjusted to be optimum moisture content (w_{opt}). The mix mass ratios of bamboo fibers were 0%, 0.3%, 0.4%, and 0.5%. Six specimens were used for each mix ratio. The unconfined compression test was performed with reference to *The Japanese Geotechnical Society: Soil Tests* (JGS, 2010).

RESULTS AND DISCUSSION

Figure 2 shows the test results in terms of compressive stress-strain curves. These curves demonstrate that after a unconfined compressive strength has been attained, compressive stress is maintained for soil that contains bamboo fiber, while that is not the case for soil containing no bamboo fiber. This result suggests that the addition of bamboo fiber to soil helps to increase the

toughness of the soil. It is also seen that the toughness of soil increases with increase in the mix ratio of bamboo fiber.



(a) Mix ratio of 0.3%

(b) Mix ratio of 0.3%

(c) Mix ratio of 0.4%

(d) Mix ratio of 0.5%

Fig. 2 Compressive stress-strain curves

Table 1 shows the test results in terms of the unconfined compressive strength and deformation modulus. As shown in Table 1, the unconfined compressive strength increases from the addition of bamboo fiber to soil. The variation coefficient of unconfined compression strength is 11.0% when the mix ratio is 0.0%, while the variation coefficient at other mix ratios is 18.0%. This result likely owes to the heterogeneous property of the soil mixed with bamboo fiber, which points to the need for examining methods of mixing bamboo fiber with soil more uniformly. The deformation coefficients calculated by using the data shown in Fig.2. As shown in Table 1, the deformation coefficient for the soil mixed with bamboo fiber is similar to the deformation coefficient for the original soil containing no bamboo fiber. This result suggests that the uniformity in mechanistic deformation is ensured in the soil mixed with bamboo fiber. Thus, it is not necessary to give special consideration to the possible effects of bamboo fiber on deformation when designing the earth structure.

Table 1 The results of unconfined compression tests

Mix mass ratios of bamboo fibers [%]	0.0	0.3	0.4	0.5
The unconfined compressive strength q_u [kN/m^2]	94.6	129.1	125.2	137.8
Failure strain [%]	2.4	3.3	3.2	3.3
Deformation modulus E_{50} [MN/m^2]	4.9	4.9	4.8	5.1

Photo 3 shows the failures of the specimens after the tests. The specimens whose bamboo fiber mix ratio was 0.0% or 0.3% were occurred shear failure, and specimens whose bamboo fiber mix ratio was 0.4% or 0.5% were occurred breakage that produced barrel-shaped specimens. The shear failure surface of a specimen containing bamboo fiber at a mix ratio of 0.3% is shown in Phot. 4. In the photograph, a bamboo fiber spans the shear failure surface. No bamboo fibers were broken during the tests. Thus, it is said that the pull-out resistance of bamboo fibers works against shear failure and helps to prevent brittle failure. In the case of higher bamboo fiber content (e.g., 0.4% or 0.5%), it is presumed that the large failure resistance caused the failure mode to be barrel-shaped failure instead of shear failure. This suggests that the toughness of subgrade soil increases from the addition of bamboo fiber. It can be said that soil mixed with bamboo fiber is adequate as a soil improvement material that is applicable to pavement subgrade which needs to have good bearing capacity and durability.

(a) Shear failure (b) Barrel-shaped failure

Photo 3 Failure of specimens after the compression test

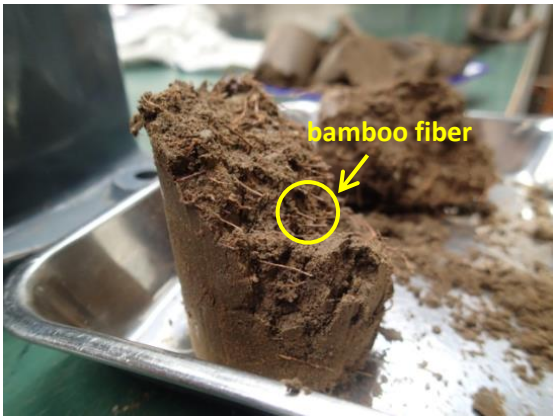


Photo 4 Shear failure surface of a specimen containing bamboo fiber

CONCLUSION

In this study, applicability of bamboo fibers extracted by steam explosion for the soil stabilization technique was examined. In order to understanding the mechanical properties of soil mixed with bamboo fiber produced by steam explosion, unconfined compression tests were conducted. The major findings of this study are as described below.

(1) That the addition of bamboo fiber to cohesive soil helps to increase the unconfined compression strength of the soil. Moreover, the addition of bamboo fiber to soil helps to increase the toughness of the soil.

(2) An increase in the mix ratio of bamboo fiber results in a change in the failure mode of test specimens. Then, at a mix ratio by weight of 0.4% or higher, specimens did not occur shear failure, but instead broke such as to become barrel-shaped.

(3) The deformation coefficient of the soil mixed with bamboo fiber is similar to the deformation coefficient of cohesive soil containing no bamboo fiber. The addition of bamboo fiber does not affect deformation properties. Thus, uniformity of mechanical deformation is ensured.

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Research article

The Effectiveness of Different Net-coverings on Production Yield of Chinese mustard (*Brassica juncea*) at Royal University of Agriculture

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Abstract Cambodia, among other nations in South East Asia, is a developing country that relies on its agricultural sector. More than 70% of the population farms rice is a staple crop and vegetables as a secondary crop for domestic demand and consumption. In 2013, Cambodia produced only 40-50% of the domestic demand for vegetables and the shortage was filled by imported vegetables from neighboring countries including Vietnam and Thailand. The shortage is caused by a number of factors including that vegetables are cultivated in small quantities and farmers lack funds to support improvements in crop cultivation that are necessary to address climate change, poor irrigation systems, disease outbreaks, and particularly crop destruction by pests. For instance, in 2016 crops in some provinces of Cambodia were damaged by Spodpter spp. Other insects also cause crop destruction which prompts farmers to change chemical pesticides to control additional pests. Using chemical methods to control the variety of pests that destroy Cambodian crops is not a viable long-term solution because it affects the health of both producers and consumers, the environment, and the microorganisms that are useful for cultivating high quality crops. The net-house is an installation structure using high quality mosquito netting that tolerates weather. It is suitable for growing vegetables and other crops because it creates a barrier between pests and crops to prevent damage. Using a net-house is an effective way to reduce pesticide use in vegetable production. It is also reported that net-houses have other benefits such as preventing weeds, reducing soil moisture loss, depleting sunlight, increasing yields and providing safe food. This research study has two aims (1) to assess the effects of different shapes of net-houses on growth and yield of Chinese mustard, and (2) to study the economic efficiency of growing Chinese mustard in differently designed net-houses. Experiments were conducted in triplicate using Randomized Complete Block Design. Treatments included standard net-house, covered-ridge net-house and open field as a control. Analysis revealed that using net houses increased the yield and economic efficiency of growing Chinese mustard and that the degree of benefit was affected by the design of the net house. Based on the results, recommendations are made about the most suitable method for growing high quality, pesticide-free Chinese mustard.

Keywords net-house, IPM, humidity, soil erosion, Chinese mustard

INTRODUCTION

Cambodia is a country located in tropical region with a monsoon wind, which is separated into the main two seasons: dry season and rainy season from May to October, and the dry season from November to April. This climate conditions that cause the cultivation of almost all types of crops grow well. Especially, most of vegetables commonly cultivated in lowland areas along rivers and other lowland areas. In that, vegetable crops with short harvesting time, such as mustard, are also cultivated. Due to the increase in demand for vegetables, local farmers cannot supply to import vegetables from neighboring countries such as Vietnam, Thailand, etc. These causes urge farmers to find ways to produce high-yield vegetables. The population is growing rapidly, which is why food demand is increasing every year. To solve these problems, scientists and technicians have tried to study new techniques to increase food production to meet daily needs (Nai, 2005).

Many of these foods, such as rice, wheat, corn, beans, sesame, and all kinds of vegetables, including Chinese mustard is a crucial crop to the people, Cambodian prefer to grow and take it as a vegetable to eat, or take it to cook for food and as supported substances such as protein, vitamins and other minerals and has been widely grew in all of Cambodia, especially along the river and other provinces. Farmers often grow as small and medium scale to supply families and markets with no technical limitations to increase yields. As a researcher for Chinese mustard grows well and no pests destroy and get better yields, we have to practice which techniques are relatively easy to spend little bit and get high yields to apply these techniques to farmers and to make their family life better (Chanchhaya, 2006).

The Net-house is an installation, which be built with large surface of net that allows plants to grow well and be environmentally-controlled to allow for better plant growth. In addition, the net-house has many roles: reduce weed, reduce the loss of soil moisture, reduces soil erosion, prevent sunlight, reduces the damaging as strong winds, increase yield and food safety to reduce soil erosion, and it is easy to harvest crops, use of nets is a good way to reduce the use of pesticides in the production of vegetable crops (Dany, 2010).

Chinese mustard is a type of vegetable that prefers to grow and eat because it has many benefits and is a crop that is resistant to hot and rainy those have same to the type of variety. In addition, Chinese mustard has no longevity of cultivation, farmers are often grown in vegetable gardens, family or farm produce for marketing in all seasons. Chinese mustard is a leafy vegetable that can contribute to the nutritional content and can be processed according to the need for cooking, or boiling and mixing with other vegetables or eating raw shoots of young leaves, as well as pickled mustard. Besides, it can be extracted deliciously and dried so that it can be stored for a long time. On the other hand, about 20-30% of Chinese mustard seeds can be refined as cooking oil and good quality (Vanarith, 2005).

OBJECTIVES

The objectives of this experiment were (1) to assess the effects of different shapes of net-houses on growth and yield of Chinese mustard and (2) to study the economic efficiency of growing Chinese mustard in differently designed net-houses.

METHODOLOGY

The Chinese mustard grown in front faculty of Agricultural Engineering in Royal University of Agriculture, Cambodia, in two seasons, rainy and dry season during academic year 2016-2017. The experiment was designed in a randomized block design with selection two models of net use and outside as Control. There were 3 treatments in this experiment as shown in Table 1 below. For each treatment was done in three replicates of which one plot containing 3 m^2 (1 m x 3 m) and all plots of this experiment were 27 m^2.

Treatment

- 1.T1: Opened-type (Control treatment)
- 2.T2: Net-house (7 m x 4.50 m x 3.40 m)
- 3.T3: Cover-bed net (3 m x 1 m x 1.5 m)

Fig. 1 Net-house

Fig. 2 Covered-bed net

After 12 days of germination stage, Chinese mustard plants were transplanted with a distance of 0.01 m × 0.01 m between rows and plants, respectively.

The Chinese mustard plant soil was sandy silt, pH 7, humus 0.8, containing total Nitrogen (0.21%), total Phosphorous (0.08%), total Potassium (0.90%), total Carbon (0.156 mil/100 g soil), a C/N of 5, with Organic Matter 0.26% (GDA, 2016). Net-house has installed same size (7 m x 4.50 m x 3.40 m) with three net-house for three replicates on flat land located different places. Covered-bed net has installed each bed with size (3 m × 1 m × 1.5 m) with three replicates to cover on each bed as well. The white net was used in this experiment and those were used same net for all net-house with mesh (32*32). For outside, is conventional method that has no covering or Control treatment. Chinese mustard were harvested manually when they had reached proper stage through cutting root, data collection was determined on number of insects, weight of weed, branch of plants, leaf area, weight per plant, and total weights. On economic analysis was determined on gross profit that took from calculation of total income minus total cost of Chinese mustard production. Below were some formulas to calculate economic cost in Chinese mustard production.

Formula GP=TI – TC, and
TC=TFC + TVC

Where: GP = Gross profit (US$)
TI = Total income (US$)
TC = Total cost (US$)
TFC = Total fix cost (US$)
TVC = Total variable cost (US$) (Farris et al, 2010).

Data as subjected to analyze of variance in Statistix 8 app. If interactions were significant, they we used explain the data. If interactions were not significant, means have separated with Tukey test.

RESULTS AND DISCUSSION

The Net-house and outside growing were determined in growth rate to analysis completely, as result shown that each data in Table 2. In addition, ANOVA determined that Covered-bed, type of growing and their two-way interactions had a significant effect on all measured characteristics of Chinese mustard interaction between different types of growing in net (Table 1).

Table 1 ANOVA table of Net-house Experiment on growing rate and total yield

	Mean Square				
S.O.V	Replicate	Treatment	Error	Total	CV (%)
d.f	2.00	2.00	4.00	8.00	
Insects (n/cm^2)	0.39	104.93	0.56		4.55
Weeds (g)	1773.88	11686.98	463.34		23.91
Branch/Plant	0.14	0.82	0.37		6.11
Leaf area (cm^2)	202.82	850.38	18.38		3.50
Plant height (cm)	13.72	88.94	3.51		7.16
Weight per plant (g)	98.98	1844.26	58.41		10.89
Total weight (t/ha)	0.94	64.12	2.02		10.59

*Note: S.O.V. = Sources of Variance; d.f. =degree of freedom; CV. = coefficient of variance; ns, ***, **, * non-significant and significant at P≤ 0.001, P≤ 0.01 and P≤ 0.05 respectively*

Table 2 Treatment of each replicates of chili yield and total yield characteristics

Treatments	Insect (N/cm^2)	Weigh of weed (g)	Number of leaf (N/plant)	Leaf area (cm^2)	Plant height (cm)	Weigh per plant (g/plant)	Weigh per square meter (t/ha)
T1	23.28a	113.69	9.39	109.61c	20.74c	51.25c	9.10c
T2	13.44b	90.08	10.24	116.45b	26.19b	61.06b	12.90b
T3	12.67c	66.27	10.33	141.58a	31.63a	98.25a	18.30a
Meaning	***	ns	ns	**	**	**	**
F-value	186.73	3.64	2.20	46.26	25.30	31.57	32.07
P-value	0.0001	0.1257	0.2268	0.0017	0.0054	0.0035	0.0034
CV	4.55	23.91	6.11	3.50	7.16	10.89	10.56

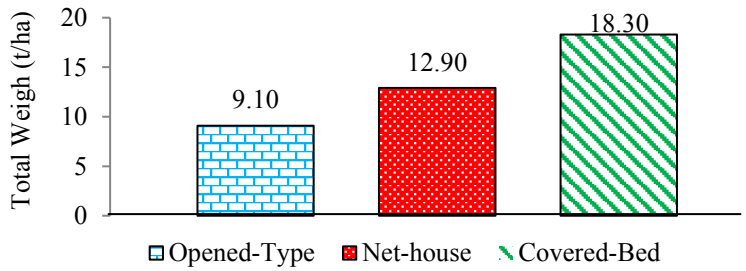

Fig. 3 Total weight of all treatments in t/ha

For production cost, Chinese mustard production costs have calculated AVERAGE of total weight per bed with 3 m^2 (1 m x 3 m) through first and second season. At first season of Opened-type, Net-house, and Covered-ridge weights per bed are 2.97, 3.87, and 5.49 kg/bed. In the table was separated costs into 2 types that were fixed cost and variable cost.

Table 3 Production Cost Analysis on each treatment in dollars ($)

Production cost	Formula	Opened-type	Net house	Covered-ridge
Fixed cost (FC)				
Irrigated tank(280 L) (5 years)	20 $ / 5 years / 4 times / 3 places	0.3333	0.3333	0.3333
Water sprayer	3 $ / 3 years / 8 times	0.375	0.375	0.375
Net (Mesh size=32)	29.40 $ for small and139.93 $ for net house (period 5years up and 8times)	-	0.5830	0.735
Wood posts	(9 post x 5 $) / 7 years / 8 times	-	0.0835	-
Wood bar	(13 bars x 5 $) /3 years / 8 times / 6 plots	-	0.45	-
Bamboo	3 $ / 2 years / 8 time	-	-	0.1875
Cable	10 $ / 500 m / 8 times	0.0025	0.0025	0.0025
Variable cost (VC)				
Land preparation	(5 $ / 162 m^2) x (1 time)	0.0102	0.0102	0.0102
Seeds or variety	1 $ / 2 times	0.5	0.5	0.5
Chemical fertilizer	40 $ / 50 kg / 5 times	0.16	0.16	0.16
Water for irrigation	(35 days) x 3 L x 2 times x 0.5/1000	0.105	0.105	0.105
Cow manure	2.5 $ / 100 kg / 30 times	0.0008	0.0008	0.0008
Power tiller renting	2.5 $ / 162 m^2 / 1time	0.0154	0.0154	0.0154
Weed cleaning cost	(5 $ / 27 ridges) x 3 times	0.5555	0.5555	0.5555
Installation cost	(10 $ / 27ridges / 6 beds)	-	0.0617	0.0617
Yields				
Weight	(0.91 kg/m^2, 1.29 kg/m^2, 1.83 kg/m^2) x 3	2.97	3.87	5.49
Total cost (TC)				
Include labor force		2.0578	3.2360	3.0420
Not include labor force		0.5555	0.6172	0.6172
Total income (TI)	Price x kg (1 kg = 2 $)	5.9400	7.7400	10.9800
Profit	Total income (TI) - TC	3.8822	4.5040	7.9380
Include labor force		3.8822	4.5040	7.9380
Not include labor force		5.3845	7.1228	10.3628

On the result, number of insects shown that much insects treatment was T1=23.28 N/cm^2, and least insects was T3=12.67 N/cm^2 which be used covered-bed net had a significant 0.1% with CV=4.55% and P-value = 0.0001. For leaf area, the biggest size treatment was T3=141.38 cm^2 and the smallest size treatment was T1= 119.61 cm^2 had a significant 1% with CV=3.50% and P-value = 0.0017. In addition, plant height of each treatment had a significant 1% with CV=7.16% and P-value = 0.0054 shown that the tallest treatment was T3=31.63 cm and the shortest treatment was T1=20.74 cm. Also, weight per plant of each treatment had a significant 1% with CV=10.89% and P-value=0.0035, treatment which be heaviest was T3=98.25 g/plant and lightest treatments was T1=51.25 g/plant. For weight per plant of each treatment had a significant 1% with CV=4.71%, heaviest treatment of weight per plant was T2=129.85 g per plant and lightest weight per plant was T0=95.45 g per plant. Furthermore, total weight of all treatments were significant 0.1% with CV=10.56% and P-value = 0.0034, which be heaviest was T3 = 18.30 t/ha and lightest was T1 = 9.10 t/ha. Otherwise, number of leaf and weight of weed were not significant.

Refer to data calculation in Table 3 was shown that income of each treatment are opened-type (US$ 5.94/bed), net house (US$ 7.74/bed), and covered-ridge is US$ 10.98/bed. In addition, treatment which be more profit is T3 (US$ 7.93/bed), next is net-house (US$ 4.50) and last treatment is opened-type got US$ 3.88/bed.

According to compare on the growth rate of Chinese mustard (Table 2), we were recorded on some data such as plant height, leaf area. ANOVA of these factors had shown that three factor were not same on some reasons such as soil of experiment plots, closing net-house doors and wind flow.

Total weight had obtained by grower be good thing to get such weight of Chinese mustard, so after ANOVA Table 2 and total weight of all treatments were significant 0.1% with CV=10.56% and P-value = 0.0034, which be heaviest was T3 = 18.30 t/ha and lightest was T1 = 9.10 t/ha (Fig. 3). After this research, result observation was proved that some reasons can be good for this study such as soil moisture on covered-bed treatment. we have observed some frogs and yellow tree frogs

those are nearby covered-bed treatment. According optimal condition of frog lifecycle is shown that proper humidity to live is 97.80% and temperature is 27.5 ^{0}C (Lannoo et al, 2005).

CONCLUSION

For the net-house and outside application in two seasons on Chinese mustard yield be effective and well than another treatment no need net. It makes Chinese mustard grow well and obtain high yield as well. Covered-bed application can keep humidity in soil, reduced pest on vegetable, reduce soil erosion and prevent the crop from heavy rain and insects destroying. And according to the results, where the criterion for net-house selection and its application rate is based on total yield as total weight, then the following net regimes can be recommended: T3=18.30 t/ha stand for covered-bed net-house was obtained highest yield and got highest profit (US$ 7.93 per bed) in this experiment and next suitable was T5=4.50 t/ha with profit was US$ 3.88 per bed.

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I have tried hard and soul to gather all relevant documents regarding this subject. I do not know how far I am able to do that. Furthermore, I do not claim all the information in this manuscript is included perfectly. There may be shortcoming, factual error, mistaken opinion which are all mine and I alone am responsible for those but I will try to give a better volume in future.

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Research article

Feasibility Study of Using Vermicompost Extract on Seed Germination on Green Romaine (*Lactuca sativa* L. var. Jericho) and Green Batavia (*Lactuca sativa* L. var. Concept) Lettuce

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Abstract Agriculture sector is under pressure in producing more foods in order to feed the growing population. Vegetable production is also the important part to solve the problem in the agricultural market. Nowadays, organic productions are in demand in order to promote health awareness and food safety. Vermicompost extract is liquid biofertilizers which able to boot up plant nutrients and plant productions. Thus, this study was conducted to investigate the effect of vermicompost extract on germination of green Romaine (*Lactuca sativa* L. var. Jericho) and green Batavia (*Lactuca sativa* L.var. Concept) and to identify the treatment which is suitable to enhance seed germination. The experiment was arranged in a Complete Randomized Design with 3 replications in the petri dish. The concentration of vermicomposting extract was diluted to (0, 25, 50, 75 and 100%) to irrigate seeds. Seed germination, root length, shoot length, seed vigor index, fresh weight, and dry weight were measured after 13 days of seed germination. The seed germination percentage of green Romaine and Batavia lettuce were significantly ($p<0.05$) increased up to (86-95%) and (87-95%) when irrigated with 100% vermicomposting extract as compared to control. In conclusion, using 100% vermicomposting extract as the nutrient source could enhance seedling growth.

Keywords vermicomposting extract, seed germination, green Batavia lettuce and green Romaine lettuce

INTRODUCTION

The food processing industries are one of the most essential activities in the agriculture market due to rapid economic growth. During food processing, industries produce a huge amount of organics waste such as food and vegetable. It has been observed that this organic waste can cause disease, air pollutant and water pollutant. However, the waste contains organic and inorganic nutrients which can recycle to use in the agricultural field. Therefore, eco-friendly and sustainable technology are needed to manage organic waste. Many publications have been established that organic waste can be used and converted into humus as vermicomposting. It is an important source for plant nutrients such as N, P, and K which can enhance the plant development (Garg and Gupta, 2011). Presently, more focus has been given to vermicomposting technique. This technology uses the assistance of earthworm to stabilize the organic waste material and produce microorganism-rich medium that enhances the process of composting. After the vermicomposting, an aqueous extract of vermicompost may contain a series of bioactive molecules as well as microbial population which may be enhanced during the production of extracts. For instance, mineral nutrients and biologically active metabolite such as humic acid and plant regulators present in vermicompost would be extracted during the brewing cycle and those compounds also improve root development, nutrient

uptake, and plant growth (Ancuta et al., 2013). Moreover, Lettuce is one of the essential vegetables in agricultural market; nevertheless, producers always supply a lot of chemical fertilizers which are not friendly to the environment and human health since they apply over limited of chemical fertilizer. Vermicompost extract is liquid organic fertilizer which also can boot up the lettuce production as well as promote health awareness and food safety since the organic productions are in demand in the market. Vermicompost extract has been studied for its effect on seed germination. Several studies have assessed on vermicompost water extract on seed germination and seed growth of tomato and lettuce (Ancuta et al., 2013). Lazcano et al. (2010) demonstrated that vermicompost extract can enhance seed germination maritime pine (*Pinus pinas* Ait). Ievinsh (2011) also reported vermicompost extract treatment differently affect to seed germination, seedling growth physiological of vegetable species. Esteban et al. (2017) also studied the effect of germination of Saluyot (*Corchorus olitorius*). There are many studies focus on the effect of vermicompost extract on seed germination but most of them conducted with different kinds of vegetables. Therefore, The study "feasibility study of using vermicomposting extract on seed germination and seedling green Romaine (*Lactuca sativa* L. var. Jericho) and green Batavia lettuce (*Lactuca sativa* L.var. Concept)" will be raised to study in this paper.

OBJECTIVE

The objective of this paper was to investigate the effect of vermicompost extract on seed germination and seed performance of green Romaine (*Lactuca sativa* L. var. Jericho) and green Batavia lettuce (*Lactuca sativa* L.var Concept) and to identify the treatment which is suitable to enhance seed germination.

METHODOLOGY

Vermicomposting Preparation

Vermicomposting was prepared with the reference (Iwai, 2011). The substrate of vermicompost was composed of soil, cow manure, rice husk ash, vegetable in proportion ration 4:4:1:3 w/w. The vegetable was collected from waste yard from the Si Mueng Thong market locates in Khon Kaen province. Roi et series soil was sampled in the agricultural file, located in Khon Kaen University. Cow manure was collected at cow farm located in the Khon Kaen University. Rice husk ash was collected in agronomy section located in the university. Vermibed was conducted with pot size 15 cm wide and 30 cm length with the 19 cm high. Pre-compost was 15 days to avoid thermophilic stage (increased temperature above cause earthworm death in vermicomposting process) and earthworm species (*Eisenia fetida)* was introduced to the substrate by using 150 earthworms per pot with the moisture content 80 to 90%. After the pre-compost processing, vermicomposting was manually turn up to 12 weeks.

Vermicompost Extract

Vermicompost extract was prepared as described by Archana et al. (2009). Briefly, vermicompost was extracted with tap water in ration 1:4 (w/v) by using the aerated method. Water was allowed to stand for 24 h for passive chlorine before mixing. Vermicompost was put in cheesecloth and mixture with tape water using aquarium air pump for 72 h. For fresh solution was kept for each treatment.

Seed Germination Experiment

Seed germination experiment was conducted for 13 days at Ecotoxicology Laboratory, Department of Land Resource and Environment, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand. The experiment was conducted as a Completely Random Design (CRD)

with three replications. Lettuce verities Roman (*Lactuca sativa* L. var. Jericho) and Batavia (*Lactuca sativa* L.var. Concept) were sterilized with deionized water for 15 minutes to remove microbe from the seed. Fifty seeds from each varieties were put on Whatman Grade 181 No. 1 filter papers in 9 cm Petri dishes and treated with different concentration of vermicompost extract (0, 25, 50, 75 and 100%), and then incubated at 25 ^{o}c in dark cycle for 3 three days and 12 hours light cycle for 10 days in an incubator. After completed of seed germination, seeding from each treatment was measured for germination percentage, root length, shoot length, seedling vigor index, fresh weight, and dry weight.

Seed Germination Percentage Estimation

The total number of seed germination percentages were calculated following (Manisha and Angoorbala, 2015).

$$\text{Germination (\%)} = \frac{\text{Total number of seed germinated in particular treatment}}{\text{Total number of seed treated in particular treatment}} \times 100$$

Root and Shoot Length Estimation

The root and shoot length of seed germination was measured in the centimeter scale.

Fresh and Dry Weight Estimation

Fresh and dry weight was measured using an Ohaus PA 2102 electronic balance. After fresh weight measurement, seeding weight was placed in a hot air oven for 80 ^{o}c for 24 hours.

Seeding Vigor Index

Seed germination, root length, and shoot length were used to calculate seed vigor index, which followed the formula (Abdul Baki and Anderson, 1973).

Vigor index= (Mean root length + Mean shoot length) x Percentage germination

Statistical Analysis

The Statistic 10 software (version 10, USA) was used to analyze the data including the analysis of variance (One Way ANOVA). Treatment means were compared using least significance difference (LSD) at $P< 0.05$.

RESULTS AND DISCUSSION

The results of seed germination of green Romaine (*Lactuca sativa* L. var. Jericho) and Batavia (*Lactuca sativa* L. var. Concept) were shown in Table 1 and Table 2. Different concentration of vermicomposting extract has different effect on seed germination of green Romaine and Batavia lettuce. It showed that 100% of vermicomposting extract got higher germination 95 and 95% of Romaine and Batavia lettuce. The result was similar with finding of Ancuta et al. (2013) that germination increased when the seed was soaked in vermicomposting extract compared with seeds soaked with water and it was also reported that water-soluble bioactive substances such as humic acids, phytohormones or microbial metabolites present in vermicompost extract could be responsible for earlier emergence, increased seed germination percentage and seedling growth. Esteban et al. (2017) reported that microbial activity in vermicompost could result in the production of significant quality of plant growth regulators such as IAA, gibberellins, and cytokinins.

Table 1 Effect of vermicomposting extract of green Romaine seed germination (GM), roots length (RL), shoots length (SL), seeding vigor index (SVI), fresh weight (FW) and dry weight (DW)

Treatments	GM (%)	SL(cm)	RL(cm)	SVI	FW (g)	DW(g)
0%	86d	0.560c	2.660b	276.910b	0.736c	0.026c
25%	90c	0.566bc	4.620b	469.960b	0.956b	0.053b
50%	92b	0.566bc	7.546a	746.430a	1.046ba	0.060b
75%	92b	0.586b	8.286a	821.720a	1.046ba	0.073a
100%	95a	0.653a	8.520a	875.400a	1.146a	0.076a
F value	**	ns	**	**	**	**

Values in same letters in the columns are not significantly different (LSD test, p≤ 0.05), Asterisks (**) show significant differences at the 0.01 level, Asterisk (*) shows significant differences at the 0.05 level, and (ns) shows no significant differences between treatments

Table 2 Effect of vermicomposting extract of green Batavia seed germination (GM), roots length (RL), shoots length (SL), seeding vigor index (SVI), fresh weight (FW) and dry weight

Treatments	GM (%)	SL(cm)	RL(cm)	SVI	FW (g)	DW(g)
0%	87d	1.346b	3.380b	412.790a	0.863c	0.050b
25%	90c	1.526ab	3.593b	460.800a	0.996bc	0.066a
50%	92b	1.586a	5.953a	693.680b	1.136ba	0.071a
75%	92b	1.586a	6.566a	755.440b	1.176ba	0.073a
100%	95a	1.653a	6.380a	765.870b	1.196a	0.076a
F value	**	ns	**	**	*	**

Values in same letters in the columns are not significantly different (LSD test, p≤ 0.05), Asterisks (**) show significant differences at the 0.01 level, Asterisk (*) shows significant differences at the 0.05 level, and (ns) shows no significant differences between treatm

The longest root and shoot length of Romaine and Batavia (2.660, 3.380, 560, and 1.346 cm, respectively) were reported with 100% vermicompost extract. Esteban et al.(2017) also reported that vermicompost can promote ecomorphological characters such as plant high and length. Moreover, vermicompost can be able to supply balanced the nutrients to the roots and stimulate growth and increase the organic matter content including humic substances that affect nutrient accumulation and promote the root growth. 100% of vermicompost extract showed the highest vigor index of Romaine and Batavia (875.4 and 765.87) which indicated that 100% vermicomposting extract promoted healthy and vigorous seeding response compared with other treatments. Esteban et al. (2017) also indicated that vermicompost extract could produce healthy and vigorous growth of seeding. 100% vermicompost extract also showed higher in fresh weight and dry weight of both lettuce verities (1.146, 1.196, 0.07, 0.076 g, respectively). It was also reported that when the shoot and root were healthier, the plant weight will be heavier (Hussain et al., 2013). The result also similar with the finding of Zaller (2007) reported that vermicompost extract can promote the tomato biomass production and it was also suggested that vermicompost not only stimulate the plant growth but also effect inhibition of plant pathogen, rhizosphere micro floral, nutrient uptake and beneficial of microorganism.

CONCLUSION

From this study, it could be concluded that vermicompost extract was influenced the seed germination of green Romaine (*Lactuca sativa* L. var. Jericho) and green Batavia (*Lactuca sativa* L. var. Concept) and 100% vermicompost extract showed the best result compared with other treatments since this concentration enhance seed germination percentage, shoot length, root length, seed vigor index, fresh weight and dry weight of Romaine and Batavia seeds. Therefore,

vermicompost extract could be used as the alternative organic fertilizer to improve the seedling growth and crop production in the field.

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Review article

Status and Issues in Ecological Engineering Techniques for Conserving Fish in the Paddy Field Areas of Japan

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Abstract Though land consolidation for paddy field areas has contributed to an increase in food supplies and an improvement in convenience, it has changed the physical structures and deteriorated paddy field ecosystems throughout Japan. Eco-friendly land consolidation in paddy field areas has been conducted based on the implication of ecosystem deterioration. Ecological engineering techniques, such as the placement of fish ladders between paddy fields and irrigation canals, were developed and applied to actual paddy fields to conserve fish. However, the techniques were not evaluated sufficiently. Therefore, I reviewed status and issues of ecological engineering techniques for conserving fish, which are often reported in Japan. This review showed the installation of fish ladders between paddy fields and drainage canals, as well as the construction of artificial ponds and wetlands, have contributed to providing fish with spawning and nursery areas in the paddy fields areas of Japan. On the other hand, the effects of ecological engineering techniques in canals, such as the construction of concrete block habitats, are not clear, although the techniques have already been applied to actual paddy field areas. Studies evaluating the effects of these techniques, which were applied for canals especially, should be conducted, and researchers and engineers should elucidate the most suitable structures, locations, scales and maintenance techniques for these constructions to best conserve fish in paddy field areas.

Keywords ecological engineering technique, paddy field ecosystem, fish, conservation, Japan

INTRODUCTION

Paddy fields have substituted for the back marshes of rivers, and play a role in the wetlands of low and flat-land areas (Moriyama, 1997; Natsuhara, 2013). They are not only food production areas, but also habitat, spawning, and nursery areas for aquatic organisms, such as fish, frogs, and aquatic insects.

Land consolidation in paddy field areas has contributed to an increase in food supplies and an improvement in convenience for farmers, and has exceeded 60 % of the paddy field areas in Japan. On the other hand, land consolidation has changed the physical structures of paddy fields, and deteriorated paddy field ecosystems in Japan (Lane and Fujioka, 1998; Hata, 2002a). For example, fish species that use paddy fields as spawning areas such as Japanese killifish (*Oryzias latipes* and *O. sakaizumii*) and mud loach (*Misgurnus anguillicaudatus*), cannot migrate from canals to paddy fields, because the creation of drainage canals create large drops between the paddy fields and themselves. Consequently, many endemic and/or dominant species in paddy field areas such as Japanese killifish and mud loach were designated as endangered species by the Ministry of the Environment and several prefectures of Japan.

Eco-friendly land consolidation in paddy field areas has been conducted based on the implications of ecosystem deterioration. A section of the "Land Improvement Act" of Japan was revised in 2001, and "consideration of harmony with the environment" was added a principle of the land improvement project.

Ecological engineering has been researched with the aim of designing sustainable ecosystems that integrate human society with its natural environment for the benefit of both humans and

animals (Mitsch, 2012). Therefore, ecological engineering techniques in land consolidation projects are required to strike a balance between the increase in production and improvement in maintenance by farmers, and at the same time aid the conservation of aquatic organisms. The ecological engineering techniques, such as fish ladders between paddy fields and drainage canals, were adapted for paddy field areas where eco-friendly land consolidation was conducted. However, the techniques have been rarely evaluated.

OBJECTIVE

I have reviewed studies of ecological engineering techniques in the paddy field areas of Japan to discuss the status and issues with these techniques. In this paper, I have placed focus on the techniques for conserving fish in paddy field areas, because the development of these techniques has been adapted for actual paddy field areas in Japan frequently.

ISSUES OF PREVIOUS REVIEWS

Some researchers have reported studies on fish ecology and habitats in paddy field areas. Koizumi et al. (2012) showed that studies on fish lifecycles and ecology in the paddy field area have increased since 2000; however, the development of methods for estimating and predicting the fish populations and ecosystem of paddy field areas has been limited. Takemura et al. (2012) reviewed the methods of evaluating habitat quality, and the connectivity between the habitats and spatial arrangement of habitats for fish in paddy field areas, and discussed the issue of these methods. In addition, Nakano (2017) reviewed that previous studies have examined habitat preference of fish growth, spawning, wintering, migration, and dispersal of fish, in paddy field areas. These reviews did not focus on ecological engineering techniques.

Several researchers have reviewed conservation measures and ecological engineering techniques. Ogino and Ota (2007), Suzuki (2011), and Natuhara (2013) referred to the structure and installation method of fish ladders installed in paddy field areas of Japan; however, other techniques were not reported sufficiently. Mizutani (2011) and Minagawa (2015), and Mori (2017) presented some conservation measures for fish in paddy field areas; however, the status and issue of these measures and techniques were not discussed sufficiently. In addition, a large number of studies have been conducted with respect to ecological engineering techniques in the paddy field areas of Japan; however, it is difficult for people except those who speak Japanese to recognize these ecological engineering techniques, because many existing studies are published solely in Japanese.

Previous reviews in other countries have indicated the importance of paddy fields as habitats that are deteriorated by modern agricultural practices (Fernand, 1993; Herzon and Helenius, 2008; Luo et al., 2014). In addition, Chen et al. (2015) reported preliminary installation of fish ladders in the paddy field area of Taiwan. However, reviews and studies that focused on the ecological engineering techniques in the paddy fields have been rarely reported.

Sato (2014) conducted a questionnaire survey on the current status of ecosystem conservation in land consolidation projects to be carried out in the prefectures of Japan. He focused on ecological engineering techniques for fishes and frogs, because these measures have been conducted frequently based on their ecology and behavior, which has been revealed by previous studies (e.g., Saitoh et al., 1988). The techniques for fish in land consolidation projects in Japan shown by his questionnaire are summarized as follows (1-4 in Table 1). Although Sato's questionnaire survey did not report this fact, artificial wetlands and ponds were also constructed in land consolidation projects (Sugihara and Mizutani, 2006; Moriyama et al., 2010; Takemura et al., 2010; Nishida et al., 2014). Therefore, I have focused on and reviewed the below ecological engineering techniques for fish in land consolidation projects in Japan (1-5 in Table 1).

Table 1 Ecological engineering techniques for conserving fish in paddy field areas, which were often conducted in Japan

	Conservation measures	Ecological engineering techniques
1	Improvement of canal revetment	a) Construction of masonry and wooden revetment works (Takahashi et al., 2009). b) Construction of concrete block habitats.
2	Improvement of canal bed	a) Avoiding installation of concrete lining (Sato and Azuma, 2004). b) Installation of habitat pool section (Hiramatsu et al., 2010; Minagawa et al., 2015). c) Installation of spur dikes (Mukai et al., 2011) and blocks (Watabe et al., 2016).
3	Improvement of canal form	a) Construction of meandering section (Nishida et al., 2011). b) Construction of broaden section (Conservation Society-Japan, 1995; Nishida et al., 2011).
4	Installation of migration pathway	a) Installation of fish ladders between paddy fields and drainage canals (Hata, 2002b; Suzuki et al., 2004; Tanaka, 2006; Sato et al., 2008; Nakamura et al, 2009; 2012). b) Installation of fish ladders in canals (Moriyama et al., 2008).
5	Construction of calm waters	a) Construction of ponds (Sugihara and Mizutani, 2006; Takemura et al., 2010). b) Construction of wetlands (Nishida et al., 2014, 2015).

(a) Masonry revetment work (b) Wooden revetment work

Fig. 1 Example of (a) masonry and (b) wooden revetment works in canals
Riparian plants grow between the wooden stakes

IMPROVEMENT OF CANAL REVETMENT

Construction of Masonry Revetment Works

Stream and canal riparian structure influence the habitats of aquatic organisms (Pusey et al., 2003). The growth of riparian plants influences the habitation of fish and aquatic organisms (Kawaguchi, 2003). Masonry and wooden revetment works (Fig. 1), and similar structures, were traditional methods of canal improvement and repair. These structures have many spaces between materials, and it is considered that these spaces and the plants that grow in them provide habitats for fish (Katano, 1998). Takahashi et al. (2009) installed an experimental dummy of a wooden mattress dike, one of the traditional methods of revetment (shown in the middle right of Fig. 6), in a drainage canal to evaluate to the effects on fish habitation. They showed that this dike was frequently used by fish, such as crucian carp (*Carassius* spp.), in paddy field areas. However, other revetment works in canals were not investigated for their effects on fish habitats.

Construction of Concrete Block Habitats

Concrete block habitats (Fig. 2) were often installed for canal revetments to enable fish to use canal improvements as habitats in Japan (Sato, 2014; Japanese Society of Irrigation, Drainage and Rural Engineering, 2016). These blocks have cavities inside in the expectation that fish may use them as habitats. However, no study has evaluated the exact effects of these concrete block habitats on fish and other aquatic organisms in irrigation canals. In addition, there is no knowledge on which species and growth stages of fish can use these concrete blocks as habitats.

Fig. 2 Example of a concrete block habitat installed in a drainage canal

IMPROVEMENT OF CANAL BED

Avoiding the Installation of Concrete Lining

Concrete lining was usually installed in canals during conventional canal improvements. However, the number of fish species and individuals was reported to drastically decrease because fish habitats were often removed by the improvements (Kihira, 1983; Tsubokawa, 1985). Therefore, the installation of concrete lining was partially avoided as much as possible to allow eco-friendly canal improvements. Sato and Azuma (2004) investigated the difference in fish habitation among construction methods after canal improvements. Some canal sections improved by eco-friendly construction methods such as concrete revetment works with concrete block habitats, and concrete canal beds were not installed in these sections to enable fish to inhabit (Fig. 3).

(a) Straight section (b) Meandering section

Fig. 3 Example of (a) straight and (b) meandering sections of the drainage canal
These photographs were taken five years after canal improvement was undertaken

Numbers of fish species and individuals, and diversity indices in conventional concrete lining canal sections were significantly smallest than those in other sections. On the other hand, these values in concrete revetment canal sections were not significantly different from those in earth canal sections. These observations indicated that avoiding the installation of concrete lining is

the key to conserving fish in paddy field areas.

Installation of a Habitat Pool Section

Sato (2014) indicated that habitat pools (Fig. 4) were often installed during land consolidation projects in Japan. Hiramatsu et al. (2010) and Minagawa et al. (2015) investigated fish assemblages and physical environments in pools that were installed by canal improvement projects. These pool beds were concrete and 0.30-0.50 m deeper than other canal sections. Their findings indicated that these pools were important for fish to winter in. On the other hand, Minagawa et al. (2015) also reported that sand and silt had accumulated excessively, and the water depth was lower in some pools. Further studies are needed to elucidate how to wash away or remove these sand and silt accumulations to maintain a water depth that is inhabitable by fish.

Fig. 4 Example of a habitat pool installed in a drainage canal
This pool bed was dug 0.3 m deeper than the normal canal section.
Sand and silt were accumulating, and the water depth had been reducing gradually

Installation of Spur Dikes and Blocks

Mukai et al. (2011) experimentally installed spur dikes with notches on the canal bed crossing the canal to form sand bars, riffles, and pools for aquatic organisms. They investigated the temporal change in the formation of sand bars and invertebrate assemblage before and after the installation. The formation of sand bars was observed by investigation after one year of the installation of the dike. Riparian plants were formed on the sand bars six months after the sand bar formation. The number of invertebrate individuals increased after the formation of sand bars and riparian plant zones, indicating these formations created invertebrate habitats. These methods might provide fish habitats, as well as help to explain the findings of Nishida et al. (2011) described below. However, the effect on fish habitation was not investigated.

Fig. 5 Example of concrete blocks on the concrete lined canal bed
These blocks captured sediments and created sand bars and/or small riparian plant zones

Watabe et al. (2016) also installed concrete blocks, such as the one seen in Fig. 5, on the concrete lining of a canal bed, and investigated the fish assemblage and canal environment before and after the installation. They arranged the long sides of the rectangular concrete blocks perpendicular to the water direction in the canal. Their observation showed that the blocks created calm water and sand sediment zones in the canal. However, the change in the number of fish individuals before and after the installation was small. There is no sufficient evidence that these concrete blocks create suitable fish habitats.

IMPROVEMENT OF THE CANAL FORM

Construction of Meandering Sections

Nishida et al. (2011) investigated the temporal change in fish assemblages and physical environments of drainage canals before and after canal improvements by eco-friendly construction methods. In particular, they focused on the differences in temporal changes between meandering and straight sections where revetments were installed (Fig. 3). Sand bars did not form, riparian plants did not grow, only mud loach were dominant, and the number of species and diversity indices had declined in the straight sections five years after the canal improvement. On the other hand, sand bars formed, riparian plants grew, and a number of fish species and diversity indices did not change before and after canal improvements in the meandering sections. These differences between straight and meandering sections may be due to the presence or absence of calm waters made by sand bars and riparian plants, which create natural hiding spots for fish. Further studies are needed to elucidate how canal form and structure can form sand bars and riparian plant zones.

Construction of Broadened Sections

Ecosystem Conservation Society-Japan (1995) reported that the number of fish species increased in a broadened section of a canal after canal improvements (Fig. 6). The construction of broadened sections probably provided calm water areas in the canal. However, which factor increased the number of fish species was not clear. In addition, studies that elucidate the effect of construction of broadened canal sections on fish assemblage are limited.

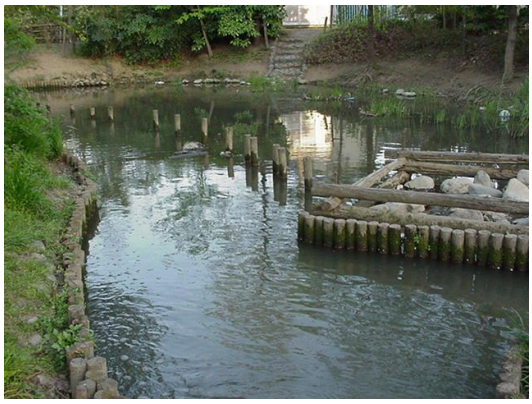

Fig. 6 Example of a broadened section in a canal
The previous canal width before improvement was between the left bank and stakes located in the center of this photograph

Some meandering sections that Nishida et al. (2011) investigated were also broadened by the eco-friendly canal improvements. Large sand bars formed and riparian plants thrived in these broadened sections. This increased plant growth perhaps increased the management efforts of farmers and prevented drainage water flow. Research into construction methods that strike a balance between improving the convenient management of canals and conservation of aquatic organisms is required.

INSTALLATION OF A MIGRATION PATHWAY

Fish Ladder between Paddy Fields and Drainage Canals

Endemic and/or dominant fish in paddy field areas such as mud loach and Japanese killifish migrate from canals and spawn in paddy fields (e.g., Saitoh et al., 1988). However, these fish species often cannot migrate to paddy fields after a land consolidation project, because drainage canals are dug to improve the draining ability of paddy fields (Hata, 2002b). This digging creates a large drop between the paddy field and drainage canal.

Japanese researchers have tried to develop fish ladders to enable these fish species to migrate from drainage canals to paddy fields (Hata, 2002b; Suzuki et al., 2001; Tanaka, 2006; Sato et al., 2008). These fish ladders were classified into two types, and were installed in paddy field areas as follows.

1) Paddy field outlet ladder (Fig. 7a): This ladder type was installed at each outlet of paddy fields in order to allow fish migration from drainage canals. Fish ladders of variable structures were developed, and they were installed in every region of Japan by farmers and/or local governments.

2) Up-dam ladder (Fig. 7b): This fish ladder type was installed at drainage canals and dams with a higher water level at the upper section of drainage canal from this ladder. This improvement enables fish to migrate from downstream of the ladder to the paddy field because the water level between the drainage canal and the paddy fields is lower. This fish ladder type has been utilized in paddy field areas around Lake Biwa.

(a) Paddy field outlet ladder (b) Up-dam ladder

Fig. 7 Example of the two type of fish ladders in use
(a) paddy field outlet ladder and (b) up-dam ladder between paddy fields and the drainage canal

The effects of the fish ladders have been investigated by some researchers. Suzuki et al. (2004) investigated the effects of fish ladders between drainage canals and paddy fields. They indicated that mud loach and crucian carp migrated from drainage canals to paddy fields through fish ladders, and spawned in the paddy fields. After hatching, their larvae probably grew in the paddy fields and then migrated to the drainage canals. As a result, increases in fish wet weights in paddy fields after land improvement projects were equal to or larger than those before them.

Nakamura et al. (2009, 2012) reported that the drainage of water from paddy fields through fish ladders was greater than that from the outlets of paddy fields in which the fish ladder was not installed. This finding indicated that irrigation water is required in the paddy fields that fish ladders are installed. Therefore, new water management practices are crucial to enable fish to migrate through the fish ladder and spawn in the paddy fields.

Installation of Fish Ladders in Canals

Fish ladders were also installed at drop structures and outlets of the canals (Fig. 8). Pool and canal types of fish ladder that were developed by river engineering researchers were installed at the drop structures. Moriyama et al. (2006) reported new fish species were detected in the irrigation canals after the installation of fish ladders on outlets, suggesting that these fish ladders enabled fish to migrate from lower water areas. On the other hand, the fish ladders may also allow alien fish species to invade the irrigation canals.

(a) Fish ladder at a drop structure in a canal (b) Fish ladder at an outlet of a canal

Fig. 8 Examples of fish ladders installed (a) at a drop structure and (b) outlet of a canal

CONSTRUCTION OF CALM WATERS

Construction of Ponds and Wetlands

Sugihara and Mizutani (2006) investigated fish habitation in an artificial pond (Fig. 9), and the migration between an artificial pond and the adjacent water areas, in paddy field areas. A large number of age-0 pale chub (*Opsariichthys platypus*) as well as crucian carp and Japanese killifish were captured in the artificial ponds in winter, indicating that these fish species wintered there. In addition, for fish that spawn in paddy fields, such as the field gudgeon (*Gnathopogon elongatus elongatus*), adults ascended from connected drainage streams to the pond, and oppositely, juveniles and sub-adults descended from the pond to the drainage streams. These findings indicated that these fish species probably used the pond as a spawning and nursery areas, as well as paddy fields.

(a) Artificial pond (b) Artificial wetland

Fig. 9 Examples of an (a) artificial pond and (b) artificial wetland constructed in a paddy field area

Takemura et al. (2010) reported that ninespine stickleback (*Pungititus* sp. 2) made nests on aquatic plants in artificial ponds. On the other hand, they also suggested that artificial ponds will become unsuitable for nesting by ninespine stickleback if aquatic plant mowing is abandoned and plant cover is increased throughout the pond, because ninespine sticklebacks often made nests on the edge of each plant zone, but did not make nests in the center of the plant zone. On the other hand, intense mowing may remove all nest substrate for ninespine sticklebacks. In addition, in these shallow and calm waters, sand and silt accumulates and aquatic plants grow easily. Therefore, maintenance of these water areas may be crucial to conserve fish habitats. Further studies are needed to elucidate how to suitably maintain these water areas.

Nishida et al. (2014) investigated fish habitation in an artificial wetland (Fig. 9), and migration between an artificial wetland and connected stream, and the migration of the mature mud loach and eight-barbell loach (*Lefua echigonia*) was detected between late winter and spring. Juveniles and sub-adults of these two loach species migrated from the wetland between summer and winter. These results confirmed that wetlands act as spawning and nursery habitats for these two species of loach. On the other hand, fish species other than the mud loach and eight-barbell loach, frogs, and aquatic insects that were found in the adjacent paddy fields, were rarely detected (Nishida et al., 2015). The unique characteristics of artificial wetlands that are frequently used by many aquatic organisms are not known yet.

CONCLUSION

This review showed that the installation of the fish ladders, which were developed by Japanese researchers and engineers, between canals and paddy fields provides fish, such as mud loach and crucian carp, with spawning and nursery areas . Similarly, artificial ponds and wetlands constructed in a paddy fields area were sufficiently used by fish as spawning and nursery areas especially. On the other hand, the effects of ecological engineering techniques on canals where fish spent most of their life cycles are not clear, although the techniques have already been applied to actual paddy field areas. Studies evaluating the effects of these techniques in canals should be conducted, and researchers and engineers should elucidate the most suitable structures, locations, scales, and maintenance techniques for these constructions to best conserve fish in paddy field areas.

Middle- or long-term monitoring is required to evaluate these techniques, because ecosystems and physical environments often fluctuate, and previous studies have indicated it can take a long time until they stabilize after disturbance. However, this monitoring is rarely conducted in Japan; the development of monitoring methods and mechanisms are needed.

In Japan, many studies evaluating the effects of these techniques are published in Japanese, because the local language is useful to easily show the effects to the Japanese and local governments, as well as domestic engineers. On the other hand, studies published in English are needed to provide knowledge of these ecological engineering techniques to people globally. This knowledge may be useful in Southeast Asia especially, because paddy fields in this area could be improved to increase future agricultural production and convenience.

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Research article

Genetic Identification of Myanmar Sein Ta Lone Mango (*Mangifera indica* L.) Landrace from the Different Eco-Geographic Regions using Microsatellite Markers

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Abstract Eighty eight Sein Ta Lone mango individuals from five Sein Ta Lone orchards (populations), namely, Mya Na De, Htone Bo, Se Bauk, Taik Kyi, and Nam Latt, and 100 years old plant as control, and a landrace of Yin Kwe individual, a total of 89 individuals, were genotyped using 38 polymorphic markers showed 147 alleles with an average of 3.87 alleles per locus. Polymorphic information content varied from 0.02 to 0.83 and averaged of 0.37.Twenty four loci were Sein Ta Lone unique markers. Cluster analysis depicted those SP4 plant individuals from Se Bauk stand as an out-group from the rest of Sein Ta Lone individuals which scattered independently from their locations. Principal coordinate analysis confirmed grouping of Sein Ta Lone individuals closely to control Sein Ta Lone (100 years old) rather than Yin Kwe variety, and the first three principal coordinates explained 62.05% of total variation. Analysis of molecular variance explained 75% of genetic variation occurred within populations and 25% among populations. The fixation index (Fst) 0.63, pointed the high level of genetic differentiation among populations, it might be due to Yin Kwe control rather than five Sein Ta Lone populations. Limited gene flow (Nm = 0.31) occurred among the populations. Almost the same value (0.32 to 0.35) of the expected heterozygosity and the observed heterozgosity (0.16) were observed in Sein Ta Lone populations. The number of effective alleles varied from 1.88 to 2.13, Shannon Index ranged from 0.54 to 0.61, and same positive fixation index of (0.4), same value of the percentage of polymorphic loci (52.63%). Pairwise Nei genetic identity showed higher value to Sein Ta Lone control (100 years old), highest among five populations ranged from 0.916 to 0.957.

Keywords genetic identification, Sein Ta Lone populations, Sein Ta Lone unique marker, cluster analysis, analysis of molecular variance

INTRODUCTION

Mango (*Mangifera indica)* consisted of two distinct types such as monoembryonic and polyembryonic type. Based upon taxonomic and molecular evidence, the mango (polyembryonic type) probably evolved in north-western Myanmar, Bangladesh and north-eastern India (Bompard, 1993; Mukherjee and Litz, 2009). Hirano et al. (2010) identified the uniqueness of Myanmar mango individuals from Vegetable and Fruits Research and Development Center (VFRDC), Yangon, using 11 SSR markers and results revealed that mango individuals from Myanmar were distinguishable from those of Florida, India, and Southeast Asia.

Polyembryonic mango seeds contain several nucellar and zygotic embryo. Since adventitious embryos develop from the nucellus, or can also originate by direct budding from the cotyledons and hypocotyls of other nucellar, embryos seedlings are genetically identical to the maternal parent (Juiano, 1934). However, there was a little variation among seedlings derived from polyembryonic mangoes, due to somatic mutation (Mukherjee and Litz, 2009) and various biological and cultural factors (Begum et al., 2013). Even, mango has cross-pollinated nature; Moore and Castle (1988) recorded about 88-94% of self-pollinated zygotic seedlings using isozymes.

Nowadays, orchards are being used grafted plants (stock and scion), however, home yard gardens are still using plants directly from seeds. Since Sein Ta Lone mango previously sown from seed, and to date grafted Sein Ta Lone orchards were necessary to document their DNA profile for fingerprinting and genetic variability on farm.

OBJECTIVE

This study aims to analyze genetic diversity and population structure of Sein Ta Lone individuals, using SSR markers.

METHODOLOGY

From May to July, 2017, the leaf samples from 88 Sein Ta Lone sample plants: 18, 15, 18, 18 and 18 sample plants from Mya Na De, Htone Bo, Se Bauk, Taik Kyi, and Nam Latt, respectively, and one control Sein Ta Lone (assuming 100 years old according to villagers of Pae Gin Village, Kyauk Se Township, Mandalay region), were collected. Mya Na De, Htone Bo and Se Bauk orchards are from Mandalay region, Taik Kyi orchard from Yangon region, and Nam Latt orchard from Shan region, respectively. In addition, Yin Kwe landrace, which widely used as rootstock for Sein Ta Lone orchards, was also used as control. This experiment was carried out at the Plant Biotechnology Center (PBC), Department of Agriculture (DOA), Myanmar.

Total genomic DNA was isolated from pale-brown young leaves using the hexadecyl trimethyl ammonium-bromide (CTAB) method (Doyle and Doyle, 1987) with few modifications. A total volume of 10 μl of reaction mixture of PCR cocktails were performed in Labnet (Labnet international Inc.) thermal cycler programmed for 5min at 94°C for initial Denaturation, 35 cycles of 1 min at 94°C, min at 55°C - 60°C (marker dependent), 1 min at 72°C and final extension at 72°C for 5 minutes. PCR products were fractionated through 8% (w/v) polyacrylamide gel and the expressions of gels were recorded on UV light using Cannon G12 digital camera.

SSR fragment sizing was performed with LabImage 2.7.1 Software and genetic distance and cluster analyses were evaluated for 89 individuals with 38 polymorphic loci using NTSYS-pc 2.01 program (Rohlf, 2000). Nei and Li's genetic distance (1979) was conducted to calculate pair-wise genetic distance among all individuals and the dendrogram was constructed by using a distance matrix using the unweighed pair group method with arithmetic average. The polymorphic information content (PIC) was calculated by applying the formula provided by Anderson *et al.*

(1993). To elucidate the genetic relationship among the populations, principal coordinate analysis was conducted using Genalex6.2 (Peakall and Smouse, 2006).The F_{st} value was, in turn, used to estimate gene flow (N_m) as $N_m = (1/F_{st}-1)/4$ (Whitlock and McCauley, 1999).The number of alleles per locus (N_a), the effective number of alleles per locus (N_e), and the genetic heterozygosity (H) were used to detect the level of population genetic diversity.

RESULTS AND DISCUSSION

Genetic Diversity Analysis

The 89 mango individuals from five orchards (viz. Mya Na De, Htone Bo, Se Bauk, Taik Kyi, Nam Latt), were assessed by using 64 SSR markers. A total of 58 markers were well amplified; 20 were monomorphic and 38 were polymorphic markers (Table 1). Among the polymorphic markers, 24 were Sein Ta Lone unique markers; 18 homozygous loci (MiIIHR03a, MiIIHR05c, MiIIHR07a, MiIIHR12a, MiIIHR16a, MiIIHR22a, MiIIHR25a, MiIIHR29a, MiIIHR31b, MiIIHR32a, MiIIHR33a, MiIIHR34b, SSR-16, SSR-19, SSR-20, SSR-52, SSR-89 and MiMRD_l656), and 6 heterozyous loci (MiIIHR02c, MiIIHR04c, MiIIHR17b, MiKVR_a009, MiKVR_ao28 and MiIIHR_f879).

A total of 147 alleles were detected, the average number of alleles per locus was 3.87, with a range from 2 to 8 (Table 1). Polymorphic Information Content (PIC) values ranged from 0.02 to 0.83 with 0.37 averaged, showing that a moderately low diversity exists in mango individuals under study.

Cluster Analysis

A total of 89 mango individuals using 38 SSR were subjected into cluster analysis based on UPGMA. In group I, Sein Ta Lone control (100 years old) clustered together with 12 Sein Ta Lone individuals (viz. NL17, TK1, TK15, MND1, MND20, MND8, MND2, SP14, SP15, HB18, MND16 and TK2) with genetic similarity of (0.86, 0.83, 0.8, 0.79, 0.83, 0.77, 0.75, 0.85, 0.75, 0.75, 0.8, and 0.76, respectively) (Fig. 1). Group II comprised of most of the individuals from five orchards were clustered independent of their locations. Group III consisted of the ten individuals (TK3, TK5, TK6, TK4, TK14, TK13, TK7, TK12, TK18, and TK20), from Taik Kyi orchard were clustered together. Group IV depicted that Yin Kwe stand as separately from other. Interestingly, Se Bauk (SP4) had distinct away the rest of Sein Ta Lone.

In dendrogram, individuals from Mya Na De orchard, MND1 and MND20 showed 0.89 and MND10 and MND13 showed 0.86 genetic similarity and cluster together. In Htone Bo orchard, HB6 and HB15 had 0.91, HB9 and HB10 had 0.88, HB5 and HB13 had 0.84, and HB1 and HB8 had 0.82, genetic similarity and cluster together. For Se Bauk orchard, SP10 and SP13 had 0.93, both SP2 and SP3, and SP1 and SP5 had 0.86, genetic similarity, and clustered as a pair. Similarly, individuals from Taik Kyi orchard, both pairs of TK1 and TK15, TK4 and TK14 had 0.90, TK18 and TK20 had 0.88, TK7 and TK12 had 0.87, TK3 and TK5 had 0.86, and TK10 and TK16 had 0.85, genetic similarity and clustered together. Likewise, individuals from Nam Latt orchard, NL9 and NL10 had 0.90, NL3 and NL6 had 0.86, NL7 and NL8 had 0.84, NL15 and NL16 had 0.78 and NL18 and NL20 had 0.77, genetic similarity, and clustered together.

Principal Coordinate Analysis

In order to explore the distribution pattern of genetic diversity contained in individuals of each population, a principal coordinate analysis was performed on 38 markers in 89 mango individuals (including Sein Ta Lone-100 years old and Yin Kwe controls). DNA scored of these two controls was arbitrarily doubled in order to assume as separate populations. Therefore, a total of 91 individuals were subjected into multivariate analysis. Similar as cluster analysis, PCoA clearly depicted all the individuals from five Sein Ta Lone orchards showed closely grouped to control

Sein Ta Lone (pop2) rather than Yin Kwe (pop1) (Fig. 2).The first three PC showed 62.05 % of total variations, PC1 explained 29.75% of total variations, and PC2 and PC3 showed 17.90% and 14.39%,respectively. Sein Ta Lone controls (100 years old sample, pop2) were close to most of Sein Ta Lone individuals from Nam Latt orchard (Shan region), Se Bauk orchard (Mandalay region), Mya Na De orchard (Mandalay region).

Table 1 Polymorphic markers with their product size, motif, no. of alleles amplified and PIC value

No.	Marker name	SSR motif	No. of alleles	Size (bp)	PIC
1	MiIIHR09c	(CT)3TTGC(CT)2GT(CT)4TC(GT)2(CT)2	7	284-300	0.79
2	MiIIHR21b	(GTTT)3(GT)2TTTTGTC(TG)4(AATGA)2	8	258-275	0.76
3	MiIIHR24b	(CA)9TACC(CATA)6	6	242-252	0.78
4	MiKVR_a394	(TG)7	5	245-256	0.78
5	MiKVR_d864	(ATC)4	7	282-300	0.78
6	MiMRD_l744	(AAAT)4	7	283-303	0.8
7	MiKVR_a152	(ATTAT)4	5	253-265	0.73
8	MiKVR_a965	(AAAAT)4	7	278-300	0.82
9	MiKVR_c273	(TAAAA)5	6	239-255	0.8
10	MiKVR_d656	(TAAAA)4	7	252-277	0.81
11	MiKVR_n259	(CACCCA)4	6	248-266	0.71
12	MiKVR_n613	(TGATGG)4	7	244-264	0.83
13	MiKVR_u796	(GGAAGG)5	4	208-216	0.67
14	MiKVR_t130	(GAAAAA)4	5	255-267	0.72
15	MiIIHR02c	(CA)2A(CA)7AG(CA)5	3	176-239	0.51
16	MiIIHR04c	(CA)11	4	170-202	0.51
17	MiIIHR03a	(CTT)6(CA)2	2	237-243	0.02
18	MiIIHR05c	(CT)8C(CT)2TTTT(CT)4	2	207-213	0.02
19	MiIIHR07a	(GA)11	2	170-192	0.02
20	MiIIHR12a	(GA)11	2	174-180	0.02
21	MiIIHR16a	(GA)10	2	205-211	0.02
22	MiIIHR17b	(GT)13GAGT(GA)10	4	248-284	0.51
23	MiIIHR22a	(GTCTC)2(TGTCTC)3T(CTC)2	2	224-230	0.02
24	MiIIHR25a	(GTTT)3ATTTG(ATT)2	2	147-156	0.02
25	MiIIHR29a	(GT)10	2	153-158	0.02
26	MiIIHR31b	(GAC)6	2	213-217	0.02
27	MiIIHR32a	(GA)12	2	194-206	0.02
28	MiIIHR33a	(GA)12	2	171-173	0.02
29	MiIIHR34b	(GGT)9(GAT)5	2	232-240	0.02
30	SSR-16	(TA)2(CA)10TA(CA)3TA(CA)4	2	180-188	0.02
31	SSR-19	(ACACACAT)3(ACACACACAT)3	2	170-254	0.02
32	SSR-20	(AT)14(GT)18	2	248-252	0.02
33	SSR-52	(GA)16	2	113-115	0.02
34	SSR-89	NA	3	105-119	0.04
35	MiKVR_a009	(GT)8	4	200-246	0.51
36	MiKVR_ao28	(TA)	4	221-259	0.51
37	MiMRD_l656	(ATTT)5	3	278-324	0.04
38	MiIIHR_f879	(TTGGAC)4	3	116-131	0.51
		Average	3.87		0.37

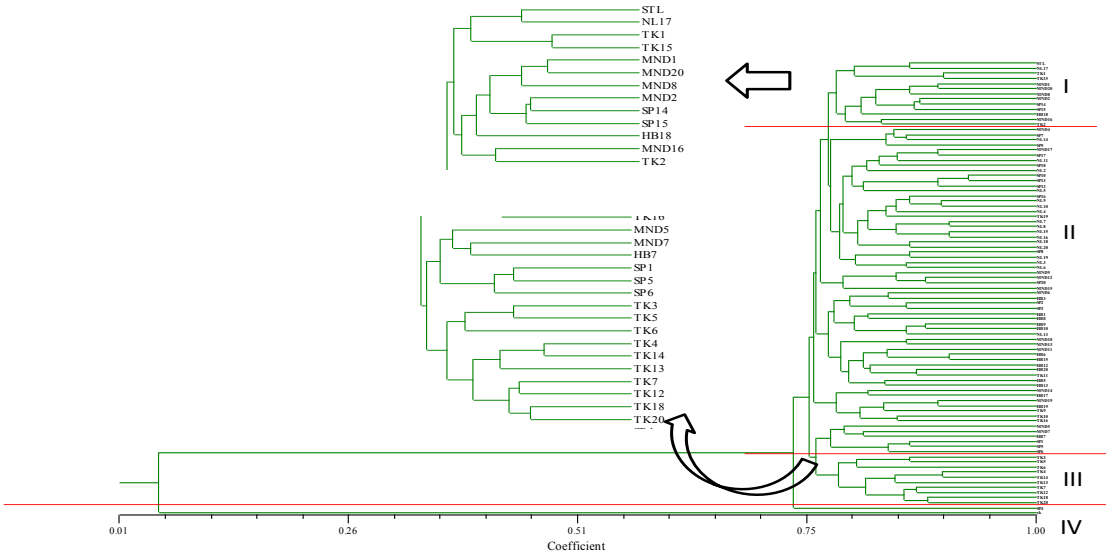

Fig. 1 Dendrogram of 89 mango individuals on the basis of 38 SSR markers using Nei and Li's genetic distance (1979)

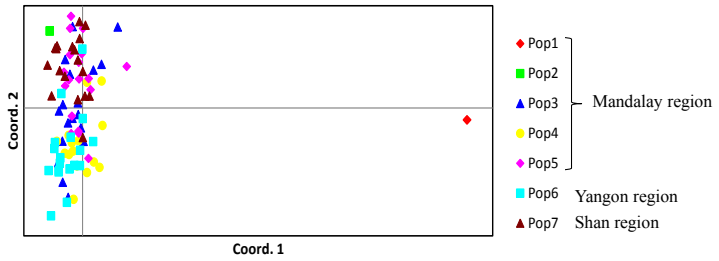

Fig. 2 Two dimensional axis of Principal coordinate analysis (axis 1 vs axis 2) of 91 mango individuals, using 38 markers

pop1-Yin Kwe , pop2 - Sein Ta Lone, pop3 - Mya Na De orchard, pop4 - Htone Bo orchard, pop5- Se Bauk, pop6 - Taik Kyi orchard, and pop7 - Nam Latt orchard

Population Structure and Gene Flow

To determine the pattern of diversity between and within the mango orchards (pop), an analysis molecular variance (AMOVA) in the 91 mango individuals was conducted and results reveal 7 main groups as the orchards which obtained DNA samples and two controls (Yin Kwe and 100 years old Sein Ta Lone). AMOVA using 7 populations suggested that the largest proportion of genetic diversity (75%) was found among plants belonging to the same population, whereas variation present among populations was 25% and no divergence observed between regions, all sources variation were significant at P>0.01 (Table 2). Large variability detected within populations could be explained by the occurrence of gene flow or most probably, by sowing the same materials in different regions. The fixation index (F_{st}), showed the value of 0.63, confirming the high level of genetic differentiation among the populations (Hartl and Clark, 1997). This differentiation might be mainly due to Yin Kwe individuals differ from Sein Ta Lone individuals.

Hirano et al. (2011) mentioned that Yin Kwe and Sein Ta Lone showed significantly variance at DNA level (F_{st}= 0.44). Gene flow (N_m) was equal to 0.31 indicating that limited gene flow among the populations (a local differentiation of populations). It may be due to the occurrence of zygotic seedling (2% to 90%) in polyembryonic cultivars or various biological and cultural practices like continuous grafting from one population to others (Begum et al., 2013). Diaz-Matallana et al. (2009) observed high gene flow value in analysis of diversity among six

Colombian mango populations, and they concluded that it is probably caused by both insect pollinators and human intervention. Since pop1 and pop2, arbitrary population, used the same DNA samples as controls in each pop, there had no consideration for population analysis. Expected heterozygosity (H_e) values of populations from five orchards (i.e. pop3 to pop7) showed 0.31 to 0.34, which pointed that not much difference in population diversity (Table 3). Observed heterozygosity (H_o) was the same value (0.16) in all populations. Observed heterozygosity of each pop was smaller than the expected heterozygosity based on Hardy-Weinberg expectations. Consequently the fixation index was positive over five pops (0.4). The number of effective alleles (N_e) ranged from 1.88 (pop7) to 2.13 (pop 5).The Shannon index (I) ranged from (0.54) in pop7 to (0.61) in pop3 and pop5. The percentage of polymorphic loci (P) across populations was the same value (52.63) %.

Table 2 Analysis of molecular variance for mango individuals

Source	df	SS	MS	Est. Var.	%
Among Regions	2	140.67	70.33	0	0%
Among Pops	4	348.56	87.14	6.84	25%
Within Pops	84	1719.1	20.47	20.47	75%
Total	90	2208.3		27.31	100%

Table 3 Parameters (Mean and SE) of genetic variability of mango populations

Pop*	**N_a**	**N_e**	**I**	**H_o**	**H_e**	**F**	**%P**
Pop 1	1.16±0.06	1.16±0.06	0.11±0.04	0.16±0.06	0.08±0.03	-1±0.00	15.79
Pop2	1.16±0.06	1.16±0.06	0.11±0.04	0.16±0.06	0.08±0.03	-1±0.00	15.79
Pop3	2.55±0.31	2.13±0.22	0.61±0.11	0.16±0.06	0.34±0.06	0.4±0.15	52.63
Pop4	2.37±0.26	1.88±0.16	0.56±0.1	0.16±0.06	0.32±0.05	0.4±0.15	52.63
Pop5	2.47±0.28	2.10±0.21	0.61±0.10	0.16±0.06	0.34±0.05	0.4±0.15	52.63
Pop6	2.42±0.29	1.98±0.20	0.57±0.10	0.16±0.06	0.32±0.05	0.4±0.15	52.63
Pop7	2.26±0.25	1.92±0.18	0.54±0.09	0.16±0.06	0.31±0.05	0.4±0.15	52.63
Total	2.06±0.10	1.76±0.07	0.44±0.04	0.16±0.02	0.26±0.02	0.25±0.06	42.11±6.79

**For abbreviation see Figure 2*

N_a = no. of alleles

N_e = no. of effective alleles = 1/(sum pi^2)

*I = Information index = -1*sum (pi*ln(pi))*

H_o = Observed Heterozygosity =no. of Hets/N

H_e = Expected Heterozygosity = 1- Sum pi^2

F = Fixation Index= $(H_e - H_o) / H_e = 1 - (H_o / H_e)$

%P= Percentage of polymorphic loci

All populations (pop3 to pop7) from five orchards showed high pairwise genetic identity to control Sein Ta Lone (100 years old) (pop2) than Yin Kwe (pop1) (Table 4). Likewise, pairwise genetic identity among five orchards were high, indicating quite similar mango clone, pop7 (Nam Latt orchard) and pop3 (Mya Na De orchard) showed high value of genetic identity (0.831 and 0.822). Pop4 (Htone Bo orchard) showed the lowest value of 0.766. Pop 5 (Se Bauk orchard) showed high genetic identity (0.957) to pop7 (Nam Latt orchard), and (0.951) to pop3 (Mya Na De orchard). Five populations (grafted orchards) showed more similar to each other than Sein Ta Lone (100 years old control), it might be mainly due to cross pollinated nature of mango (gene flow).

Table 4 Pairwise population matrix of Nei genetic identity

Pop*	Pop1	Pop2	Pop3	Pop4	Pop5	Pop6	Pop7
Pop1	1.000						
Pop2	0.000	1.000					
Pop3	0.084	0.822	1.000				
Pop4	0.096	0.766	0.935	1.000			
Pop5	0.095	0.803	0.951	0.945	1.000		
Pop6	0.055	0.789	0.923	0.929	0.918	1.000	
Pop7	0.072	0.831	0.916	0.917	0.957	0.919	1.000

CONCLUSION

As Sein Ta Lone mango is an economically important crop in Myanmar, this study provides insight into extent and genetic variability at DNA level of five Sein Ta Lone orchards to control Sein Ta Lone (100 years old plant). Genotyping with 38 SSR markers confirmed differentiation of Yin Kwe and Sein Ta Lone at DNA level which was consistent with Hirano et al. (2011). Moderately low genetic diversity in PIC value indicated five Sein Ta Lone orchards(grafted trees) have high genetic similarity to 100 years old Sein Ta Lone control (seeded tree). Moreover, variation within populations (within orchards) were observed and next grafting procedure from present Sein Ta Lone individuals should be carefully carried out for ensure to get true to type Sein Ta Lone mango. Sein Ta Lone unique markers will be useful in varietal identification in mango varieties. This study will provide valuable information to varietal identification and protection, and further varietal improvement program at the national and global perspective.

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Research article

Classification by Characteristics of Farm Management for Development Aid in Rural Area of Cambodia

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Abstract The main objective of this study is to clarify the characteristics of farm management based on the indicators of agricultural production. A categorical principal component analysis was applied to categorize and clarify the effectiveness of their farm management. The research site was Samroung Commune, Prey Chhor District, Kampong Cham Province, Cambodia. The results of the analysis are summarized as follows. 1) Even in the same commune, the differences were found among villages when the features were grasped from the indicators of agricultural production of each village. 2) Based on the categorical principal component analysis results, farm management was classified and clarified based on the characteristics of each category. According to the results of the analysis, it was indicated that it is necessary to classify agricultural production information of the target area in order to support effectively with full use of the abilities of support organizations.

Keywords categorical principal component analysis, Cambodia

INTRODUCTION

In recent years, industrialization has progressed rapidly in Cambodia. However, the main industry in Cambodia's rural areas is still self-sufficient agriculture. In Cambodia there are many local farmers who cannot emerge from poverty due to low productivity of their land and increased expenditure on pesticides and chemical fertilizers. Development aid has been diversified by support organizations with the Official Development Assistance (ODA) through NGOs, universities, research institutes, or CSR activities of companies. In order to tackle the problems in rural areas, development aid project is expected to formulate and plan by using technology, know-how and networks based on the characteristics and strengths of each support organization. Support organizations require detailed investigation and analysis of local agricultural production in order to formulate an effective plan and to select a reasonable target site. In addition, it is also important to know exactly what kinds of technology and support that meets the needs of local farmers. According to the above mentioned background, the main objective of this study was to clarify the characteristics of farm management based on the indicators of agricultural production. Also, a categorical principal component analysis was applied to categorize and clarify the effectiveness of their farm management.

METHODOLOGY

An Index of Agricultural Production of Each Village

The research site was Samroung Commune, Prey Chhor District, Kampong Cham Province, Cambodia. The Kampong Cham Province is located in the northeast of Phnom Penh, and southeast of Siem Reap. In the Kampong Cham Province during the French colonial period, the hilly terrain was developed as a rubber plantation zone. The population of Kampong Cham Province is about 1,750,000 and much of the population is engaged in agriculture. At the target area in Samroung commune of Kampong Cham Province, the amounts of agricultural chemicals have increased over the last ten years. Although it contributed to an increase in the agricultural productivity in the short term, the degradation of soil and water environment became more severe. Also, local farmers have suffered from several diseases such as throat pain or dermatitis due to the inappropriate application of agricultural chemicals (Kobayashi, T. and Yamamoto, H. 2009). Therefore, there are many farmers who expect to shift to a sustainable farming system based on natural resource circulation. At this site, the Institute of Environmental Rehabilitation and Conservation (ERECON) carried out the project on promothing sustainable Agriculture at Kampong Cham Province in Cambodia (April/2011-March/2016). This project aims to promote sustainable agriculture based on natural resource circulation with low chemical input by targeting the local farmers.

The target area of the questionnaire survey consisted of the following eleven villages: Bonteay Thmey, Kondal Koang, Preykhcheay, Samroung, Smei, Sodey, Svayprey, Takrit, Thmey, Tompang Risey, and Veal. The survey period lasted from July to August 2011. The number of useful responses we received per area are as follows: Bonteay Thmey: 61 respondents (13.8% of the total respondents), Kondal Koang: 33 respondents (7.4%), Preykhcheay: 35 respondents (7.9%), Samroung: 54 respondents (12.2%), Smei: 13 respondents (2.9%), Sodey: 56 respondents (12.6%), Svayprey: 49 respondents (11.1%), Takrit: 38 respondents (8.6%), Thmey: 37 respondents (8.4%), Tompang Risey: 37 respondents (8.4%) and Veal: 30 respondents (6.8%). There were 443 respondents in total.

RESULTS AND DISCUSSION

Table 1 shows the aggregated results of indicators showing the characteristics of agricultural management for each village. The following are the characteristics of Bonteay Thmey. The average agricultural annual income is the highest among the 11 villages, and the ratio of answering that the aged cultivated land area is 1.5 ha or more is relatively high. In addition, irrigation development rate and expenditure amount and usage amount for chemical fertilizer were the largest among the 11 villages. The following are the characteristics of Kondal Koang. Local farmers replied that 75.8% had 3-5 family members. All respondents replied that they have irrigation facilities. Furthermore, the expenditure on chemical fertilizer is high. The following are the characteristics of Preykhcheay. The proportion of full-time farmers is the lowest among the 11 villages. The proportion of farmers responding that the cultivated land area is 0.2-0.5 ha is 45.7%. Local farmers raising chickens are as many as 91.4%. The following are the characteristics of Samroung. All the farmers who answered are producing rice. Ownership of tillers, harvesters, and threshing machines is higher than that of other villages. Also, the proportion of farmers producing vegetables is 64.8%, the highest among the 11 villages. The following are the characteristics of Smei. The proportion of full-time farmers is the largest among the 11 villages. In addition, the characteristics of agricultural management are farmers who are engaged in vegetable production and fruit tree production, mainly with rice production. The following are the characteristics of Sodey. Local farmers responding that the number of family members was 6-8 was 50%. Sodey was characterized by a relatively large number of family members compared to other villages. The following are the characteristics of Svayprey. The proportion of farmers doing livestock production is the largest among the 11 villages. It is also the village with the lowest expenditure and usage of chemical fertilizer. The following are the characteristics of Takrit. The characteristics of the agricultural management of Takrit are rice production and breeding of livestock.

Table 1 An index of agricultural production of each village

Actual number		All Sumple	Bonteay Thmey	Kondal Koang	Preykhch eay	Sam roung	Smei	Sodey	Svay prey	Takrit	Thmey	Tompang Risey	Veal
Index		443	61	33	35	54	13	56	49	38	37	37	30
Number of	Less than 2 persons	49	41	0	3	2	0	0	0	1	0	2	0
family members	3-5 persons	233	17	25	19	31	8	25	28	22	13	22	23
	6-8 persons	137	2	6	12	15	4	28	19	15	19	11	6
	9-10 persons	18	0	2	1	6	1	0	1	0	4	2	1
	More than 14 persos	2	0	0	0	0	0	0	1	0	1	0	0
Type of	Full-time farmers	277	39	22	15	34	10	35	34	26	28	21	13
farm management	Rice	437	58	33	35	54	12	55	49	38	37	36	30
	Vegetables	161	27	5	14	35	8	18	15	11	5	18	5
	Fruits	91	16	5	14	3	6	16	2	7	2	8	12
	Live stock	397	50	27	32	51	9	51	48	36	31	34	28
	other	7	0	2	1	0	1	1	0	0	2	0	0
Average of farmers' revenues (1000 Riel)		3,772	6,420	3,537	3,859	2,689	3,158	3,216	2,815	3,804	3,858	2,772	4,362
Total area	Less than 0.2 ha	10	2	0	1	4	0	0	0	0	2	0	1
(owned)	0.2-0.5ha	86	6	7	16	8	4	11	13	4	4	11	2
	0.6-1ha	140	16	9	11	25	5	18	20	11	6	9	10
	1.1-1.5ha	78	10	10	1	10	0	13	6	9	8	5	6
	More than 1.5 ha	125	24	7	6	7	4	14	10	14	17	12	10
	Don't have	3	3	0	0	0	0	0	0	0	0	0	0
Using irrigation	Fully	98	24	6	3	13	3	16	6	4	12	6	5
	Partly	307	35	27	15	40	9	36	40	32	23	26	24
	Not at all	38	2	0	17	1	1	4	3	2	2	5	1
Number of	Chickens	383	47	28	32	46	12	52	42	27	34	35	28
livestock farms	Cattle	414	55	33	34	53	12	54	47	38	36	22	30
	Pig	33	5	3	5	7	0	2	1	2	5	3	0
	Duck	66	10	7	4	7	3	12	13	2	3	2	3
	Water buffalo	22	0	0	0	0	0	0	0	0	0	22	0
Using chemical	Riel (1000 Riel)	971	1,398	1,160	786	805	861	759	634	1,176	1,048	1,077	918
fertilizer	USD	237	341	285	192	197	210	185	155	287	256	263	224
	Kg.	412	578	479	304	419	367	326	271	488	466	418	358
	Sack	8	11	10	6	7	7	7	6	10	9	8	7
Farm machinery	Yes	421	57	33	31	53	13	53	48	35	37	32	29
	Not	22	4	0	4	1	0	3	1	3	0	5	0

Composition ratio		All Sumple	Bonteay Thmey	Kondal Koang	Preykhch eay	Sam roung	Smei	Sodey	Svay prey	Takrit	Thmey	Tompang Risey	Veal
Index		443	61	33	35	54	13	56	49	38	37	37	30
Number of	Less than 2 persons	11.1	67.2	0	8.6	3.7	0	0	0	2.6	0	5.4	0
family members	3-5 persons	52.6	27.9	75.8	54.3	57.4	61.5	44.6	57.1	57.9	35.1	59.5	76.7
	6-8 persons	30.9	3.3	18.2	34.3	27.8	30.8	50	38.8	39.5	51.4	29.7	20
	9-10 persons	4.1	0	6.1	2.9	11.1	7.7	0	2	0	10.8	5.4	3.3
	More than 14 persos	0.5	0	0	0	0	0	0	2	0	2.7	0	0
Type of	Full-time farmers	62.5	63.9	66.7	42.9	63	76.9	62.5	69.4	68.4	75.7	56.8	43.3
farm management	Rice	98.6	95.1	100	100	100	92.3	98.2	100	100	100	97.3	100
	Vegetables	36.3	44.3	15.2	40	64.8	61.5	32.1	30.6	28.9	13.5	48.6	16.7
	Fruits	20.5	26.2	15.2	40	5.6	46.2	28.6	4.1	18.4	5.4	21.6	40
	Live stock	89.6	82	81.8	91.4	94.4	69.2	91.1	98	94.7	83.8	91.9	93.3
	other	1.6	0	6.1	2.9	0	7.7	1.8	0	0	5.4	0	0
Average of farmers' revenues (1000 Riel)		-	-	-	-	-	-	-	-	-	-	-	-
Total area	Less than 0.2 ha	2.3	3.3	0	2.9	7.4	0	0	0	0	5.4	0	3.3
(owned)	0.2-0.5ha	19.4	9.8	21.2	45.7	14.8	30.8	19.6	26.5	10.5	10.8	29.7	6.7
	0.6-1ha	31.6	26.2	27.3	31.4	46.3	38.5	32.1	40.8	28.9	16.2	24.3	33.3
	1.1-1.5ha	17.6	16.4	30.3	2.9	18.5	0	23.2	12.2	23.7	21.6	13.5	20
	More than 1.5 ha	28.2	39.3	21.2	17.1	13	30.8	25	20.4	36.8	45.9	32.4	33.3
	Don't have	0.7	4.9	0	0	0	0	0	0	0	0	0	0
Using irrigation	Fully	22.1	39.3	18.2	8.6	24.1	23.1	28.6	12.2	10.5	32.4	16.2	16.7
	Partly	69.3	57.4	81.8	42.9	74.1	69.2	64.3	81.6	84.2	62.2	70.3	80
	Not at all	8.6	3.3	0	48.6	1.9	7.7	7.1	6.1	5.3	5.4	13.5	3.3
Number of	Chickens	86.5	77	84.8	91.4	85.2	92.3	92.9	85.7	71.1	91.9	94.6	93.3
livestock farms	Cattle	93.5	90.2	100	97.1	98.1	92.3	96.4	95.9	100	97.3	59.5	100
	Pig	7.4	8.2	9.1	14.3	13	0	3.6	2	5.3	13.5	8.1	0
	Duck	14.9	16.4	21.2	11.4	13	23.1	21.4	26.5	5.3	8.1	5.4	10
	Water buffalo	5	0	0	0	0	0	0	0	0	0	59.5	0
Using chemical	Riel (1000 Riel)	-	-	-	-	-	-	-	-	-	-	-	-
fertilizer	USD	-	-	-	-	-	-	-	-	-	-	-	-
	Kg.	-	-	-	-	-	-	-	-	-	-	-	-
	Sack	-	-	-	-	-	-	-	-	-	-	-	-
Farm machinery	Yes	95	93.4	100	88.6	98.1	100	94.6	98	92.1	100	86.5	96.7
	Not	5	6.6	0	11.4	1.9	0	5.4	2	7.9	0	13.5	0

Source: Surveyed data

In particular, all local farmers replied that they were breeding cattle. The average number of cattle raised was 5.03. The following are the characteristics of Thmey. In Thmey, the proportion of local farmers with a total area of more than 1.5 ha is 45.9%. The following are the characteristics of Tompang Risey. The average agricultural annual income is 2,771,621.62 Riel (4,000 Riel = 1 USD), the lowest among 11 the villages. The following are the characteristics of Veal. The average agricultural longevity amount is 4,361, 533.33 Riel, the second largest among the 11 villages. The characteristics of agricultural management of Veal are rice production and fruits. Based on the

above information, even in the same commune, differences were found in each village when the features were grasped from the indicators of agricultural production of each village.

Grouping of Respondents by Category Principal Component Analysis

In this section, information on each variable, such as farmer attributes, cultivated land, labor force indicator, agricultural product awareness in the target area is summarized and a "total index" is created and grouped. We employed a categorical principal component analysis for this purpose. Index and answer patterns used for categorical principal component analysis were as follows.

Table 2 Index and answer patterns for categorical principal component analysis

	Index	Answer category
X1	Gender	1. Male, 2. Female
X2	Age	1. Less than 20years old, 2. 20–29years, 3. 30–39years, 4. 40–49years, 5. More than50 years old
X3	Educational background	1. Never had been to school, 2.Primary, 3. Secondary, 4.High school, 5. College, 6. University
X4	Numbers of family persons	1. Less than 2 persons、2. 3-5、3. 6-8、4. 9-10、5. More than 10persons
X5	Children less than ten years old	1. No one, 2. 1-2, 3. 3-5, 4. 6-8, 5. 9-10, 6. More than 10
X6	Family living years in this village	1. Less than 2 years, 2. 3-5, 3. 6-10, 4. 11-15, 5. 16-20, 6. 21-25 7. 26-30、8. 31-35、9. 36-40、10. More than 41 years
X7	Duration of agricultural experience	1. Less than 2 years、2. 3-5、3. 6-10、4. 11-15、5. 16-20、6. 21-25, 7. 26-30, 8. 31-35, 9. 36-40, 10. More than 41 years
X8	Full-time farmer	1. Yes, 2.No
X9	Family agricultural workers(Full time)	1. No one, 2. 1-3, 3. 4-6, 4. 7-9, 5. More than 10
X10	Family agricultural workers(Part time)	1. No one, 2. 1-3, 3. 4-6, 4. 7-9, 5. More than 10
X11	Employed worker	1. Yes, 2. No
X12	Paddy field	1. Less than 0.2 ha, 2. 0.2-0.5 ha, 3. 0.6-1.0 ha, 4. 1.1-1.5 ha, 5. More than 1.5 ha
X13	Farmland irrigated	1. Yes, fully, 2. Yes, partly, 3. Not at all
X14	Common forests	1. Yes, 2. No
X15	Farmers Group	1. Yes, 2. No
X16	Raise poultry	1. Yes, 2. No
X17	Raise cattle	1. Yes, 2. No
X18	Raise pigs	1. Yes, 2. No
X19	Reduction targets of chemical fertilizer	1. 0-20%, 2. 20-40%, 3. 40%-60%, 4. 60%-80%, 5. 80%-100%
X20	Reduction targets of chemical pesticide	1. 0-20%, 2. 20-40%, 3. 40%-60%, 4. 60%-80%, 5. 80%-101%
X21	Agricultural machinery	1. Yes, 2. No
X22	Conversation about agriculture with children	1. None, 2. Once a week, 3. Few times a week, 4. Once a month, 5. Few times a month, 6. Once a 6 months, 7. Once a year, 8.Other
X23	Knowledge on sustainable agriculture	1. Don't know, 2. Know less, 3. Know, 4. Know better, 5. Know well
X24	Participation in agricultural cooperatives	1. Yes, 2. No
X25	Collaboration with people from other villages	1. Yes, 2. No
X26	Important for agricultural production	1. Taste, 2. Shape, 3. Size, 4. Other
X27	Important for agricultural products sales	1. Safety of food, 2. Brand of food, 3. Place of market, 4. Other
X28	Acquisition of agricultural information and technology	1. Government officer, 2. Village leader, 3. Other farmers in the village, 4. Scientist, 5. NGO officer, 6. Other
X29	Introduction of chemical fertilizer	1. Before 1960, 2. 1961-1970, 3. 1971-1980, 4. 1981-199, 5. 1991-2000, 6. 2001-2005, 7. 2006-2010, 7. Other
X30	Introduction of chemical pesticide	1. Before 1960, 2. 1961-1970, 3. 1971-1980, 4. 1981-199, 5. 1991-2000, 6. 2001-2005, 7. 2006-2010, 8. Other

Source: Surveyed data

In Table 3, the estimation results of the categorical principal component analysis is shown. At the same time, the eigenvalues of each factor were factor 1: 2.87 and factor 2: 2.52. In the following, it is confirmed for each principal component what index feature an element is constituting.

Firstly, the indices positively contributing to factor 1 were X3: Educational background (0.42), X8: Full-time farmer (0.17), X12: Paddy field (0.20), X13: Farmland irrigated (0.11), X21: Agricultural machinery (0.13), X29: The commencement of chemical fertilizer (0.72) and X30:

The commencement of chemical pesticide (0.72). From these indices, factor 1 can be interpreted as "the factor representing the degree of achievement of modernization of agricultural production".

Secondly, the index positively contributing to factor 2 were X1: Gender (0.31), X15: Farmers Group (0.32), X24: Participation in agricultural cooperatives (0.46), X25: Collaboration with people from other villages (0.28), X26: Important for agricultural production (0.42), X27: Important for agricultural products sales (0.37) and X28: Acquisition of agricultural information and technology (0.40). From these indices, factor 2 can be interpreted as "Factors expressing intention to form production areas by collaboration" For local farmer grouping, it can be classified into the following 4 groups from each positive and negative combination of factor 1 and factor 2. In addition, Table 4 shows average values of scores of factor 1 and factor 2 of all respondents for each village.

Table 3 Estimation results of categorical principal component analysis

	Index	FACTOR 1	FACTOR 2
X1	Gender	-0.10	0.31
X2	Age	-0.69	-0.22
X3	Educational background	0.42	-0.30
X4	Numbers of family persons	-0.10	-0.16
X5	Children less than ten years old	0.36	0.18
X6	Family living years in this village	-0.64	-0.20
X7	Duration of agricultural experience	-0.56	-0.24
X8	Full-time farmer	0.17	-0.14
X9	Family agricultural workers(Full time)	-0.11	0.05
X10	Family agricultural workers(Part time)	-0.10	-0.20
X11	Employed worker	-0.06	0.01
X12	Paddy field	0.20	-0.21
X13	Farmland irrigated	0.11	-0.15
X14	Common forests	-0.11	0.00
X15	Farmers Group	0.14	0.32
X16	Raise poultry	-0.10	-0.08
X17	Raise cattle	-0.02	-0.08
X18	Raise pigs	-0.12	-0.04
X19	Reduction targets of chemical fertilizer	0.03	-0.58
X20	Reduction targets of chemical pesticide	0.10	-0.59
X21	Agricultural machinery	0.13	-0.16
X22	Conversation about agriculture with children	-0.24	-0.46
X23	Knowledge on sustainable agriculture	0.06	-0.42
X24	Participation in agricultural cooperatives	-0.01	0.46
X25	Collaboration with people from other villages	-0.12	0.28
X26	Important for agricultural production	-0.17	0.42
X27	Important for agricultural products sales	-0.04	0.37
X28	Acquisition of agricultural information and technology	-0.16	0.40
X29	The commencemen of chemical fertilizer	0.72	-0.06
X30	The commencemen of chemical pesticide	0.72	-0.13

Source: Surveyed data
Note: Eigenvalue Factor 1; 2.867, Factor 2; 2.520

The group 1 is a local farmer that is positive for both "factor representing the achievement degree of modernization of agricultural production" and "Factors expressing intention to form production areas by collaboration." The average of respondents is Thmey. This group is in a state where infrastructure for agricultural production such as irrigation facilities and agricultural machinery is in place, has an interest in improving the quality of agricultural crops and sales outlets and also shows an understanding of cooperation with others. Therefore, it is suggested that the

support target is suitable as a target area for new projects in all support organizations such as government agencies, NGOs, educational research institutes, and companies.

The local farmer of group 2 is "factor representing the achievement degree of modernization of agricultural production" positive and "Factors expressing intention to form production areas by collaboration" negative. The average of respondents are Preykhcheay and Samroung. This group is already aiming to achieve modern agricultural production and to advance agricultural management on an individual level. This is considered to be highly adaptable to projects aimed at improving the agricultural techniques of local farmers, such as the start of new crops. Therefore, a support organization suitable for this group is regarded as a research institution, such as a university with advanced technology.

Table 3 Average value of respondents by village

Village	Bonteay Thmey	Kondal Koang	Preykh cheay	Sam roung	Smei	Sodey	Svayprey	Takrit	Thmey	Tompang Risey	Veal
Group	Group 3	Group 4	Group 2	Group 2	Group 3	Group 4	Group 4	Group 4	Group 1	Group 3	Group 3
Factor 1	-0.02	-0.06	0.50	0.10	-0.01	-0.08	-0.09	-0.10	0.13	-0.17	-0.17
Factor 2	-0.11	0.39	-0.13	-0.45	-0.10	0.14	0.22	0.01	0.60	-0.39	-0.11

Source: Surveyed data

The group 3 is a local farmer that is negative for both "factor representing the achievement degree of the modernization of agricultural production" and "Factors expressing intention to form production areas by collaboration." The average of respondents are Smei, Veal, Tompang Risey and Bonteay Thmey. The local farmer of this group is not sufficiently developed for agricultural production infrastructure. In addition, a project is needed to disseminate basic agricultural production techniques. Economic assistance is indispensable for the development of agricultural production infrastructure. Therefore, it is suggested that a support organization capable of financial assistance, like a company, is effective.

The local farmer of group 4 is "factor representing the degree of achievement of modernization of agricultural production" negative and "Factors expressing intention to form production areas by collaboration" positive. The average of respondents are Takrit, Kondal Koang, Sodey and Svayprey. Similar to Group 4 and Group 3, the development of agricultural production infrastructure is not sufficient. However, the local farmer is expecting the development of regional agriculture by collaborating with others to offset its weaknesses. Therefore, a support organization suitable for this group is effective NGO which can support agriculture by cooperation for villages and communes.

CONCLUSION

In this study, the main objective of this study was to clarify the characteristics of farm management based on the indicators of agricultural production. In addition, a categorical principal component analysis was used to categorize and clarify the effectiveness of their farm management. The results of the analysis are summarized as follows.

Even in the same commune, differences were found among villages when the features were grasped from the indicators of agricultural production of each village.

According to the categorical principal component analysis results, farm management was classified and clarified on the basis of the characteristics of each category.

Specifically, for local farmer grouping, it may be classified into the following 4 groups from each positive and negative combination of factor 1 and factor 2. According to the results of the analysis, it was indicated that it is necessary to classify agricultural production information of the target area in order to support effectively with full use of the abilities of support organizations.

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Research article

Accumulation of Copper in Kale (*Brassica alboglabra*) and Soil Fertilized with Swine Manure, Compost and Vermicompost under Different Thai Soil Series

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Abstract The aim of the study was to evaluate the variation in the copper (Cu) accumulation in kale and two different Thai soil series (Korat and Nampong soil series) treated with swine manure, compost and vermicompost. Completely randomized design (CRD) experiment was conducted on the soil samples collected from Korat and Nampong soil series. Same amount of treatments namely swine manure, compost and vermicompost of 18.75 t/ha were applied in each experimental unit and harvested after 45 days. Results showed that the accumulation of Cu in roots and shoots were found higher in Nampong soil series than Korat soil series. The Cu accumulation in roots and shoots was highest when treated with swine manure. The Cu content in roots and shoots were 6.62 and 3.69 $mgkg^{-1}$ respectively. However, there was no significant difference in the Cu content when treated with compost and vermicompost. The Cu accumulation in Korat soil series was found higher than Nampong soil series at 6.29 and 6.19 $mgkg^{-1}$ respectively when treated with swine manure. However, accumulation of Cu in Kale and soil depend on difference in soil texture and speciation of Cu in swine manure, compost and vermicompost. This is because Korat soil contains clay mineral which absorbs Cu whereas Nampong soil series is more of sandy which absorbs less Cu.

Keywords swine manure, compost, vermicomposting, Nampong soil series, Korat soil series

INTRODUCTION

Fertilization of crops with swine manure is a common practice throughout the world. Due to the relatively high Cu contents in swine manure, continuous application of swine manure could have negative effects on soil and plant. Cu is nutrient for plant growth and development, Cu may become phytotoxic and cause metabolic disorders at high soil concentrations, and lead to a potential threat to human health through the food chain (Xu et al., 2013). The increase of Cu in human body causes some major diseases such as brain, skin, pancreas, and heart diseases (Nurdan and Okan, 2013). The bioavailability and toxicity of metals in soil can vary over several orders of magnitude depending on soil modifying factors. The effect of soil types on the bioavailability and toxicity of metals to soil organism has been studies (Olugbenga et al., 2010). Clay minerals are generally regarded as important natural ion exchange materials because they are generally coated with metal oxide and organic matter. Clay has small particle size and a large surface area per unit weight, these properties is believed to be a good adsorbent for heavy metal (Sajidu et al., 2006). Many researchers studied heavy metal uptake and transports within the plants and accumulation of Cu in soil. But the most of widely studies with different kind of plant, raw material and soils.

OBJECTIVE

The aim of this study was to evaluate the accumulation of copper in kale planted in two different soil series (Korat and Nampong soil series) that treated with swine manure, compost and vermicompost.

METHODOLOGY

Soil Sample Collection and Preparation

The soil used in this study came from Northeast of Thailand were collect from Korat and Nampong soil series. Soil was sample from 0-15 cm. depth, air-dried at ambient temperature and finally, sieved to < 2 mm. used for pot experiment and for measurement of the soil's physical-chemical properties.

Soil pH and electrical conductivity (EC) were measured in a 1:5 soil/water mixture, organic matter was determined by the Walkley-Black (Walkley and Black, 1965), particle-size distribution (clay, silt and sand content) was determined by Hydrometer method, cation exchange capacity (CEC) was measured by the ammonium acetate saturation method (Bremner, 1965) and determined of Cu in the soil extraction with DTPA measured by Atomic absorption spectrophotometer.

Composting and Vermicomposting Preparation

Compost and vermicompost were pepared with swine manure, cassava peel, rice husk ash and soil in propotion ration 2:6:1:1 and earthworm species (*Eudrillus eugeniae*) was introduced to the substrate for vermicomposting with the moisture content 80 to 90%. After 60 days separate earthworm and air-dried at ambient temperature for compost and vermicompost, finally sieved to < 2 mm. used for pot experiment and for measurement chemical properties.

Analysis chemical property of compost and vermicompost; pH and electrical conductivity (EC) were measured in a 1:10 mixture with water, organic matter was determined by the Walkley-Black (Walkley and Black, 1965), Total nitrogen was determined by the Kejldahl method, Total phosphorus, Potassium and Cu digested with mixture of HNO_3: $HClO_4$ (1:1) followed by standard method (AOAC, 2000).

The sequential extraction of speciation of Cu in swine manure, compost and vermicompost following five fraction were exchangeable, bound of carbonate, bound of iron and manganese oxide, bound of organic matter and residual (Tessier, 1979).

Pot Experiment

Plastic pots were filled with 1 kg of air-dried soil sieved to <2 mm. (Ruiz et al., 2009) Four different experiment series were; control soil without swine manure, compost and vermicompost, soil with swine manure, soil with compost and soil with vermicompost under Korat and Nampong soil series. Each series consisted of three replicate in CRD experiment.

Kale (*Brassica alboglabra)* seed were sown 10 seeds per pot. After 10 days subsequently reduced to 3 seeds per pot. Same amount of treatments namely swine manure, compost and vermicompost of 18.75 t/ha were applied in each experimental unit and harvested after 45 days. Plant shoots and root were thoroughly washed with de-ionize water, weighed, stored at 75 ºC, finely ground to fine powder and sealed in plastic bags for subsequent Cu analysis. The dry plants were digested using mixture of HNO_3: $HClO_4$ (1:1) followed by standard method (AOAC, 2000) The total metal accumulation rate (TMAR) in K ale was calculate using the following equation.

$$TMAR = [(M_{root} \times DW_{root}) + (M_{shoot} \times DW_{shoot})] / (DW_{root} + DW_{shoot})$$

Where M_{shoot} and M_{root} represent the total Cu concentration in Kale shoot and root ($mgkg^{-1}$), respectively, while DW_{root} and DW_{shoot} represent the weight of Kale roots and shoots (g.) respectively. **(**Ruiz et al**.**, 2009**)**.

Statistical Analysis

The Statistic 10 software (version 10, USA) was used to analyze the data including the analysis of variance (One Way ANOVA). Treatment means were compared using least significance difference (LSD) at $P< 0.05$.

RESULTS AND DISCUSSION

Material Characterization

The main physical-chemical property of the soil (Korat and Nampong soil series) were analyzed and classified as loam and loamy sand include clay content at 16.61 and 6.46% respectively (Table 1).

Table 1 Physical-chemical property of the soil used for experiment

Soil properties	Korat soil series	Nampong soil series
1. pH (1:5)	6.42	6.79
2. EC (1:5; ds/m)	0.04	0.03
3. CEC (cmol/kg)	7.93	3.38
4. Organic Matter (%)	1.59	0.97
5. Total Nitrogen (%)	0.08	0.03
6. Available Phosphate (%)	49	53
7. Exchangeable Potash (%)	33	29
8. Copper (Cu; mg/kg)	0.83	0.26
9. Texture	Loam	Loamy sand
Sand (%)	50.94	78.87
Silt (%)	32.45	14.67
Clay (%)	16.61	6.46

Table 2 Chemical-property of the swine manure, compost and vermicomost used for experiment

Property	Swine manure	Compost	Vermicompost
1. pH (1:10)	7.4	7.94	7.46
2. EC (1:10; ds/m)	2.2	1.013	1.223
3. Total Nitrogen (%)	2.3	0.63	0.54
4. Total Phosphate (%)	9.4	1.10	1.32
5. Total Potash (%)	1.3	0.78	1.00
6. Organic Matter (%)	52.7	19.8	15.9
7. Copper (Cu; mg/kg)	731.7	175.5	209.1

The swine manure, compost and vermicomost used for experiment were analyzed chemical properties (Table 2). Contamination of Cu in swine manure has been found in high concentration because Cu is added to feed additive for pig growth promoting.

Speciation of Cu in swine manure, compost and vermicompost as show in Fig. 1, the swine manure has high concentration of Cu in exchangeable fraction. But compost and vermicomposting process cloud reduced the exchangeable form and changed to bound of organic matter.

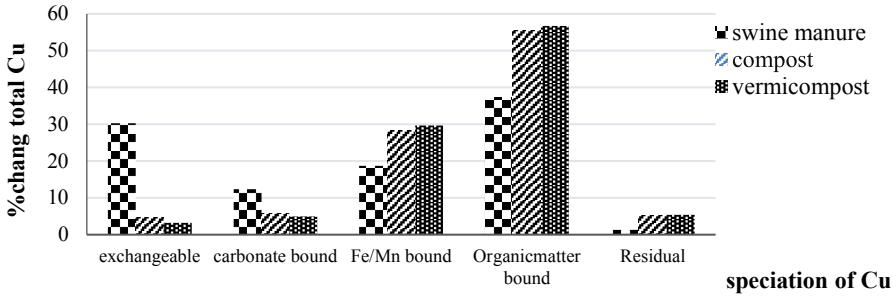

Fig. 1 Speciation of Cu in swine manure, compost and vermicompost

Effect of Swine Manure, Compost and Vermicompost on Accumulation of Cu in Kale and Soils

The total metal accumulation rate (TMAR), shoot and root Cu concentration for Kale are presented in Table 3. The result show that the treatment with swine manure significantly increased the TMAR of Cu. This is a direct consequence of the observed increase in the Cu root concentration **(**Ruiz et al**.**,2009**).** The accumulation of Cu in roots and shoots were found higher in Korat soil series than Nampong soil series. The Cu accumulation in roots and shoots was highest when treated with swine manure. The Cu content in roots and shoots were 6.62 and 3.69 mg/kg respectively. However there was no significant difference in the Cu content when treated with compost and vermicompost. The accumulation of metal concentration in root and shoot was only observed for the most mobile metal. The nutrients with lower mobility are mainly accumulated in the roots, while those with relatively higher mobility are accumulated in the shoots to greater extent (Materechera, 2002). From the roots, transition metals are mainly transported to the shoot via the xylem. Chelation of metals with certain intracellular chelators, e.g. histidine, nicotianamide and citrate, appears as a key process that protes root-to-shoot mobility of a metal via xylem transport (Clemens et al., 2002).

Table 3 Effect of swine manure, compost and vermicompost on shoots, root and total accumulation of Cu (mgkg^{-1}) in Kale

Treatment	Korat soil series			Nampong soil series		
	shoot	root	TMAR	shoot	root	TMAR
Soil (control)	n.d.	0.03b	0.00b	n.d.	0.03b	0.00b
Soil + swine manure	2.61	4.49a	2.67a	3.69	6.62a	3.80a
Soil + compost	n.d.	0.40b	0.01b	n.d.	1.37b	0.03b
Soil + vermicompost	n.d.	0.47b	0.02b	n.d.	1.50b	0.03b
F value	-	**	**	-	**	**

Values in same letters in the columns are not significantly different (LSD test, p< 0.01), n.d.: Not detect

Table 4 Effect of swine manure, compost and vermicompost accumulation of Cu (mgkg^{-1}) in soil

Treatment	Korat soil series	Nampong soil series
Soil (control)	0.59b	0.11c
Soil + swine manure	6.29a	6.19a
Soil + compost	1.90b	1.64b
Soil + vermicompost	1.91b	1.70b
F value	**	**

Values in same letters in the columns are not significantly different (LSD test, p< 0.01)

Table 4 showed the Cu accumulation in Korat soil series was found higher than Nampong soil series at 6.29 and 6.19 mg/kg respectively when treated with swine manure. But there was no significant difference in the Cu content when treated with compost and vermicompost. This is

because Korat soil contains clay mineral which absorbs Cu whereas Nampong soil series is more of sandy which absorbs less Cu. Clay is a potentially good adsorptive material because of its large surface area, high cation exchange capacity, chemical and mechanical stability, and layered structure (Nurdan and Okan, 2013).

CONCLUSION

Swine manure has a significant influence on the amount of Cu accumulation in root and shoot uptake by kale. The most of Cu in swine manure included exchangeable form and organic matter compound. Exchangeable form is availability of Cu and organic matter compound e.g. histidine, nicotianamide and citrate, appears as a key process that promotes root-to-shoot mobility of a metal via xylem transport. Therefore, accumulation of Cu high concentration in root and shoot when treat with swine manure However, accumulation of Cu in Kale and soil depend on kind difference of soil and texture. This is clay mineral cloud absorption heavy metal. Therefore Korat soil series contains clay mineral which absorbs Cu whereas Nampong soil series is more of sandy which absorbs less Cu.

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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.

Purposes of ISERD:

The primary purposes of ISERD are to contribute to sustainable rural development through social and economic development in harmony with the natural environment and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

In order to enhance the realization of the primary purposes of ISERD, the secondary purposes are;

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- to hold conferences or symposia on environmental and rural development,
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