Research article

The Application of Intervention Mapping in Developi ng a Parental Behavior Modification Program for Pesticide Exposure Prevention Among Children in Agricultural Areas for a Sub-District Health Promotion Hospital, Thailand

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Abstract Child health problems in agricultural areas of Thailand are still a problem and must be addressed urgently. This study used a research and development (R&D) design consisting of two phases. Phase 1 aimed to understand parental behavior regarding pesticide exposure among children in agricultural areas. Data were collected by key informants with purposive sampling that used focus group discussion (8 informants/group) from 5 groups of parents of 1-3 years old children living in agricultural areas in Sakon Nakhon Province, totaling 40 people. Data were collected by multiple parent focus group in Sakon Nakhon Province. Data collected was then analyzed using content analysis. Phase 2 aimed to develop and study the quality of a parental behavior modification program for pesticide exposure prevention among children in agricultural areas. The results in phase 1 were used as input factors to develop the foreside program by the Intervention Mapping (IM). The developed program was then tests and reviewed by nine experts. Data were analyzed with mean and standard deviation. We found that parent's behavior in preventing pesticide exposure in their children was influenced by a least three factors, namely: attitudes toward pesticide exposure in their children, social norms and perceived behavioral control about pesticides exposure in their children. This meets the basic structure of Theory of Planned Behavior. The second phase involved developing a parental behavior modification program for pesticide exposure prevention in children in agricultural areas for a Sub-District Health Promotion Hospital. The components of the developed program were:1) background and significance; 2) objective; 3) organization; 4) role of involved people; 5) guidelines for organizing four learning activities for the parent behavior modification program; 6) monitoring and evaluation and 7) program management. The results of the program's quality assessment found that the overall quality of the program is in a very good level. When considered each aspect, it was found that all aspects; accuracy standard, utility standard, appropriateness standard, feasibility standard and generalizability standard were in very good quality as well. The findings of this study suggest that the developed program should be implemented with parents who had desirable pesticide exposure prevention behaviors.

Keywords Theory of Planned Behavior, pesticide exposure, prevention behavior, health program modification, intervention mapping (IM).

INTRODUCTION

44.36 percent of land in Thailand is agricultural. The Northeast of the country has the most agricultural land, up to 63.86 percent of the entire country (OAE, 2020). Pesticides are used in agricultural societies for pest, insect and disease control (U.S. EPA, 2015). In 2011-2017, Thailand imported more than one hundred thousand tons of pesticides (OAE, 2020). While pesticides are widely used in agriculture society and households, the exposure to pesticides in large quantities affects human health and the environment (Snelder et al., 2008). Symptoms of pesticide exposure can include skin irritation, nausea, vomiting, loss of appetite, cough, runny nose, etc. When ingested, organophosphate and carbamate pesticides will inhibit the activity of choline esterase in red blood cells, which can result in both acute and chronic health problems (Suarez-Lopez et al., 2012). Especially, in children, very sensitive to chemicals more than adults because of ages, development, behavior and hygiene that may lead to a greater risk of exposure to environmental contaminants than adults (WHO, 2019 & Curwin et al, 2007). Children living in agricultural societies are exposed to pesticides at a much higher rate than those living in other areas (Panuwet et al., 2008; Petchuay et al., 2006; & Lu et al., 2000). They may be at high risk from exposure to pesticides both from agricultural activities and farmer families (Suarez-Lopez et al., 2012). Young children (1-3 years old) living in an agricultural areas are likely to have play activities on the ground in contact with the soil, both indoors and outdoors. This puts them greatly at risk of being exposed to agricultural pesticides (Curwin et al, 2007 & U.S. EPA, 2008). Studies on pesticide exposure in 1-3 years old children living in agricultural areas in Sakon Nakhon Province found pesticides on children' hands skin up to 60 percent of the children surveyed (Siriwat et al, 2019). This is consistent with the annual report of cases of pesticide poisoning in 2014-2016 of the Department of Disease Control, Ministry of Public Health, which found that Sakon Nakhon Province is the top 10 provinces of the country with highest number of cases of chemical poisoning and residues by pesticides on health symptoms may include contact dermatitis, nausea, sweating, diaphoresis, lacrimation, diarrhea, salivation and headache in children under the age of 5 years.

Although various departments involved in managing diseases from poisoning and pesticides in children have been looking for solutions, previous studies show that the problem is not truly solved (siriwat et al, 2019). One reason may due to pesticide prevention behavior in the individual or parents. There are multiple factors, mostly related to parent's internal issue and external factors in the environment, consisting of physical environment and social environment. However, when analyzing the causal factors leading to real and sustainable behavior change, causal factors from individuals seem more important as external factors are constantly changing due to a dynamic society. Therefore, finding causal factors of pesticide prevention behavior in children' patients (as opposed to factors unique to the individual) might result in the design of behavior change program for the target group that is sustainable.

After reviewing the literature of effective and efficient parental behavior modification programs in the prevention of pesticides exposure in children living in agricultural areas, we found that there is no such program in Thailand that focuses on solving the problem using an individual model. Meanwhile, Intervention Mapping (IM), a model that integrates theory and empirical evidence for planning and designing health promotion and health education (Bartholomew et al, 2006), has been successfully applied in many countries (Voogt, et al, 2014; Kwak et al., 2006; & Tortelo et al., 2005). IM as an alternative way for health educators and health promoters to plan and design health behavior development leading to effective health promotion and health education program. The research team aimed to apply IM as a basis for planning, designing and building a high quality and practical parental behavior modification program in the prevention of pesticides exposure among children living in agricultural areas to result in the prevention of pesticide exposure among children living in agricultural areas.

OBJECTIVE

This study, therefore, aims to develop and study the quality of a parental behavior modification program for pesticide exposure prevention among children in agricultural areas for a Sub-District Health Promotion Hospital in Sakon Nakhon Province, Thailand.

METHODOLOGY

Research design

This research was conducted as a research and development (R&D) by dividing into two phases. Phase 1 was the search for the internal causal factors of parents with children aged 1-3 years in agricultural areas. The research results were input and applied as data in Phase 2 for the development and study of the quality of the developed program by applying IM as a base for development because IM is a systematic process in developing a program design that promotes health and health education. More importantly, its application based on the concept and the theory integrated with empirical data for designing health promotion and health education program used for planning before implementing with a blueprint., as follows:

Phase 1 began with the implementation of Step 1 of IM: conduct a needs assessment or problem analysis using a qualitative research process with focus group discussion. A group of key informants included 40 parents of 1-3 years old children who were selected by purposive sampling (Palys, 2008) with the following criteria: 1) parents of 1-3 years old children living in agricultural areas in Sakon Nakhon Province for more than 1 year, 2) parents who were taking care of their children closely and living in the same house, 3) residential area was within 50 meters radius away from the agricultural areas, and 4) being voluntary participants in the study by signing a consent form for human research ethics. Together, there were 5 groups of informants from 5 agricultural areas in Sakon Nakhon Province, grouped into 8 people each, resulting in 40 informants.

Phase 2 was conducted with the process of Step 2 - 6 of IM, including; Step 2: create matrices of change objectives based on the determinants of behavior, Step 3: Select theory-based intervention methods and practical strategies, Step 4: translate methods and strategies into an organized program, Step 5: Plan for adoption, implementation, and sustainability of the program, and Step 6: Generate an evaluation plan. The program was drafted by the research team and quality was evaluated by nine experts (3 experts of behavioral research scientist, 3 experts of environmental health research scientist, and 3 experts of children health).

Research instruments

There are two separate instruments used in phase1 and phase 2 detailed as follows:

Phase 1: For the range of questions used in group discussion, the researchers applied a semi-structured interview based upon a review of the literature regarding parent behavior and causal factors for the prevention of pesticide exposure among 1-3 years old children (Adgate & Sexton, 2001). The interview guideline consisted of an open-ended questionnaire for informants to freely express their opinions and own feelings freely. Accuracy and comprehensiveness of the content as well as appropriateness of the question were reviewed by three experts.

Phase 2: The program quality assessment form assessed standards of accuracy, utility, appropriateness, feasibility and generalizability, as well as an overview of the program. The rating scale had five quality levels: very good, good, moderate, fair and needs improvement (Best, 1977).

Ethical approval

Ethical approval was obtained from the Human Research Ethics Committee, Kasetsart University, Bangkok, Thailand. (COA No. COA62/046 approved dated 2019/December/2).

Data analysis

Phase 1, content analysis with a three-stage process of data reduction, data display, and drawing conclusions/verification (Miles et al, 2018).; Phase 2, means, and standard deviation.

RESULTS AND DISCUSSION

Phase 1 Participants' characteristics. The majority of participants were female (95.0%), ages ranging from 20 to 60 years (Mean = 40.7), with educational levels ranging from elementary school to diploma level, All the informants worked as cantaloupe melon, chili, potato and tomato farmers. The relationship with children aged 1 – 3 years, mothers (52.5%). The important research findings are as follows: parents still had unwanted pesticide prevention behavior for children in agricultural areas reflected in three areas of parents' individual behavior:

1) Unpreventable exposure

Parents were aware that children living in the agricultural areas often cannot avoid being exposed to pesticides. Even though children might not be taken to agricultural areas where chemicals are applied, chemicals still might get to their bodies by unavoidable touching from someone else. This parental internal factors made parents sometimes unable to take care of their children to prevent pesticide exposure, even when they wanted to do so.

2) Everyone must accept the condition

Parents recognized that people who influences them are parents of other 1-3year old children living in the same community, village or agricultural areas, Most of their child care is no different. Parents often had expectations and decision making which followed their reference group.

3) Difficulty of parental duty

Parents believed it is difficult to control or take action for very young children in their care, even to prevent or reduce pesticide exposure. Particularly when parents were taking care of their children alone, they believed that they were unable to perform demanding pesticide prevention for their children.

In Phase 2, the research team applied the results of Phase 1 as input to develop a program, by following the Step 2-6 of IM.

Parental behavior modification program in the prevention of pesticide exposure in children living in agricultural areas was a program for Sub-district Health Promotion Hospital as it is a department close to farmers and children aged 1-3 years. The research team focused on the practical and integration principles in designing this program with the following elements of the program.

1) Background and significance: Principles of parental health behavior modification to care and protect 1-3 years old children from pesticides in agricultural areas.

2) Objective: Modify the internal behavior of the parents based on the findings, including (1) attitudes toward pesticide exposure in their children, (2) social norms and (3) perceived behavioral control about pesticides exposure in their children, in order to achieve desirable parental behavior in preventing exposure to pesticides in children aged 1 - 3 years.

3) Organization: Sub-District Health Promotion Hospital that operates the program in the future, and the District Public Health Office that controls, monitors and directs the effective use of the program.

4) Role of involved people: (1) Director of Sub-District Health Promotion Hospital who supports and drives the implementation of the program, (2) program users who are the Public Health Officer of Sub-District Health Promotion Hospital and Village Health Volunteer (VHV), and who are also responsible for studying the program, and (3) parents of 1-3 years old children who are responsible for participating in the program and implementing the program for their children in a concrete manner.

5) Guidelines for four learning activities for the parent behavior modification program: Learning Activity 1 – It can be prevented with understanding; Learning Activity 2 - Everyone can take good care of their children; Learning Activity 3 – Believe that you can do it; and, Learning Activity 4 – Visit and follow up "Can it be done?". The four learning activities took six hours to complete, divided into three learning activities integrated and organized by Public Health Officers over 4.5 hours and another learning activity organized by VHVs for 1.5 hours.

6) Monitoring and evaluation: The program was conducted in three phases with objective questionnaires, including the phase before using the program, the phrase right after using the program, and the follow-up phase 3 months the program.

7) Program management: District Public Health Office must have at least one responsible person for monitoring and evaluating the overall program. There was also the program server to implement the program by adapting it to the context of the organization, report the results of the

program usage to the management team and then also delivery suggestions to improve and develop the program after completing it.

Quality assessment tools placed the overall quality of the program is the "very good" range. Each standard, individually, also fell in the "very good" quality range (table 1):

Table 1 Number and percentage of program quality from the improvement

Program quality	Mean	SD.	Interpretation
Accuracy standard	4.56	.527	Very good
Utility standard	4.89	.333	Very good
Appropriateness standard	4.22	.972	Very good
Feasibility standard	4.56	.527	Very good
Generalizability standard	4.22	.441	Very good
Overall program quality	4.67	.500	Very good

*9 experts were evaluated the quality of program.

Parental behavior in the prevention of pesticide exposure among 1-3 years old children living in agricultural areas did not meet the desirable level due to at least three important individual causal factors. This could be explained by the Theory of Planned Behavior (TPB) (Ajzen, 1991), which holds that human behavior is guided by three beliefs, including behavioral beliefs, normative beliefs and control beliefs. Each belief influenced various variables, including attitude toward behavior, social norms and perceived behavioral control, respectively, which also affected behavioral intention leading to behavior as a result. The developed program applied IM as a model development in planning and designing this program, because IM was a model for integrating theory and empirical evidence for the design of health promotion and health education (Bartholomew et al, 2006). The design was essential to rely on behavioral science theory together with empirical evidence for co-design (Kok, et al, 2004). The results of this research applied the findings from Phase 1 as an input for the design and development by applying all 6 steps of IM until the program achieved a very good level of quality that was also practical and possible to be integrated into the Sub-District Health Promotion Hospital.

CONCLUSION

This study described a parental behavior modification program for pesticide exposure prevention among children in agricultural areas for a Sub-District Health Promotion Hospital with the application of IM. The program was able to reach a "very good" quality level. This study suggests that public health agencies in agricultural areas where pesticide exposure is a problem might place such program into practice by integrating with the routine work of those agencies in such a way that they fit sustainably into the life context of local people and society.

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Research article

Rice Varietal Assessment for Climate Change Adaptation from a Socioeconomic Point of View: A Study in Myittha Township, Myanmar

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Abstract Myanmar is the second most vulnerable country in the world to the effects of climate change, with agriculture highly vulnerable. This study was conducted to determine farmers' knowledge on how to respond to the impacts of climate change, to identify climate-resilient adaptation technologies in rice farming, to also identify the desired characteristics of chosen rice varieties, and to estimate the cost and benefits for different rice production systems for the chosen varieties. The study was carried out in Myittha Township, a major rice-growing area in the middle of Myanmar. Most of the rice areas are irrigated. Primary data were collected by conducting a socio-economic survey. Descriptive analysis and cost benefit analysis were applied. More than 95 percent of the farmers adopted an adaptation strategy of using quality seeds. A change to the time of sowing, was favored by only 27% of respondents. About 41% of farmers grew Manaw Thukha rice variety, followed in popularity by Ayeyar Min (33.62%), and Shwe Manaw (20.49%) varieties. The traits of rice variety most desired were high yield and high marketability. The farmers practiced two different methods of rice establishment: direct seeding and transplanting, and grew in both monsoon and summer seasons. In monsoon, direct-seeded Ayeyarmin achieved the highest BCR (1.75) whereas the Manaw Thukha variety yielded the highest BCR in summer (1.70). The study area is an irrigated rice-growing area and has not yet suffered much from climate change impacts on rice production. This is despite a trend to scarcity of rainfall, which implies that improved irrigation facilities will comprise an essential adaptation strategy.

Keywords: farmers' perception, knowledge, climate change adaptation, rice variety, irrigation facilities

INTRODUCTION

In many empirical studies, climate change is manifest in various forms, such as changes in temperature and rainfall patterns, more frequent extreme climate events (e.g. floods, typhoons, droughts, storms, etc.), unusual timing of seasons, and sea level rise (Apata, Samuel & Adeola 2009; Deressa, Hassan & Ringler 2011; Mertz et al. 2009; Smit, McNabb & Smithers 1996; Thomas et al. 2007; Vedwan & Rhoades 2001). Climate change adaptation is one policy option to reduce the negative consequences of the climate change. Adaptation to climate change is a critical issue for many developing economies. The issue is particularly important to agriculture, as this sector which relies substantially on climate-sensitive resources, is highly vulnerable to climate change. Rice remains the staple food in Myanmar, and Myanmar is the world's sixth-largest rice producing country. Rice is the country's most important crop and is grown on over 8 million hectares, or more than half of the arable land. Rice is also the most important crop for millions of small farmers who grow it on millions of hectares throughout the region, and to the many landless workers who derive income from working on these farms. Empirical studies assessing the rice varieties best suited for climate change adaptation are limited in the Myanmar context.

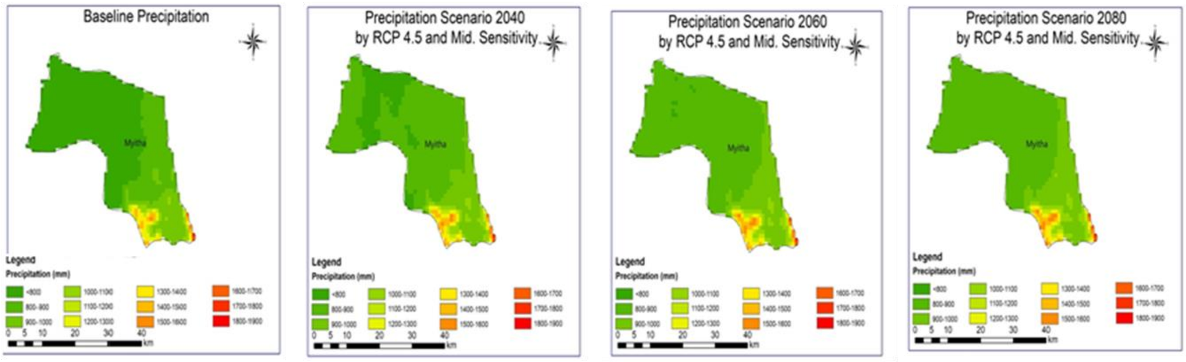

Fig. 1. Climate Change Scenario Maps for Myittha Township with RCP 4.5 Scenario.

Previously, monsoon began in mid-May and ended in mid-October whereas it now begins at the end of May and ends at the end of September. That is, the monsoon season has shortened by about 40 days (Aung, 2019). A longer pre- and post-monsoon period has been observed, and may result in extreme weather such as thunder, lightning, hailstorms and thunder showers. To reflect probable climate change impacts on the study area, the climate change scenario maps were developed for rainfall patterns for a Representative Concentration Pathway (RCP) 4.5 scenario (Fig. 1). A RCP 4.5 is a scenario that stabilizes radiative forcing at 4.5 W m^{-2} in the year 2100 without ever exceeding that value (Thomson *et. al*., 2011). These scenario maps convinced the continuation of climate change in future.

OBJECTIVES

This paper makes a general investigation of a rice variety to determine its suitability for climate change adaptation from a socioeconomic point of view. However, the specific objectives of the study are as follows:

- To determine farmers' knowledge of responses to the impacts of climate change on agriculture,
- To explore location-specific climate resilient adaptation technologies in rice farming,
- To determine the desired characteristics of any rice varieties chosen, and
- To estimate cost and benefits of different rice production systems for the chosen varieties

METHODOLOGY

Selection of the Study Area

Myittha Township, which is located in Kyaukse District, Mandalay Region, central Myanmar, was selected as the study area. It is situated at 21° 25' North, and 96° 8' East. It is a major rice growing area and most of the rice grown is irrigated. The survey was conducted in Yit Kan, Yakhaing Gyi, Ku Phyu and Ngar Su villages in 2018. The total number of respondents was 122. Data collection was carried out using a simple random sampling method and the use of a structured interview schedule.

For data analysis, descriptive analysis and cost and benefit analysis were calculated using Microsoft office excel and the software, STATA (Version 14). Mean, minimum, maximum, standard deviation, frequency and percentage values were applied to reveal the indigenous knowledge of farmers on how to respond climate change impacts, the preferences of farmers of traits for suitable rice varieties, and any climate adaptation strategies practiced by farmers in the study area.

Enterprise budget

The following equations were used to do enterprise budgeting and to estimate the benefit-cost ratio; Costs for cash and non-cash material inputs, hired labor, family labor and interest on cash, were calculated to obtain the total production cost.

Return above variable cash cost = Total gross benefit – Total variable cash cost
Gross margin = Total gross benefit – Total variable cost
Benefit Cost Ratio (BCR) = Total gross benefit / Total variable cost
Return per unit cash cost = Total gross benefit / Total cash cost ×100

RESULTS AND DISCUSSION

Characteristics of the farmers in the study area

The average age of the respondents in the study area was 51.69 years. The youngest age was 19 years and the oldest age was 80 years. The range of farming experience was from 0 to 53 years with an average of 24.75 years. Average length of schooling of respondents was 4.66 years, with a range from 0 (illiterate) to 20 years (tertiary qualifications). Respondents had an average 5.69 acres of lowland farming area. Land ownership ranged from 0 (landless) to 50 acres. The average upland farming area possessed by the respondents was 2.44 acres. The minimum and maximum upland ownership areas were from 0 to 15 acres. Farmers also had 0.39 acres of orchard area on average. In general, the respondents can be described as elderly with low (primary) formal education but with high levels of farming experience.

Table 1 Demographic information of respondents in the study area

Item	Unit	Average	SD
Age	Year	51.69 (19-80)	12.18
Farming Experience	Year	24.75 (0-53)	12.29
Education(Schooling years)	Year	4.66 (0-20)	3.10
Ownership of Lowland	Acre	5.69 (1-50)	5.92
Ownership of Upland	Acre	2.44 (0-15)	3.70
Ownership of Orchard	Acre	0.39 (0-8)	1.25

*Values in parentheses represent range.

Indigenous knowledge of farmers to respond climate change impacts

Seventeen agricultural practices, based on farmers' indigenous knowledge of climate change adaptation, were identified in the survey. More than one quarter of respondents (25.41%) have changed varieties grown and another 25 percent have changed crops, for example, by now growing summer rice instead of sesame. Changed cropping systems and crop management practices were practiced by 17.22% of farmers. Other indigenous responses to climate change impacts were through changing sowing time (6.56%), growing varieties of shorter duration (5.74%), using chemical inputs differently (4.92%), applying FYM (3.28%), using better quality seeds (3.28%), using underground water (2.46%), practicing the line sowing method (2.46%), changing cropping patterns (1.64%), using irrigation water (1.64%), growing more marketable varieties (1.64%), practicing crop rotation (0.82%), growing low-cost crops (0.82%), changing seeds yearly (0.82%) and the willingness to adopt organic farming (0.82%) (Fig. 2). In the study area, it can be assumed that farmers are aware of climate change and are actively adapting to changes.

Climate resilient adaptation technologies

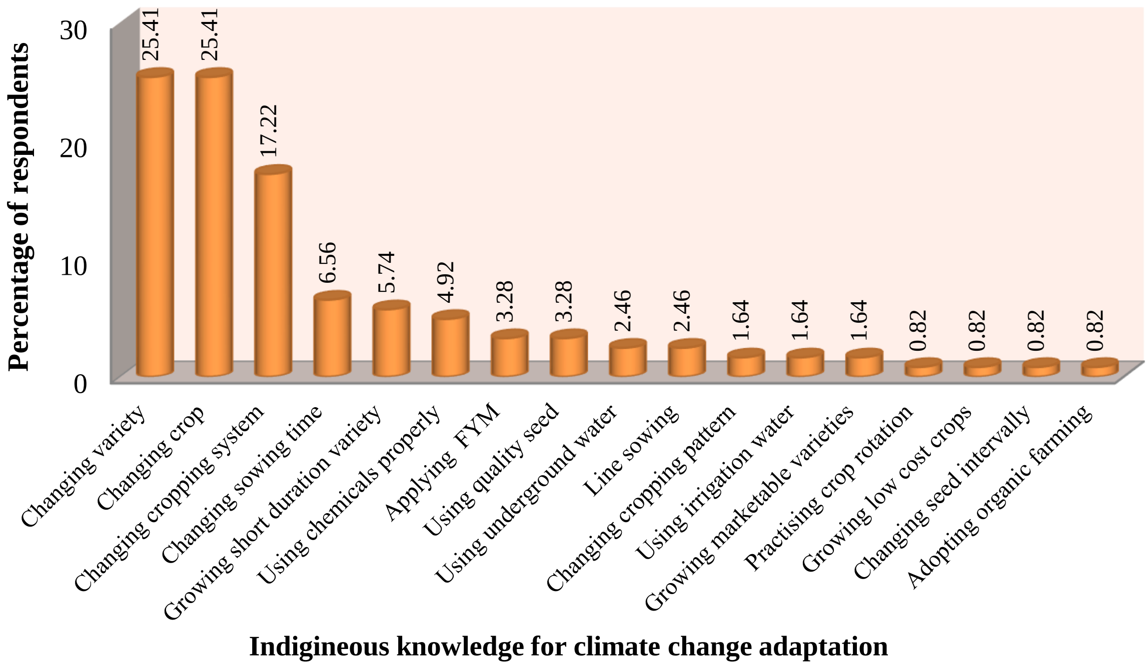

Fig.2 Indigenous Knowledge of farmers to respond Climate Change impacts (n=122)

Adapting to climate change requires that the correct measures, utilizing appropriate adjustments and changes, are made to reduce negative effects.

Table 2 Climate Change Adaptation Strategies Practiced by Farmers in Myittha Township (n=122)

No.	Adaptation Strategies	Frequency	Percent(%)
1	Using quality seeds	115	95
2	Using fertilizers	108	89
3	Using Farm Yard Manure (FYM)	98	81
4	Changing crop types	98	81
5	Changing varieties	96	79
6	Practicing crop rotation	92	76
7	Changing cultural practices	91	75
8	Using traditional varieties	43	36
9	Using underground water	38	31
10	Changing sowing time	33	27

Table 2 ranks ten climate adaptation strategies, practiced by farmers in the study area. Almost all respondents (95%) used quality seeds. Most were using fertilizers (89%), using farm yard manure (FYM) (81%), changing crop type (81%), changing variety (79%) and practicing crop rotation (76%)

followed by using traditional varieties (36%), making use of underground water (31%) and changes to sowing time (27%). Results show almost all respondents were using quality seeds as a climate change adaptation strategy. This reflects that seed is the basic and most vital input of agriculture. Without high quality seed, other inputs and better technologies remain worthless.

Desired characters of the rice varieties

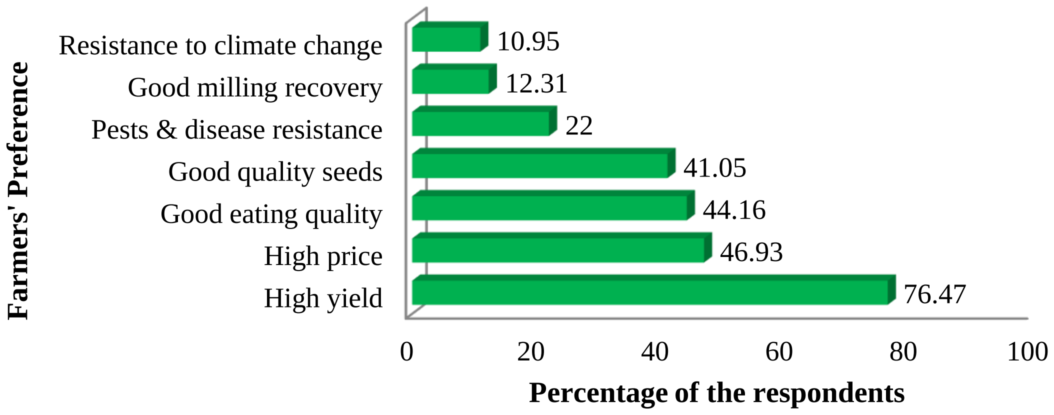

Fig. 3 Farmers' Preference on Rice Variety Traits(n=122)

Rice variety traits and characteristics such as high yield, market price, eating quality, seed quality, pest and disease resistance, good milling recovery and resistance to climate change were found to be what respondents prioritized. Most farmers (76.47%) desired high yielding varieties with high market price, whereas good eating quality, good quality seeds were the desired characteristics sought by 46.93%, 44.16% and 41.05% of farmers respectively. Fewer farmers (22%), (12.31%) and (10.95%) prioritized pest and disease resistance, good milling recovery and resistance to climate change (Fig 3). From this it can be assumed most farmers in the study area have not suffered severely from the impacts of climate change to this point.

Cost and benefit analysis of rice varieties

Cost and benefit analysis of selected rice varieties in both summer and monsoon was made and the results are presented in Table 3. Farmers practiced two different rice establishment methods: transplanting and direct seeding and grew throughout both seasons. Only the Manaw Thukha rice variety was grown, using both methods, in summer, with other varieties not grown in summer using only direct seeding. The Manaw Thukha rice variety exhibited a higher Benefit Cost (BC) ratio (1.70) when transplanted compared to the direct seeding method (1.64), in summer. Also in summer, GW1 gave the highest BC ratio (2.16) of all rice varieties grown after transplanting. GW1 is a Chinese hybrid rice, and although it showed the highest BC ratio, few farmers grew it. It is a newly introduced variety whose plant characteristics and yield potential are not well known. In monsoon season, the Shwe Manaw variety gave the highest BC ratio (1.65) of all rice varieties using transplantation, and the Ayeyar Min variety gave the highest BC ratio (1.75) when the direct seeding method was used.

Table 3 Cost and Benefit Analysis of Selected Rice Varieties by Establishment Methods

Name	Transplanting Method			Direct Seeding Method		
	Total Cost (MMK)	Total Revenue (MMK)	BCR	Total Cost (MMK)	Total Revenue (MMK)	BCR
Monsoon Season						
Shwe Manaw	325,302	535,441	1.65	379,487	652,500	1.72
Ayeyar Min	354,823	556,341	1.57	329,250	567,500	1.75
Manaw Thukha	346,598	473,666	1.37	366,485	584,450	1.59
Summer Season						
Great Wall (GW1)	266,050	575,000	2.16	-	-	-
Manaw Thukha	306,192	519,089	1.70	317,666	520,000	1.64
Ayeyar Min	260,500	375,000	1.44	-	-	-
Shwe Manaw	351,750	382,500	1.09	-	-	-

CONCLUSION

According to the survey results, farmers in the study area appear to have a good knowledge, and developed local strategies to adapt to the effects of climate change, evidenced by practices such as using quality seeds, using fertilizers, employing FYM and changing crop types in their efforts to cope with the impacts of climate change. Switching to high yielding varieties is mostly favored. During monsoon, direct seeding methods yielded higher BC ratios for all varieties. In summer, farmers did not practice direct seeding method much because they are able to irrigate to manage their nursery. Thus, irrigation facilities become essential infrastructure for successful climate change adaptation strategies.

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Research article

Soil Organic Carbon Stabilization on Forested and Deforested Red-yellow Soil under Different Temperature Conditions

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Abstract Soil organic carbon (SOC) has an important role as a key indicator for soil health due to its contributions on mitigation and adaptation to climate change. Tropical areas cover with Red-yellow soil (Udults) such as Amazon represents the highest amount of soil carbon sources in the earth. Although it is affected by human impacts due to deforestation, it is important to maintain and increase SOC of tropical Red-yellow soil toward an optimal level for meeting challenges such as mitigating climate change effects. The aim of this study is to analyze the stabilization of soil organic carbon from Red-yellow soil under different temperatures conditions. A detailed comparison was made between forested and deforested conditions of Red-yellow soil. In order to analyze the temperature sensitivity, each treatment was kept under 25ºC and 35ºC, and the soil respiration ratio (SRR) was measured as well as SOC content by spectrophotometry method. Lastly, a treatment of biochar at 5% was added as part of stabilization mechanisms of carbon. The experimental results showed that there were significant differences in SOC content between forested conditions in contrast to deforested conditions, where 7.25 mg C/g was found in forest conditions while deforested conditions was 5.68 mg C/g. Although it was not found significant change in SOC under different temperature, SRR increased at 39% from 8.87 μL CO_2/h/g to 11.90 μL CO_2/h/g with temperature changes from 25ºC to 35ºC. Additionally, biochar application contributes to increase the value of SOC at more than 2.66 mg C/g in all treatments, however, it did not make a significant difference in SRR by temperature changes. Thus, biochar works as carbon sources to maintain and increase SOC content, but stabilization effects on Soil Respiration Ratio (SRR) should be observed in long term.

Key words: soil organic carbon, soil respiration rate, temperature sensitive, biochar.

INTRODUCTION

The SOC represents between 50% to 58% of the soil organic matter content, which has an important function of storing nutrients for plants, improving soil structural stability to enhance soil fertility and providing mechanism to mitigate climate change effects. Turnover of SOC in terrestrial ecosystems is dynamic and human impacts can turn SOC into either a net sink or a net source of greenhouse gases (GHG) to the atmosphere (Trivedi, Singh and Singh, 2018).

The impact of climate change on SOC stocks is variable according to the soil type and location, however temperature changes and increasing frequency of extreme drought events are probably leading to increased loss of SOC. Although significant scientific progress has been achieved related to understanding of SOC dynamic, mechanism of protection and stabilization of SOC stocks in short-term and at different conditions still face complicated challenges impeding effectives conservation strategies (Pribyl, 2010).

The Red-yellow soil (Udults), mainly located in Amazon area, has an important role in global carbon changes, making this area as a considerable interest to quantify emissions when deforestation converts these forests into pasture or other land uses (de Oliveira Marques et al., 2017). Maintaining carbon stocks in Red-yellow soils of tropical forests such as Amazon area has increasingly become a justification for governments to take measures of reforesting rather than allowing them to be deforested. Nevertheless, deforestation has accelerated the process of forest fragmentation in Amazon area, resulting in changes in carbon stocks in biomass and soil (Barros and Fearnside, 2016).

The enhance of soil microbe's activity is stimulated by increasing of environment temperature, causing a higher release of microbial CO_2 (Lloyd and Taylor, 1994), leading to soil C losses, higher soil respiration rate and a positive contribution to global warming. In the short-term, increasing of temperature results in a significant increase of microbial activity and decomposition rates. It has been shown that decomposition of SOC increases with temperature, with the greatest proportional increases being observed at low temperatures. It is a fundamental issue to estimate the extent to which rising temperatures could destabilize SOC and make it available to decomposing microorganisms. The proportion of SOC stored in the world's soils is still argued and how it is vulnerable to the impacts of warming of this century (Crowther et al., 2016).

Therefore, modeling approaches that consider changes in carbon availability and microbial activity may be needed to improve understanding under different conditions on Red-yellow soil. Forested and deforested conditions of soils have a significant effect on SOC that must be connected with respiration rate, decomposition and possible conservation strategies on Amazon area.

OBJETIVE

The present study aimed to analyze the quantity and stabilization of soil organic carbon from Red-yellow soil, under different temperatures (25ºC and 35ºC) and conditions (forested and deforested). Such study is important to provide information about potential carbon emissions and climate change effects.

METHODOLOGY

Soil sample source and preparation

The current investigation involved sampling and analyzing two sites of Red-yellow soil to measure SOC and SRR. The sites were selected from Miyako Island, which is located in Okinawa Prefecture, south of Japan. The soil sample was collected from a deforested and forested area with four samples each site as repetitions (Carter and Gregorich, 2008). 1000g of air-dried soil were sieve and weighed into a labeled tray followed by adding 5% (w/w) of biochar as a biochar treatment. Samples were kept at approximate a field capacity moisture condition. Each treatment was divided into soil at ambient conditions (25ºC) and warm conditions (35ºC), and by conditions (Forested and Deforested) and biochar rate (0% and 5%).

Soil organic carbon determination

Each one of the treatments and repetitions were analyzed by Spectrophotometric Procedure of Organic Carbon Contents of Soil (Wallinga, Kithome, Novozamsky, Houba and Van der Lee, 1992). 50 mg of soil were weight precisely, and it was transferred carefully to a dry 100-mL volumetric flask. 10.0 mL of 0.333 M potassium dichromate solution ($K_2Cr_2O_7$) was added to each flask. 16.0 mL of concentrated sulphuric acid were added following by putting the flasks in a boiling water bath for 45". The samples were cooled in the sink made up to the volume with distilled water. The samples were centrifuged for 10" at 3000 RPM.

For the preparation of standard series, 100 mL flasks containing sodium oxalate ($Na_2C_2O_4$) with volumes of 0, 25.0, 50.0, 75.0 and 100.0 mL were used as standard into the volumetric flask. These standard series worked as 0, 5, 10, 15 and 20 mmol Cr^{+3} per litter of solution of standard series. The absorbance was measured in a 1 cm cuvette at a wavelength of 590 nm within 2 hours after oxidation.

SOC percentage were calculated by multiplying the Cr^{+3} concentrations found by 0.2250/w, where "w" is the weight of the air-dry soil sampled.

Soil respiration rate determination

Ten grams of air-dried soil were weighted from each treatment into a 450 mL glass bottle followed by adding 3 mL of distilled water. The soil and water were mixed in the bottles then covered with perforated films to reduced evaporation. The SRR was determined by using the infrared gas analyzer at time zero and measure again at the end of 1-h incubation (Sparda, Miller, Anderson and Hsieh, 2016). The soil respiration rate (SRR, μL CO_2/h/g air-dried soil) was calculated as:

$$SRR = \left(CO_{2f} - CO_{2i}\right) * V * \frac{1000}{S} \quad (1)$$

Where CO_{2i} and CO_{2f} are the initial and final CO2 concentrations (ppm) of the 1-h incubation, respectively, and V is the space volume of the bottle with the soil sample (450 mL). The amount of soil (S) was 10.0 g. Four repetition were measured for each one of the treatments.

Statistical analyze

The comparison of the average of each one of the treatments were analyzed through Shapiro-Wilk Normality and Levene Homogeneity test. The one-way ANOVA test were performed to determine if there are differences through variance analysis. Then, Tukey test was applied to determine the differences between treatments. In addition, a Box-Cox transformation was performed to fit the ANOVA test. All the tests were performed using RStudio (version 1.2.5042) for statistical analyses of the data. Analyses were performed at the significant level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Mean values and standard deviation of Soil Organic Carbon (mg/g) and Soil Respiration Rate (μLCO_2/h/g) of treatments at Forested and Deforested condition, biochar rates and temperature, are shown in Table 1. The amount of organic carbon obtained in this study indicated significant differences ($P<0.05$) between treatments (Forested vs Deforested). In previous studies, the amount of Soil Organic Carbon has been analyzed at Forested and Deforested conditions (Fujisaki et al., 2017), where the values on Forested condition were found higher that Deforested condition. The theoretical basis for this is as follows. The forest keeps equilibrium between incomes and outcomes of carbon while deforestation cuts incomes and increase outcomes in the short term.

Table 1 Soil Organic Carbon (SOC) content and Soil Respiration Rate (SRR) of different conditions, biochar rate and temperature.

Condition	Biochar	Tº	SOC (mg/g)	SRR (μL CO_2/h/g)
Forested	0%	25º	7.24 ± 0.04 a	8.87 ± 0.20 a
		35º	7.61 ± 0.43 a	12.14 ± 0.20 b
	5%	25º	10.27 ± 0.39 b	8.53 ± 0.04 a
		35º	10.97 ± 0.37 b	11.9 ± 0.13 b
Deforested	0%	25º	5.68 ± 0.46 c	6.57 ± 0.02 c
		35º	6.6 ± 0.44 cd	4.93 ± 0.13 d
	5%	25º	4.99 ± 0.09 c	5.51 ± 0.09 d
		35º	5.52 ± 0.53 c	4.88 ± 0.24 d

The letters indicate the significant different of result among the treatments at 95% of confidence level.

On the other hand, the addition of biochar at 5% rate on soil showed a considerable different on SOC rather than 0% treatment. Biochar is composed by high values of organic matter which includes organic carbon (Oladele and Adetunji, 2020). The biochar increased values of SOC in Forested conditions at 5% rate in contrast of 0%, however, there were not differences found on Deforested at 5% in contrast of 0%. Temperature changes did not show significant difference between treatments in short term. Liu et al. (2021) describe the degradation of organic carbon in long-term by microbes at warm conditions as a reduction in the amount of SOC, this explain the non-significant change in the values of SOC by temperature in short-term.

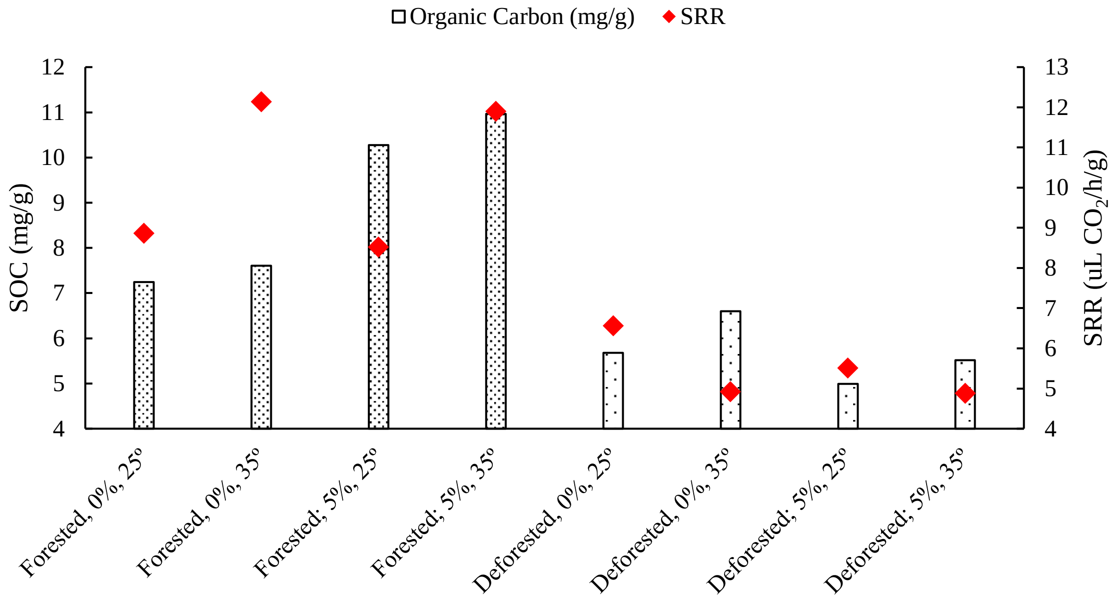

Fig. 1 Soil Organic Carbon content and Soil Respiration Rate of each treatment.

It can be seen in Fig.1 that the Soil Respiration Rate was altered by temperature in the short-term. In Forested conditions, values of SRR reached 12 uL CO_2/h/g in contrast to values lower than 9 uL CO_2/h/g (39% higher in warm conditions). The increased of temperature in soil reflects a considerable change in microbial activity in the short-term, which means an increase of CO_2 released. Although biochar addition shows a considerable increase of SOC, there is not stabilization of SRR under warm conditions. Xu et al. (2019) describe the activation and stabilization of carbon by biochar in the middle-term, which not only increase carbon but also reduce the release of it.

Deforested conditions showed values of SRR lower in comparison with Forested. It is clear due to the low amount of carbon in the Red-yellow soil and the relation with microbial activity. The SRR reached values of 6.57 uL CO_2/h/g and the lowest 4.93 uL CO_2/h/g with significant differences (25% lower than Forested conditions). Effect of temperature on Deforested conditions showed an increased in SRR values, but in the same way, biochar did not have a significant effect. Biochar application has affected the SOC but the effects on SRR stabilization in the short-term is depending by temperature and the microbial activity (Xu et al., 2019).

CONCLUSIONS

It is demonstrated that Deforested condition reduces significantly the amount of organic carbon in the soil. Although Red-yellow soil has a low organic carbon content, this reduction can be recovered by biochar addition. The loss of carbon by microbial activity increases by the effect of temperature which has an important role through Soil Respiration Rate. The Forested conditions of Red-yellow soil showed an increase of microbial activity due to the high carbon content, thus, the changes on respiration are easily affected by weather such as temperature conditions. This process of organic carbon degradation is not stabilized by biochar addition in the short-term. Finally, biochar works as carbon sources to maintain and increase SOC content, but stabilization effect on Soil Respiration Ratio (SRR) should be observed in long term under warm and ambient conditions as part of the stabilization process.

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Research article

Assessment of Some Promising Lines of Rice (*Oryza sativa* L.) for Salt Tolerance using Microsatellite Markers Associated with the *saltol* QTL

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Abstract Rice is one of the most important staple food crops in the world that grown extensively under irrigation. Salinity is an important physical factor influencing rice (*Oryza sativa* L.) production. To assess this limiting factor, YAU developed 100 breeding lines of rice. After screening at seedling and vegetative stages at different salinity levels (0.2, 6.0, and 8.0 dS m^{-1}), seven rice lines were selected as moderately saline-tolerant genotypes. These seven lines (V1: YAU- 1211-14-1-1; V2: YAU1201-90-2-4; V3: YAU-1211-18-1-1; V4: YAU1211-195-1-1; V5: YAU-1201-26-1-1; V6: YAU1201-26-1-3; and V7: YAU-1211-82-1-1) along with three local control varieties (Yatanatoe, Superhnankaut and Theehtatyin), one salt tolerance check (Pokkali) and one susceptible check (IR 29) were used in this study. Seven *Saltol* QTL associated SSR markers (RM5, RM9, RM140, RM472, RM493, RM1287 and RM3412) were used to check the usefulness of microsatellite (SSR) markers associated with *Saltol* QTL. The number of alleles on the SSR markers ranged from 2 for RM140 to 4 for RM3412. Polymorphic information content (PIC) value varied from 0.00 for RM140 to 0.62 for RM3412, with an average of 0.36. The SSR marker, RM3412, was found to be superior for analysis as an indicator of genetic diversity in this study. Cluster analysis of the rice genotypes based on SSR data divided the genotypes into three groups, each of which include Yatanatoe, Theehtatyn, Superhnankaut and susceptible check IR29 (cluster 1), V1, V2 and V3 (cluster 2), V4, V5, V6, V7 including salt tolerance genotypes Pokkali (cluster 3), respectively. Of the seven lines, four SSR markers (RM5, RM493, RM1287 and RM3412) could discriminate Pokkali (*saltol*) from the IR29 (susceptible) genotype. Two specific alleles were found by RM5 (170) and RM493 (220) for Pokkali. At locus RM140, almost all genotypes possessed the same allele as Pokkali (260) except Theehtatyin and IR29 (null allele). RM1285 indicated four YAU rice lines (V4, V5, V6 and V7) as salt tolerance lines. The study revealed V4: YAU1211-195-1-1 as a tolerance genotype. The RM5, RM493, RM1287 and RM3412 markers were able to discriminate the tolerant genotypes and hence could be useful for marker-assisted selection of *Saltol* QTL.

Keyword Promising rice lines, *Saltol* QTL, SSR marker

INTRODUCTION

Rice (Oryza sativa) is the staple food of half of the population of the world. Identifying a rice crop that resists saline incursions due to climate change is prevalent among farmer's requirements. Soil salinization has become a serious problem all over the world and around 20% of the world's cultivated land is affected (Sumner, 2000). In Myanmar, soil salinization is found in both coastal and inland regions, and about 3% of the total rice sown area is affected by salinity (DOA, 2012). Coastal salinity is often due to seawater intrusion/ infiltration during floods, resulting in salt accumulation in the topsoil in the summer season. It occurs commonly in Ayeyarwady, Yangon, Yakhaing and Taninthari regions. Inland salinity is common in dry zone areas of central Myanmar such as the Mandalay, Magway and Sagaing regions. Rice productivity is quite low due to this salinization, with limited water resources, and low soil fertility in these inland areas of Myanmar (Oo et al., 2017). Swe and Ando (2017) have pointed out that salinity is becoming a prominent abiotic problem, with declining rice production in the central dry zone and which has had little attention paid to it. An improvement in rice breeding programs which offers rice varieties suitable for these changing conditions is important.

There are many salt tolerant rice varieties providing an opportunity to improve crop salt-stress tolerance through genetic means. Some attempts based on highly tolerant traditional rice cultivars i.e. Pokkali and Nona-Bokra have been made to these develop salt-tolerant genotypes (Akbar et al., 1985; Gregorio and Senadhira, 1993). DNA based molecular markers have been used extensively to assess the genetic diversity in most crop species (Mohammadi-Nejad et al., 2008). Currently, simple sequence repeats (SSRs) or microsatellite markers have been used to study genetic diversity, phylogenetic relationships, classification, evolutionary processes and quantitative trait loci in many crops. This technique has been used effectively to map QTLs associated with salt tolerance (Lang et al., 2000 and 2001; Singh et al., 2007). A major QTL located on chromosome 1 has been identified for salt tolerance using F8 recombinant inbred lines (RILs) of Pokkali/ IR29 cross (Gregorio et al., 1997). Therefore, it could be stated that Pokkali represents the most widely used salt tolerant parent by rice breeders. Our group have developed hundreds of rice breeding lines to transfer salt tolerance gene of Pokkali to local height yielding varieties.

OBJECTIBES

The present study intended to (i) evaluate salt tolerant rice breeding lines at different growth stages; seedling and vegetative, and (ii) test the usefulness of microsatellite (SSR) markers associated with *Saltol* QTL to identify promising YAU rice lines.

MATERIALS AND METHODS

Evaluation of Selected Improved Rice Lines at Vegetative Stage

This experiment was conducted as a two-factor factorial in a randomized complete block design, with three replications at vegetative stage. Seven YAU promising lines were formerly selected by conducting farmer participatory variety selection based on their preference of eating quality and visual assessment in the field. The seven rice selected lines with Pokkali (tolerant check) and IR29 (susceptible check), were grown at three different levels of salinity (0.2, 6.0, and 8.0 dS m^{-1}). Salinity tolerance was rated using a modified standard evaluation system (SES) rating the visual symptoms of salt toxicity (Gregorio et al., 1997) as shown in Table 1. Following Gregorio et al. (1997), who modified the method for the screening of rice genotypes at vegetative stage, the wall of plastic pot was drilled with 3-4 mm diameter holes 2 cm apart, with the topmost circle of holes at least 3 cm below the rim of the plastic pot. Cotton cloth was used to line the plastic pots. The pots were filled with fertilized soil, and then placed in the plastic tray filled with ordinary tap water, which served as a water bath. Four to five pre-germinated seeds of the tested varieties were placed on the soil surface of each pot. Two weeks after seeding, seedlings were thinned to one per pot and the water level was raised to a level about 1 cm above soil. When the seedlings were 25 days old, all water was siphoned out. Then salinized water, at the different EC saturations, was introduced. The water level was maintained on a daily basis and the plants protected from any pests and diseases. Scoring was started at two weeks after salinization by using a modified standard evaluation system to rate the visual symptoms of salt toxicity (Gregorio et al., 1997) with results presented in Table 1. Plant height (cm) and the number of tillers per hill were recorded at 6 weeks after salinization.

Table 1 Modified Standard Evaluation Score (SES) of visual salt injury at seedling and vegetative stages

Score	Observation	Tolerance
1	Normal growth, no leaf symptoms	Highly tolerant
3	Nearly normal growth, but leaf tips of few leaves whitish and rolled	Tolerant
5	Growth severely retarded, most leave rolled	Moderately tolerant
7	Complete cessation of growth, most leaves dry, some plant dying	Susceptible
9	Almost all plant dead or dying	Highly susceptible

Source; Gregorio et al., 1997

Microsatellite (SSR) analysis

A total of twelve genotypes including seven YAU promising rice line (V1: YAU- 1211-14-1-1; V2: YAU1201-90-2-4; V3: YAU-1211-18-1-1; V4: YAU1211-195-1-1; V5: YAU-1201-26-1-1; V6: YAU1201-26-1-3; and V7: YAU-1211-82-1-1) and three local control varieties (Yatanatoe, Superhnankaut and Theehtatyin), one susceptible check (IR29) and one tolerance check (Pokkali) were used to extract total genomic DNA. A modified CTAB method was used to extract DNA from the plants' young leaves. The relative purity and concentration of extracted DNA was estimated with NanoDrop ND-1000 (NanoDrop Technologies, Inc., Wilmington, DE, USA). The final concentration of each DNA sample was adjusted to 50 ng/µl.

Seven *Saltol* QTL associated SSR markers (RM5, RM9, RM140, RM472, RM493, RM1287 and RM3412) were used to check the usefulness of microsatellite (SSR) markers associated with *Saltol* QTL in the identification of promising YAU rice lines (Mohammadi-Nejad et al., 2008). GoTaq®Colorless Master Mix M713 was used according to the manufacturer's procedure for PCR amplification. The PCR reaction was a 10 µl volume using a Boeco Thermal Cycler TC-SQ (Boeco Germany). The PCR profile; 5 min of denaturation at 94°C, 35 cycles were performed for 1 min at 94°C, 45 s at 55°C, 1 min at 72°C, and a final extension step of 5 min at 72°C. PCR amplified products were separated in 2% agarose gel at 100 V for 1 h in 1 x TBE buffe. RedSafe™ Nucleic Acid Staining Solution (20,000x) was used to stain DNA in the agarose gel. The resulting DNA bands were scored as base pairs using grid lines in photoshop, comparing 100 bp DNA ladder bands.

Data Analysis

The data collected were analyzed statistically using Analysis of Variance (ANOVA) techniques, and rice lines means were compared by least significant different (LSD) method at a 5% probability level. All statistical analyses were done using Statistix 8.0 software and Excel program (2010).

The variability at each locus was measured in terms of the number of alleles, major allele frequency (MAF), and polymorphic information content (PIC) using PowerMarker 3.25 (Liu and Muse, 2005). The UPGMA algorithm of MEGA6 software embedded in PowerMarker was used to construct an unrooted neighbour-joining tree of each accession based on the shared allele distances (Tamura et al., 2007).

RESULTS AND DISCUSSION

Evaluation of Selected Improved Rice Lines at the Vegetative Stage

The sight evaluation scores (SES), showed a variation in response to salt stress among the rice lines. SES increased with an increase in stress level, indicating greater susceptibility at higher stress level (Table 2). All seven improved rice lines at vegetative stage grew strongly and showed uniform green colour in non-salinized conditions (0.2 dS m^{-1}). In salinized conditions (6.0 and 8.0 dS m^{-1}), the rice lines showed significant differences for salt tolerance at the vegetative stage, with scores ranging from score 1 (highly tolerant) to score 9 (highly susceptible) (Table 2). The seven rice lines selected showed a high degree of tolerance and moderate tolerance, respectively, under increasing salinity levels (6.0 and 8.0 dS m^{-1}).

The reactions of the selected improved rice lines in terms of plant height and number of tillers per hill, under three different salinity levels at the vegetative stage, are showed in Table 3. The plant heights are significantly different among the rice lines in the non-salinized condition (0.2 dS m^{-1}). In contrast, these parameters were not significantly different among the rice lines in the two salinized conditions. Similarly, the number of tillers per hill was not significantly different among the rice lines in all conditions.

Table 2. Reactions of improved rice lines at vegetative stage to salinity at three different levels measured by Standard Evaluation Score (SES)

Improved rice lines	Reaction to salinity at 6 weeks after salinization		
	0.2 dS m^{-1}	6.0 dS m^{-1}	8.0 dS m^{-1}
YAU-1211-14-1-1	Highly tolerant	Tolerant	Moderately tolerant
YAU-1201-90-2-4	Highly tolerant	Tolerant	Moderately tolerant
YAU-1211-118-1-1	Highly tolerant	Tolerant	Moderately tolerant
YAU-1211-195-1-1	Highly tolerant	Tolerant	Moderately tolerant
YAU-1201-26-1-1	Highly tolerant	Tolerant	Moderately tolerant
YAU-1201-26-1-3	Highly tolerant	Tolerant	Moderately tolerant
YAU-1211-82-1-1	Highly tolerant	Tolerant	Moderately tolerant
Pokkali	Highly tolerant	Tolerant	Tolerant
IR29	Highly tolerant	Highly susceptible	Highly susceptible

Table 3 Reactions of selected improved rice lines at the vegetative stage to salinity at three different levels measured by plant height and number of tillers per hill

Improved rice lines	Plant height (cm)			Number of tillers per hill		
	0.2 dS m^{-1}	6.0 dS m^{-1}	8.0 dS m^{-1}	0.2 dS m^{-1}	6.0 dS m^{-1}	8.0 dS m^{-1}
YAU-1211-14-1-1	39.0 bcd	32.7	26.3	4.7	4	3
YAU-1201-90-2-4	37.3 de	32.3	25.7	4.3	4	3.3
YAU-1211-118-1-1	42.0 ab	32.7	23.7	4.3	3.7	3.3
YAU-1211-195-1-1	39.7 bcd	33.3	24	4	3.7	3.3
YAU-1201-26-1-1	44.7 a	32	26.7	5	4.3	4
YAU-1201-26-1-3	38.0 cde	35.7	22.7	4	3.3	3.3
YAU-1211-82-1-1	40.7 bc	34	27.3	4.3	3.7	4
Pokkali	35.3 ef	36.3	25	4.3	3.3	3.3
IR29	33.0 f	31.7	24	3.7	3.7	3.3
F-test	**	ns	ns	ns	ns	ns
C.V %	4.6	5.5	9.2	15.2	18.6	19.4

Values in the same column followed by the same letter are not significantly different at the 5% level by the LSD test, (**) significantly different at $P \leq 0.01$, ns − not significant

Microsatellite (SSR) analysis

The number of alleles of the SSR markers ranged from 2 for RM140 to 4 for RM3412. Polymorphic information content (PIC) values varied from 0.00 for RM140 to 0.62 for RM3412, with an average of 0.36 (Table 4). The measure, or value of the PIC, is determined by the ability of a marker to establish polymorphism in the population depends on the number of alleles detected and on their distribution frequency (Botstein et al., 1980). The PIC value of the marker is defined as the expected fraction of informative offspring from the type of pedigree (Hildebrand, et al. 1992). In this regard, SSR marker, RM3412, was found to be superior for discrimination of potential breeding lines in this study.

Cluster analysis of the rice genotypes based on SSR data, separated the genotypes into three groups, each of which had Yatanatoe, Theehtatyn, Superhnankaut and susceptible check IR29 (cluster 1), V1, V2 and V3 (cluster 2), V4, V5, V6, V7, including salt tolerance genotypes Pokkali (cluster 3), respectively (Figure 1). Out of the seven varieties, four SSR markers (RM5, RM493, RM1287 and RM3412) were able to discriminate Pokkali (*Saltol*) from IR29 (susceptible) genotype. Two specific alleles were found by RM5 (170) and RM493 (220) for Pokkali. At locus RM140, almost all genotypes possessed the same allele as Pokkali (260), except for Theehtatyin and IR29 (null allele). Null alleles were likely to be encountered in populations with a large size, with unusually high mutation rates in the flanking regions, and those that have diverged from the population from which the cloned allele state was drawn and the primers designed (Chapuis and Estoup, 2007). Theehtatyin and IR29 would exhibit mutations in this locus, RM140. RM1285 was an indicator that four YAU rice lines (V4, V5, V6 and V7) are salt tolerant lines. These results, in combination, revealed V4: YAU1211-195-1-1 as saline tolerant genotypes. The RM5, RM493, RM1287 and RM3412 markers were able to discriminate for tolerant genotypes and hence could be useful for marker-assisted selection of *Saltol* QTL.

Table 4. Number of alleles and polymorphism information content (PIC) values of SSR markers for 12 rice genotypes.

Marker	Frequency of major allele	No. of allele	PIC	Amplicon size range (bp)
RM5	0.92	2	0.14	150-170
RM9	0.44	3	0.57	100-170
RM140	1.00	1	0.00	260
RM472	0.83	2	0.24	320-350
RM493	0.50	3	0.48	220-250
RM1287	0.56	3	0.49	125-160
RM3412	0.42	4	0.62	200-260

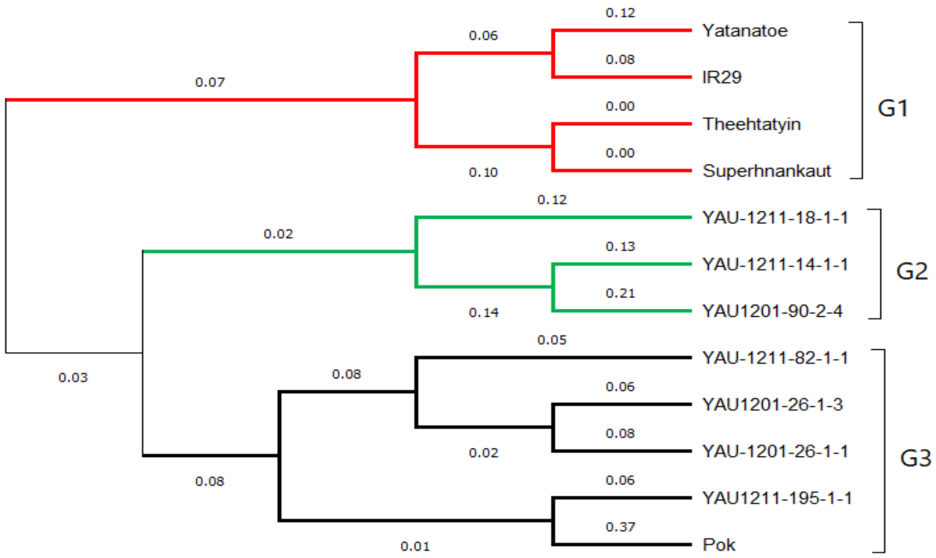

Figure 1. Dendrogram of 12 rice genotypes based on 7 polymorphic SSR markers derived from the Shared allele distance with neighbor joint method

CONCLUSION

In conclusion, in this study 100 improved rice lines were observed for relative salt tolerance in terms of agronomic parameters such as tiller numbers, panicle numbers and grain yield. Results show that four rice breeding lines; V4, V5, V6, V7 have the potential to be developed for future improvement as salt tolerant rice varieties. Furthermore, the result highlights the usefulness of SSR markers associated with *saltol* QTL for the screening of rice breeding lines. The RM5, RM493, RM1287 and RM3412 markers may be useful for marker-assisted selection.

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Research article

Evaluation of school gardens as a method of scaling up sustainable agriculture technologies

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Abstract Current research on school gardens is primarily focused on improving student nutrition. Less examined is their potential to be agents of knowledge transfer to the wider community. This paper seeks to determine the potential of school gardens as a pathway to scaling agricultural innovations. Literature is reviewed for best practices and recommendations conducive to scaling up agricultural technologies using school gardens. Findings indicated that school gardens have the potential to play a key role in scaling sustainable intensification (SI) technologies. They provide opportunities for knowledge transfer through teacher-student-parent communication. Best practices for scaling through school gardens comprised: including parents in the learning process and upkeep of school gardens; collaboration and commitment among all stakeholders; establishment of hands-on, research-based agricultural curriculum in schools; financial assistance from government or outside organization for startup and upkeep; and establishment of home gardens alongside school gardens. Primary barriers to scaling included: focusing on the 'what' and not the 'how'; social mores and the relationship between parent/child; capacity building for and involvement of school heads, teachers, and parents; lack of social, human, and/or economic capital; and unintegrated commitment and partnership among stakeholders.

Identified best practices and barriers are then applied to a case study analysis of a USAID-funded project in Cambodia: Scaling Suitable Sustainable Technologies (S3-Cambodia) project. S3-Cambodia targets youth as an entry point to extend target SI technologies to farm families. The project engages students in experiential learning opportunities by establishing "green labs" at secondary schools. S3-Cambodia is found to already be implementing many of the best practices listed above. Suggestions are made to increase parent involvement in the project and to increase awareness of the challenges that come with a transnational project.

Keywords Adoption, scaling, school garden, knowledge transfer, agriculture

INTRODUCTION

School gardens are a well-known tool to develop agricultural education curriculum and food system knowledge within primary and secondary schools worldwide. Current research on school gardens is primarily focused on improving student nutrition and increasing vegetable consumption (Ratcliffe et al., 2011; Schreinemachers et al., 2019; Leuven et al., 2018; FAO, 2004; Ferguson et al., 2019). Less examined is their potential to be agents of food system reskilling and knowledge transfer to the wider community (Cramer et al., 2019). Yet, students have significant potential to be agents of change in their homes and communities. Using knowledge gained through school garden education, students can serve as credible sources of information to their parents on best agriculture practices (Okiror et al., 2011).

School gardens provide a pathway to evaluate new technologies without personal risk. Often, implementation and scaling up of new technologies and innovations is met with apprehension due to fear of the economic, social, and health risks that come with crop failure (Shilomboleni and De Plaen, 2019; Westermann et al., 2019). Understanding the process of and barriers to scaling are not newly developed streams of social science research. Feder and Umali (1993) in their literature review of agricultural innovation adoption during the prior decade detail risk, information availability, credit, and farm size as major factors influencing farmer adoption of new technologies. This understanding of risk severely limits ability to scale new agricultural technologies which seek to improve livelihoods and combat impacts of climate change. Often, scaling is described as either 'scaling up' or 'scaling out'. 'Scaling up' can be likened to the act of increasing, often in terms of number, speed, size, etc. On the other hand, 'scaling out' refers to the act of expansion, such as the spread of a particular technology to new geographical locations (Wigboldus et al., 2016). This paper will combine the distinction into the phrase 'scaling up' which covers the expansion, replication, and adaption of successful technologies, practices, or innovations to reach a greater number of people (Finn, 2012).

Understanding the role of risk in agriculture adoption and scaling is of particular relevance for sustainable intensification (SI) technologies. SI is a method of agricultural production which seeks to balance environmental, economic, and social factors of farming. Zurek et al. (2015) define sustainable intensification as, "production of more food on the same piece of land while reducing the negative environmental impacts and at the same time increasing the contributions to natural capital and flow of environmental services" (p. 24). This has been further expanded to include social issues, economics, and the human condition as non-environmental factors for a balanced application of SI processes (Musumba et al., 2017). Barriers to the adoption of SI technologies include, but aren't limited to, demographic variables, farm-location characteristics, fiscal capital, information access and human capital, and the occurrence of climate shocks. Often, these barriers vary based upon time and location. For example, Kassie et al (2015) finds the primary barriers of SI adoption in eastern and southern Africa to be, "social capital and networks, quality of extension services, reliance on government support during crop failure, incidence of pests and diseases, resource constraints, tenure security, education, and market access" (p. 400).

This paper seeks to determine the potential of school gardens as a pathway to scaling agricultural innovations, particularly SI technologies. Specifically, it will assess if school gardens are able to limit barriers to adoption such as risk and information availability. Literature is reviewed for best practices and recommendations conducive to scaling up agricultural technologies using school gardens. Identified challenges and suggestions are then applied to a case study analysis of a USAID-funded project on scaling of SI technologies in Cambodia.

OBJECTIVE

Objectives of research are as follows:

1. To identify current and historical literature regarding scaling and adoption of agricultural innovation
2. To determine the impact of school gardens as a method of scaling up agricultural technologies.

METHODOLOGY

This paper reviewed theoretical and empirical literature on school gardens with a focus on scaling of agricultural technologies and innovations. Literature was found using key word searching through using the University of Tennessee libraries database and Google Scholar (Google Inc., Mountain View, CA, USA). Key words included: 'adoption', 'scaling', 'agriculture', 'school garden', 'knowledge', 'transfer', 'education', and 'sustainable intensification'. Themes and key activities were then drawn from the literature to determine best practices of scaling successful school garden programs. Research gaps and challenges to school garden implementation were determined for each piece of literature and used to determine key barriers to scaling.

Findings were then applied to a case study analysis of the Scaling Suitable Sustainable Technologies (S3-Cambodia) project. S3-Cambodia is a 3-year project funded by the USAID Sustainable Intensification Innovation lab to examine pathways for scaling. S3-Cambodia will advance the capacity and roles of scaling agents in technology diffusion through applied research, technical assistance, curricula development and organizational strengthening. This process will demonstrate the potential for and provide critical information on scaling technology through local, national, and regional networks.

Previous research in Cambodia has identified, evaluated, and promoted SI technologies that addressed gaps within the production systems. These innovations promote the diversification and resilience of smallholder systems by introducing new sources of income and nutrition during seasonal "food gaps," across different agricultural spaces and serving different functions in livelihood strategies. S3-Cambodia will pursue diffusion and adoption of technologies for different user groups. Cambodian youth serve as an entry point to extend target technologies to farm families through experiential learning opportunities in schools by establishing "green labs". Students will receive a combination of hands-on training in SI practices and STEM-based instruction in SI principles. This preparation will culminate in the establishment of student home gardens featuring SI technologies. The process of technology evaluation and diffusion will be supported by applied, participatory research on the agronomic and nutritional qualities and marketing potential. In order to improve the rate of success of S3, it is important to identify previous work in scaling through school gardens and the lessons learned from attempts.

RESULTS AND DISCUSSION

Current and Past Studies regarding scaling and adoption of agricultural innovation

Based on extensive review of literature on school gardens in various world regions, a list of best practices to assure scaling of agricultural technologies was developed. Additionally, primary barriers to scaling up through school gardens were identified (Table 1).

Inclusion of parents in the learning process and upkeep of school gardens was found to be a key component in assuring a successful and scalable school garden. Active parent involvement increased the likelihood of knowledge transfer from students to parents. Schreinemachers et al. (2017) in their assessment of a pilot school garden program in Bhutan highlighted the positive impact of the program's inclusion of parental involvement throughout the learning process. Parents were involved through land preparation, crop care, material provision, and student advising. Additionally, teachers took the time to visit parents at home and encouraged the use of home gardens. The authors determine the impact to be that parents were highly accepting of the school garden and families increased their knowledge about sustainable agriculture and nutritious food. Along the same lines, Schreinemachers et al. (2019) in their study on school gardens in Burkina Faso involved parents through contributions in determining garden vegetables choice, volunteer garden upkeep, land preparation, and fencing. The authors determined the impact of parental involvement to be that children's knowledge about agriculture, food, and nutrition improved. However, the scope of the study did not directly assess changes in attitudes and behavior of children, teachers, or parents. The authors specifically describe the need for such a component to be included in future study design. Furthermore, barriers to scaling arise if parents are uninterested are unable to commit the necessary time and energy for school garden involvement. This is especially true if a teacher spearheading the school garden effort leaves the school. Ferguson et al. (2019) acknowledge that highly motivated parents/schools are necessary to keep school gardens going on their own if the project leader leaves.

Inclusion of parents in the learning process was directly tied to another identified best practice for scaling – the establishment of home gardens alongside school gardens. The utilization of home gardens to test methods and technologies learned by children in school settings allows for streamlined transfer of knowledge and practices to the parents. This in turn increases usage of new agricultural technologies on a larger scale within households and communities. Calub et al. (2019) in their School-Plus-Home Gardens Project (S+HGP) in the Philippines found that through this methodology, the school gardens became learning laboratories; a place where both students and parents learned about appropriate technologies and practices relevant to sustainable intensification, organic agriculture, edible landscaping, climate change, and the interconnection of food and nutrition. Likewise, Okiror et al.'s (2011) study on school gardens in eight Ugandan schools shows how home gardens allow for the transfer of knowledge from student to parent. The authors find that students were able to effectively pass along their new agricultural knowledge to their parents despite potential barriers such as language constraints, timidness, and social mores. This was accomplished by providing visible examples of agricultural techniques to parents through their home gardens, showing income earned from sale of grown vegetables, and increasing the amount of food eaten at the household level. The likelihood of adoption of these new agricultural practices by parents was improved when inputs (seeds, chemicals, etc.) were provided for home garden projects. Conversely, barriers to scaling arose if parents lacked inputs, household land size was small, or there was a poor relationship between parent and child. Social mores of respect between parent and child could limit youth's confidence or ability to share knowledge with their elder. This phenomenon was found to be a key barrier to scaling in Uganda.

In continuation, child to parent transfer of knowledge is evident in the United Nations University flagship project, network of Regional Centres of Expertise (RCE) on Education for Sustainable Development (ESD) in Cambodia entitled 'RCE Greater Phnom Penh' (GPP). Tabucanon and Mihara (2016) look specifically at the GPP project entitled, 'Promoting Sustainable Agriculture at Kampong Cham Province in Cambodia.' The authors find evidence of transfer of learning through school gardens by incorporating sustainable agriculture and ESD into school curriculum. They highlight that because most students were children of farmers, they were easily able to discuss and test learned SI concepts/practices at home using home gardens/fields. The school gardens, compounded with home garden practice, resulted in increased adoption of sustainable agriculture practices among farming communities in the region. Similarly, Ran et al. (2013) highlight the 'Promoting ESD through Food, Agriculture and Environment Education in Elementary Schools and Rural Communities in Cambodia' project under GPP. While they also acknowledge the positive outcome of ESD to be transfer of knowledge, they also highlight lack of resources as a key barrier to scaling of sustainable agriculture. Many schools in the project lacked adequate buildings, desks, chairs, books, and materials for learning. Additionally, many students are unable to spend necessary time in school due to commitments on their home farms or financial strain forcing them to seek additional employment. Lack of social, human, and/or economic capital can severely impact the ability of a school garden program to contribute to scaling of sustainable technologies.

The implementation of ESD into curricula in Cambodia detailed by Tabucanon and Mihara (2016) and Ran et al. (2013) highlights another identified best practice of scaling: the establishment of hands-on, research-based agricultural curriculum in schools. FAO (2004)'s concept note regarding school gardens calls for the, "integration of school gardening into the curriculum to ensure adequate time is available for school gardening and related teaching activities without compromising the rest of the curriculum" (p. 1). ESD serves as a great example as it is a, "holistic and transformational education which addresses learning content and outcomes, pedagogy and the learning environment" (UNESCO, 2019). ESD incorporates SI learning, promotes exploratory learning, and seeks collaborative decision-making learning outcomes. However, ESD is not the only pathway to integrating hands-on, research-based curriculum into schools. Sprague (2016) in her study of opportunities for and barriers to scaling school gardens using the case study of the Edible Schoolyard Pittsburgh project notes the importance that school gardens offer, "dynamic learning experiences via experiential and inquiry-based learning" (p. 18). Remarks from the author's surveys of garden educators and parents both centered around the advantages of experimental learning. In fact, some parents indicated that they had actually sent their child to the particular school because of the school garden curriculum and desired an increased focus on, "outdoor classroom, experimental, inquiry-based learning" (Sprague, 2016, p. 97).

Ferguson et al. (2019) focused on the utilization of action research and inquiry-based learning in the classroom, the garden, and through farmer visits. They highlighted this curriculum approach as a key factor of success for their program scaling agroecology through education in Chiapas, Mexico. Likewise, The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) (2017) also used participatory action research through their discussion of a school and home gardens project in the Philippines. Through the project, "one hundred and twenty-five (125) lesson plans integrating the concepts of nutrition, organic agriculture, climate change mitigation and adaptation, and solid waste management were prepared by Grade 4 and Grade 7 Science, Mathematics, English, Edukasyong Pantahanan at Pangkabuhayan (EPP) (Home Economics) and Technology and Livelihood Education (TLE) teachers" (p. 2). This resulted in significant sustainable agriculture and nutrition knowledge increase among students and their families. However, important to note is that creating well-established experiential school garden curriculum is a long and tedious process that requires collaboration and patience (SEARCA, 2020).

Building a successful school garden curriculum and then teaching said curriculum is only possible through collaboration and commitment among all stakeholders. Stakeholders include, but are not limited to, teachers, parents, students, school leadership, local government, policymakers, local community members, and research organizations. Without all school garden stakeholders working together, barriers to scaling become paramount. For example, Tabucanon and Mihara (2016) use a multi-stakeholder networking approach in their study and impress upon readers that it produces, "awareness-raising and learning among farmers, curriculum transformation in schools, and implementing the notion of sustainable livelihood" (p. 4). SEARCA (2020) also highlight the necessity of stakeholder collaborations in their briefing of the 'International Conference on School Gardens: Leveraging the Multifunctionality of School Gardens.' The editors describe lack of partnership and leadership between academia, local government, policymakers, schools, parents, and teachers as a key barrier to school garden start-up and maintenance.

Sprague (2016) proclaims that collaboration and commitment among school administrators, teachers, parents, garden coordinators, and community volunteers is necessary for the scaling of an instructional school garden. She introduces the necessity of a reliable system to track levels of stakeholder commitment, capacity, and confidence – dubbed the 3Cs. The 3C approach uses a framework that provides a 3C score that serves as, "a measurement of readiness for change or improvement of a given stakeholder group, arrived at and agreed upon by the stakeholder group" (p.131). Sprague claims this framework serves as a research roadmap with realistic, actionable timelines that do not cause stakeholders to overextend themselves, creating a balanced, scalable school garden system. Similarly, Rositsa and Hernandez (2018), in their comparative case study analysis of three locations for scaling up agricultural technologies, find coalition building between participants, government, and market institutions to be essential for scaling up of innovations. An example of appropriate stakeholder collaboration is seen in SEARCA (2017)'s project report on home and school gardens in the Philippines. The project provided support to the school gardens through partnership with local government and other stakeholders. Local Government Units (LGU) were created to support households in establishing home gardens in pilot schools. This was done to sustain necessary resource inputs and services as well as mainstream the project into LGU development programs.

Concerning resource inputs for school gardens, another best practice of scaling centered around the provision of financial assistance from the government or outside organization for startup and upkeep of school gardens. Many school gardens struggle to maintain the necessary amount of economic capital to run their programs effectively. For example, in 2012, 4-H, a youth centered agricultural program from the US, began a club in rural Ghana that encouraged students to plant hybrid maize seeds donated by DuPont Pioneer. While Pioneer provided the startup costs, the project failed in 2015. Pioneer only provided one round of seeds and additional seeds and inputs (pesticides, herbicides, fertilizers) were simply too expensive for farmers and schools to purchase on their own. The project would have required substantial subsidies in order to be sustainable long-term (Butler, 2014). In Giliberti (2018)'s study on the barriers to adoption and scaling of school gardens he finds that over 50% of agricultural educators surveyed viewed lack of finances as a key barrier to adoption. He suggests the offering of monetary incentives in order to increases rates of school garden adoption. FAO (2004) provides a guideline for minimum budgetary provisions for a national school garden program including start-up costs, teacher preparation and planning costs, and physical input costs.

If fiscal concerns for a school garden program are diminished, more time and attention is able to be given to focus on adequate methods for development and scaling. A key barrier found in literature was focusing too much on the 'what' and not the 'how' of a school garden program (i.e., scaling is not ‘one size fits all’). Trying to implement the school garden curriculum without considering social, political, economic, geographic, etc. factors will result in substantial gaps in success (Wigboldus et al., 2016; Glover et al., 2019). Not one of the studies or projects examined for this review used the exact same methodology. Each school garden was situated in a unique geographical, cultural, social, and economic setting that required different tools to address barriers to scaling. To use the same methods of school garden implementation and maintenance in Pittsburgh as in Ghana would make the scaling of agricultural technologies immensely challenging, if not impossible.

Further, a key barrier to scaling was found to be poor capacity building for and involvement of school heads and teachers. At SEARCA’s ‘International Conference on School Gardens: Leveraging the Multifunctionality of School Gardens’, capacity building was a key discussion point with overall issues/challenges section including, “capacity building for school heads, teachers, and parents as part of social and technical preparation to school gardens” (SEARCA, 2020, p. 68). This was often founded in lack of adequate training for teachers and administration working with school gardens. DeMarco (1997) found in his study on factors affecting elementary school teachers’ adoption of school gardens into curriculum that teachers’ education and knowledge on gardening principals was essential for implementation. However, their knowledge was found to be considerably lacking. In his survey of 236 teachers in the United States, only 18 (8%) indicated that, “their training was sufficient to successfully handle school gardening with their students and no further training was necessary” and 217 (92%) stated they felt additional training was needed. Undertaken 21 years after DeMarco’s study, Giliberti (2018)’s study on adoption of school gardens by Agricultural Science teachers in Alabama found almost identical teacher concerns. He found that perceptions of planning, time, incentives, and teaching were key barriers to scaling. If teachers did not feel they had adequate school garden knowledge and training, strategic planning resources, monetary incentive, and/or time outside of the traditional classroom setting, then school gardens were far less likely to be implemented.

Capacity is also a key barrier to scaling outside of the United States as we see in Okiror et al. (2011)’s study on transfer of knowledge from school gardens in Uganda. They find lack of practical skills among teachers and administration support to be key barriers to scaling of school garden knowledge. Limiting factors were listed as: administrative conflicts between teachers and head teacher, negative actions of the school management committee (SMC), inadequate agricultural skills among teachers, and ineffective teachers. Conversely, enabling factors were listed as: teamwork among teachers, supportive school administration, assistance from extension workers, and availability of skilled teachers. Unfortunately, many teachers and administrators in the Global South lack the educational resources and training desired for school garden instruction (Okiror et al., 2020; Ferguson et al., 2019; Tabucanon and Mihara (2016); Comia et al., 2018; Calub et al., 2019; SEARCA, 2017; Schreinemachers et al., 2017; Schrienemachers et al., 2019). As such, it is essential to provide capacity building opportunities to educators to assure effective scaling of agricultural technologies through school gardens.

Table 1. Best practices and primary barriers to scaling through school gardens

Best Practices	*Primary Barriers*
• Including parents in the learning process and upkeep of school gardens • Establishment of home gardens alongside school gardens • Establishment of hands-on, research-based agricultural curriculum in schools	• Focusing on the ‘what’ and not the ‘how’ (i.e., scaling is not ‘one size fits all’) • Social mores and the relationship between parent/child • Poor capacity building for and involvement of school heads, teachers, and parents • Lack of social, human, and/or economic capital • Unintegrated commitment and partnership among stakeholders

• Collaboration and commitment among all stakeholders	

It is of note that a limitation to our review was that while the intended focus was to highlight scaling of agricultural technologies, much literature on school gardens focused on nutrition and food security. While these are important benefits of school gardens, we found literature regarding the knowledge transfer of school gardens to the lacking. However, we were able to pull out the best practices that lead to scaling potential to highlight as tools for future use as well as barriers that would limit a school garden's ability to be used for scaling of agricultural technologies.

Case Study: S3 Cambodia

School gardens have the potential to play a key role in scaling sustainable intensification (SI) technologies. They provide opportunities for knowledge transfer through teacher-student-parent communication. We can apply best practices and address key challenges through analyzing S3-Cambodia. S3-Cambodia seeks to target youth as an entry point to extend target SI technologies to farm families. The project will engage students in experiential learning opportunities by establishing "green labs" at six pilot secondary schools. Students will receive a combination of hands-on training in SI practices and STEM-based instruction in SI principles from Cambodian teachers trained on this topic (Fig. 1, 2). This preparation will culminate in the establishment of student home gardens featuring SI technologies learned in the schools (Fig. 3).

In order to apply best practices and avoid the barriers to scaling S3 will incorporate the findings from the literature. For example, home gardens will be implemented alongside school gardens as a key project activity. It will be done to increase learning and to allow school communities to evaluate new practices before applying them at the field or farm scale. Additionally, hands-on, research-based agricultural curriculum will be developed and applied in the pilot secondary schools. As part of its youth development strategy, the project will work hand-in-hand with the Cambodian Ministry of Education, Youth, and Sport (MOEYS) to develop new 4-H style[1] curriculum and adapt existing curriculum to provide agricultural-based STEM instruction that can be scaled nationally.

Additionally, S3-Cambodia implements the best practice of providing financial assistance to the schools for the startup and upkeep of the school gardens. As a USAID funded project with additional leveraged funds, S3-Cambodia is able to provide the necessary monies to establish green labs, trainings, and necessary inputs. To assure green lab infrastructure and curriculum will be maintained after project close, the project will provide training, supplies, curriculum, and government support to Cambodian educators.

Furthermore, S3-Cambodia will assure collaboration and commitment among stakeholders through adhering to its detailed capacity building plan. This plan includes collaboration and mentorship with project counterparts (CE-SAIN, RUA, UBB[2]), a train-the-trainer program, and direct engagement with end-users. However, it is necessary to be aware of the challenges that may be faced with collaboration of a transnational project funded and directed from the United States but taking place in Cambodia. For example, the COVID-19 pandemic, though unprecedented, has resulted in the stunting of first year project activities because of school closures and travel delays. This was only exacerbated by extreme flooding events in Cambodia during October, 2020[3].

Thankfully, because the project is solely focused on Cambodia and particular regions therein, it is not likely to be hindered by the barrier of focusing on the 'what' and not the 'how'. S3-Cambodia is very context-specific and leverages knowledge from past projects (i.e., 2015-2020 WAgN-Cambodia project[4]) and national partners (CE-SAIN, RUA, UBB).

[1] https://4-h.org/about/what-is-4-h/

[2] Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CE SAIN), Royal University of Agriculture (RUA), University of Battambang (UBB)

[3] https://reliefweb.int/disaster/fl-2020-000212-khm

[4] https://smithcenter.tennessee.edu/women-in-agriculture-network-wagn-cambodia-gender-and-ecologically-sensitive-agriculture/

However, not finalized in the project implementation is parental involvement. As the project moves forward, acknowledging how to incorporate parents into implementation of school gardens should be a key goal. This will be necessary in order to overcome potential barriers such as social mores and the relationship between parent/child. For example, this could be done through welcoming parents to visit the school demonstration plots once a week to view how the SI technologies are working and gain a first-hand understanding of what their children are doing at school, encouraging parent volunteers to help in the green labs, or having parents provide their farms for field visits. Such activities will add to the potential for successful transferring of SI technology knowledge from child to parent.

Fig. 1 Students trimming trees in the wild food plant nursery

Fig. 2 Students propagating wild food plants

Fig. 3 Farmer planting grafted vegetables using conservation agriculture techniques

CONCLUSION

School gardens serve as a useful tool worldwide to enhance student agriculture education and food systems knowledge. This paper addressed a key gap in research on school gardens by reviewing literature to assess their potential to serve as agents of knowledge transfer. While much of current research focuses on nutrition and vegetable consumption, there is literature supporting school gardens' ability to play a key role in scaling agricultural, specifically SI, technologies. Best practices and barriers were identified for scaling through school gardens. The best practices provided plausible opportunities for knowledge transfer through teacher-student-parent communication; the barriers limited these opportunities. S3-Cambodia has strong potential to successfully transfer knowledge of SI technologies from the green labs to the home farm. The project utilizes a significant amount of the best practices identified in literature and has measures in place to avoid the barriers. If parental involvement is increased, project scaling objectives are likely to be met.

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Research article

Factors Driving the Effectiveness of Community Fisheries Management Resulted from Fisheries Policy Reforms

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Abstract: The fisheries policy reforms on co-management in Cambodia have been implemented for almost two decades, starting its first reform in 2000 and its second reform in 2012. These reforms had promoted the organization of 516 Community Fisheries (CFis) around the country. After two decades of the CFis operation, it is noteworthy to identify the driving factors that brought the functionality and effective operation of the CFi on co-management of the fisheries resources in Cambodia. The study aims to identify the different driving factors that led to the functionality and effective operation of the CFis co-management of the fisheries resources development and sustainability resulting in the improvement of food security and socio-economic status of the CFi members. To identify those factors, the study purposely selected 16 CFis among the 516 CFis and randomly interviewed 527 CFi members from these CFis. To support the quantitative information from the interviews, the study conducted 16 Focus Group Discussion (FGD) in the 16 selected CFis for validation and qualitative information. The results show that there are two key main factors influencing the functionality and effective operation of the CFis. First, according to 96% of the CFis members respondents and all FGDs respond, the legal framework that supports the process of CFi establishment and co-management of the fisheries resources have given them the legal rights and opportunity to use and sustain the fisheries resources. The legal frameworks supporting the CFis establishment includes the Royal Decree on the Establishment of CFi, the Sub-decree on CFi Management, and the amendments of Fisheries Law immediately after the reforms and the declaration on CFi Guideline. The second factor according to 93% of the total respondents and all 16 FGDs is the benefit of being a member of the CFi. Being a CFi member and small-scale fisher, they were given more access to the fishing ground, harvesting more fish for consumption and income that improve their socio-economic status, recognition of their value in participating in a co-management concept of governance, capacity building and working together as one and trusting each other. Aside from these influencing factors, challenges and lessons learnt were also documented for a brighter future of CFi co-management. These include the actions on the amendment of CFi legal framework particularly on the CFi economic creation and financial support for a functional and effective CFi co-management. This should include the expansion of CFi rights and roles on economic activities and benefits of being CFi member, which needs to be clearly defined in the Fisheries Law and CFi sub-decree amendment followed by the development of the CFi Guideline. The government, development partners and the private sector should financially and technically support the CFis to function and operate effectively in co-managing the fisheries resources development and sustainability.

Keywords: Fisheries policy reform, Community Fisheries (CFi), CFi legal framework, benefits of CFi membership, and fisheries management.

INTRODUCTION

Cambodia is endowed with rich natural fisheries resources in both freshwater fisheries from the Mekong Region and Tonle Sap Lake system, and the marine fisheries from the coastal region. Fish is one of the most important foods and necessities of life for a rice-fish-eating population, and potentially an important contributor to improve food security and nutritional status of the population. Therefore, the management of the fisheries resources is an important responsibility that requires development and improvement overtime according to its context, demands and needs that will occur. As the situation became unfavorable for subsistence farmers-fishers to get equal benefits from the natural fisheries resources, the government decided to reform the fisheries management in October 2000 by cancelling 56 % of the fishing lots and providing to the public/fishers for communal use. Finally, in 2012 the government cancelled all remaining fishing lots (industry/large fishing scale) in the Great Lake as part of the deep reform of the government to sustain the fisheries resources and improve the socio-economic development of the communities in the rural areas. To support this reform, the government supports the small-scale fishers to organize Community Fisheries (CFi) to implement fisheries co-management with the government to develop and sustain the fisheries resources.

As a result of the fisheries policy reforms for almost two decades, the government was able to establish 516 CFi around the country. Witnessing the impacts of the reforms, it raises the question of what factors have driven the functionality and the effective operation of the CFi co-management that can be learned to improve CFi legal framework for the sustainability of the fisheries resource management in Cambodia.

METHODOLOGY

Sixteen (16) CFis were purposely selected from the three regions (Tonle Sap, Mekong and Coastal region) based on the geographical fisheries ecosystem in Cambodia. The CFIs were organized and established in these three regions after the implementation of the fisheries reforms as shown in Figure 1 and table 1. A total of 527 CFi members (169 women, 32%) as respondents was randomly selected in the 16 CFi members' list. Primary data was collected through a face-to-face interview with the 527 respondents using a structured questionnaire that was conducted in 2018. The 16 Focus Group Discussion (FGD) from the 16 CFis was conducted in 2020 providing qualitative information to support the quantitative data from individual interviews. The 16 FGDs were facilitated with the CFi Committee (CFiC) members to get their views and perceptions about the factors driving CFi functionality, effective operation and identifying the strengths, weaknesses, opportunities and threats of each CFi using SWOT analysis. FGD data is mainly on qualitative analysis to substantiate the quantitative analysis with the multiple responses of CFi members on key indicators to understand the effects and causes of factors driving the functionality and effective operation of CFi management after the fisheries reforms in Cambodia.

Table 1: List of CFi target study by province and region

No.	CFi Name	Province	Region
1	CFi Kaoh Kaev	Kampong Chhnang	
2	CFi Kanlaeng Pe		

3	CFi Roha Suong	Battambang	Tonle Sap Great Lake
4	CFi Phneat Koh Pongsath	Bantheay Meanchey	
5	CFi Chong Khneas	Siem Reap	
6	CFi Samaki Kampong Kou	Kampong Thom	
7	CFi Samaki Akphyrak Stung Kombot		
8	CFi Beung Krapet	Tboung Khmom	Mekong
9	CFi Rokakoy	Kampong Cham	
10	CFi Chroy Check		
11	CFi Boeung Chulen	Kandal	
12	CFi Put Sar Cham Pei	Takeo	
13	CFi Kok Thlok		
14	CFi Trapeang Ropov	Kampot	Coastal
15	CFi Trapeang Sangke		
16	CFi Tumnub Rolok	Preah Sihanouk	

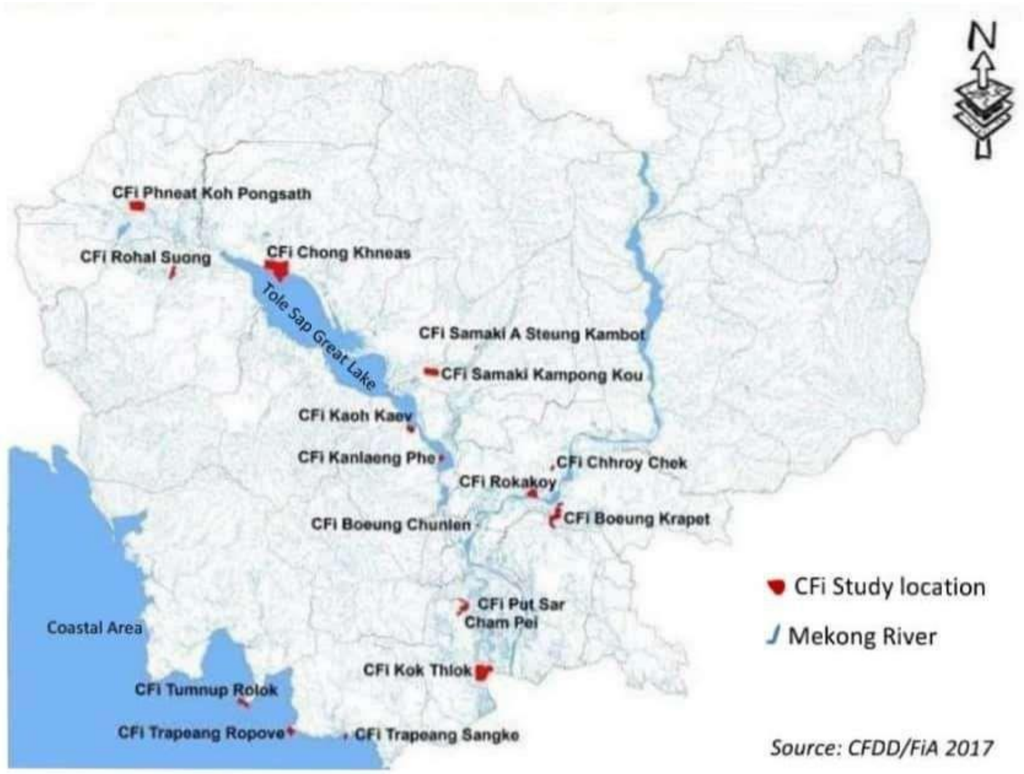

Figure 1: Study Location

RESULTS AND DISCUSSION

There were several key factors driving the functionality and effective operation of CFi co-management reported by the 527 representatives of CFi members and 16 CFi Committees as presented in Table 2. The factor with the highest percentage 96% of the total respondents is the provision of CFi legal framework to the community fisheries. The second important factor mentioned with a total percentage of 93% of the CFi members respondents and all 16 Focus Group Discussion from CFi Committee is the benefits that they received being a member of the CFis. Moreover, other factors presented in Table 2 below are same important parameters that interlinked with the other factors that contributed to the functionality and effective operation of CFi co- management of the fisheries as a whole.

Table 2: Factors driving CFi functionality and effectiveness CFi management

Factor*	Frequency	Percent
- CFi legal framework's support	505	96
- CFi membership's benefits	488	93
- Financial and technical support	475	90
- Collaboration and support and from local authorities	466	88
- Collaboration and support from technical agencies	443	84
- Collaboration and support from DP	433	82
- CFiC ability and capacity	339	64
- Participation of CFi members	321	61
- Others (people willingness, support and work together…)	303	57

** Multiple responses*

The results of the 16 Focus Group Discussion with CFi Committee members expressed their views that CFi legal framework and CFi members' benefit are the most key necessary factors driving the functionality and effective operation of CFi in their co-management of the fisheries resources. While the other factors are of equal importance contributing to the functionality and effective operation of CFi co-management of fisheries resources. The study explored the reasons for these two factors as presented in table 3-4 below.

Table 3 presented the reasons why CFi legal framework is an effective driver for the CFi operation and co-management. Around 99% of all CFi member respondents and all CFiC Focus Group Discussion expressed that the legal framework had guided them to establish their CFi organization, this includes the Royal Decree on the Establishment of the Community Fisheries (*Nor Sor/Ror Kor Tor/0505/240, 2005*) for them to work closely with the government in managing and developing the fisheries resources. According to 97% of the CFi member respondents, the legal framework had been an instrument for them to be recognized by other stakeholders including development partners as an official and legal entity that co-managing the development of the fisheries resources. Around 95% of the CFi member respondents mentioned that the legal framework had provided a clear roles and responsibilities to the CFs including their mandates to function effectively in co-managing with the government the development and sustainability of the fisheries resource sustainability. The role and responsibility of the CFi are clearly indicated in the Sub-decree on CFi management (*No. 25 OrNor Kror. BorKor, 2007*). These three top reasons are inter-related and the main provision of the official and legal recognition of the Community Fisheries organization in the form of co-management approach that are financially and technically supported by the government and development partners according to 89% of CFi member respondents. Based on these legal frameworks the CFis were provided and promoted fisher groups' tenure rights, user rights, and rights to protect and co-manage their natural fisheries resources to develop and sustain in an effective way. The CFis legal recognition is also indicated in the amended Fisheries Law of 2006 as a result of the first fisheries reform in 2000, which never before in the history of fisheries resources management in the country. In article 59 of Chapter 11 on Community Fisheries of the Fisheries Law, stated that "all Cambodian citizens have the rights to form Community Fisheries in their own areas on a voluntary basis to take part in the sustainable management, conservation, development and use of the fishery resource". Therefore, the legal framework is an important legislation and key factor at the grass-root level and people can officially and legally form their Community Fisheries organization that legally provides their rights and responsibility in protecting and co-managing their natural fisheries resources in an effective way. Moreover, this local community fisheries organizations have received substantial support and cooperation with the local authorities from all levels, development partners and private sector more than before when they do not have their CFi organization. Finally, the respondents also mentioned that the legal framework has empowered them socially and economically including mainstreaming of gender and fisheries resources ownership.

Table 3: Reason of CFi legal framework driven factor the CFi effective management

Reason*	Frequency	Percent
- Legal guidance for CFi establishment	521	99
- Official and legal recognition of CFi	518	97
- Legal guidance for CFi function and management	502	95
- Official support from the government and development partners	467	89
- Fisher's rights and responsibility in the natural fisheries resources management	436	83
- Increased support and collaboration more than before CFi establishment	328	62
- Others (CFi empowerment, commitment and resource ownership)	311	59

** Multiple responses*

Table 4 shows the reasons why being a CFi membership benefits is a driving factor for the functionality and effective operation of the CFi in a co-management approach. According to 97% of the total CFi member respondents the benefits of being a CFi member is about building trust among each other, among villagers with other villagers, among fishers with other fishers, in particular for small-scale/family and poor fisher families. Another reason is the unification among the community fishers and working as a group and organizations and recognizing equity and rights to their fisheries resources, especially for the family scale fishers in the CFi fishing areas. According to 89% of the CFi member respondents after becoming members of the CFi they were provided more access to the CFi fishing ground that was previously fishing lots. Other benefits of being a CFi members include; the official recognition and value from other stakeholders, the CFi builds trust and foster cooperation among the community which improve social and economic development within the community, the CFi members gain knowledge on how to protect and manage their natural fisheries resources in the effective and sustainable way, empowered and built capacity of individual member and fisher group through participating in meetings, workshops and trainings as well as other events taken place in the CFis area, the government and other stakeholders heard their voices and demands, and noted and addressed, being member , they receive more support for social welfare and help to alleviate their family poverty, and finally their living conditions have improved including security, violence, gender, and child labor were taken into high consideration in the CFi.

Table 4: Reason of CFi membership benefits driven factor the CFi effective management

Reason*	Frequency	Percent
- Building trust to each other (villagers and villagers) as united	518	97
- Being recognized as group work (work together)	502	95
- Equal rights for fishing by family scale	480	91
- Can do fishing (more access to fishing ground) more than before	467	89
- Their membership and participation being recognized and valued (resources ownership)	436	83
- Gaining knowledge on fisheries resource protection and management	388	74
- Building empowerment and capacity (from meeting, workshop…)	353	67
- Voices and demands can be addressed	321	61
- Received more support for social welfare and poverty alleviation	313	59
- Others (more safety than before, no stolen, no violence…)	301	57

** Multiple responses*

However, there are still challenges that the CFis are facing as presented in Table 5, these include generation of income or finance that will support the CFi operation especially the co-management activities for the development of the fisheries resources. The CFi respondents expressed that the CFi legal framework should have a section that articulates the possible sources of income for CFi in order to generate their own income or finance in a collective way to effectively function and operate their activities for the conservation of the fisheries resources and help their CFi members on their social welfare and poverty alleviation. Another challenge that was ranked high is the limited benefits of some CFi members regarding their rights for fishing in the CFi fishing areas because outsiders could still encroach and fish in CFi fishing areas. They suggested that the CFi legal framework should consider defining the differences between the fishing rights of the CFi members and outsiders then support the implementation of control and surveillance of these outsiders. They further suggest that CFi members should have all the rights in doing fishing freely in the CFi fishing area, while non-CFi members and outsiders should pay fishing fee according to the legal fishing gears used, which need to be defined clearly and effectively applied based on the CFi by-law and regulation. Other key challenges are also important areas for improvement, which require actions accordingly.

Table 5: Key challenges facing the CFi effective management

Key Challenges**	Ranking
- Lacking of CFi self-financial support and generation	1
- Still limited benefits for being CFi members regarding with rights for fishing, everyone can do small-scale fishing in CFi area	2
- Limited financial support for CFi operation and functioning from the state and development partners	3
- 5 years of CFi Area Agreement is short, which could not enough to produce tangible imparts of CFi development and management	4
- Poor enforcement of CFi by-laws and internal rules by members and non- members in CFi villages	5
- Poor implementation of CFi Area Management Plan due to budget lacked	6
- CFi Committee (CFi leader team) capacity is still limited, leading to take poor rules and responsibilities, and affectively poor CFi function and management	7
- Still limitation support from local authorities	8
- Limitation of technical support and follow up by technical agencies	9
- Local people's awareness on CFi legislation/legal framework is still limited	10

*** Results of FGD*

CONCLUSION

Community Fisheries is a voluntary fisher organization in Cambodia, which is officially established and legally recognized by the state with the provision of suitable legal framework, which never before in the history of fisheries management in Cambodia. It is a prime objective and achievement of the Governments' fisheries reforms, in 2000 and in 2012, to ensure that the local fisher communities and small-scale fishers can obtain access to the fisheries resources for food, livelihood and poverty alleviation. The achievements and results produced after the fisheries reforms are due to the support of the legal framework for CFi that was provided at the right time and direction. Through these CFi legal frameworks, the small-scale and poor fishers are receiving benefits and rights to share their roles and responsibilities for the co-management of their natural fisheries resources for development and sustainability. These are the most important factors that guide and drive the functionality and effective operation of the CFis. However, there are still key areas that are facing challenges for the CFis to be more functional and effective in co-management of the fisheries resources in the long run, which included the improvement of CFi legal framework. The CFi respondents recommended the improvement of the legal framework to consider the provision of guiding the CFi to generate income to self-finance their activities, suitable fisheries related livelihoods, and harvesting their resources.

Finally, the CFis recommended to define clearly the rights of the CFi members and non-members/outsiders in fishing in the CFi fishing areas. They suggest that they should be given higher benefits for being a CFi members as well as CFi committee members as prime incentives for their participation and efforts to actively protect and co-manage the natural fisheries resources development in an effective and sustainable manner.

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Research article

Status of Cassava Production and Distribution Channels in Cambodia: Prospects for Sustainable Production

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Abstract Cassava is expected to become a major industrial crop in Cambodia, but most studies on its cultivation only discuss the potential for improving its production scale, productivity, and suitable cultivation techniques, including ways to protect the crop from diseases and pests. However, sustainability of its cultivation as the country's main industrial crop cannot be achieved only by introducing agronomically suitable cultivation methods. The cultivation must be economically viable, socially beneficial, and environmentally sustainable. Therefore, this study aims to identify and analyze the characteristics of cassava cultivators and their business activities, the current distribution channel and the challenges and prospects for sustainable cassava cultivation in Cambodia. Semi-structured interviews of 24 cassava cultivators were conducted in two major cassava-growing provinces in Cambodia—Battambang and Pailin—to understand the series of production events, including the way they sell their produce. In addition, owners of six consolidating points that collect and process cassava root to sell domestically or for export were interviewed about their sales partners and destinations to identify the distribution channel. As a result, three different distribution types, from producers to collecting points, were identified, and their selection criteria appeared to be the distance between the producers and the collection points. The direct and indirect destination of the produce from the collecting points was identified as Thailand. The identified distribution channel, including collection points, comprised only cassava cultivators and exporters to Thailand, and no production specialization was observed. This reveals that building an efficient and viable distribution mechanism and strategy by utilizing the existing system will be one of the most important challenges in making cassava cultivation a major industrial crop and thus expanding the revenue source for the country.

Keywords cassava, distribution channel, small farmers, Cambodia

INTRODUCTION

Cassava (*Manihot esculenta Crantz*) is an important food crop cultivated in more than 90 countries, mainly in the tropical and subtropical latitudes in Latin America, Africa, and Asia. Cassava products are consumed by 770 million people worldwide. In Cambodia, cassava is one of the most important cash crops for farmers, even though it is consumed less as human and animal food. The market demand for dried cassava chips has increased because of ethanol production and starch processing in China, which is the largest buyer of the produce (RGC 2020). Cambodia is located between Thailand and Vietnam, which are the two main suppliers of cassava to the Chinese market. However, these two countries have limited cassava cultivation area because of their governments' policies. This situation provides an opportunity for Cambodia to become a major producer of the crop in the region.

Cassava cultivation in Cambodia has been increasing rapidly since 2010, and it has become the country's largest crop, exceeding rice, which is the country's staple food(Figure 1). In 2020, over 13 million tons of fresh cassava that is more than that of Vietnam were harvested (FAO 2021). Cassava has been exported indirectly to China as a raw material through Thailand and Vietnam, therefore, the country is unknown in the market and is recognized as a marginal supplier despite being 3rd in the regional and 7th in the global production of the crop (FAO 2021). Recently, cassava is envisioned to be a strategic crop for the country in line with the Cambodia Industrial Development Policy 2015-2025 (RGC 2015). Furthermore, the government of Cambodia has prepared a National Policy on Cassava 2020-2025 to transform the country into a cultivation and processing hub of the crop by improving the cultivation, processing, and exporting mechanisms (RGC 2020).

The development must be economically viable, socially beneficial and environmentally sustainable, and it must be beneficial for both commercial and individual producers because cassava cultivation is an important source of income for small-scale producers in Cambodia. To establish such a system, it is essential to identify current status and challenges from both socio-economic and agronomic points of view. However, the majority of existing studies have focused on the potential of cassava cultivation in Cambodia from an agronomic point of view, including cultivation methods (Sopheap et al., 2012; Ou et al., 2016), occurrence of insect pests and diseases (Wang et al.,2016; Uke et al., 2018), management of insect pests and diseases (Smith et al., 2018), and land suitability (Teamhy et al., 2017). Although a limited number of studies have reported on cultivators' perception (Sopheap et al., 2011, Chanda et al., 2016) and their profit (Sopheak, 2015), little is known about locally existing sales and distribution mechanism that will contribute to maintain or improve the economic viability of cassava cultivation in Cambodia.

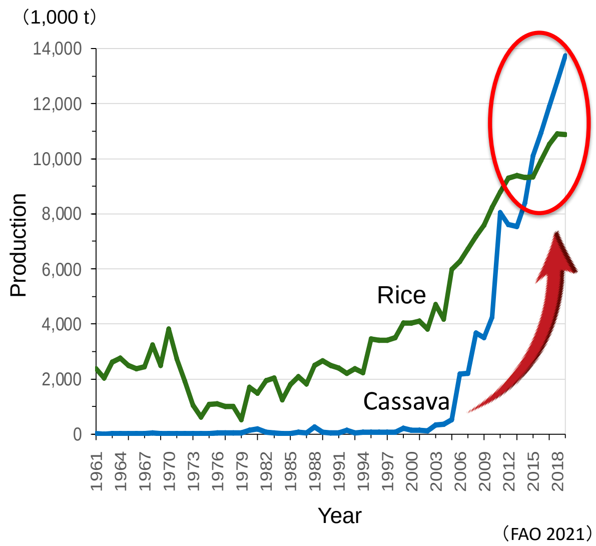

Fig. 1 Cassava production in Cambodia

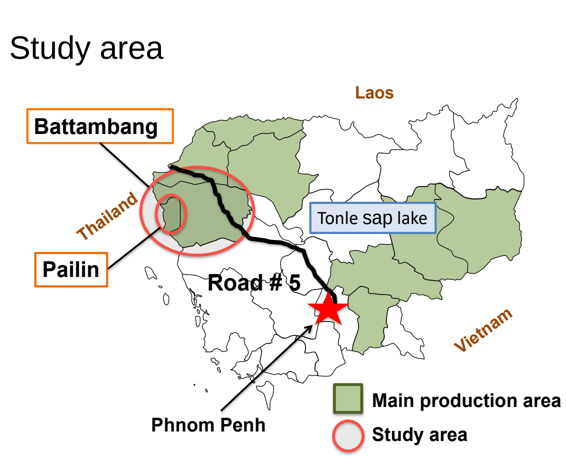

Fig. 2 Study area

OBJECTIVE

This study aims to identify and analyze the characteristics of cassava cultivators and their business activities, the distribution channel, and the challenges and prospects for its sustainable production in Cambodia.

METHODOLOGY

This study selected two major cassava producing provinces in Cambodia—Battambang and Pailin—as the study area (MAFF 2018). These two provinces are located in the north-western part of the country, and both border on Thailand, the third largest cassava producing country in the world (Figure 2). Semi-structured interviews of 24 cassava producers in the study area were conducted to understand their cultivation methods, annual schedule, and sales destination. Additionally, owners of six collection and processing points (known as silos in Cambodia) that collect cassava roots, make dried chips, and sell domestically or export them were interviewed about their customers and sale destinations to identify the distribution channel. The collection and processing points were located mostly in Pailin, along the National Road No. 57 near the country's border with Thailand. This survey sampled six major points to conduct the interviews. The field surveys were conducted between July 2017 and February 2018.

RESULTS AND DISCUSSION

Interviewees and characteristics of their households

Table 1 shows the numbers of producers interviewed for this study as well as their valid responses for analysis. Cassava cultivators in Battambang were younger, had been living there for longer time, and had longer experience of agriculture than those in Pailin. By contrast, cultivators in Pailin had larger cultivation area, more experience in terms of cassava cultivation, and a larger variety of agricultural produce. The Pailin province was invaded by the Khmer Rouge because of its extensive gem deposits and former leaders of the Pol Pot regime continued in the area even long after the war. Additionally, the province was extensively mined during the war, and demining activities continue. Therefore, it is inferred that migration from the other provinces and agricultural production became active very recently, and that these situations influenced cassava cultivation.

To analyze the characteristics of cassava cultivators, the interviewees valid answers were divided into three groups according to the size of their cassava plantations. Those with less than 5ha of cassava plantations were categorized as small-scale (58.3%), 5ha or more but less than 10ha as medium-scale (20.8%), and 10 ha or more as large-scale (20.8%) (Table 2). Even though the large-scale cultivators owned larger farmlands, their cassava plantations were even larger than their own lands. This indicated that large-scale producers were renting farmland to produce cassava. Small- and medium-scale producers were using about half their own farmland to cultivate cassava. However, the small- and medium-scale cassava cultivators grew slightly more varieties of crops than their large-scale counterparts (Figure 3). These results imply that unlike the others, large-scale producers focus more on cassava cultivation than other crops. However, almost half of the small- and medium-scale producers were not cultivating rice, an important staple food in Cambodia; therefore, they may be part-time farmers who have income generating activities other than agriculture that make them capable of buying rice (Figure 4).

Table 1 Interviewees

Summary of producers*	Battambang (n=18)	Pailin (n=6)
Age (year)	35.0	50.8
Length of stay (year)	23.1	11.3
Agri experience (year)	18.4	9.8
Cassava experience (time)	2.3	4.0
Cassava area (ha)	5.3	12.5
Other Agri products (ha)	10.6	18.5

* average

Created by authors according to the results of the survey

Table 2 Scale of production

Area	Cassava* (ha)	Own land* (ha)	#of HHs
Small (< 5ha)	2.55	5.76	14
Medium (5ha < 10 ha)	5.50	11.22	5
Large (> 10ha)	21.50	17.33	5

* average

Created by authors according to the results of the survey

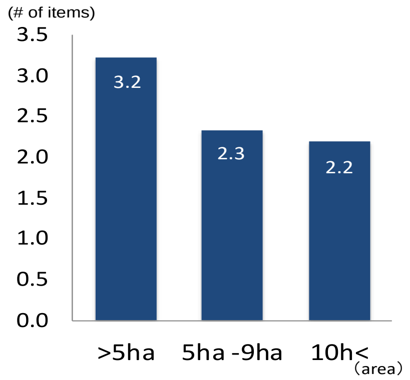

Fig. 3 Other agricultural production

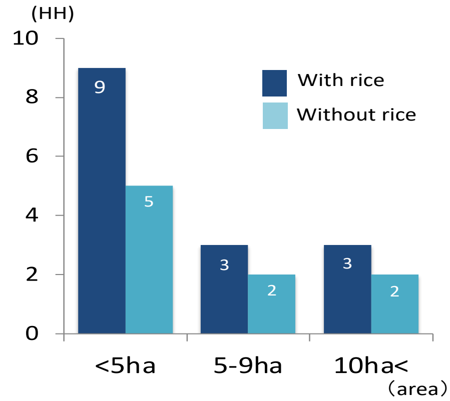

Fig. 4 Rice production of cassava producers

Production status

Annual schedule and cultivation methods were compiled as figure 5 according to the results of interview. Cultivators in the study area plant cassava stems at the beginning of the rainy season, and all of them used stem cuttings from the previous crop as usual. For most cassava varieties, the stems can be stored vertically in the shade for up to two months before planting (IAEA 2018). Some producers also bought stem cuttings from neighbors and sellers for planting and replanting. The cassava is harvested after 9–12 months, generally after the onset of the dry season. Most cultivators prepare their land for the next cultivation in February and March, immediately after the harvest.

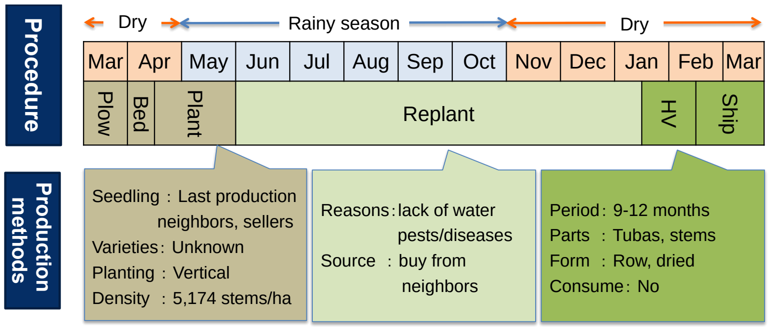

Fig. 5 Annual production schedule and methods

Distribution from producers to collection and processing points

This study identified (Table 3) three different types of cassava distribution: (1) harvested, transported, and sold to collection points directly by producer; (2) harvested, transported and sold to collection points exclusively by middleman; and (3) harvested by producers, but transported and sold by middlemen. Cultivators adopting Type 1 need to own or rent all necessary machines and equipment for planting, harvesting, and transportation, such as power tillers, harvesters, and trucks.

By contrast, those adopting Type 2 do not need any machinery or equipment except those for land preparation and planting. Cultivators adopting Type 3 need to own or rent machines and equipment for both planting and harvesting but not for transportation. The results discussed in the previous section show that most cassava cultivators are also growing several other crops. These cultivators have some machinery available to them that can also be used in cassava cultivation. Middlemen who harvest or transport the cassava roots are mostly large-scale cultivators in the neighborhood. According to Table 3, the majority of cultivators are categorized as Type 3, however, there is no clear relationship between their production scale and the distribution type. At the same time, the producer's location (province) seems to have an effect on the distribution type. Most cultivators (six out of five) in Pailin belong to Type 2, whereas only one of 18 cultivators in Battambang belong to this type. On the contrary, most producers (14 out of 18) in Battambang belong to Type 3.

Table 3 Flows from cultivators to collection points and selling price

	(1) Producer only		(2) Middleman only		(3) Combination		Total (%)
	BTB (%)	PL (%)	BTB (%)	PL(%)	BTB (%)	PL (%)	
Production scale							
< 5ha	1 (100.0)	2 (40.0)	2 (66.6)	0 -	8 (57.1)	1 (100.0)	14 (58.3)
5-9 ha	0 -	1 (20.0)	1 (33.3)	0 -	3 (21.4)	0 -	5 (16.7)
> 10ha	0 -	2 (40.0)	0 -	0 -	3 (21.4)	0 -	5 (25.0)
sub-total	1 (100.0)	5 (100.0)	3 (100.0)	0 -	14 (100.0)	1 (100.0)	24 (100.0)
Total number (%)		6 (25.0)		3 (12.5)		15 (62.5)	24 (100.0)

BTB: Battambang province, PL: Pailin province *Created by authors based on the results*
"-"indicates no respondents for the category.

The number of cultivators and the selling price of cassava roots according to distribution types and location (province) are shown in Table 4, and the selling prices according to production scale and location are shown in Table 5. In these tables, cassava roots are categorized as fresh and dried, and the numbers of cultivators and sales are analyzed according to the province and distribution type. The dried cassava roots are generally made by chopping them into small bits and drying them in the sun. Drying reduces the weight by two thirds, making it easier to transport even though chopping is heavy work and requires a large space for drying.

Table 4 shows that five out of six producers in Pailin sell their cassava as fresh roots, whereas majority of producers (14 out of 24 producers) in Battambang sell their cassava as dried roots. This difference might also have influenced the selection of distribution type. Table 6 shows the information about the collection and processing points surveyed, where both producers and middlemen were selling their cassava roots. Five out of six points were in Pailin, which is closer to the border with Thailand than Battambang. It is inferred that producers in Battambang were trying to avoid heavy and costly work such as harvesting and transporting the cassava, and either depended more on middleman or dried the roots so that they could transport them in one lot. It is also inferred that proximity to the collection points and ease of transportation allows cultivators in Pailin to save the effort of drying the roots and they do everything themselves as mentioned in Type 1. Although it is difficult to analyze the selling price according to the distribution type owing to lack of data for some categories, the price of fresh roots in Pailin is slightly higher than that in Battambang. It is assumed that the selling price reflects the transportation fee from the collection points to the next destination, which is mostly Thailand.

Table 4 Distribution types from producers to collection point and selling price

	(1) Producer only		(2) Middlemen only		(3) Combination		Total	
	price	HHs	price	HHs	price	HHs	price	HHs
Fresh roots	177.48	5 (38.5)	135.44	3 (23.0)	192.25	5 (38.5)	182.97	13 (100.0)
BTB	-	0 (0.00)	176.67	3 (42.9)	184.25	4 (57.1)	181.00	7 (100.0)
PL	177.48	5 (83.3)	-	0 (0.00)	224.25	1 (16.7)	185.28	6 (100.0)
Dried roots	440.00	1 (6.7)	-	0 (0.00)	492.36	14 (93.3)	488.87	15 (100.0)
BTB	440.00	1 (6.7)	-	0 (0.0)	492.36	14 (93.3)	488.87	15 (100.0)
PL	-	0 (0.0)	-	0 (0.0)	-	0 (0.0)	-	0 (0.0)

BTB: Battambang province, PL: Pailin province *Created by authors based on the results*
"-"indicates no respondents for the category.

An analysis of the production scales and selling prices according to location revealed that the average selling price at each location is the lowest for middle-scale cultivators and the highest for large-scale producers (Table 5). This trend was observed for both fresh and dried roots. However, this survey did not have enough variables to explain the cause.

Table 5 Production scale and selling price by location

	Small (< 5ha)		Medium (5<10 ha)		Large (>10ha)		Total	
	price	HHs	price	HHs	price	HHs	price	HHs
Fresh roots	183.63	7 (53.8)	166.00	3 (23.1)	198.42	3 (23.1)	182.97	13 (100.0)
BTB	185.75	4 (57.1)	168.50	2 (28.6)	187.00	1 (14.3)	181.00	7 (100.0)
PL	180.81	3 (50.0)	161.00	1 (16.7)	204.13	2 (33.3)	185.28	6 (100.0)
Dried roots	509.44	9 (60.0)	429.00	3 (20.0)	487.00	3 (20.0)	488.87	15 (100.0)
BTB	509.44	9 (60.0)	429.00	3 (20.0)	487.00	3 (20.0)	488.87	15 (100.0)
PL	-	0 (0.0)	-	0 (0.0)	-	0 (0.0)	-	0 (0.0)

BTB: Battambang province, PL: Pailin province *Created by authors based on the results*
"-" indicates no respondents for the category.

Table 6 Surveyed collection and processing points

Collection point	A	B	C	D	E	F
Location	PL	PL	PL	PL	PL	BTB
Chipping period	Dec-Mar	Nov-Mar	-*	Nov-Apr	-	Oct-Mar
Amount (t/day)	1,820	20〜30	-	50	-	200
Production (ha)	6		300		15	50

* *Collection points that do not do processing activities such as chipping and drying*
Average daily quota for chipping workers was 1 ton per person of family.

Destination: From collection points to consumers or exporters

To study their modes of operation and the destination of collected cassava roots (Table 6), data were collected from interviews with the owners of six collection and processing points and revealed several types of operations. Whereas collection points A, B, D, and F were making dried cassava chips, the other two were not. From these consolidating points with processing facilities, the cassava chips are sent to other collection and processing points, starch factories, and even directly to Thailand by trading companies from that country. This type of consolidating point was trading both fresh and dried roots. The fresh roots were either sold to other consolidating points for processing or exported to Thailand without processing, whereas all the dried roots were directly exported to Thailand. Fresh roots exported to Thailand are processed in starch factories across the border. Collection points without processing facilities such as C and E (Table 6) were only transporting and selling fresh roots to starch factories which in turn exported them mainly to Thailand. Thus, the characteristics of collection and processing points are found to have a relation to the destination of the collected cassava roots. Interestingly, most collection and processing points are established and operated by large-scale cassava cultivators such as A, C, E, and F in Table 6. In addition to owning large cassava plantations, these cultivators also play the roles of harvesters, middlemen, collectors, processors, transporters, and traders. They collect cassava roots from small-scale cultivators to fill the gap between the demand from Thailand and their own production. In sum, this research has found that the cassava distribution channel in the study area comprised only various types of cassava cultivators and traders from Thailand, and there was no division of labor for efficiency (Figure 6).

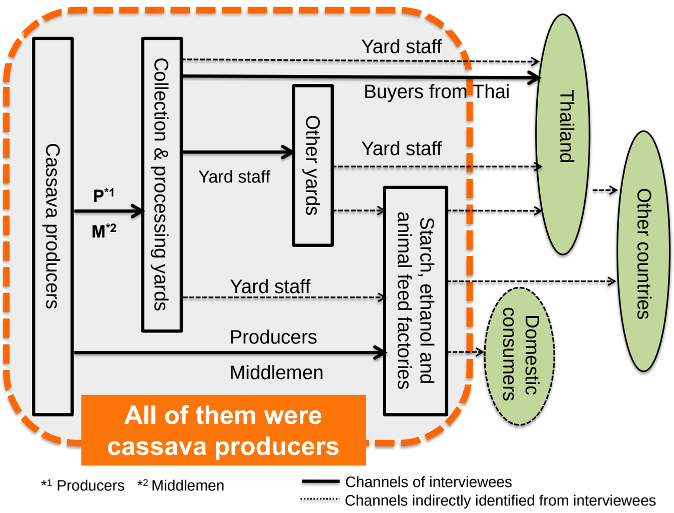

Fig. 6 Distribution channel of cassava root

CONCLUSION

This study aimed to identify cassava distribution channels in Cambodia as well as the characteristics of cultivators and their mode of business operations. The results revealed that the production scale and characteristics of the producers, such as average age and experience in agriculture, especially cassava cultivation, are influenced by the historical and geographical characteristics of each province. This study identified three different types of distribution channels from producers to consolidating points. The first type is direct distribution wherein all related processes such as planting, harvesting, transporting and selling are handled by the cultivators. In the second type, apart from cultivation, everything is handled by middlemen. The third type features a combination of both cultivators and middlemen. The distribution type also depended on the type of root being traded—fresh or dried—and the distance from farms to the collection and processing points. Moreover, analysis of selling price and characteristics of income from cassava cultivation need further study with sufficient sampling with statistical methods. This study also found that large-scale cassava cultivators, who also operate root collection and processing points, were playing important roles as collectors, middlemen, and transporters in the cassava root distribution system of Cambodia. The existing cassava root distribution mechanism in the country is well-concerned about its benefit to cultivators including small-scale producers; however, there is more room for improving efficiency such as introducing division of labor. Thus, building an efficient and viable distribution mechanism and strategy by utilizing the existing system as its base will be one of the most important challenges for making cassava a major industrial crop and increasing revenue from its cultivation. The results of this study were based on qualitative analysis only due to small number of samples. Further studies with quantitative analysis on cultivators' profits, characteristics of sales activities, and distribution types according to their production scale and location are desirable to find out suitable distribution mechanism that is efficient and viable as main industrial crop in Cambodia.

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Research article

Contracting and Negotiation Attributes: A Case of Sunflower Seed Crop in Central Tanzania

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Abstract In most developing countries like Tanzania, poor farmers have limited access to agricultural inputs. One of the proposed solutions is to link farmers with the private sector through contract farming. In Tanzania, sunflower oil has been preferred as edible cooking oil for many households since it has a low cholesterol level for human consumption. Moreover, sunflower-contract farming was adopted as part of the new agricultural policy in 2009-2010 cropping season, majoring in providing triangular benefits to the stakeholders, including sunflower-farmers, private companies, and the Government of Tanzania. Despite the government of Tanzania's efforts to link the sunflower farmers with the private sector, contract farming has been facing some challenges in coordination such as pricing, production services and credit services. The purpose of this study is to investigate the impact of the contract farming program among sunflower farmers. Specifically, the study aims to: (i) determine the socio-economic characteristics of the sample farmers; (ii) identify private firms providing contract farming to the sunflower farmers; and (iii) evaluate the relationship of the negotiation attributes in income growth among sunflower farmers.
The field survey was conducted in March 2020, targeting 40 contracted farmers and 40 non-contracted farmers in the two regions of Central Tanzania. In relationship of the negotiation attributes the paper points out the credit access and production services were significant with farmers' income. Besides, the results show that there was no statistically significant relationship between advance pricing and income growth among sunflower farmers. This was because in contract terms price is not set in advance.

Keywords: contract farming, sunflower seed crop, Central Tanzania.

INTRODUCTION

Contract financing has been a promising linkage strategy between smallholders and agribusiness firms with vested interests in sharing the risks associated with producing of a specific crop. Consequently, the World Bank also recognizes contract financing as an avenue to create strategic partnerships between private capitals and smallholders leading to the transfer of modern agricultural technology, quality inputs, entrepreneurial development of smallholders and market growth (World Bank, 2008).

Contract farming is not a new phenomenon in Tanzania. It dates back during the colonial era, where contract farming arrangements were practiced in some of the major cash crops plantations of sugarcane and tea. Contract arrangements in the Tanzania farming industry fall under the four models as explained by Eaton and Shepherd (2001); centralized, multipartite, intermediary and the informal models. For sunflower sector, contract farming among sunflower farmers in Tanzania has been developed widely since 2010 in solving the problems faced by farm households such as poor access of modern seeds, in-adequate use of farming techniques and provides a secure purchaser for their production (SDC, 2018). Likewise, from the countryside the main motivation of introducing sunflower contract farming was to reduce the shortage and burden of edible cooking oil importation from foreign countries (URT,2009).

Due to its low cholesterol level, sunflower oil is highly preferred as an edible and safe cooking oil for many households in the country. The crop accounts for 40% of the total national cooking oil requirements (URT, 2014). For the countryside, contract farming policy attempted to reduce the burden of importing edible cooking oil from foreign countries by offering opportunities of high yield varieties together with aim of the income generation to farmers.

Despite the government's new agricultural policy, sunflower contract farming has faced some challenges in coordination such as pricing which leads to side-selling, production services such as delay of paying farmers-produce and credit services which is not provided as agreed in advance. Additionally, in contract terms, major negotiation attributes between the companies and contract farmers include pricing, credit access and production services such transport and inputs access.

OBJECTIVE

The study aims to investigate the impact of contract farming program among sunflower farmers. Specifically, the study aims to (i) determine the socio-economic characteristics of the sample farmers; (ii) identify private firms providing contract farming among the sunflower farmers; and (iii) evaluate the relationship of the negotiation attributes in income growth among contract sunflower farmers.

The following research hypotheses were formulated and tested:

H01: Capital has no significant influence on income growth among sunflower farmers in Tanzania; H02: Advance pricing has no significant influence on income growth among sunflower farmers in Tanzania; and H03: Contractor credit services have no significant influence on income growth among sunflower farmers in Tanzania.

METHODOLOGY

The field study was conducted in Dodoma and Singida regions located in Central Tanzania in March 2020 "Fig.1". These regions were selected because contract farming has been extended to sunflower farmers since 2020. Based on the observation, it was found that there were two types of sunflower seed producers: i) sunflower farmers with contract farming and ii) sunflower farmers without -contract farming. Data collected comprised mainly data from the 2018/2019 cropping season, therefore farmers had to recall on some aspects such as costs of production, yield of different crops and inputs use.

Considering this observation, a total of 80 farmers from two types of category farmers were selected from two regions: Dodoma and Singida regions. Among them, 40 farmers were selected from each category of farmers. A two-stage sample design was used to collect the data. First, two villages were purposefully selected because of the presence of sunflower contract farming. Then, the contract farmers were randomly selected from the list of contracted farmers, and non-contract farmers were randomly selected from the village households list (after removing the contract farmers). The study adopted a semi-structured questionnaire as an instrument for data collection. Both qualitative and quantitative methods of data collection were collected. Major information collected includes socio-economic characteristics of the farmer-respondents such as age, farm size (ha), average cultivated area (ha), education of head of households, objectives of the contract farming among sunflower farmers, production characteristics such as cost and sales of produce and current problems and farmers suggestions on sunflower production.

This study employed data analysis techniques, and descriptive statistics, correlation analysis between variables was used to measure how well the variables are related. Descriptive statistics such as frequencies means, and cross-tabulation of some critical values were used to compare basic characteristics of farmers who participated in contract farming and farmers who did not participate.

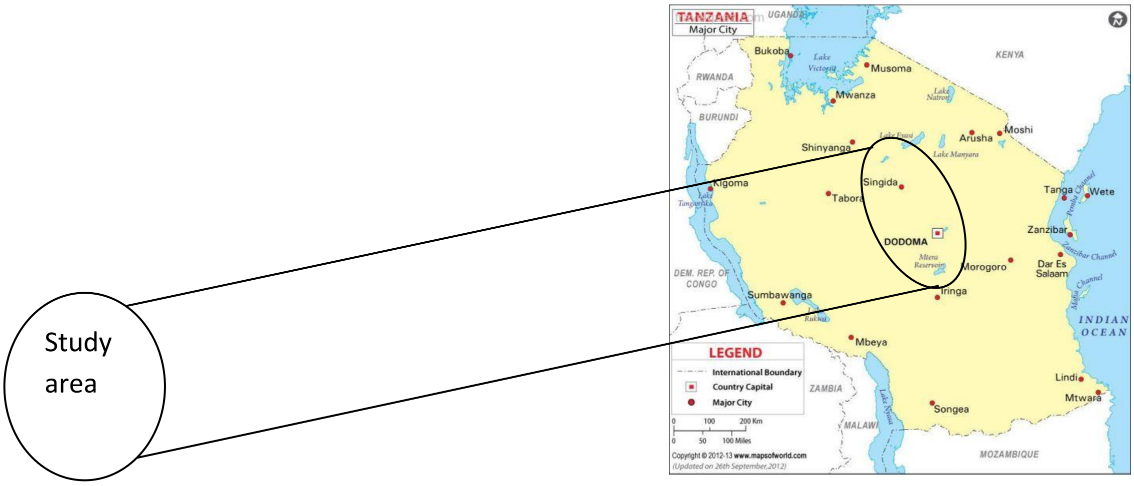

Figure 1 Study area

Source: Available at https://www.google.com/ united-republic-of-Tanzania-map-vector

RESULTS AND DISCUSSION

1) Socio-economic characteristics of the sample farmers

The the field study showed that the average age for both contract farmers and non-contract farmers was 48 years “Fig. 2”. In terms of gender distribution, the sunflower is a men’s crop where men constitute (95%) of the contract farmers and (74%) of the non-contract farmers respectively “Fig.3”. The very low proportion of women contract farmers may indicate contractual arrangements and tools that still discriminate against women participation and access. In most Nyanturu societies in Singida region and Rangi societies in Dodoma region, women still require the approval of men when borrowing money, which tends to limit women’s participation and access to contract farming.

Considering the education background, the study shows that (82%) of the contract farmers had attained at least secondary education compared to (67%) of the non-contract farmers “Fig.4”. This clearly shows that most of the contract farmers had attained a good level of education to enable them to have a better understanding of how contractual arrangements work.

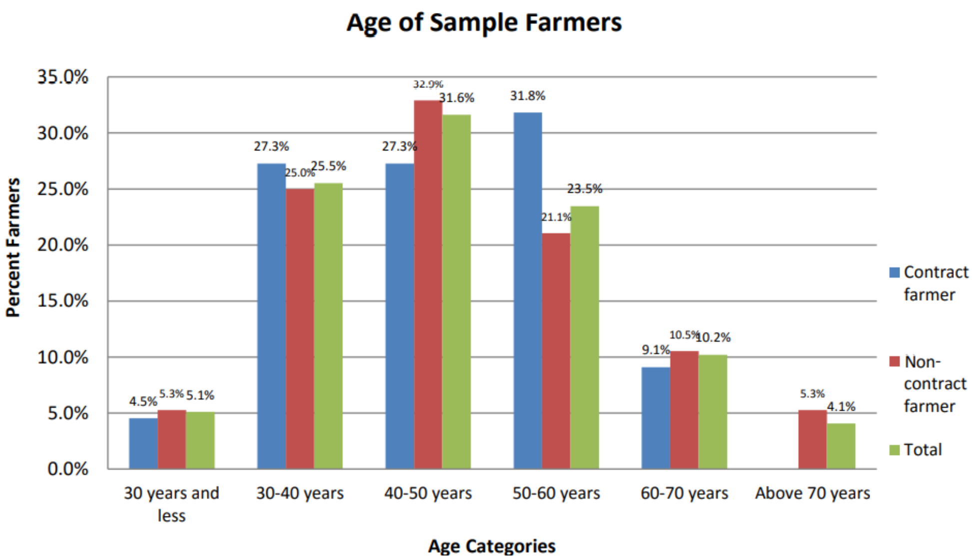

Figure 2 Age distribution of sampled farmers

Source: Field survey, 2020

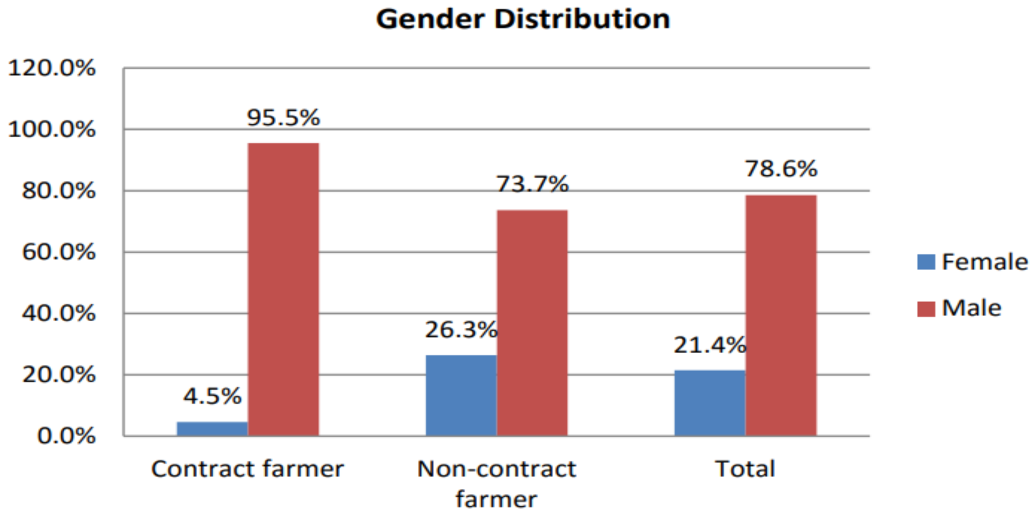

Figure 3 Gender distribution of sampled farmers

Source: Field survey, 2020

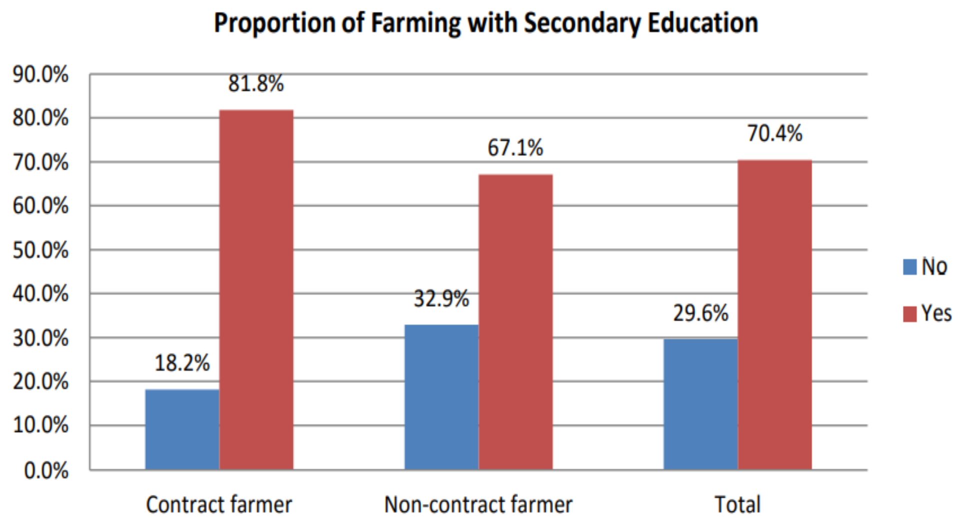

Figure 4 Education level of sampled farmers

Source: Field survey, 2020

2) Private firms providing contract farming among sunflower farmers

Based on the observations, the major actors in sunflower contract farming were farmers; the company; and the Government of Tanzania who closely oversee the progress of the contract farming program. Initially, the contract farming among sunflower farmers was introduced by eight (8) private firms. However, major private firms still having contract farming among sunflower farmers include: Three Sisters Company Limited in Dodoma region and Ikungi Sunflower Edible Cooking Oil Company in Singida region (Table 1). Additionally, both Three sisters in Dodoma and Ikungi Sunflower Edible Cooking Oil provide a long-term contract for a period of eight (8) years. However, some farmers did not join the contract in the first instance as they wanted reassurance that the company would fulfil its obligations in terms of providing improved seeds and purchasing all produce before contracting. Farmers subsequently joined the program. Other contract companies did not continue providing contract farming because of some challenges such as side selling among the contract farmers, financial constraint, and their contract were short- term such as one-year, two-years, and three-years of contract (Table 1).

Table 1 Private firms providing contract farming among sunflower farmers in Tanzania.

Private firm	Still having contract	Region, the company operates	Number of villages	Years of doing contract
Uncle Millo	No	Dodoma	20	3(2010-2013)
Ringo consolidated	No	Dodoma	25	2(2010-2012)
Furaha Dodoma	No	Dodoma	11	2(2010-2012)
Three Sisters	Yes	Dodoma	5	8(2011-to date)
Ikungi Edible Cooking Oil Ltd	Yes	Singida	3	8(2012-to date)
Nyemo Investment	No	Singida	28	3(2010-2013)
Ring Investment	No	Dodoma	10	2(2011-2013)
Kibaigwa Oil Suppliers	No	Dodoma	70	1(2010-2011)

Source: Field survey, 2020

2) Relationship of the negotiation attributes in income among contract sunflowers farmers

To understand the gross income of two category farmers, the economic return analysis was employed. Gross income was calculated as a gross revenue minus total production cost excluding family labor cost. The study shows that, contract farmers receive higher gross income (1228.9 TZS/ha) after joining the contract farming compared to the non-contract farming (602.1 TZS/ha) (Table 1). For the good aspect, this result imply that contract farming has a positive impact on household income.

Additionally, the study adopted the correlation analysis to examine the negotiation attributes in income growth among the sunflower contract farmers. The correlation between variables was used to measure how well the variables are related. Table 2 presents the results of the correlation coefficient analysis, which shows a statistically insignificant weak positive relationship between capital and income growth among sunflower farmers ($r = 0.037$, $p > 0.05$). Surprisingly, the results show that there was no statistically significant relationship between pricing and income among sunflower farmers ($r = 0.23$, $p > 0.05$). This was because in contract terms price is not set in advance. However, contractor credit ($r = 0.71$) and production services ($r = 0.78$) among sunflower farmers show static significant relationship with income growth among sunflower farmers (Table 2)

Table 1 Income comparison of non-contract sunflower farmers and contract sunflower farmers

Unit of cost: `000TZS/ha

Item	Non-contract farmers (a)	Contract farmers (b)	Difference (b)-(a)
Head of household	(n=40)	(n=40)	
Yield (tons/ha)	1.20	2.41	1.21
Seeds cost	10.6	12.2	1.6
Chemical fertilizer cost	22.7	37.9	15.2
Pesticide cost	1.20	10.8	9.60
Transport cost	40.00	55.5	55.5
Hired labor cost	23.4	27.9	4.5
Total variable cost	57.9	144.8	86.9
Total production cost	98.3	196.9	98.6
Gross Revenues	660.0	1373.7	713.7
Gross Income	602.1	1228.9	626.8
Gross Profit	561.5	1176.8	615.3
Price	550	570	

Table 2 Relationship of the negotiation attributes in income growth among contract sunflower farmers

		Capital	Pricing	Contractor credit	Production services	Income
Capital	Pearson correlation	1				
	Sig(2tailed)					
	N	40				
Pricing	Pearson correlation	0.32	1			
	Sig(2tailed)	.818				
	N	40	40			
Contractor credit	Pearson correlation	.062	.255**	1		
	Sig(2tailed)	.661	.000			
	N	40	40	40		
Production services	Pearson correlation	.022	.615**	.345		
	Sig(2tailed)	.876	.000	.012		
	N	40	40	40		
Income	Pearson correlation	.037	.023	.741**	.779**	1
	Sig(2tailed)	.791	.000	.000	.000	
	N	40	40	40	40	40

Note: **Correlation is significant at the 0.05 level (2-tailed-test); N is the total number of the contract sunflower farmers; Production services means transport provision during harvesting and inputs provision such as seeds, pesticides and fertilizers.

Source: Field survey, 2020

CONCLUSION

The study aimed to investigate the impact of contract farming program among sunflower farmers. In the sunflower sector, only two major private firms still provide contract farming among the sunflower farmers. Additionally, in relationship of the negotiation attributes the paper points out the credit access and production services were significant with farmers' income. Besides, the results show that there was no statistically significant relationship between advance pricing and income growth among sunflower farmers. This was because in contract terms price is not set in advance.

In relation to the findings and conclusion, the following were recommended to alleviate the existing challenges. First, fixed price should set in advance; this can work as an incentive if the sunflower-contract producers feel their work is rewarded. Secondly, there is a definite need for the Government of Tanzania to provide proper monitoring to ensure both contract parties adhere to the terms of contract. Finally, non-contract farmers need more education and training for more contract participation.

ACKNOWLEDGEMENTS

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Research article

Possibility of Value Addition on Traditional Rice Liquor in Cambodia

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Abstract Rice liquor is one of the traditional alcoholic beverages produced by small-scale farmers in rural areas. However, rice liquor production faced deficits and low profitability due to low sales price and productivity, frequent production failure, and low quality. It was hypothesized that improving the quality could increase the product value and the profitability of rice liquor production. The key modifications of production techniques to improve rice liquor quality include sanitary control of the working place, equipment, and raw material, and production process and quality management. However, it remains unclear if improving the product quality may result in value addition on traditional rice liquor in Cambodian markets. This study aimed to assess the possibility of value addition on the traditional rice liquor in Cambodian markets. First, consumers had structured interviews with questionnaires to identify consumption trends and preferences on rice liquor and other alcoholic beverages. Second, liquor produced with the modified techniques underwent consumer tests on its quality and sales price in 2009. Finally, quality liquor with the required registration for commercialization was trialed to identify the possibility of adding value to the products in Phnom Penh markets from 2010 to 2011. The survey results found that traditional rice liquor was consumed more in rural areas than the urban areas. More males consumed rice liquor than females, who mostly consumed medicinal and fruit liquor. A consumer test was conducted with tasting, observing bottled products, and labeling after a quality check. Both Cambodians and foreigners' evaluated liquor produced with modified techniques and indicated the possibility of putting a higher price as commercialized products. After registering for commercialization, the quality rice liquor was trialed for marketing and sales. These activities attracted several supermarkets, restaurants, and souvenir shops, and a sales contract was agreed for more than ten times higher than the sales price at the local markets. These results showed that the traditional rice liquor with value addition might gain market shares by ensuring product quality and safety.

Keywords Value addition, agro processing, rural development, marketing, rice liquor

INTRODUCTION

Value addition to agricultural products is expected to increase farmers' incomes and reduce poverty in rural areas (Royal Government of Cambodia 2006; Royal Government of Cambodia, 2013). Rice liquor is one of the traditional alcoholic beverages produced by small-scale farmers in rural areas. It contributed to income generation combined with pig farming, which became profitable by using rice liquor residue that reduces feeding costs. However, rice liquor production faced deficits and low profitability (Yagura et al., 2010). Main factors of low profitability include low sales price and productivity and frequent production failures, and many producers recognized the issues of low quality (Hamano et al., 2020). It was hypothesized that improving quality could increase the profitability of rice liquor production (Hamano et al., 2020).

The general production methods of traditional alcoholic beverages from rice in Vietnam and Laos have been clarified (Kozaki et al., 2002; Kozaki et al., 2005). Kozaki (2007) also revealed the production methods of traditional brewed and distilled liquor from rice in Cambodia. Yamamoto and Matsumoto (2011) identified the production methods of starter culture and its raw material for rice liquor and wine in Cambodia. Hamano et al. (2014) identified the key modifications of production techniques to improve rice liquor quality, such as sanitary control of working place, equipment, and raw material, and production process and quality management.

However, it remains unclear if improving product quality may result in value addition on traditional rice liquor in Cambodian markets.

OBJECTIVE

This study aimed to assess the possibility of value addition on the traditional rice liquor in Cambodian markets.

METHODOLOGY

This study employed a series of action research (Greenwood and Levin, 1998; Popplewell and Hayman, 2012) to examine the possibility of value addition on the traditional rice liquor through interview surveys on consumption behavior, consumer tests on quality, and marketing and sales trials in domestic markets of Cambodia.

First, structured interviews were conducted with questionnaires to the consumers to identify the consumption trends and preferences on the rice liquor and other alcoholic beverages in 2008 during the Water Festival and One Province One Product Exhibition (OPOP) in 2008 at the capital city, Phnom Penh (Fig. 1). Second, rice liquor produced with the modified techniques by rice liquor farmers in Takeo Province was provided for consumer tests on its quality and sales price during the OPOP in 2009 at Phnom Penh. Third, the trial marketing and sales of the quality liquor with the required registration for commercialization were conducted to identify the possibility of adding value on the products at Phnom Penh markets from mainly 2010 to 2011. Finally, the possibility of the value addition on rice liquor was discussed with the necessary conditions.

Fig. 1 Target area

RESULTS AND DISCUSSION

The interview survey was performed with questionnaire on alcoholic beverage consumption to the Water Festival visitors in Phnom Penh, the capital city of Cambodia. The interviews were conducted to 111 males and 121 females, and 230 valid answers were obtained. Most interviewees at 94% came from provinces outside Phnom Penh.

Table 1 shows the alcoholic beverage consumption behavior of the interviewees. The results indicated that beer is consumed by 73% of the interviewees, with rice liquor at 60% and medicinal liquor at 55%. More people drink beer than traditional rice liquor and medicinal liquor processed from the rice liquor, followed by palm juice wine at 48%, and fruit liquor at 34%, which are both traditionally produced and consumed in Cambodia. On the other hand, the traditional rice liquor, medicinal rice liquor, and palm juice wine were more frequently drunk on a daily or weekly basis than beer. Rice liquor, medicinal liquor, and palm wine were consumed by 27%, 21%, and 15%, respectively, more than once per week, while beer was consumed by 11%. On the other hand, whiskey and wine were consumed a few occasions per year.

Table 1 Consumption of alcoholic beverage by the interviewees

	Beer		Rice Liquor		Herb Rice Liquor		Fruit Rice Liquor		Whisky		Wine		Palm Juice Wine		Brewed Rice Wine	
	Number	%	Number	%	H	%	Number	%	Number	%	Number	%	Number	%	Number	%
No drink	61	27%	93	40%	103	44%	153	66%	178	77%	162	70%	123	52%	220	96%
1-11 times/year	99	43%	50	22%	57	25%	43	19%	49	21%	64	28%	64	28%	10	4%
1-3 times/month	44	19%	24	10%	22	10%	7	3%	1	0%	2	1%	8	3%	0	0%
1-4 times/week	21	9%	33	14%	26	11%	10	4%	1	0%	2	1%	23	10%	0	0%
5-7 times/week	5	2%	30	13%	21	9%	16	7%	1	0%	0	0%	11	5%	0	0%
No answers	0	0%	0	0%	1	1%	1	1%	0	0%	0	0%	1	1%	0	0%
Total	230	100%	230	100%	230	100%	230	100%	230	100%	230	100%	230	99%	230	100%

**Most interviewee (94%) were from provinces out of Phnom Penh*

Figure 2 shows the interview results during the One Province and One Product Exhibition in 2008 about the rice liquor consumption comparing urban and rural residences. Interviews were conducted with 393 visitors and obtained 337 valid answers (by 303 male and 34 female) consisted of 202 from Phnom Penh and 135 from other provinces out of Phnom Penh.

The results indicated that both urban and rural people consumed rice liquor since more than 59.9% by Phnom Penh visitors and 66.7% by consumers from other provinces. The weekly or daily drinkers shared 13.9% at Phnom Penh and 17.0% at other provinces. Although rural people tended to consume rice liquor more frequently, people in Phnom Penh also consume traditional products.

Table 2 Consumption behavior of rice liquor in urban and rural areas

	Phnom Penh		Other provinces		Total	
	Answers	%	Answers	%	Answers	%
No drink,	81	40.1	45	33.3	126	37.4
1-5times/year	68	33.7	48	35.6	116	34.4
1-3times/month	25	12.4	19	14.1	44	13.1
1-2times/week	20	9.9	13	9.6	33	9.8
Everyday	8	4.0	10	7.4	18	5.3
	202	100.0	135	100.0	337	100.0

The interviewees were asked about their impression of the rice liquor quality. Among the answers, 116 (34.4%) recognized rice liquor as low quality at a nearly same ratio in Phnom Penh and from provinces, while 76 (22.6%) evaluated it as high quality. Among the 116 interviewees who answered "low quality", the reasons were described and appearances of keywords were counted. As a result, "added industrial alcohol" or "other kinds of harmful chemical" was 47 (41.6%), followed by "bad for health" at 23 (20.4%), "unstable quality" at 14 (12.4%), and "no quality control" at 13 (11.5%).

Table 3 Impression on traditional rice liquor quality in urban and rural areas

	Phnom Penh		Other Provinces	
	Number	%	Number	%
High quality	41	20.3	35	25.9
Low quality	70	34.7	46	34.1
No idea	79	39.1	43	31.9
No-answer	12	5.9	11	8.1
Total	202	100.0	135	100.0

Table 4 Factors of low quality

	Frequency	%
Add industrial alcohol/chemical	47	41.6
Bad for health	23	20.4
No standard/ Various quality	14	12.4
No quality control	13	11.5
Add water	3	2.7
Others	11	9.7
No idea	2	1.8
Total	113	100.0

**Frequency of key words in the answers to the open-ended question. 108 out of 116 respondents answered and 113 key words were counted. No answer by 8 respondents.*

Hamano et al. (2013) identified the modified production techniques for quality improvements by improving sanitary conditions and quality control through trial productions with a selected farmer in a rural area of Takeo province. Consumers recognized the improved quality and high possibility of commercialization in the trial rice liquor during consumers' tasting tests, comparing with the farmer's liquor in the One Province and One Product Exhibition in 2008. However, people were suspicious about the quality and safety control of the local rice liquor as shown in Table 3. It indicated that the consumers refused pay high value without the guarantee of the products quality and safety under a strict production control.

During the OPOP exhibition in 2009, the quality liquor was provided to the second consumer test with tasting and observation of the rice liquor products, which have been developed to ensure the necessary conditions for the commercialization. The rice liquor was produced under strict quality management, such as ensuring the sanitary condition of raw material, equipment, and production place, checking and recording the production process, measuring the alcohol degree, and conducting the sensory tests for checking taste, fragrance, color, and smell. The rice liquor was packaged with sealed glass bottles. Front and back labels were attached to the bottle with the product logo mark and named as "Sraa Takeo," which means rice liquor from Takeo province in Khmer language. The label included the information on producers, and product information such as alcohol percentage, raw material, and production process with strict sanitary and quality control (Fig. 2).

Checking fermentation Recording production | Sensually test and alcohol degree check | Final sensually test and alcohol degree check | Bottling and labeling

Fig. 2 Quality check during the rice liquor productions

Fig. 3 shows comparison results of retail prices of general rice liquor at local shops between Phnom Penh and Takeo province. The price setting at Phnom Penh has three price ranges of R2,000 –R3,000/L (USD0.5–0.75), while the price at Takeo province has only one price range at R2,000/L. It seemed that the Phnom Penh market could be more sensitive in differentiating the prices and quality. However, the prices and the alcoholic degree did not have a significant correlation. It means that the traditional rice liquor was not clearly evaluated its quality with price setting.

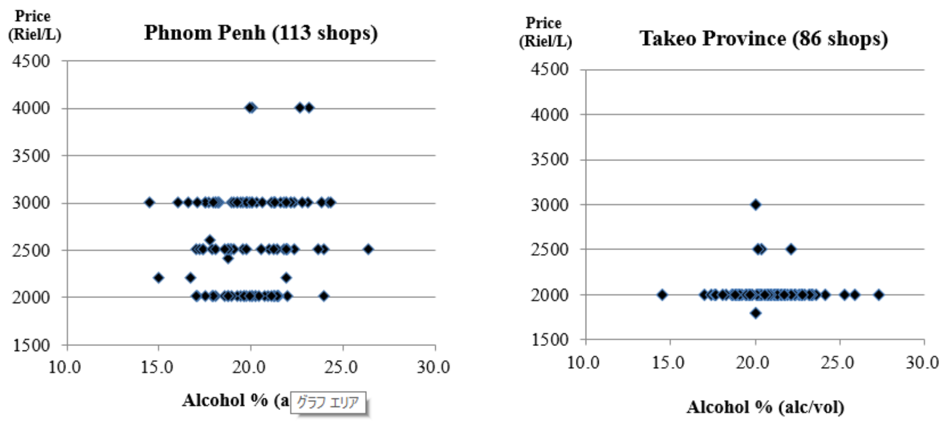


Fig. 3 Rice liquor price (Riel/L) and alcohol contents

The prices of the trial products for commercialization were also based on the production cost and market survey results on alcoholic beverages in Phnom Penh. Table 5 shows the retail prices at 10 shops, including supermarkets and local shops. Local liquor was sold at USD0.5–1.0/L in local shops and supermarkets. On the other hand, imported whiskey, vodka, and wine were sold at USD5/L in the lowest price, and USD10–20/L in general. The alcohol contents varied from 20%–40% in the case of distilled liquor.

For the consumer test, two trial products with different alcohol degree at 25% with a green label and 40% (alc/vol) with a black label, and one local liquor from the market in Phnom Penh were provided to the OPOP exhibition visitors in 2009 at Phnom Penh to compare the liquor quality and examine the marketability of the packaged products (Fig. 4). The total number of interviewees was 349, consisting of 332 Cambodians (314 males and 18 females) and 17 foreigners (14 males and 3 females). Among the Cambodians, 86.5% lived in Phnom Penh, and 13.2% were from other provinces. The eight foreigners included were Japanese, Americans, and Europeans.

Table 5 Sales of alcoholic beverages in different retailers

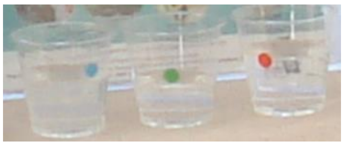
	Type	Price /Liter	Package	Alcohol contents (%)	Producer info.
Rice liquor (local shops)	Distilled liquor	USD0.5-1	Re-used PET bottles	Provided only oral information Inaccurately at 2 times higher than real alcohol content.	Unwritten and unavailable
Local distilled liquor (Super-markets)	Distilled liquor	USD1-2	Recycled glass bottles	Written on label inaccurately at 2 times higher than real alcohol content.	Unwritten and unavailable
Whisky (Imported)	Distilled liquor	USD5-	Glass bottles	Written on label Accurate alcohol percentage.	Written on label
Vodka (Imported)					
Wine (Imported)	Brewed	USD10-			

Note: Rice liquor (local shops) were distributed with plastic container from local farmers and sold after putting in re-used PET bottle without showing any information such as alcoholic contents and raw material.

Green label:
25% alc/vol
at USD5.00

Black label:
40% alc/vol
at USD8.00

Sample of quality rice liquor products



Samples for tasting

Interviews after tasting and observation of the products

Fig. 4 Consumer tests during One Province One Product exhibition in 2009

The results of interviews after the tasting and observations of the products most interviewee preferred the trial products sharing Sraa Takeo 25% (alc/vol) and 40% (alc/vol) at 50.7% and 40.7% of total answers respectively (Table 6). The fragrances of two Sraa Takeo products were highly evaluated that more than 66% of interviewees recognized them as the more preferred aromas, while only 23.8% preferred the aroma of the local rice liquor (Table 7). The color of Sraa Takeo products, which were mostly transparent, were preferable for the consumers, while nearly 70% of the interviewees described the cloudy local liquor as unpreferable, as it usually appeared in general local rice liquor in Cambodia (Table 8). The prices set per 500-mL bottle, which were USD5 for Sraa Takeo 25% and USD8 for Sraa Takeo 40%, were recognized as the appropriate price for commercial products by respectively 56.7% and 53.2% of all interviewees, even though the local rice liquor was sold at USD0.75/L (Table 9).

Table 6 Preference of rice liquor

	Answers (%)
Sraa Takeo 25%	177 (50.7)
Sraa Takeo 40%	142 (40.7)
Local rice liquor	30 (8.6)
Total	349 (100.0)

Table 7 Evaluation on fragrance of rice liquor

	Local rice liquor (%)	Sraa Takeo 25% (%)	Sraa Takeo 40% (%)
Aromatic	83 (23.8)	232 (66.5)	236 (67.6)
Not aromatic	266 (76.2)	116 (33.2)	112 (32.1)
No idea	0 (0.0)	1 (0.3)	1 (0.3)
Total	349 (100.0)	349 (100.0)	349 (100.0)

Table 8 Evaluation on color of rice liquor

	Local rice liquor (%)	Sraa Takeo 25% (%)	Sraa Takeo 40% (%)
Good	106 (30.4)	321 (92.0)	314 (90.0)
Bad	242 (69.3)	27 (7.7)	34 (9.7)
No idea	1 (0.3)	1 (0.3)	1 (0.3)
Total	349 (100.0)	349 (100.0)	349 (100.0)

Table 9 Evaluation on price setting of trial rice liquor

	Sraa Takeo 25% (%)	Sraa Takeo 40% (%)
Reasonable	2 (0.6)	3 (0.9)
Appropriate	198 (56.7)	186 (53.3)
High	149 (42.7)	160 (45.9)
Total	349 (100.0)	349 (100.0)

Questionnaires about the place of drinking rice liquor were answered to be mainly consumed at the house (Fig. 5), while the other alcoholic beverages were consumed at house and restaurant (Fig. 6). On the other hand, rice liquor was purchased directly from producers at 36.0% and local markets at 30% (Fig. 7). Other alcoholic beverages were bought from local markets, street stoles, and at supermarkets (Fig. 8). These results indicated that the traditional rice liquor has not been introduced to the supermarkets and restaurants, where popularly high valued alcoholic beverages were served and sold. In other words, high-quality rice liquor could have room to enter those markets.

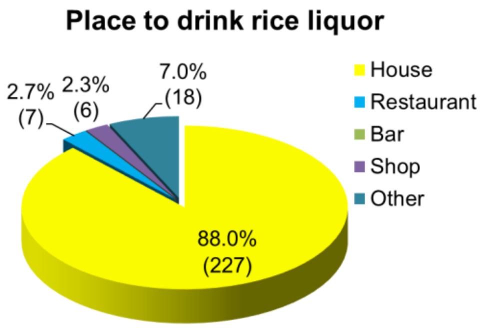


Fig. 5 Drinking place of rice liquor

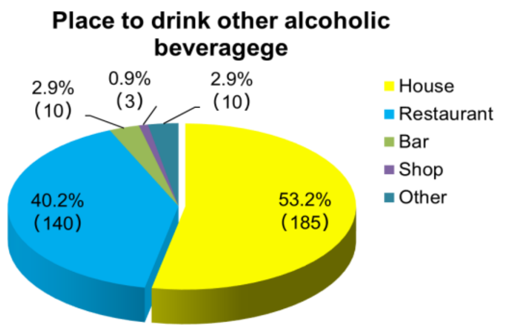


Fig. 6 Drinking place of other alcoholic beverage

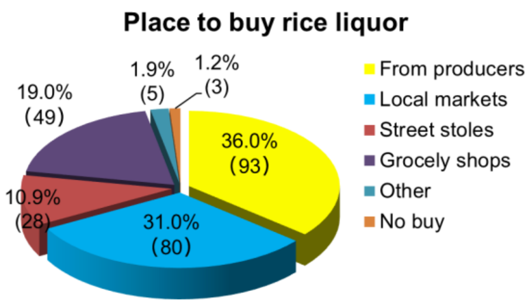


Fig. 7 Buying place of rice liquor

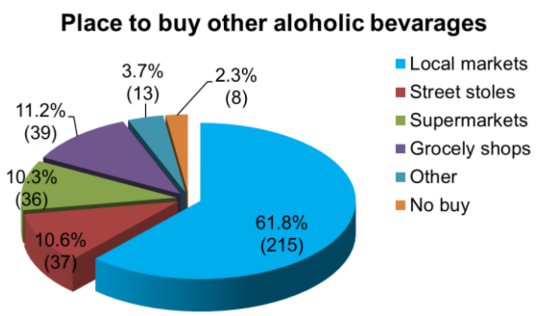
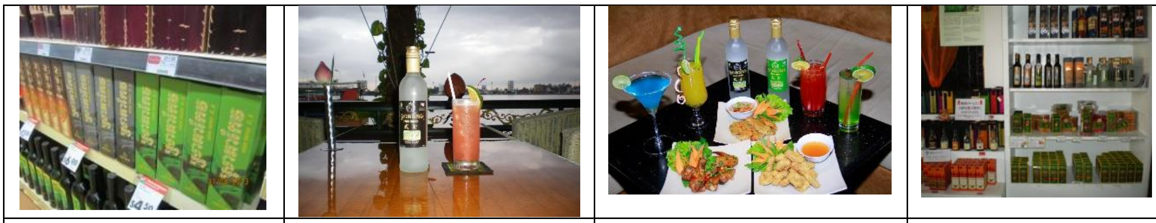


Fig. 8 Buying place of other alcoholic beverage

Based on the consumers' concerns for unsafety of the rice liquor especially by the contamination of the industrial alcohol and other chemical material into the products, it was assumed that the safety control has remained as a fundamental issue toward value addition on rice liquor product. Thus, the trial rice liquor was packaged by glass bottle and sealed cap after completing the commercial registration under the Ministry of Commerce and manufacturing registration under the Ministry of Industry, Mine, and Energy with quality test which certify the alcohol degree, appropriate acidity and no contamination of methyl alcohol.

After the required registrations for commercialization in terms of business (company) registration, tax, small-medium manufacturing and product test, and trademarks, the Sraa Takeo 25% and 40% were trialed for marketing and sales from 2010 September. The marketing and promotion activities targeted around 80 clients including 4 supermarkets and 7 minimarts, 10 souvenir shops, 50 restaurants, 7 hotels in Phnom Penh and Siem Reap (Fig. 9).

These activities resulted to get 35 clients who bought Sraa Takeo 25% and 40% at least one time and sell at the suggested consumer price consumer price at USD5 for Sraa Takeo 25% and USD8 for 40% with 500 ml in minimum which were more than 10–16 times higher price than the local rice liquor price at the local markets during the 1st year. Then two supermarkets, three restaurants/bar, six souvenir shops repeated to purchase the products within the first-year sales.



Supermarkets	Restaurants	Bars	Souvenir shops

Fig. 9 Marketing and sales of Sraa Takeo 25% and 40%

Figure 10 shows the first-year results of the sales every 3 months. The average monthly sales were about 100 bottles in the first 6 months and increased to 200 bottles in the second 6 months. The main clients were several souvenir and food shops and restaurant in the first 6 months and 2 supermarkets in the second 6 months in Phnom Penh, and a part of sales were accepted by souvenir shops in Siem Reap, a famous tourism area.

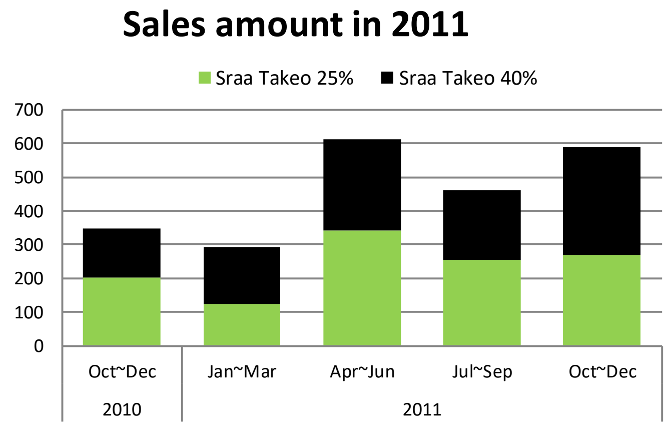


Fig. 10 Sales (bottle numbers) of Sraa Takeo

Hamano et al. (2013) has clarified that the rice liquor production techniques can be modified for quality improvement based on the local famers' processing know-how without introducing high-cost material and equipment and difficult techniques from other countries. Keeping the sanitary condition and quality control were the fundamental technical improvements.

Local markets in general did not have significant differences the values on the traditional rice liquor even though the alcoholic percentage was different. Thus, the commercialized markets such as supermarkets, restaurants and bar, or survivor shop that were sold the high value alcoholic beverages in the urban areas could be considered as possible areas for value addition.

In order to enter those markets, the rice liquor with improved quality should be developed as commercialized products with commercial registration including not only business and manufacturing registration but also obtaining the certification on product safety and quality from the authorized laboratories. In addition, the products packaging with bottling, sealing, and labeling with necessary information to indicate the product name, product quality, raw material, and producers.

One year marketing and sales activities to the high value markets in urban areas revealed that supermarkets and souvenir shops, and also restaurants and bars have accepted to sell the high-quality rice liquor at USD5–8 which were 6–10 times higher than the local products. Some of them become frequent buyers and continuously purchased. These indicated that there were needs of the traditional rice liquor by both domestic consumers and international customers. In the following year, the souvenir shops in the international airports at Phnom Penh and Siem Reap accepted the Sraa Takeo. The one of the largest chain supermarkets in Cambodia also continuously purchased the Sraa Takeo and extended the sold stores in their distribution system. In December 2020, at the time of writing this paper, the products have been continuously sold in these retail markets.

These results indicated the high possibility of value addition on the traditional rice liquor in the domestic markets of Cambodia through the quality improvement and the safety control. However, the efforts of the marketing and promotion activities or further product development should be necessary for the further market extension and sustainable commercialization.

CONCLUSION

This study was conducted by using action research method to examine the possibility of value addition through conducting the interview surveys on consumption behavior, market survey on the price setting of local rice liquor, and impression on quality of the trial products for the commercialization with tasting and observation. Finally, the sales of the commercialized products were trialed in the domestic markets. These results indicated the possibility of value addition on the traditional rice liquor under ensuring not only the high and stable quality but also the product safety under the appropriate quality control and testing.

ACKNOWLEDGMENTS

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Research article

Farmers` Perception on Contract Farming: A Cas e of Sunflower Seed Crop in Central Tanzania

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Abstract In most developing countries like Tanzania, poor farmers have limited access to agricultural inputs. In case of sunflower seed, one of the proposed solutions is through use of contract farming among the farmers. In the country, sunflower oil has been preferred as edible cooking oil for many households since it is much safer for human consumption. Despite the government's new agricultural policy, contract farming has been facing some challenges in coordination such as pricing, trust, arrangement for the delivery of the inputs, procedures for paying farmers, poor credit (cash) services as agreed of the contract.
The study aims to investigate the impact of contract farming program among sunflower farmers. Specifically, the study aims to (i) determine households' background characteristics; (ii) examine contract arrangement of sunflower seeds in Tanzania; (iii) discuss the farmers' perception in terms of trust, and personal relations play for their coordination. The field study was conducted in August and September 2019, selecting 80 farmers in two regions in Central Tanzania. Among them 40 farmers were sunflower producers with contract farming with Three Sisters Company Ltd and Ikungi Sunflower Edible Cooking Oil Company for eight (8) years; 40 farmers were sunflower producers without contract farming. Based on the field study, contract terms and conditions, hereafter called contract design attributes such as mode of payment and price setting of farmers' crop produce can affect farmers' decisions to participate in contract farming, varyingly affecting their expected level of utility from participation. On the other hand, in contract farming, farmers produce quality seeds with high cooking oil content. Surprisingly, in contract terms, prices are not set in advance, contract farmers sell their produce with similar price to the local sunflower seed. Finally, lack of education was the factor for non-contract farmers to participate in contract farming.

Keywords: contract farming, sunflower seed crop, Central Tanzania.

INTRODUCTION

Contract Farming (CF) among sunflower farmers in Tanzania has been developed widely since 2010 as an alternative approach to solving the problems faced by farm households and provides a secure purchaser for their production. At the same time, households receive the necessary inputs for their farm and advice on necessary farming techniques, while the buyers benefit from assured production from the contract farming (SDC, 2018). Due to its low level of cholesterol, sunflower oil is highly preferred as edible and safe cooking oil for many households in the country. The crop accounts 40% of the total national cooking oil requirements (URT, 2014). For the country-side, contract farming policy attempted to reduce the burden of importing edible cooking oil from foreign countries by offering opportunities of high yield varieties together with aim of income generation to farmers. Despite the government's new agricultural policy, contract farming has been facing some challenges in coordination such as pricing, trust, arrangement for the delivery of the inputs and procedures for paying farmers.

OBJECTIVE

The study aims to investigate the impact of contract farming program among sunflower farmers. Specifically, the study aims to (i) determine households' background characteristics; (ii) examine contract arrangement of sunflower seeds in Tanzania; (iii) discuss the farmers' perception in terms of trust, and personal relations play for their coordination.

METHODOLOGY

The field study was conducted in Dodoma and Singida regions located in Central Tanzania in August and September 2019. Region and district were sampled purposively due to the potentiality in production of sunflower seed at the central corridor. In addition, contract farming has been promoted to sunflower farmers since 2019. These regions are located in semi-arid area characterized by inadequate rainfall. Recently, there had been a tremendous shift of the population in these regions towards farming sunflower seed crop. The crop is drought tolerant and survives harsh conditions.

The study adopted a semi-structured questionnaire as an instrument for data collection. Both qualitative and quantitative methods of data collection were applied. Secondary data were obtained from the two companies providing sunflower contract farming in Central Tanzania, sunflower farmers, ministry of agriculture and rural development, published reports, books and journals. Educational status, the level of awareness and willingness of the respondents to participate in contract farming was collected.

Considering the observation, a sample of 80 farmers were selected from Dodoma and Singida regions "Fig. 1". Among them, 40 farmers were sunflower producers with contract farming with Three Sisters Company Ltd and Ikungi Sunflower Edible Cooking Oil Company for eight (8) years; 40 farmers were sunflower producers without contract farming. A two-stage sample design was used to collect the data. First, two villages were purposefully selected because of the presence of sunflower contract farming. Then, the contract farmers were randomly selected from the list of contracted farmers, and non-contract farmers were randomly selected from the village households list after removing the contract farmers.

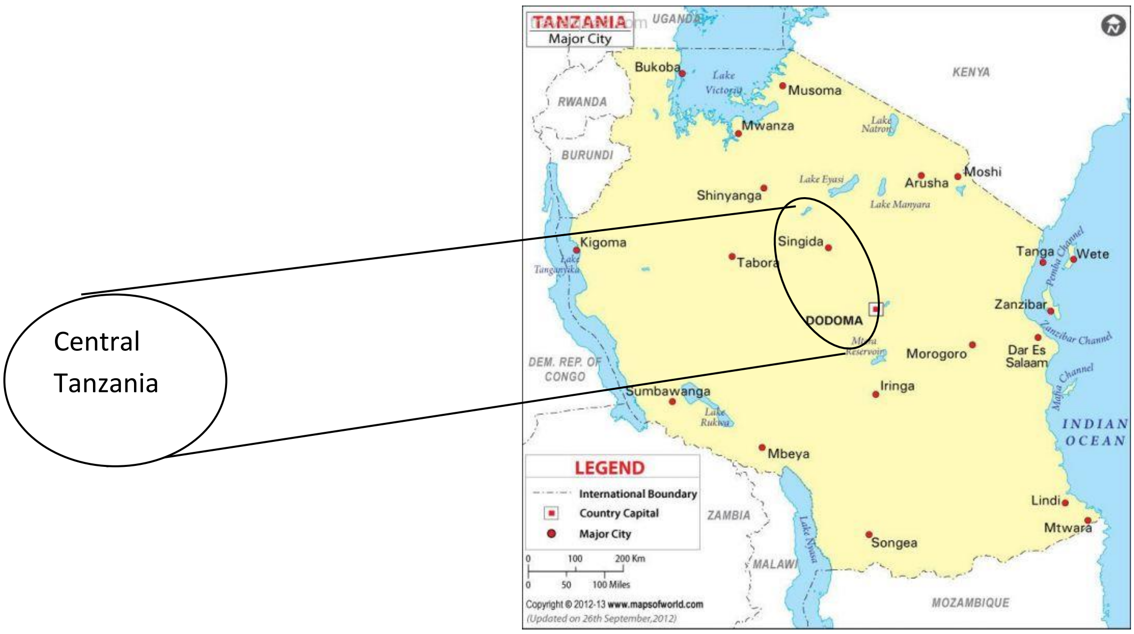

Figure 1 Map of study area

Source: *https://www.google.com/ united-republic-of-Tanzania-map-vector*

RESULTS AND DISCUSSION

This study employed data analysis techniques namely descriptive statistics and parametric estimations. Descriptive statistics such as frequencies means, and cross tabulation of some critical values were used to compare basic characteristics of farmers who participated in contract farming and farmers who did not participate.

1) Households' background characteristics

From the field study it was found that sunflower farmers with contract farming were older (42.3 years) than sunflower farmers with non-contract farming (37.1 years). This implies that the elder farmers participate in contract farming compared to younger farmers. Moreover, with respect to the farm size, sunflower producers without contract farming were relatively small (0.82 ha) compared to sunflower farmers with contract farming (2.41 ha) (Table 1).

Considering the education background, contract farmers have reached high school level and college level. But, majority of heads of household producing sunflower seed without contract farming have reached to primary level only (Table 1).

Table 1 Households' background characteristics

	Contract farmers (n=40)		Non-contract farmers (n=40)	
Characteristics	Mean	SD	Mean	SD
Age of heads of household (years)	42.30	7.06	37.10	6.82
Average cultivated area (ha)	2.41	1.20	0.82	0.40
Gender of farmers	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Male	32	80.0	12	30
Female	8	20.0	28	70
Farmers' education				
Primary level	26	65.0	40	100
Secondary level	4	10.0	0	0
High school level	1	2.5	0	0
College level	9	22.5	0	0
University level	0	0.0	0	0

Source: Authors' computation based on the data collected from field survey, 2019

Note: (1) SD refers standard deviation (2) Primary level is seven years of schooling (3) Secondary level is four years of schooling (4) High school level is two years of schooling (5) College level is two years of schooling (6) University level is three to four years of schooling

2) Contract arrangement of sunflower seeds in Tanzania

The use of contract farming in the production of sunflower in Central Tanzania began in the 2010/11 crop season. Major actors in sunflower contract farming are the farmers, the company and the government of Tanzania. The contract states the obligation of the company, farmers, and other features. In the contract, the company obligate itself to deliver improved seeds to farmers usually of the record-type, buy up all the produce grown from the seeds provided to the farmer. In addition, the price is not fixed, and the contract firm buy the produce at the farm gate price and sometimes by negotiations. The cost of the input seeds is deducted at the period of selling of produce after harvesting.

In the study area, both Three sisters in Dodoma and Ikungi Sunflower Edible Cooking Oil provide a long-term contract for a period of eight (8) years cropping season. In production, individual sunflower farmers organize themselves into contract farming and non-contract farming. The contract company provides inputs such as fertilizers, seeds, and pesticides. The contract is through vertical coordination and major support institutions in sunflower contract arrangements are Rural Livelihood Development Corporation (RLDC), Private and Small Medium Sunflower Oil Processors and International Agriculture Non-Government Organization (NGOs) "Fig. 2".

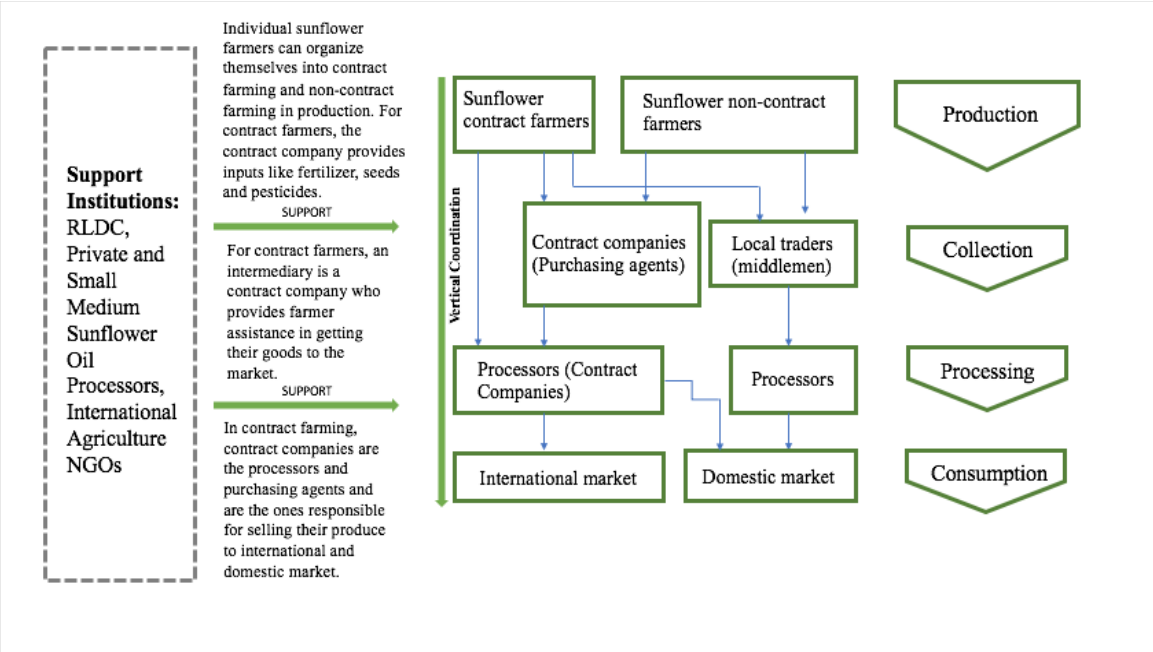

Figure 2 Coordinating production and contract arrangement of sunflower seeds in Tanzania
Source: Field survey, 2019

3) Farmers' perception in terms of trust, and personal relations play for their coordination

To understand the farmers' perception in terms of personal relations play for their coordination, the Garret ranks were calculated based on the data obtained in the field survey 2019, by using appropriate Garret Ranking formula. This method provides out the most significant factor which influences the respondent.

$$\text{Percent position} = \frac{100\,(R_{ij} - 0.5)}{N_j}$$

Where: Rij = Rank given for the ith variable by jth respondents, Nj = Number of variables ranked by jth respondent.

In terms of trust and personal relations, the study noted a prevailing mistrust between the two parties in the mode of payment on crop produce (63.0 Garret score). Farmers were arguing that; the cost of inputs were inflated to maximize companies` profits. In an interview with one farmer, she said; " After harvesting sunflower I take them to XXX company that I have a contractual agreement with. But, honestly, I am not satisfied with the costs of inputs, I think they tend to inflate them…" (Interview, 2019). Moreover, contract farmers did not have written signed contract papers. Another important factor is lack of government monitoring (58.0 Garret score). In the study area farmers reported that the contracts are not well monitored by the ward and village officers that are responsible to oversee compliance. Therefore, the absence of proper government control discourages small-holder participation in contract farming. In addition, price of produce was reported as another challenge among farmers (55.0 Garret score). In contract farming, farmers produce quality seeds with high cooking oil content. Surprisingly, in contract terms, prices are not set in advance, contract farmers sell their produce with similar price to the local sunflower seed. Based on this finding, non-contract farmers were not willing to participate in contract farming.

Table 2 Farmers` perception in terms of trust personal relations play for their coordination

Serial number	Constraint	Garret Score	Rank
1	Mistrust in the mode of payment	63.0	1
2	Lack of government monitoring	58.0	2
3	Price of produce	55.0	3

Source: Field survey, 2019

CONCLUSION

The study aims to investigate the impact of contract farming program among sunflower farmers. It was indicated that contract terms and conditions, hereafter called contract design attributes such as mode of payment and price setting of farmers' crop produce can affect farmers' decisions to participate in contract farming, varyingly affecting their expected level of utility from participation. In other words, lack of education was the factor for non-contract farmers to participate in contract farming.

In relation to the findings and conclusion the following were recommended to alleviate the existing challenges by all stakeholders of this sector. First, there is a definite need for the government of Tanzania to monitor and ensure that both parties adhere to the contract terms. In addition, price should be set in advance and reflect the quality of the crop. This will increase the willingness of farmers to participate in contract farming.

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Research article

Factors Affecting the Teaching Attitude of High School Agriculture Teachers in the Philippines

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Abstract The Enhanced Basic Education Act of 2013, also known as K to 12 Program, primarily aims to bring the Philippine education system at par with international standards through preparing graduates for college education, employment, or entrepreneurship. The Philippines has a clearer model with four Senior High School tracks compared to other countries. As the new program puts focus on student-centered learning, the quality of agriculture teacher education seems to be left behind. Previous literatures show that majority of the Teacher Education Institutions (TEIs) still has not aligned their curriculum to the needs of the K to 12 Program while current high school agriculture teachers have insufficient relevant trainings or seminars that relates to teaching strategies and in-service specialization. Aside from the effect of TEIs, one of the factors that can affect the quality of teachers is their teaching attitude. Teaching attitude encompasses complex topics, but this study focused only on preferences and motivations of high school agriculture teachers as these can be reflected to the interventions done in concurrent challenges in the Philippine education and agriculture. This study employed a semi-structured questionnaire for preferences on teaching and teaching agriculture and motivations in teaching. A five-point Likert-type scale revealed that the median for both preferences was '5' which means most of the respondents have 'very high' preferences. This is despite only one (1) among seven (7) respondents stated that the first choice of profession was teaching. Qualitative analysis revealed that respondents encountered challenges in school facilities, professional development focusing on content knowledge, and lack of teaching and non-teaching personnel. The recommendation of this study is to focus on improving the holistic skills of high school agriculture teachers not only in teaching strategies but in content knowledge as well since these relate to their professional development.

Keywords Teaching Attitude, Preference and Motivation, High School Agriculture Teachers, Content Knowledge

INTRODUCTION

The Enhanced Basic Education Act of 2013, also known as the K to 12 Program, primarily aims to bring the Philippine education system to international standards by preparing graduates for college education, employment, or entrepreneurship. This initiative entails two additional years of basic education, called the Senior High School (SHS) Program. The Philippines' SHS Program has four tracks with 10 strands which makes it a more detailed model compared to that of Japan and USA (Sarmiento and Orale, 2016).

The four tracks of the Philippines' SHS Program are: Academic; Arts and Design; Sports; and Technical-Vocational-Livelihood (TVL). A school offers a track based on the capability and potentiality of the community where the school is located. Before the students choose a track, they are required to take the exploratory components of the Technology and Livelihood Education (TLE) subject, which includes: Agri-Fishery Arts (AFA), Home Economics (HE), Information and Communications Technology (ICT), and Industrial Arts (IA). (Perolina, 2019)

The K to 12 Program focuses on student-centered learning, as can be seen in the 2019 Voluntary National Review of the Philippines on the status and implementation of the United Nations' Sustainable Development Goals (SDGs). However, there are still gaps in providing quality education to the students as the Department of Education (DepEd) identified that the proportion of teachers teaching in line with their specialization must be increased. According to the Philippine Business for Education (PBEd), as cited by Montemayor (2018), only 20% of the Teacher Education Institutions (TEIs) have aligned their curriculum to the needs of the K to 12 Program. There have been inadequate teacher training programs that can help teachers acquire new knowledge and approaches (Alegado, 2018). Aside from the effect of TEIs and teacher training, one of the factors that can affect the quality of teachers is their teaching attitude. Teaching attitude encompasses complex topics. However, this study focused only on the preferences and motivations of high school agriculture teachers (HSATs).

OBJECTIVE

This study aimed to determine the teaching attitude of HSATs in terms of preferences and motivations since these can be reflected in the interventions done in contemporary challenges in Philippine education and agriculture.

METHODOLOGY

This study utilized Life History Approach (LHA) through one-on-one interviews. LHA does not follow a chronological path as it aims for the participants to tell the story of their life without obstruction (Bakar and Abdullah, 2008). A total of seven (7) teachers from three (3) public high schools were interviewed. There were two (2) teachers from School A, a college preparatory high school and one of the basic education units of University A; two (2) teachers from School B, a science and technology high school; and three (3) teachers from School C, an agro-industrial high school. These schools were chosen to adhere to the primary function of the K to 12 Program, which is to prepare the students for college education, employment, and entrepreneurship, respectively. This study employed a semi-structured questionnaire for teaching and teaching agriculture preferences and motivations in teaching. A five-point type Likert scale (1 as very low preference; 5 as very high preference) was used to determine teaching and teaching agriculture preferences, while open-ended questions were used to identify the challenges encountered. In addition, the teachers were asked to rate the extent of how the challenges affect their teaching.

RESULTS AND DISCUSSION

Preferences of High School Agriculture Teachers (HSATs) on 'Teaching as a First Choice of Profession', 'Teaching', and 'Teaching Agriculture'

Table 1 shows the characteristics and preferences of HSATs on teaching, teaching agriculture, and teaching as the first choice of profession. Four (4) out of seven (7) teachers stated that they have very high preferences for teaching. Teacher A1 stated that teaching was not his first choice since he had other plans when he was in college. Teacher A1, who graduated from BS in Forestry, has been teaching in School A as part-time for four (4) years and as full-time for 29 years. During his part-time teaching in School A, he took the offer to teach agriculture; hence, he had to take his second degree, BS in Agriculture. He was hired as a full-time teacher before he finished his second degree. He also took units on education which qualified him to take the Licensure Examination for Teachers (LET). However, at that time, he was the appointed principal of School A. Teacher A1 rated a 'high preference' on teaching stating, *"When you are in School A's system, your position is relatively stable* *but then at the same time you need to satisfy the school's requirements like an advanced degree, publication… things like that. It is stable, and at the same time, you have professional growth since you are required. If you do not take further studies, you will be dismissed from teaching."* Moreover, Teacher A1 rated a 'very high preference' in teaching agriculture stating, *"Some of our students here are really alien on agriculture since most of our students here come from private schools. … There is a different challenge in high school since you do not just teach them; you also mentor them which sometimes become an additional effort."* Teacher A1 also stated that he shows the actual condition of agriculture in the Philippines not to discourage the students but to challenge them.

Teacher A2 stated that teaching was not her first choice of profession. She took the Licensure Examination for Agricultural Engineer administered by the Professional Regulation Commission (PRC). She tried practicing her expertise in public office for six (6) months, but when she did not feel any professional growth, she resigned then applied for a position in School A instead. Teacher A2 originally wanted to teach college students, but her husband, who has the same course and major as hers, was accepted as a college instructor in University A, where she wanted to teach. She did not pursue applying for the teaching position at University A since she did not want to be in the same working environment with her husband. She also stated, *"I thought to myself, I will just teach here in School A since the topics are somewhat similar."* Teacher A2, who has been in School A for seven (7) years, rated a 'very high preference' on teaching but asked to clarify the question, *"Is this based on what I felt before or what I feel now?"* which may imply that she may have had a lower preference during her early years in teaching since it was not her first choice of profession. Teacher A2 also rated a 'very high preference' in teaching agriculture and stated that she wanted to encourage students to take the same degree as hers or any agriculture-related courses.

Teacher B1, whose major was fish culture in Bachelor of Secondary Education (BSE), teaches crop production in School B. He stated that teaching was not his first choice of profession. According to Teacher B1, *"I took it because back then, it was the only four-year course offered in our province, which sounded very professional."* He has a 'high preference' for teaching because of the stable income while a 'very high preference' on teaching agriculture because of the suitability of crop production in the Philippine setting. Teacher B1, a member of a religious organization, also shared that he wanted to insist agriculture to students since agriculture existed as early as the bible recorded.

Teacher B2 took BS Agricultural Education and technical courses in cookery and pastry. She has developed her interest in teaching during her 40 years of experience but stated that teaching was not her first choice of profession. She shared, *"This was what my family could afford back then. It would have been very expensive had I taken nursing since my siblings, and I were simultaneously studying."* Teacher B2 rated both preferences on teaching and teaching agriculture as 'very high' because of having a stable income.

Teacher C1 stated that he originally wanted to work overseas on a different job despite graduating with a degree in BSE. He was underqualified with the work he applied for overseas. Therefore, he decided to settle in the Philippines and apply for a teaching position in School C. This was also why he rated 'high preference' on both teaching and teaching agriculture.

Among the seven (7) teachers interviewed, Teacher C2, who has the shortest experience in teaching of two (2) years, stated that teaching was his first choice of profession. He stated, *"It is the only course that comes to my mind. It is like being a teacher is the only profession that I want."* He also rated his preference on teaching as 'very high preference' not because of income but because he wanted to impart knowledge to his students. However, he hesitantly answered 'neutral preference' when asked about his preference for teaching agriculture. Teacher C2 stated that his interest and pre-service specialization was IA, one of the four components of TLE, yet his in-service specialization was organic agriculture. In addition, there were only a few units for agriculture during the time he was taking his major courses.

Teacher C3 would have been a priest not until he decided he wanted to get married and have his own family. He left the seminary and would have taken BS Electrical Engineer, but due to financial constraints, he opted to take BSE instead with the reason, *"Being a priest and a teacher is almost the same. The only difference is that one teaches the word of God, the other teaches academic lessons."* Teacher C3 rated his preferences on both teaching and teaching agriculture as 'very high,' stating that *"As of now, maybe I am already in the highest preference because I am already here. I have* *come to like what I am teaching."*

Table 1 Characteristics and preferences of high school agriculture teachers on teaching as a first choice of profession, teaching, and teaching agriculture

Respondent	Bachelor' degree	Educational attainment[a]	Teaching as first choice of profession	Teaching[b]	Teaching agriculture[b]
Teacher A1	Forestry; Agriculture	3	No	4	5
Teacher A2	Agricultural Engineering	2	No	5	5
Teacher B1	Secondary Education	2*	No	4	5
Teacher B2	Agricultural Education	2; 4	No	5	5
Teacher C1	Agricultural Education	2	No	4	4
Teacher C2	Secondary Education	1	Yes	5	3
Teacher C3	Secondary Education	2	No	5	5

Source: Field Survey, 2019
[a](1) Bachelor's degree (2) Master's degree (3) Doctoral degree (4) Technical/vocational degree (*) Units only
[b](1) Very Low Preference (2) Low Preference (3) Neutral Preference (4) High Preference (5) Very High Preference

Challenges Encountered and Interventions Done by the High School Agriculture Teachers (HSATs)

Table 2 shows the factors affecting the challenges encountered by the HSATs and the extent of their effect daily. One (1) teacher and two (2) teachers from Schools B and C, respectively, rated 'low extent' for their problems on school facilities in terms of Information and Communication Technology (ICT) units and demonstration garden. According to Teacher B1, School B has the budget to provide the ICT units such as laptops and Liquid Crystal Display televisions (LCD TV) for their laboratory room. This situation makes it easy for him to teach as his limited teaching time will not be spent on the preparation of these materials. Regarding Teachers C1 and C3 related school facilities, specifically demonstration garden and ICT units, School C has enough area for hands-on farming activities. However, both teachers use their own laptop for everyday teaching, sharing that it has become a part of their daily routine as teachers. As per Teacher C3, he had to loan money to buy a laptop which has been a great help to him during the preparation of instructional materials and computation of final grades.

On the other hand, Teachers B2 and C2 rated 'moderate extent' for their problems with school facilities regarding their respective demonstration gardens. The garden for School B gets flooded when typhoons and heavy rains come, while Teacher C2 thinks that the area for the garden is still small. Typhoons and heavy rains are usually experienced in the Philippines from June to November, and this has been a problem for Teacher B2 for years. To cope with the environmental challenges, she does not plant leafy vegetables during these months as these can be easily damaged. In contrast to the previous statement of the other two (2) teachers in School C, Teacher C2 thinks that the school can still expand the demonstration garden to give the students more areas to experiment on their classroom learning.

Teachers A1 and A2 related their problems on school facilities in terms of the quality and availability of classrooms and laboratories and rated it as 'high extent.' School A borrows rooms and various types of machinery from University A (approx. 5.5 km away) while its laboratory was only improvised. The improvised laboratory of School A, a four-poster shed with a galvanized iron sheet for the roof, is where the students conduct food processing. Teachers A1 and A2 shared that it becomes difficult for them to teach in the improvised laboratory, especially when it is raining, as their voices need to compete with the sound of rain on the roof. Animal production is also a part of the curriculum of School A; however, due to financial constraints, School A would ask the students for contributions to build cages and buy animals such as chicks and pigs. The students will, later on, be taught how to dress the chickens and slaughter the pigs, then take them home.

Three (3) out of seven (7) teachers rated 'moderate extent' for their problems on content knowledge. Teacher A2 related content knowledge not only on the topics that she teaches but also on the teaching strategies. As previously mentioned, Teacher A2 graduated from an engineering course; hence, she assessed that she lacks knowledge on the how-to of teaching. Teacher A2 plans to take education units in University A. Teachers C1 and C3 felt the need for more training or seminar for the reasons of interest in other fields and difference in pre- and in-service specialization, respectively. Teacher C1 wanted to know more about food processing as he thinks that learning how to grow agricultural products is not enough; the students also need to know how to put additional value to their produce. Meanwhile, Teacher C3's pre-service specialization was electrical under HE but is now teaching organic agriculture. He has attended several trainings on organic agriculture before being assigned to teach it.

Table 2 Factors affecting the challenges encountered by the high school agriculture teachers and the extent of its effect

Respondent	Years in teaching	School information	School facilities[a]	Content knowledge[a]	Lack of personnel[a]
School A					
Teacher A1	33	Basic education unit of University A	3	1	3
Teacher A2	7		3	2	3
School B					
Teacher B1	15	Under the management of Department of Education (DepEd)	1	3	1
Teacher B2	40		2	1	1
School C					
Teacher C1	12		1	2	1
Teacher C2	2		2	3	1
Teacher C3	10		1	2	1

Source: Field Survey, 2019
[a](1) Low Extent (2) Moderate Extent (3) High Extent

Teachers A1 and B2, who have been teaching for more than 30 years, rated 'low extent' on content knowledge. Teacher A1 thinks that this problem would have been rated 'high extent' if he were a new teacher, while Teacher B2 uses her own experience in farming as a reference in teaching. The World Bank (2005) as cited by Wongsamun et al. (2012), stated that one of the powerful tools that teachers can use in the learning environment of the students are their local or indigenous knowledge. Conversely, Teachers B1 and C3 rated 'high extent' for their problems on content knowledge. They both felt the need for more training and seminar for different reasons. Teacher B1's pre-service specialization was fish culture, yet he teaches crop production in School B, while Teacher C2 has been teaching in School C for not more than five (5) years. Teacher B1 shared that if the designated topic for the day is too difficult for him to teach due to his lack of knowledge, he will opt not to teach the topic and search for another topic somehow related to it. He also shared that whenever his students ask questions that are too difficult for him to answer, he gives that question an assignment for them. As for Teacher C2, he would ask his co-teachers to explain unfamiliar topics to him.

The lack of personnel was rated as 'low extent' by two (2) teachers and three (3) teachers in Schools B and C, respectively. Since Schools B and C are under the DepEd, along with the implementation of the K to 12 Program is the hiring of non-teaching personnel. The non-teaching personnel are tasked to do administrative works. Teacher B1, on his initiative, maintains their demonstration garden during his free time. Teacher C3 was appointed by their principal to be the canteen coordinator of School C. He also attends to the repair and maintenance of School C's facilities and other things as directed by their principal. Both teachers do not see these works as out of bounds since they think that these come as part of being a teacher.

On the other hand, both Teacher A1 and A2 rated the lack of personnel as 'high extent.' School A is the basic education unit of University A. Therefore, the implementation of K to 12 Program did not affect the hiring of additional personnel to attend to the changes in the curriculum. Teacher A2 needed to take some units/loads from Teacher A1 since the latter was appointed to an administrative position in School A. Both teachers shared that there is only one non-teaching personnel who can assist other subject's laboratories simultaneously. This situation causes a problem for the teachers since they must prepare class materials instead of doing other activities that can contribute to the betterment of their teaching performance. To cope with the lack of personnel, Teacher A1 would have to prepare the materials a day or two before the class.

CONCLUSION

Based on the interviews, only one (1) HSAT preferred teaching as the first choice of profession. However, most of the interviewed HSATs rated 'very high preference' for teaching and teaching agriculture because of developed preferences, stable income, and passion for becoming an educator. In general, HSATs from the University A-managed school rated 'high extent' on both challenges encountered in school facilities and lack of personnel while HSATs from the DepEd-managed schools rated 'low extent' on these challenges. Conversely, HSATs from DepEd-managed schools rated 'high extent' on challenges encountered in content knowledge while HSATs from University A-managed school rated 'high extent' and 'moderate extent.' Therefore, it can be concluded that despite these challenges, the developed HSATs preferences and passion for teaching primarily drives them to ensure that their students learn the know-hows of agriculture.

In this regard, the study recommends that the DepEd provide more accessible professional development activities such as lectures, seminars, or training to HSATs in Schools B and C through partnering with the nearby agricultural universities. At the same time, University A can further extend its assistance to School A by lending a kitchen laboratory used by one of its institutes.

For further study, there is a need to determine the life experiences of the HSATs that developed their preferences on teaching and teaching agriculture. The TEIs can use these life experiences to increase the number and quality of HSATs.

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Research article

Spatial Analysis of Yield Gaps Variability of Black Gram Based on GIS and Geostatistics

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Abstract Black gram, a pulse, is one of the major export crops in Myanmar. Because of a decline in the maximum possible yield of this crop in farmers' fields, a yield gap exists between potential and farmers' yields. Reducing the gap between actual and potential yields is critical for increasing crop production. This study was carried out to generate yield gap mapping, and to investigate the reasons responsible for this yield gap in black gram production. An annual survey was carried out to determine farmers' actual yield at Kyee Inn Village, Pyinmana Township during October 2017 and 2018. Drone photos were consolidated and prepared for digitizing and analyzed with Pix4D software. ArcGIS 10.7 software was used to map the spatial distribution of the yield gap of black gram in the selected area. Yield gaps of black gram with a range of 0.02 t ha^{-1} to 2.70 t ha^{-1} in the two consecutive years were observed. The yield gap between potential and farmers' actual yields (Yield Gap I) was greater in 2018 compared to the 2017 season. The gap between the yield obtained through an organized farm trials and the yield harvested by the farmers (Yield Gap II) was also larger in 2018 than that for the 2017 crop season. A technology gap for the variety Yezin-6 (0.68 t ha^{-1}) was observed in 2018 whereas there were no gaps for Yezin-2 and Yezin-5 in 2017 and non for these varieties in the 2018 post-monsoon season. The reasons these large yield gaps may exist, is probably due to differences in crop management practices used at the experimental stations and those by farmers. The results of this study should provide useful information for policymakers, researchers, extension agents, and other stakeholders to upgrade a location-specific package of practices and increase crop yield by supporting technological solutions and training for the farmers.

Keywords: Black gram, Yield gap, Mapping, Spatial, Potential yield

INTRODUCTION

In Myanmar, black gram (*Vigna mungo* L.) is one of the major exportable pulses and widely sown as a second crop after monsoon rice. The total sown area of black gram was 0.98 million hectares, with a production of 1.38 million tons from 2016 to 2018. Depending on the varieties, the average potential yield of black gram recorded by the Department of Agricultural Research (DAR) is 2.40 t ha^{-1}, whereas the average actual yield of black gram is 1.44 t ha^{-1}(MOALI, 2018). Consequently, a large yield gap exists between the farmers' actual yield and the potential yield as demonstrated at the research station.

Expansion of cropland farmed is probably not a sustainable option to increase crop production so there is a need to increase crop yield on existing cropland, providing sustainable intensification of the current crop production (Forland, 2015). Presently, spatial and temporal variability of crop yields exist across regions, even within the same climatic zones due to different levels of knowledge, different farming practices, technologies, supply chains, and policies in that area (Licker et al., 2010). This has resulted in a spatial variability of the yield gap in black gram production in Myanmar. Additionally, farmers were still facing diverse technological gap in cultivation though there were agricultural modernization in pulse crops.

Analyzing the yield gap using Geographic Information System (GIS) can provide graphic information demonstrating the variability of crop yields and possibly allow for the assessment of the underlying causes of this yield gap, which would then assist in identifying strategies for narrowing these yield gaps (Tran and Nguyen, 2006). Yield gap analysis can help to develop changes in methods of crop production to bridge the gaps between the potential yield of crop variety obtained through an organized farm demonstration during its development in research stations and the yield harvested by the farmers (Jopir and Bera, 2017). It also provides valuable information for decision makers and researchers allowing the development of strategies or action plans for minimizing yield gaps and improving production sustainability.

OBJECTIVE

The objectives of this research were to develop mapping showing the spatial variation of yield gaps of black gram in selected areas to provide information that allows the generation of good production practices for black gram production.

METHODOLOGY

Study site

The research was conducted over two consecutive years of post-monsoon season, in 2017 and 2018, at Kyee Inn Village, Pyinmana Township, Nay Pyi Taw Union Territory, which lies between 19°70'66"- 19°72'62" N and 96°22'43"- 96°25'73" E (Fig 1.). The total study area was 483 ha. The major pulse was black gram which is grown as a second crop after the harvest of monsoon rice. The study area was characterized by low content of organic matter, it has (mostly) low to high levels of total nitrogen and low to medium ranges of total phosphorus, while the level of the CEC is very low to low (Moe et al., 2019).

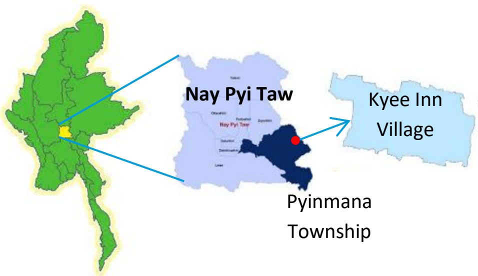

Fig. 1 The study area at Kyee Inn Village, Pyinmana Township

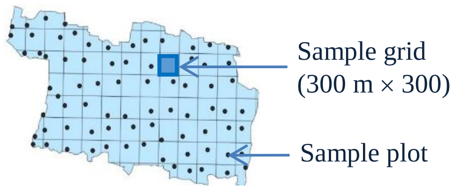

Fig. 2 Sample grids and sample plots taken in Kyee Inn Village

Source: https://myanmar.unfpa.org/…/union-report- volume -3o-nay-pyi-taw-union-territory-re
www.dop.gov.mm/sites/ dop.gov.mm/files/publication _docs/pyinmana_0.pdf

Preparation of sample plots and data collection

The base-map preparation enabling use of ArcGIS 10.7 software was accomplished by data obtained from a DJI Phantom 4 drone, with this processed using Litchi software. The photos were consolidated and processed for digitizing using Pix4D software and incorporated onto the digital base map. The study area was divided into 300 m × 300 m geographic grids. The 92 sample grids were encompassed and 78 of these sample grids were under black gram cultivation (Fig 2).

The 70 farmers cultivating the 78 sample plots were selected as respondents and interviews were conducted to identify variation in average yield and crop management practices in the sample area. The potential yield (Y_P- irrigated conditions) of black gram was provided by the Oilseeds and Pulses Crops Division, Department of Agricultural Research (DAR), Yezin, Nay Pyi Taw. The potential yield (Y_W- rainfed conditions) of black gram was obtained from on farm trials conducted by

Department of Agronomy, at Kyee Inn Village, Pyinmana Township in the 2017 and 2018 (Oo et. al., 2019). The farmers' actual yield (Y_A) was recorded from the respondents in the study area for the 2017 and 2018 crop seasons.

Preparation for mapping

The polygon boundary shapefiles and merged polygon shapefiles were created using the ArcGIS 10.7 software. According to yield gap calculation, point shapefiles of Yield gap I and Yield gap II were prepared for the study area for the two consecutive years. Because of limited number of sample points, the spatial interpolation was conducted by Kriging, it is a geostatistical interpolation method. Maps of the spatial distribution of Yield gap I and Yield gap II was generate through ArcToolbox (Spatial Analyst > Interpolation > Kriging).

Calculations

Yield gap I is the difference between potential yield (Y_P- irrigated conditions) and farmers' actual yield (Y_A) and Yield gap II is the difference between water-limited potential yield (Y_W- rainfed conditions) and farmers' actual yield (Y_A) (Equation 1 and 2).

Yield gap I = Potential yield (Y_P) – Farmers' actual yield (Y_A) (1)
Yield gap II = Water-limited potential yield (Y_W) – Farmers' actual yield (Y_A) (2)

The technology gap (Y_{TG}) was determined as the difference between the water-limited potential yield (Y_W) and the highest farmers' yield (Y_{HF}) (Equation 3). The highest farmers' yield (Y_{HF}) is an empirical concept intended to define the maximum Y_A achieved. Y_{HF} was estimated by calculating the mean of actual yields above the 90th percentile (Silva et al., 2017).

Technology gap (Y_{TG}) = Water-limited Potential yield (Y_W) – Highest farmers' yield (Y_{HF}) (3)

RESULTS AND DISCUSSION

Survey result of yield and crop management practices

In this study area, the farmers' actual yield (Y_A) was in the range of 0.08 to 1.97 t ha^{-1}, for the 2017 and 2018 post-monsoon seasons (Table 1.). Most of the respondents (85%) do not retain residues of black gram after harvesting. About 32% of respondents use optimum seeding rate recommended by DOA. Only 18% of respondents applied urea and compound fertilizers as basally at planting time. There was no evidence of the application of phosphorus and potash fertilizers for black gram production. The most common type of chemical sprayings used by respondents for black gram cultivation were foliar and fungicides and about 12% of respondents follow optimum spraying frequency (4 times for whole season) recommended by DOA. Seed sowing method was broadcasting so that weeding was not done for black gram cultivation in the study area.

Spatial analysis on the variation in yield gap I

The potential yield (Y_P) obtained from the DAR for black gram varieties used in the study area ranged from 1.75 to 2.78 t ha^{-1} while the farmers' actual yield (Y_A) was in the range of 0.08 to 1.97 t ha^{-1}, for the 2017 and 2018 post-monsoon seasons (Table 1.). The Yield gap I of black gram was recorded with the range of 0.73 to 2.70 t ha^{-1} in 2017 and 0.28 to 2.62 t ha^{-1} in the 2018 post-monsoon season (Table 2). The results indicate that variations of Yield gap I occurred during these two consecutive years.

Table 1 Potential yield and farmers' actual yield of black gram varieties in Kyee Inn Village, Pyinmana Township during 2017 and 2018 (post-monsoon seasons)

Variety	Potential yield (Y_P) (t ha^{-1})	Potential yield (Y_W) (t ha^{-1})	Farmers' actual yield (Y_A) (t ha^{-1})	
			2017	2018
Yezin-2	2.15	0.88	0.43-1.42	0.16-1.47
Yezin-5	1.75	0.73	0.16-1.82	0.16-1.47
Yezin-6	2.78	0.93	0.08-1.97	0.16-0.25

A wider Yield gap I of 0.73 to 1.99 t ha^{-1} and 0.81 to 2.70 t ha^{-1} was recorded for the varieties Yezin-2 and Yezin-6, respectively in the 2017 and 2018 post-monsoon seasons (Table 1).

Table 2 Yield gap I and Yield gap II of black gram varieties in Kyee Inn Village, Pyinmana Township during 2017 and 2018 (post-monsoon seasons)

Variety	Yield gap I (t ha^{-1})		Yield gap II (t ha^{-1})	
	2017	2018	2017	2018
Yezin-2	0.73-1.72	0.68-1.99	0.21-0.45	0.23-0.47
Yezin-5	0.80-1.59	0.28-1.59	0.02-0.57	0.08-0.32
Yezin-6	0.81-2.70	2.53-2.62	0.10-0.85	0.68-0.77

The spatial variations of Yield gap I appears to be higher and range from 1.26 to 1.60 t ha^{-1} in 2017 whereas most fields displayed a Yield gap I of 0.91 to1.25 t ha^{-1}in 2018 (Fig. 3). The highest Yield gap I (1.61-1.89 t ha^{-1}) happened in both years, but showed a greater and more scattered pattern in 2017 (Fig. 3). These differences may possibly be due to differences in crop and nutrients management practices between the trial station and the farmer's fields.

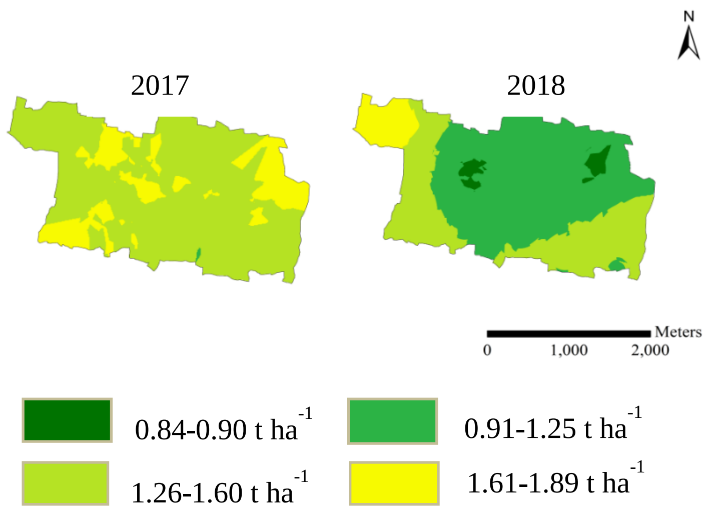

Fig 3. Spatial variations of Yield gap I of black gram in Kyee Inn Village, Pyinmana Township

Spatial analysis on variation of Yield gap II

The Yield gap II varied from 0.02 to 0.85 t ha^{-1} in 2017, and 0.08-0.77 t ha^{-1} in 2018 (Table 2). The variation in Yield gap II across the fields appears to indicate varied crop management practices among black gram farmers in the study area. The trial plantings, used as a base comparison, usually follow recommended crop management practices, especially regarding basal and foliar fertilizers application, weeding, and plant protection measures. However, the potential yield (Y_W) obtained was lower than that of some farmers' actual yield. The Yield gap II ranged from 0.20 to 0.55 t ha^{-1} in the two years (Fig. 4). The larger proportion of the fields had a Yield gap II of 0.26-0.35 t ha^{-1} in 2017 and this gap appear to be larger 0.36-0.45 t ha^{-1}in 2018. The greatest Yield gap II of 0.46-0.55 t ha^{-1} was observed in the 2018 crop season, and such a gap was not present in the 2017 crop. The slight increase of Yield gap II in the 2018 season may have been due to a steady decrease in farmers' actual yield during the study period. The study area was characterized by low content of organic matter, it has (mostly) low to high levels of total nitrogen and low to medium ranges of total phosphorus, while the level of the CEC is very low to low (Moe et al., 2019). According to the results of interviews, farmers in the study area did not apply of phosphorus and potash fertilizers for black gram production and thus, the Yield gap II was resulted for two consecutive years.

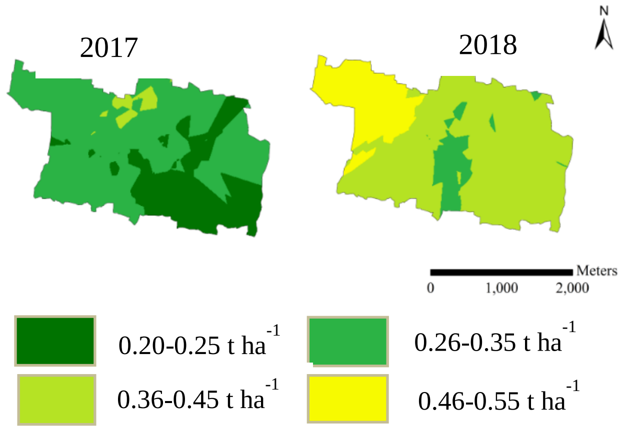

Fig 4. Spatial variations of Yield gap II of black gram in Kyee Inn Village, Pyinmana Township

Technology gap of black gram in Kyee Inn Village, Pyinmana Township

The technology gap represents the difference between the potential yield (Y_W) and the highest farmers' yield (Y_{HF}). The technology gap was not found in the 2017 post-monsoon seasons (Table 3). It was observed only by the variety of Yezin-6 (0.68 t ha-1) in 2018. From 2017 to 2018 post-monsoon seasons, the technology gap was not recorded by the variety of Yezin-2 and Yezin-5. The results indicated that the recommended crop production practices of a black gram would need to upgrade for increasing crop yield in the study area.

Table 3 Technology gap of black gram varieties in Kyee Inn village, Pyinmana Township during 2017 and 2018 (post-monsoon seasons)

Variety	Potential yield (Y_W) (t ha^{-1})	Highest farmers' yield (Y_{HF}) (t ha^{-1})		Technology gap (t ha^{-1})	
		2017	2018	2017	2018
Yezin-2	0.88	1.42	1.19	-	-
Yezin-5	0.73	0.91	1.23	-	-
Yezin-6	0.93	1.32	0.25	-	0.68

CONCLUSION

A crop yield gap was found in most farmers' fields due to their differences in crop management practices including residue management, basal and foliar fertilizers applications, weeding and plant protection measures. Therefore, it is necessary to introduce an appropriate package of production practices for the study area. Farmers should be encouraged to follow the systematic crop management practices as much as possible to increase crop production. As expected, the spatial variation of Yield gaps exists largely due to the differences in the crop management practices used at the experimental stations and those by farmers. The wide Yield gaps were observed in both years. The reason these large yield gaps may exist, is probably due to not applying phosphorus and potash fertilizers to the black gram. Therefore, the results of the study provide useful information for policy makers, researchers, extension agents, and other stakeholders to upgrade location-specific information packages outlining best practice. This study has shown that the use of new technologies such as GIS and Geostatistics can provide important information for evaluating the status of Yield gap of black gram and for allowing location-specific information packages defining best practice for increasing crop production.

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Research article

Effect of Farmers' Attitude and Behavior in Farm Succession in the Philippines

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Abstract Two of the major problems worldwide are the decreasing number of new farmers and aging of existing ones. These problems correlate to the challenges of the increasing demand on safe food and food production of the growing population. Decreased number of new farmers can be associated with the perception of new generations towards agriculture as most of them do not see farming as a lucrative profession. In addition, farming is also known to be a back-breaking, underrated, and undervalued occupation which leads the current farmers to think twice about handing-over their farm to their successors. In order to change the discernment of society towards farming and to boost the confidence of farmers to bequeath their farm to their children, this paper aimed to understand and interpret farmers' attitude and behavior towards farm succession. Specifically, this clarified the farmers' actual situation on the ground, their attitude and behavior, and their family's perception about farming. Organic farmers in Laguna, Philippines, were interviewed and observed. Life History Approach (focused on analyzing of the farmers' lives to farm succession) and Grounded Theory Approach (provided guidelines to identify categories and make links and establish relationships between categories) were utilized. Results showed that farmers had varied perceptions in transferring knowledge and motivations to their successors. Upon being acknowledged in society, most of the farmers' moral were uplifted. They displayed positive attitude and outlook towards agriculture that were reflected through their encouraging behavior to engage their children in farming. Their children were also proud of their farmer-parents. In general, farm succession is one way to ensure agricultural sustainability. In order to do so, situation of farmers on the real ground must be understood through proper interpretation of their attitude and behavior that greatly affect farm succession.

Keywords interpretation, attitude and behavior, farm succession, qualitative, GTA & LHA

INTRODUCTION

Increasing population is synonymous with the significant number of mouths to feed as the food demand also increases. This global problem demands agricultural sustainability to make sure that there will be enough food for all. Agricultural sustainability will not be reached if there are fewer new farmers and an increasing number of aging farmers.

According to FAO (2019), the number of farmers decreased from 41.3% of the world's population in 1995 to 26.7% in 2016. In the Philippines, it decreased from 44.1% to 27.0% in 1995 and 2016, respectively. In addition, Saliot (2013) stated that the food security of the Philippines is at risk, as millions of farmers and fishermen are also aging with an average age of 57 years old. In Japan, one of the greatest factors limiting agricultural sustainability is the shortage of farmers due to the lack of new farmers and the aging of existing farmers, with an average age of 67 years old (Muramoto et al., 2010).

Decreased number of new farmers may be associated with the low morale of farmers as new generations do not see farming as a lucrative profession. In addition, farming is also known to be a back-breaking, underrated, and undervalued occupation, which leads the current farmers to think twice about handing over their farm to their successors. As a parent who endured decades of hardship tilling their land, living in poverty, and being degraded by society, they naturally want their children to have better lives.

Understanding and interpreting farmers' attitudes and behavior can be a possible way to continue farm succession. This study will give the researchers, private, and government institutions the knowledge and understanding of what the farmers need and provide them with the needed technology or innovation. Moreover, policymakers will also be able to make effective and efficient policies and programs.

OBJECTIVE

To change society's discernment towards farming and boost the confidence of farmers to bequeath their farm to their children, this paper aimed to understand and interpret farmers' attitudes and behavior towards farm succession. Specifically, this clarified the farmers' actual situation on the ground, their attitude and behavior, and their family's perception about farming.

METHODOLOGY

This study is a qualitative research based on the interviews and observations of 17 farmers (doing and did OA) and some of their family members in Laguna, Philippines, in August 2017, March, July-September 2018, and July-September 2019. The farmers were selected using Historically Structured Inviting (HSI) and purposive sampling, satisfying the appropriate sample and case requirements. Consent from both parents and children regarding the interviews, observation and the use of data concerning children below 18 years old were acquired. Furthermore, parents were present during the interview.

Life History Approach (LHA), Grounded Theory Approach (GTA), and Trajectory Equifinality Approach (TEA) were utilized. Following Sato et al (2016) TEA, Historically Structured Inviting (HSI) was used as a sampling method, and the Equifinality Points (EFP), and Obligatory Passage Points (OPP) were set. LHA focused on the analysis of the lives of farmers in relation to farm succession. Farmers were asked for their lives' narratives, and these were contextualized, defined, and explained how specific event affects farmers' decisions over time (Hagemaster, 1992). As adopted from Locke (2002) and Glaser (2001), GTA was used in data collection and categorization as it provided guidelines to identify categories, make links, and establish relationships between categories. Trajectory Equifinality Models (TEM) were generated to aid the discussion of LHA. While GTA was used to uncover beliefs and meanings that underlie action and examines topics of behavior from different angles to gain insight and deeper understanding of farm succession.

RESULTS AND DISCUSSION

Farmers' perceptions in transferring knowledge and motivations to their successors

Different factors affect farm successions, such as farm's profile (e.g., land size, accessibility, commodities grown) and farmer's profile (e.g., age, educational attainment, farming experiences). This paper focuses on the farmers' attitude and behavior on transferring knowledge and motivation that affect farm succession. Table 1 shows that most or 13/17 of the farmers are from a farm family, but two of them admitted that even they are from a farm family, they had zero background in farming when they first engaged in agriculture. In contrast, the 11 farmers assisted and were involved in their family farms and later took over the farm. The remaining four farmers were motivated to do farming after learning the importance of farming and organic agriculture (OA). Four out of 11 farmers from a farm-family are still using their farming knowledge obtained from their farmer-parents, while seven of them utilizes the information gained through their attendance to trainings. Those farmers that are not from the farmer-family stated that they got their knowledge on farming from different trainings they attended. Most of the sample participants were motivated to engage, convert, or continue organic agriculture after attending different trainings provided by their municipalities. It was also noted that 12 out of 17 farmers encourage their children to engage in farming. All of the farmers were motivated and adopt or modify specific technology or innovation on OA once in their farming career as some of the interviewed farmers stopped OA, went back to conventional, or stopped farming.

Table 1 Distribution of farmers based on their family background, source of their farming knowledge and experiences, and engaging their children in farming

No. of farmers n=17	From a farm family		From a non-farm family	Total
	w/ farming experiences	w/out farming experiences		
• belongs to farm family or non-farm family	11	2	4	**17**
• that learned their knowledge from family	4			**4**
• attended trainings	7	2	4	**13**
• motivated adopt/modify/ innovations learned	11	2	4	**17**
• that are engaging their children in farming	8	2	2	**12**

Source: Field study in July-September 2019

Results showed that farmers had varied perceptions in transferring knowledge and motivations to their successors. The most common reason that was noted is the safeness of OA to farmers, consumers, and the environment as the farmer-parents want to make sure that their children will be safe in doing farming. Some farmers started farming for their family consumption and chose OA to feed their families with safe food. In time, most of them realized the importance of OA not just for the farmers and consumers but also for the environment. Some also saw the possible opportunity that OA can give them in terms of market and income.

Factors affecting morale and confidence of farmers

Low morale in farming, as it is known to be the underrated and undervalued occupation, especially in the Philippines, was noted as one of the factors why the younger generation does not want to engage in farming. In order to boost the confidence of farmers and change how the young generation perceives farming as a career, farmers' importance must be acknowledged in society. In the research area, it was observed that farmer tends to be motivated by other farmers, they are also confident if farmers, students, teachers, hobbyist, and other actors in the society asked for their help in terms of advice and other farming-related activities. They feel that their opinion matters, motivating them to continue farming and do experiments on their farm. Some of them do OA for their consumers' sake. Upon being acknowledged in society, most of the farmers' morals were uplifted. They displayed a positive attitude and outlook towards agriculture that were reflected through their encouraging behavior to engage their children in farming.

These results responded to the United Nation's Sustainable Development Goals 2, 3, and 12. Goal number 2 or zero hunger will be reached if yields will be increased and stabilized; goal number 3 or good health and well-being; and goal number 12 or responsible production and consumption will be attained if current and future farmers will avoid the use of synthetic inputs and consumers will support them. If current and future organic farmers' morals continue to be boosted, these sustainable goals will also be achieved.

Family members' perception in agriculture

Family perception plays a vital role in boosting the confidence of farmers. Their children were also proud of their farmer-parents. As per the in-depth interview, transcripts from the family members were assessed and help in the understanding of the effects of engaging in OA on the farmer's family. Based on different transcripts, farmers gained positive change in terms of having a better family relationship and gaining self-worth as the farmer can decide on his own and share his experiences and knowledge with others, especially younger generations (Transcript 1 in table 2). Another noted answer focused on the child's personal feelings and preferences, as can be seen in Transcript 2 in table 2. As a 4-year-old son, he requires the attention and affection of his parents, especially his father that he rarely sees and remembers when his father was still working as a security guard.

Table 2 Transcripts from the farmers' family members regarding the effect of farming to their family

Farmers' family members	Transcripts
Trans. 1- Wife of a farmer	"Before, when he was working as a security guard, he usually arrived very late when children were already sleeping. He was also leaving early when his children were still sleeping. He does not even have time to talk and say hi to his children. However, now, it is better. He is his own boss, he manages his own time, and he has time for us. Also, he is free to decide on matters regarding his farm. He is always with us and can still provide for the needs of the family. I also feel proud that students and other future farmers are visiting our farms to learn and to experience farming."
Trans. 2- Son of a farmer	"I like it now. I can always see my Papa. He can play with me now. I can also help him in his work (by weeding and watering plants)"
Trans. 3- Son of a farmer	"I am proud of my mother. I also often do school gardening activities similar to what she's doing on our farm. I can confidently tell my classmates that organic agriculture can be fun and easy if I do what my mom does."
Trans. 4- Daughter of a farmer	"I am happy that my mother is doing better now. She also has more time for us and can help us in school activities."
Trans. 5- Son of a farmer	"Mama is doing better for her customers; she loves farming; even if her body tells her to stop, she will not."
Trans. 6- Grandson of a farmer	"I want to help my Lola (grandmother) in doing activities on the farm, it is fun, but I saw her getting sick because it is hard, so I keep telling my Papa that we should help Lola".

Source: Field study in July-September 2018

Table 2 also shows the interview conducted from a 12-year-old son of a farmer. The grade 6 student is a proud son. During interview, it was observed that the son was shy at first and when ask about the effect of OA to his mother, he positively, and bravely answered that he is a proud son and keeps applying what he learns from her mother to his school's garden (Transcript 3). In addition, a daughter, 10 years old, grade 4 student eagerly answered the effect of OA to her mother (Transcript 4), stating that she is happy for her mom. For these children, they value more the time allotted by their parents with them greatly matters as both parents are working. In addition to the family time that leads to better family relationship, proud children also boost the morale and confidence of their farmer parents.

A transcript from a son, 32 years old and a grandson, age 5 were also distinguished. The son focused on how he sees his mother as a hardworking farmer to meet her goal to provide safe food for her consumer (transcript 5). The grandson's answer, on the other hand, was unique as he saw the hardship of farming (transcript 6) but his grandmother still enjoys it.

It can be concluded that based on the transcripts from the farmer's family members there are significant effects brought by farming aside from providing the needs for their family, farmers particularly improved their family relationships. Moreover, farmers' confidence and morale, were boosted and these improvements were all connected to the positive outlook and support of their family members.

Life History of Farmers Utilizing Trajectory Equifinality Method

To fully understand and interpret the attitude and behavior of farmers that greatly affect their decisions in farm activities, including farm succession, each of their life history was noted and analyzed with the Trajectory Equifinality Model (TEM) as shown in Fig. 1. TEM is a methodology for describing life within irreversible time which is composed of Bifurcation Point (BFP), Equifinality point (EFP) and Trajectory or the life path (Sato, et al.,2013)

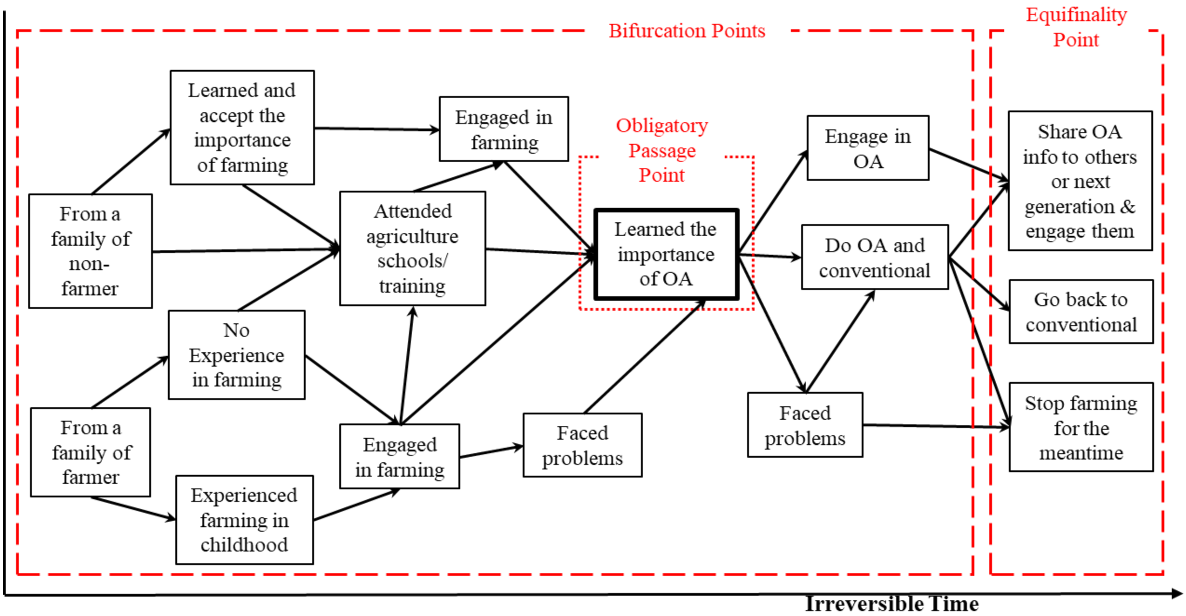

Fig. 1 Life History of the farmers using the Trajectory Equifinality Method (TEM) of selected organic farmers in Laguna, Philippines

For this paper, the bifurcation points are the points in farmers' lives that can leads to different path. The equifinality points on the other hand, are the end point or the end-goal of the farmers' farm career such as sharing OA to the next generation and engaging them, going back to conventional, or stopping farming. In addition, the decision points are the turning points on the farmers' lives (learned the importance of OA and faced problems) which affects their decision in meeting their equifinality points. The obligatory passage point (learned OA) is a point which every farmer experienced.

The 17 farmers were grouped based on five categories based on their starting and equifinality points. The first category has three (3) farmers who were from a family of farmers, two of them with no experience in farming and graduated college with a degree of BS Computer Engineering and a Bachelor of Arts in English, both worked in private companies and retire early to engage in farming. The three (3) farmers attended agricultural training at different point of their lives with different reasons and motivations, learned the importance of OA, engaged in OA, and share OA information to the next generation and persuading and encouraging younger generations in OA. They have different life paths and choices that lead to different bifurcation points but started and ended with the same starting and equifinality point.

On the other hand, the second category comprises seven (7) farmers from the family of farmers, with experiences in tending crops and livestock, assisting their parent family on their farm since childhood. Faced different problems and challenges during their farming life that lead to different life paths, but at certain point of their lives, each of them learned the importance of OA and decided to engage in OA and share it with the next generation.

One farmer belonging in this category chose to change his career from being an employee to be his own boss as he also wants to spend more quality time with his children, as per the interview with his wife, she stated that "he was preparing and leaving early for work, our children were all still sleeping, he will be back late at night from work, and our children were already sleeping." During his childhood, even when he attended an agricultural high school, his father neglected his ideas to be implemented on their farm. After attending OA training, he quit his job and started his own organic farm and executed what he learned from the training and his past experiences. His learnings were shared to his wife and children and later even to students, and other farmers. He also involves his children in farming by allowing them to do simple tasks like watering and weeding. In addition, being unheard and disregarded during his childhood while helping in his father's farm, he is now making sure that his children can try and voice-out their thoughts while assisting him in their farm.

Farmers on the third category are the two farmers who are from a family of farmers, with experiences in farming, they were doing farming, attended some trainings and learned the importance of OA. Unfortunately, even though they know the importance of OA, they just decided to stop farming when they faced problems while doing organic farming. According to the interview, both have problems managing their time as they were hired in a full-time job. For them, OA is very laborious and time consuming, even they are aware of the health benefits of growing and consuming organic produced, they chose to stop doing it and stated that if there will still be chance for them to do it after their retirement, if their body can still do the farm activities, they might go back to farming.

Likewise, the fourth category involves a farmer who is also from a family of farmers. The farmer's spouse is also a farmer. Both experienced farming during childhood and later in life engaged in farming, they also attended training related to agriculture and learned the importance of OA, they did OA and conventional, but after trying and experiencing the increased input in terms of labor, they gave up OA and go back to conventional farming. They stated that they tried their best in doing and managing OA, but regrettably, OA is not for them as it is too labor-intensive and requires too much time on the field.

Four farmers constituted the fifth category. They are the farmers who are from the families of non-farmer, learned the importance of farming and/ or attended agriculture training, engage in farming, learned the importance of OA, engage in OA, and share OA information to family members and other actors in the community including the next generation.

These categories gave us a clear picture of the life history of farmers with the aid of TEM. It also gave us background on how each point of farmer's life affects their decision making in farm activities and farm succession in terms of their attitude in information sharing and engaging younger generations in farming.

CONCLUSION

Farm succession is one way to ensure agricultural sustainability. Thus, the situation of farmers on the real ground must be understood through proper interpretation of their attitude and behavior that greatly affect farm succession. Common factors such as farm's profile, farmers' perceptions in transferring knowledge, and motivations related to farm successors are essential. Different farmers can also be understood through the utilization of TEM. TEM assisted the researchers see each farmer's life history and how each point of life affects their decision to continue and hand over their farms to their successors.

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Research article

The Challenges of Agribusiness Training on Livestock Farmers in Namibia

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Abstract Although contributing only less than five percent to GDP, agriculture remains one of the top employers in Namibia, with livestock production being the top earner. The national agriculture policy has highlighted the lack of capacity as one of the constraints in the industry. Both private and public training institutions in Namibia have had numerous training such as rangeland management, farm infrastructure, and animal health, and seldom focus on the postproduction activities such as markets and marketing. This study aimed to assess the challenges of agribusiness training in Namibia as identified by livestock farmers. An in-depth literature review on Namibian agribusiness training looking at national policies that address agricultural training and farm survey using a structured questionnaire was conducted. The 33 respondents were from three regions of Namibia: Erongo, Omaheke and Otjozondjupa regions, and three land tenures: communal, commercial, and resettlement farms. Natural phenomena including drought and lack of water were crucial challenges identified by livestock farmers. Other challenges such as access to markets, few buyers in the market, and lack of coordination were among the critical agribusiness factors highlighted by most farmers. Commercial farmers were the main market of communal livestock which are considered of low quality. Communal livestock farmers lamented the lack of market options available. Thus, Namibia needs to implement a training policy that captures aspects of livestock marketing that integrates various levels of farmers from communal to the commercial level.

Keywords agribusiness training; Southern communal area; communal farmer; resettlement farmers

INTRODUCTION

Namibia is a vast, middle-income developing country in Southern Africa. Located between two deserts, the country is the driest south of the Sahel, characterized by sporadic rainfall and frequent drought. Despite these factors, agriculture is a major industry in Namibia. Agriculture uses more land than any other activity (approx. 78% of the country is farmland), and nearly 1.2 million people (roughly 206,000 households) live on farms and/or in rural areas. Agriculture is the second main source of income for many households in Namibia (Namibia Statistics Agency, 2013) and remains one of the top employers in the country in both the formal and informal sectors (Namibia Statistics Agency, 2015). The following characterize agriculture: small scale mixed farming, cattle ranching, small stock farming and commercial crop production and other intensive agriculture (Mendelsohn, 2006). Cattle ranching is Namibian's main agricultural production sector, with an estimated value of N$ 900 million (approx. 56 million USD), 44.4% of which accounted for weaner exports (Enkono et al., 2013). Livestock production includes cattle, sheep, goats, and pigs.

Despite all these factors, agricultural contribution to GDP has been less than 5% (MAWF, 2017) (Fig 1). Several factors attributed to this include the country's well-diversified economy and high production by other sectors. The specific challenges of agriculture however are the low agricultural capacity because of aridity and poor soils and the low demand within Namibia and elsewhere for Namibian products due to the lack of market development in most communal areas and the relatively low value-added through local processing (MAWF, 2015).

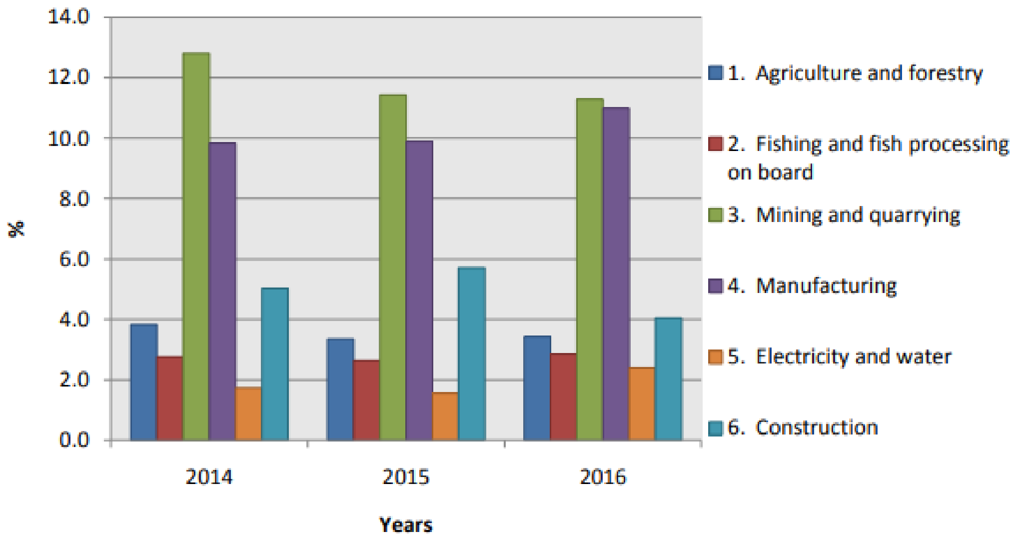

Fig.1 GDP by Primary and Secondary Sectors at Current Prices – Percentage Contribution
Source: Ministry of Agriculture Water and Forestry, 2017

Namibian agriculture is agrarian in nature, with many households depending on their crops and livestock for part of or all their income and/or nutritional needs. A key distinctive factor of the sector is its dualistic in nature with a highly developed, technology-based, and productive commercial sector and a subsistence sector characterized by low productivity dependent on manual labor and use of traditional methods of production (Namibia Training Authority, 2013) often referred to as communal farming. The communal land system is a remnant of the duality applied to land tenure by the apartheid pre-independence system. Black communities had to stay in small areas, often away from cities and share resources such as land and water. Traditional livestock rearing in Namibia is characterized by low productivity due to low calving rates, high mortality, and low off-take rates for meat and milk (JICA, 2017). Historically commercial farmers enjoyed considerable support from the government through direct assistance – such as subsidies, extension, and veterinary services – and indirectly because of the development of transport, marketing, and other services (Schmokel 1985).

At independence, studies found that farmers in the communal areas, farmers often lacked adequate agribusiness skills to make them competitive in modern agriculture (Ministry of Agriculture, Water and Forestry, 2015).

In its 2013 inaugural report, the Namibian Training Authority (NTA), the country's regulator for vocational education and training, developed the agricultural sector skills plan (SSP) to inform the agricultural sector of Namibia on the skills needs for the sector (Namibia Training Authority, 2013). This SSP set the blueprint for training in agriculture. This SSP focused on the demand for vocationally skilled labor, specifically on the primary agricultural sector, and excluded occupations of a generic and general nature which do not relate specifically to the sector. This SSP found that reliable data on qualification and skill profiles in the agricultural sector remains scarce as most studies and surveys have focused on the commercial sector (Namibia Training Authority, 2013). This is supported by studies stating that training in developing countries often focuses on production without taking cognizance of post-production activities (Mabeya et al., 2010). Hence, capacity-building exercises also often target commercial producers and professionals leading to a skills shortage in rural (communal) areas.

OBJECTIVE

Due to the highlighted factors, the objective of this study is to identify the challenges farmers face given the current agribusiness training offered in the country. Further, this study looks at findings from farmers in all three-land tenures in the country.

METHODOLOGY

Study area

This study was conducted in three regions within the Southern Communal Area: Erongo, Omaheke, and Otjozondjupa, where a combination of livestock farming takes place. A veterinary cordon fence was erected in 1896 under German colonial rule to contain a Rinderpest outbreak, resulting in the splitting of Namibia into two livestock farming zones: Northern and Southern Communal Areas.

Method of the study

This study utilized both qualitative and quantitative data. Secondary data was sourced from publications from line ministries involved in agriculture, which are the Ministry of Agriculture, Water and Forestry, the Ministry of Land Reform, and the Ministry of Industrialization and Trade, as well as documents from parastatals (refers to government-owned agencies): Meat-Board of Namibia, MeatCo (Meat Company) Namibia and the Namibia Statistics Agency. Primary data were collected from a structured questionnaire administered to livestock farmers from all land tenures (e.g., communal, commercial, and resettlement farmers) in the country in August 2019. A total of 33 livestock farmers were surveyed through convenient sampling. The questionnaire aimed to collect farmers' views on agribusiness training in the country, including what they believed were the challenges in agriculture, training, and livestock markets. It should be noted that this study is essentially a qualitative literature review, that not only considers findings from the three regions but relies on historical findings and supporting studies on Agricultural training in Namibia.

RESULTS AND DISCUSSION

Training access and content

Prior to the inaugural SSP report in 2013, Namibia conducted baseline surveys on the impact of extension services in all regions. These surveys tried to address whether impact can be proven and to whom this impact is felt (Ministry of Agriculture, Water and Rural Development, 2003). These surveys looked at advisory services, information, communication, and farmer training, and can be considered the most significant for looking at communal areas as extension services address all farmers. These surveys are also critical for assessing training access in terms of government extension services which are offered at no cost but vary in frequency and location (distance from training area), and these can be seen as challenges.

The most significant research on training access and content for Namibia in recent years is the SSP, which aimed at addressing all Technical, Vocational Education and Training (TVET) in the country by looking at factors affecting training and all the key role players. This SSP was a consultative process, to match demand and supply of Agricultural Technical and Vocational Education and Training (ATVET), the skills needed mainly include production side (e.g., anatomy and physiology, farm production). Farm management, another sub-category of the trainings, includes business planning and entrepreneurial skills, marketing skills, record keeping and administration, financial management skills, people management and management as well as transport and stores management (Namibia Training Authority, 2013). These are the skills considered to scale up farmers entrepreneurship (Schulleri, 2013). According to the TVET studies, the demand for training is high and diverse but providers are few thus there is a need to prioritize on the training needs. It is important to note that “agribusiness” is rarely explicitly mentioned in most documents, and often “agricultural training” and “marketing” and most other “finance” related terminology are the terms used to capture these critical skills.

Assessment of ATVET provision found numerous challenges including incapacity of trainers, limited training institutions, and inadequacy of practical training facilities and equipment. The government through the NTA has agreed to adopt the Competency Based Education and Training (CBET) approach to vocational training which places a high demand on the ability of the training provider to provide practical training opportunities wherein trainees can develop practice and demonstrate competence very few institutions currently can offer.

Farmer-respondents and training

Respondent profiling was done in terms of age, gender, education level, occupation sector, monthly income. Majority of the 33 farmer-respondents were male (72.7%) and were between the ages of 50-59 (36.4%), closely followed by 60-69 age group (33.3%). The education level for more than 50% of farmer-respondents was undergraduate degree and post-graduate degree levels, with 30.3% and 27.3 % respectively. Most of the farmer-respondents were full time employees in public and private sector with 18.2 and 45.4% respectively. Most of the surveyed farmers had over 21 years of farming experience, many of whom consider themselves communal farmers. Table 1 shows the detailed results of the farmer-respondents’ socio-economic profile.

Table 1. Socio-economic profile of farmer-respondents (n=33)

Socio-economic characteristic	Frequency	Percentage	Socio-economic characteristic	Frequency	Percentage
Age			**Annual Income**		
Less than 40 yr. old	3	9.1	50,000 N$ and less	3	9.1
41-50 yr. old	6	18.2	50,001-100,000	8	24.2
51-60 yr. old	12	36.4	100,001-300,000	7	21.2
61-70 yr. old	11	33.3	300,001-500,000	6	18.2
Above 70 yr. old	1	3.0	500,001-above	9	27.3
Gender			**Household size**		
Male	24	72.7	1-5 persons	18	54.5
Female	6	27.3	6-10 persons	14	42.4
			11 persons and more	1	3.0
Marital Status			**Farming experience**		
Married	25	75.8	1-5 years		
Single	8	24.2	6-10 years	1	3.0
			11-15 years	8	24.2
			16-20 years	4	12.1
			21 years and above	6	18.2
				14	42.4
Education			**Type of Farming**		
Postgraduate	9	27.3	Communal	16	48.5
Undergraduate	10	30.3	Commercial	12	36.4
Diploma	4	12.1	Resettled	5	15.2
Other	10	30.3			
Occupation					
Employed	21	63.6			
Self-employed	5	15.2			
Pensioner	7	21.2			

Source Field Survey, August 2019

Out of the 33 farmers surveyed, 25 had attended some form of training as seen in Table 2, yet two were aware of training and opted not to attend any, the remaining six were unaware of any available training and therefore had not attended any. Of the trained farmers, 12 farmer-respondents attended training identified by the farmers’ organization or ministry involved. The training institution mostly identified was government extension services provided by the ministry. Government extension training is offered on an ongoing basis through advice and farmer support services. This type of training is mostly done in the field by the extension staff and is usually not of a structured nature and is not standardized (Ministry of Agriculture Water and Rural Development, 2003 and Namibia Training Authority, 2013). Some attended training with MeatCo which provides training mainly to livestock farmers. Agribank of Namibia also offers training through its Agri Advisory Services, which offers various content packages, from financial to rangeland management, however these are often for those in urban areas or those that can attend farm excursions which is not necessarily available to all farmers. Farmers also attended training with Agrifutura, although they could not provide the training content, the institution offers training and farm visit (site-led) training on livestock management; livestock marketing; farm finances; animal health; rangeland and pasture management. Few farmers mentioned attending training provided by Agra ProVision. This is perhaps the costliest of the ATVET institutions in Namibia, its courses are tailormade and includes mentoring. Their course content ranges across the entire plethora of farming and management. The SSP has stated that Agra ProVision is one of the few institutions with the capacity to offer adequate training, its biggest constraint is resources to pay for such services.

Table 2. Awareness and participation to training

Characteristic	Frequency (n=33)
Aware of training, attended training	25
Aware of training, did not attend training	2
Unaware of training, did not attend	6

Source: Field Survey, August 2019

Although the available trainings ranged from basic livestock management to range management (as supported by Mabeya et al., 2010), it is evident that training is often production-oriented leaving a capacity gap in post-production activity. Moreover, this study found that livestock farmers, even those receiving some form of training experienced various challenges (Table 3).

Table 3. Agricultural challenges identified by number and tenurial type of farmers

Challenges identified	Commercial (n=12)	Communal (n=16)	Resettlement (n=5)
Environment-related			
Bush Encroachment	0	0	1
Drought	1	1	1
Increase in number of wildlife	0	1	1
Lack of grazing	0	1	1
Water shortages	0	1	1
Livestock technology			
Animal health	1	1	1
Quality of livestock	1	0	0
Market-related			
Few auctions/uncoordinated auctions	1	1	0
Few buyers/monopolies buyers	1	1	0
High cost of transport	1	1	0
Low market access	0	1	0
No direct marketing channels	1	1	0
Poor prices	1	1	1
Policy environment			
Few regional farmers' organizations	0	1	0
High interest loans	1	0	0
High land prices	1	0	0
Lack of capacity	1	1	1
Lack of information	1	1	1
Low government support	1	0	0
Permit bureaucracy	0	0	1

Source: field survey August 2019

Note: 1 implies that farmers agree this is a challenge and 0 implies farmers did not agree that this is a challenge. For each challenge all farmers from that tenure agreed the factor is a challenge.

Environment related challenges

All farmers identified drought as being a major threat to livestock agriculture in Namibia, the Ministry of Agriculture, Water and Forestry (2015) highlighted this as one of Namibia's major agricultural constraints as the country has had a severe drought over consecutive periods since 2013. This has worsened water shortages, especially in communal areas where farmers share resources including land and water with each other and the growing amount of wildlife. Farmers in communal areas are increasingly facing challenges of reducing grazing pastures as more areas are being fenced off by well to do families, leaving less land available for open grazing (Togarepi et al., 2016). Livestock grazes on open access commonage pastures and woodlands. The practice of transhumance has declined in recent years. Farmers also alluded the high cost of land in Namibia.

Livestock technology

Animal health was identified by all farmers as a common problem which explains why one of the main trainings on offer is on livestock health. Musaba (2010) found that increased technology adoption is only possible through capacity development, his findings show higher adoption rates for farmers located closer to extension officials. This clearly shows the importance of extension services and the need for frequency of training for livestock farmers. The SSP also identified 40 areas of skills demanded in agriculture through consultation with farmers and other key stakeholders (Namibia Training Authority, 2013), these skills are were ranked from 5 to 1 on importance. Those skills pertaining to livestock technology all ranked 3 to 5 which is high ranking.

Market challenges

The low prices, small number of buyers, and few uncoordinated auctions point to livestock market challenges. The Namibian market is small due to the country's low population with the only lucrative markets being in urban areas. Many farmers stressed how difficult it was to make a profit in livestock farming due to numerous cost constraints including the price of stock feed, high cost of transportation to markets and few auctions and buyers available in the country. Most farms are located far from markets thus prices of farm products are often also high to cover variable costs, including transport. Similarly, perishables, like meat and meat products require costly cooling or other special storage facilities, which are not readily available in rural areas. Farmers predominantly sell to a single buyer or speculator, a situation which has created monopolies within the sector, as one commercial farmer stated, "Farmers have few options but to sell to a middleman," conveying that they are often price takers.

Policy environment

One of the key factors that play a major role in livestock market participation by farmers has been found to be "business orientation by the smallholder livestock farmers" (Zuwarimwe and Mbaai 2015) which highlights a need for capacity in the industry as identified by all the farmer-respondents. Another common policy problem was the lack of information among or within the agricultural sector. Agricultural policy decision are made, without involvement of the primary recipients – the farmers (Kumba, 2003).

CONCLUSION AND RECOMMENDATIONS

Farmer-respondents clearly identified agricultural sector challenges in the country, including their personal farming challenges. Literature review of the SSP also highlighted challenges of the training. Together these sketch a foundational analysis where the two can be used to further study training needs and agricultural challenges' convergence to improve the sector. It was found that the livestock production, although dominating the Namibian agriculture sector, is faced with a myriad of challenges, some, such as drought and climate variability are beyond anyone's control. However, most of the training offered to farmers by institutions, including government extension, is production centered, yet the measures to integrate farmers into greater markets are very few. Farmers need to be given adequate training on how to market their livestock independently. Farmer capacity development cannot be the sole responsibility of the government; the private sector needs to be involved. Farmers need to be equipped with the necessary skills to cope with ever-changing environments and operate their farms more efficiently. To enhance livestock productivity in rural communities, better farm management practices should be adopted.

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Research article

Visitor Perception and Economic Value Estimation of Mekarsari Fruit Garden as Agritourism Destination in Indonesia

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Abstract With abundant natural and cultural resources, Indonesia has great potential in the tourism sector significantly contributing to GDP. To achieve its long-term benefits, there is a need to address tourism development, focusing mainly on how to create various types of tourism combined with education and the environment, such as agritourism. Mekarsari Fruit Garden (MFG) is Indonesia's largest agritourism destination and education, research, and training center for horticultural plant germplasm. Although MFG experienced a 70% drastic decrease in visitors in 2013, visitors started to increase in 2014. However, MFG has not reached the same number of visitors as its peak years. This study aimed to determine visitor perception and agritourism economic value of MFG in Bogor Regency, West Java, towards finding sustainable and innovative ways to increase visitors and expand the business. Specifically, this study aimed to identify visitor characteristics and their perception of MFG using factor analysis, determine the frequency of visits and economic value using the travel cost method, and formulate the sustainable development plan for MFG. A questionnaire survey of 321 visitor-respondents and key-informant interviews of MFG executives were also conducted. Factor analysis on visitor perception identified three factors: (1) location, facilities, and agritourism operation characteristics, (2) agritourism attractiveness characteristics, and (3) agritourism support characteristics. Moreover, the travel cost method revealed that MFG had a high economic value amounting to Rp 107 billion per year. As a recommendation, MFG should continue its operations and improve its facilities and services offered due to prevailing high economic value and the willingness of its visitors to pay more, in addition to its significant role as the preservation and education center of tropical horticulture in Indonesia.

Keywords Agritourism, Factor Analysis, Travel Cost Method

INTRODUCTION

As a tropical country with abundant natural and cultural resources, Indonesia has great potential in the tourism sector, significantly contributing to GDP. World Travel and Tourism Council (2018) reported that travel and tourism generated Rp 787,100 billion (5.8% of GDP) and created 12.2 million jobs (10% of total employment) in 2017. The World Tourism Organization (WTO) refers to the economic importance of tourism for future growth, employment, and development (WTO, 2003). The Indonesian tourism sector is one of the sectors with a positive revenue earning, based on the contribution of foreign tourists and domestic tourists spending generated 58.7% of direct travel and tourism GDP in 2017 compared with 41.3% for foreign visitors (World Travel and Tourism Council, 2018).

Along with the increasing public interest in tourism, the tourism sector could provide long-term benefits if the management carried out sustainable and environmentally (OECD, 2020). Therefore, there is a need to address the development of the tourism sector, focusing mainly on creating various types of tourism combined with education and the environment, such as agritourism. There are many definitions of agri-tourism and many types and terms of agriculture-related tourism that are similar to agri-tourism. For example, agri-tourism is identical to "farm tourism" (Busby and Rendle, 2000; Getz and Carlsen, 2000). Agri-tourism and rural tourism are not the same. Agritourism may be seen as a segment within rural tourism (Roberts and Hall, 2001; Wilson et al., 2001). Rural tourism, agritourism, and active tourism are directly connected to rural areas (Hegarty and Przezborska, 2005). Agritourism refers to commercial enterprises offering festivals and educational events related to agricultural production and processing through tourism. These enterprises attract visitors onto a farm, ranch, or other agricultural business to entertain and educate the visitors and generate income for the farm, ranch, or business owner (McGehee and Kim, 2004; The National Agricultural Law Center, 2018). Thus, opportunities for agritourism development offer the tranquility and natural atmosphere of an agricultural area to attract many tourists. Integrating agriculture (agri-industry) and tourism in a particular undeveloped region's economic development planning can be considered an alternative (Satriawan, 2005).

Located in Bogor Regency, West Java Province, Mekarsari Fruit Garden (MFG) has been the venue to cultivate, preserve and showcase Indonesian tropical horticulture since 1995. However, MFG has experienced a drastic decrease in the number of visitors. From the peak year at 1.6 million visitors in 2008, the number of visitors has decreased ever since. Due to the global crisis, MFG also experienced a drastic 70% decrease in visitors in 2012 and 2013. Although the MFG manager had a target to attract 1 million visitors in 2014, MFG has had around 200,000 visitors per year since 2016 (Mekarsari Fruit Garden, 2018), conveying that this is the most crucial issue to be addressed immediately.

OBJECTIVES

This study aimed to identify characteristics of visitors and their perception of MFG using factor analysis, determine the frequency of visits and economic value in MFG using the travel cost method, and formulate the sustainable development plan for MFG.

METHODOLOGY

This study utilized primary data from a questionnaire survey, key-informant interviews, and direct observation in August 2018, with a preliminary survey in February 2018. There was a total of 321 domestic tourist respondents.

Factor Analysis

Factor Analysis (FA) was utilized to determine visitors' perception towards MFG. The Travel Cost Method (TCM) was used to estimate the economic value and development of MFG tourist activities. Principal Component Analysis (PCA) and FA are statistical techniques applied by researchers when there is a need to find which variables are related to one another. Variables correlate with each other but are independent with other subsets, a combination of variables in the factor. Factors reflect the underlying process that correlates with variables (Bus-Umar, 2009).

Travel Cost Method

TCM is used for calculating the economic values of environmental goods or services. It is mainly applied for determining the economic of recreation. It can also serve as a basis for evaluating how an increase in entrance fees will affect the number of visitors. Peoples' willingness to pay for a site visit is thus estimated based on the number of trips they make at the different travel costs. This is called a revealed preference technique because it ‘reveals’ willingness to pay based on consumption behavior visitors (Healy et al., 2013).

Individual TCM is the best tool to estimate the value of the recreational costs incurred by the visitors to visit the place. Thus, an increase in travel costs is expected to decrease the number of visits by the visitors. Researchers use this inverse relationship between travel cost and the number of visits to map/design a travel demand function of the place of interest. Then from the demand function, the consumer surplus is calculated, representing the recreational value of the place of interest (Alam et al., 2017).

RESULTS AND DISCUSSIONS

FA revealed that visitors' perceptions of facilities are essential to make MFG one of the best examples of agritourism in Indonesia. The results of FA processing and Promax rotation are shown in Table 1.

Table 1 The result of factor analysis of visitors' perception

	Factor 1	Factor 2	Factor 3	Average	SD
Access to location	**0.892**	-0.197	0.207	3.794	0.501
Security	**0.859**	0.083	0.045	3.829	0.466
Tourism object management	**0.775**	0.121	0.093	3.838	0.480
Can eat and pick up the fruit directly	**0.696**	0.370	-0.092	3.844	0.468
Educational activities	**0.670**	0.164	0.176	3.850	0.477
Farm tour	**0.562**	0.190	0.270	3.838	0.473
Facilities and infrastructure	**0.542**	0.062	0.421	3.841	0.477
Support local economy	**0.533**	0.433	0.035	3.841	0.477
Petting zoo	**0.530**	0.253	0.203	3.841	0.477
Location hygiene	**0.521**	0.114	0.357	3.835	0.469
Trash can	**0.463**	0.139	0.416	3.847	0.466
Spend time with family	-0.193	**1.028**	0.129	3.885	0.496
Experience	0.132	**0.934**	-0.117	3.879	0.482
Family atmosphere	-0.136	**0.894**	0.211	3.866	0.498
Fresh fruit	0.383	**0.720**	-0.133	3.860	0.450
Quality	0.270	**0.668**	0.074	3.860	0.457
Price	0.304	**0.586**	0.110	3.847	0.452
Support local agriculture	0.367	**0.519**	0.128	3.860	0.464
Convenience	0.404	**0.507**	0.118	3.841	0.464
Learn or be taught how fruits is produced	0.458	**0.480**	0.086	3.850	0.450
Natural panorama	0.205	**0.468**	0.253	3.879	0.507
Souvenir kiosk	0.030	0.088	**0.904**	3.841	0.503
Toilet	0.404	-0.707	**0.659**	3.841	0.503
Restaurant	0.147	0.259	**0.613**	3.835	0.488
Proportion var	0.244	0.235	0.105		
Cumulative var	0.244	0.479	0.584		

Sources: Field Survey, 2018

Factor 1 comprises the visitor's perception of the "Location, Facilities and Agritourism Operation Characteristics." Factor 1 was the main reason why visitors chose to visit MFG rather than other tourist attractions. Specifically, "Can eat and Pick up the Fruit Directly from the tree" was the main reason that made MFG distinct from other tourist attractions and the main attraction of MFG. Factor 2 is about "Agritourism Attractive Characteristic." Factor 2 revealed that visitors could enjoy natural panoramas, spend time with their family and friends, and have a family atmosphere that cannot be found in other tourist attractions. Factor 3 is about "Agritourism Support Characteristics." Factor 3 can be considered the additional factor/reason for traveling to MFG, conveying the importance of improving its restaurants or souvenirs kiosk to attract visitors further. Improvements may include menu development for restaurants related to increasing usage of fresh fruit ingredients, facility renovation, the introduction of new souvenirs, and branch establishment of restaurants or souvenir kiosks outside MFG or nearby areas. It would be more effective if these improvements were Instagram or SNS-worthy.

The recreation demand model at MFG was carried out to estimate the effect of several socio-economic variables on the frequency of tourist visits using a zero-truncated Poisson regression model. Table 2 shows the results of Poisson regression analysis with a p-value of less than 0.05, conveying that the opportunity to reject the equation model was minimal and the occurrence of errors was very minimal. The regression coefficients that influence the frequency of visits (Y) were travel cost (X1), transportation by bus (D3), and accompany with friends (D4) at 1% level of significance, while public transportation (D1), accompany by family (D4), and no accompany (D6) at 0.1% level of significance. The zero-truncated Poisson regression analysis results indicated that five variables influence the chances of the average number of MFG visits.

Table 2 Result of Poisson regression analysis

	Coefficients	Z value	P value	
Constant	-0.166	-0.346	0.729	
Travel cost	-1.909×10^{-6}	-2.456	0.014	*
Income/month (IDR)	-1.193×10^{-8}	-0.520	0.603	
Transport by public (Yes:1, No:0)	0.840	3.227	0.001	**
Transport by car (Yes:1, No:0)	-0.167	-1.159	0.246	
Transport by bus (Yes:1, No:0)	1.039	2.143	0.032	*
With family (Yes:1, No:0)	1.325	3.011	0.003	**
With friends (Yes:1, No:0)	1.163	2.562	0.010	*
No accompany (Yes:1, No:0)	1.345	2.832	0.005	**
Marital status_NM (Yes:1, No:0)	-0.139	-1.095	0.273	
Smpl	311			
Log L	-404.577			

Source: Field survey, 2018. Note. Signif codes: 0.001 (**), 0.01 (*)

a. Travel Cost

Based on the results of analysis using Poisson regression, it is known that the probability value of actual travel costs at the 1% level conveys that the travel costs significantly affect the number of visitors. The coefficient value, which has a negative sign (-1.909b×10-6), indicates that the higher the value of travel costs will further reduce the number of goods consumed. This negative sign result had similarities with Khoshakhlagh et al. (2013). Therefore, travel cost seemed to be a significant factor in the decision to carry out recreational activities.

b. Public Transportation

The variable public transportation explains how much the availability of public transportation affects the frequency of visitor visits. Results showed that the variable had a positive coefficient with 0.1% level of significance, conveying that the more a person visits MFG by public transportation, the higher the chances of visiting again in the future.

c. Transportation by bus

Most visitors (group of friends or family members of more than ten people) come to MFG by bus (public transportation). Bus transportation is considered more effective to bring many visitors or bring visitors who come in a group. Results showed that the variable had a positive coefficient with a 1% level of significance, conveying that the more a person visits MFG in a group using bus transportation, the higher the chances of visiting again in the future.

d. Accompany with Family

Accompany with family had a positive coefficient with a 0.1% level of significance, conveying that the more a person visits MFG with their family, the higher the chances of visiting again in the future. Results showed that 54% of visitors visited MFG together with their families.

e. Accompany with Friends

Visiting with friends had a positive coefficient with 1% level of significance, conveying that the more a person visists MFG together with their friends, the higher the chances of visiting again in the future.

f. No Accompany/Alone

Variables of visiting to MFG alone had a positive coefficient with 0.1% level of significance, conveying that the more a person visit MFG alone, the higher the chances of visiting again in the future.

Determination of the total economic value of MFG is based on the surplus consumer value estimated from the previously formed recreational demand function. Consumer surplus on total visits per individual can be measured through the formula:

$$CS = -\frac{N^2}{2b1} \tag{1}$$

Whereas,
CS =Consumer Surplus (Rp/person), N =Frequency visits per person, b1 =Coefficient from variable travel cost from Table 2.

$$CS = -\frac{1}{-1.909\ x\ 10^{-6}} = Rp\ 523{,}834 = \$36.421\ US\ dollars \tag{2}$$

The consumer surplus concept is an indicator of visitors' ability who still want to pay more than the current one. Based on the calculation above, the surplus consumer value per individual per year was Rp 523,834 ($36.421, exchange rate on January 2019: 1 US dollar = 14,382.51 rupiah). Therefore, consumer surplus in a year (calculated based on 205,108 people in 2017) was Rp 107,442,640,126 ($ 7,470,368.581). This economic value of MFG conveys its high economic value. Therefore, the MFG should continuously carry out the management and operations of its facilities and infrastructure.

CONCLUSION

This study aimed to determine visitor perception and agritourism economic value of MFG in Bogor Regency, West Java, towards finding sustainable and innovative ways to increase visitors and expand the business. Visitor's perception can be divided into three factors: factor 1 as "Location, Facilities, and Agritourism Operation Characteristics" was the main reason why visitors choose to visit MFG rather than other tourist attractions, for example, can eat and pick up the fruit directly from the tree; factor 2 as "Agritourism Attractive Characteristics," which attracts visitors to visit MFG (e.g., can enjoy natural panoramas, spend time with their family and friends, and have a family atmosphere that cannot be found in other tourist attractions); and factor 3 as "Agritourism Support Characteristic" that can be considered as an additional reason for MFG visit, conveying that the improvement of services and facilities in the restaurant and souvenir kiosks should be prioritized to attract visitors further or encourage an increase in frequency visit. Improvements may include menu development for restaurants related to increasing usage of fresh fruit ingredients, facility renovation, the introduction of new souvenirs, and branch establishment of restaurants or souvenir kiosks outside MFG or nearby areas.

Travel costs, public transportation, transportation with bus, accompany with family, accompany with a friend, and accompany alone significantly influenced the frequency of visits to MFG. Travel cost method revealed that MFG had a high economic value amounting to Rp 107,442,640,126 ($ 7,470,368.581, exchange rate on January 2019: 1 US dollar = 14,382.51 rupiah) per year. Annual consumer surplus value per individual was estimated at Rp 523,834 ($36.421). Therefore, the MFG should continue its operations and improve on its facilities and services offered due to its high economic value and the willingness of its visitors to pay more for its facilities services, in addition to its significant role as the preservation and education center of tropical horticulture (fruits) in Indonesia.

We acknowledge that our study has a number of limitations because all respondents in our research are domestic tourists, for future research, it would be better if we could combine opinions about MFG from foreign tourists with domestic tourists so that MFG can develop better and be widely known by all foreign tourists. With the global recognition of MFG, Indonesia's tropical fruits will be sustainable.

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Research article

The Effects of the Application of Compost and Chemical Fertilizer on the Growth and Yield of Rice (*Oryza sativa L.*)

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Abstract The addition of compost to the soil can increase the efficiency of chemical fertilizers, improve plant growth, and sustain the environment. This field experiment was conducted at Yezin Agricultural University Farm, Yezin, Nay Pyi Taw, during the 2020 wet season, from July to November, to investigate sustainable rice production along with optimum farm productivity. The experiment was arranged in a randomized complete block design (RCBD) with four replications. The treatments were as follows; T1 (control, no fertilizer), T2 (100-16-66-12 N, P, K, S) $kgha^{-1}$, T3 (4 ton ha^{-1} Compost), and T4 (4 ton ha^{-1}Compost and 50-8-33-6 N, P, K, S) $kgha^{-1}$. Urea, Triple superphosphate, Muriate of potash, and Gypsum were used as sources of N, P, K, and S and the rice variety tested was Sinthukha. The plant growth characteristics were collected at biweekly intervals and yield and yield components were recorded at harvest time. Results showed yield and yield components responded to the application of different treatments. The number of panicles $hill^{-1}$, the number of spikelets $panicle^{-1}$, filled grain percent, and harvest index were superior in T4 than for other treatments. The maximum grain yield (7.93 ton ha^{-1}) was observed in T4, followed by (7.03 ton ha^{-1}) T2 and (6.36 ton ha^{-1}) T3 treatments and the minimum grain yield (5.71 ton ha^{-1}) was produced under T1 conditions. According to the results of this study, the application of compost reduces the number of unfilled grain per panicle compared to the control. Therefore, it is necessary to apply organic materials such as compost, which is cheaper than chemical fertilizers and which promotes the recovery soil nutrients. Application of compost increases the yield of rice grain from 11 to 39 % compared to the control.

Keywords Rice, Chemical Fertilizer, Compost, Yield

INTRODUCTION

Rice (*Oryza sativa* L.) is a main staple food and is consumed by half the world's population **(**Chauhan et al., 2017). Production of rice globally was more than 759.6 Mt in 2017 (FAO, 2018). Approximately 90% of all rice is produced and consumed annually; in Asia. However, global mean yields are high compared to the mean yields in Asia. (Haider, 2018). Significcantly, there are several ways to improve rice yields. For example, one important way of improving rice yields, is through the proper management of nitrogen (N) fertilizers (Stellacci et al., 2013).

In Myanmar, rice is critical for the economic livelihood and food security of the population (Okamoto, 2004). Throuoghout Myanmar, resource-poor rural farmers, and landless agricultural laborers combine to grow rice on small farms which average only 2.3 ha in size (Okamoto, 2004). Therefore, more efficient ways to produce rice, that are sustainable and have lower input costs are crucial to the farmers.

In recent times, farmers have mostly relied on costly chemical fertilizers to boost rice yields (Myint et al., 2011). Rice yields are increased initially, but application of chemical fertilizers often results in soil problems, declining crop yields, and contributes to worsening global environmental conditions. Therefore, we need to develop and adopt alternative ways that are environmentally sustainable and maintain soil health, by supplementing or replacing chemical fertilizers. Application of organic fertilizer can conserve the amount and quality of organic matter in the soil, and ensure supply of N, P, K, and essential micronutrients (Timsina et al., 2001; Gruhn et al., 2000). Although having many advantages, organic fertilizer application can deliver lower nutrient content compared to chemical fertilizers and may result in nutrient deficiencies and subsequently lower yield (Liu et al., 2009). However, combining the application of organic fertilizer and chemical fertilizer can ameliorate problems caused by the application of chemical fertilizer alone, by neutralizing soil pH, leading to higher levels of organic carbon and improving macro and micronutrient availability, physical properties, and microbial activity (Liu et al., 2009). The combined application also increases the crop yields (Kumar et al., 2014).

OBJECTIVE

The experiment was conducted to determine the effects of the application of compost and chemical fertilizer on the growth and yield of a rice crop and to determine which treatment best supports sustainable production along with optimum productivity.

METHODOLOGY

A field experiment was conducted at Yezin Agricultural University Farm, Yezin, Nay Pyi Taw during the 2020 wet season, from July to November. The Sinthukha rice variety was used for this experiment. Four treatments with four replications were set up with a Randomized Complete Block Design (RCBD). The treatments contained in this experiment were T1 (Control, no fertilizer application), T2 (100-16-66-12 N, P, K, S kg ha^{-1}), T3 (4 ton ha^{-1}, Compost) and T4 (4 ton ha^{-1}, Compost and 50-8-33-6 N, P, K, S kg ha^{-1}).

There were 16 plots and each plot size was $25m^2$ (5m x 5m). Double bunds were constructed 1 m apart between the plots and with 1.5 m between the blocks to prevent water and nutrients flowing from one plot to another. Twenty-five-day-old seedlings were immediately transplanted with two plants per hill at a spacing of 20 cm x 20 cm. Compost (4 ton ha^{-1}) was added one week before sowing to the T3 and T4 plots. Urea, Triple superphosphate, Muriate of potash, and Gypsum were used as N, P, K, and S sources. Triple superphosphate, Muriate of potash, and Gypsum fertilizers were applied basally by broadcast method. Urea was applied at three time splits in the basal, maximum tillering and panicle initiation stages. Regular weed control was undertaken, especially at the early stages of growth. The plots were irrigated whenever necessary. Soil physicochemical properties of the experimental site were as follow; sandy loam texture, moderately acid (pH 5.6) soil with low organic matter (1.28 %) which had low level of available nitrogen (51 ppm), medium levels in both available phosphorus (11.4 ppm) and available potassium (178 ppm).

Growth parameters such as plant height and the number of tillers hill^{-1} were recorded from 5 randomly selected hills for each plot, starting 14 days after transplanting (DAT) and at two week intervals. The grain yield was determined from a central 1 m^2 harvested area in each plot and was adjusted for 14% moisture content. The yield component parameters were measured by harvesting 5 hills per plot on a random basis.

The harvest index was calculated by using the following formula; Grain harvest index = (Grain yield)/ (Grain + Straw yield) (Fageria 2011). All the collected data were analyzed using ANOVA with Statistix 8 software. The differences in treatment means were separated by the Least Significant Difference (LSD) at a 5 percent probability level.

RESULTS AND DISCUSSION

Plant height was recorded at 2-weeks intervals from 14 DAT to 98 DAT (Fig. 1). Plants exhibit a continuing increase in height over all treatments from 14 DAT to 84 DAT and the use of compost with chemical fertilizer (T4) significantly influenced the height of the Sinthukha rice variety at 1% level. The lowest height (103.25 cm) is observed in the T1. The highest plant height (109.88 cm) was, as mentioned, in T4, followed by (107.53 cm) in T2. Greatest increases in height were observed with the T4 treatment of compost with chemical fertilizer. The results are in agreement with the findings of Masarirambi et al. (2010). They also found that a half dose of chemical and organic fertilizers significantly increases plant height.

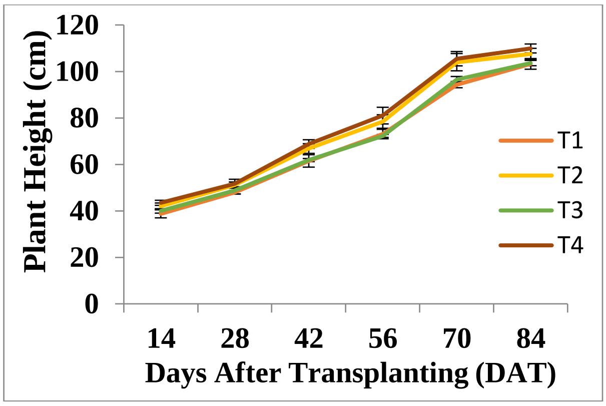

Fig. 1 Plant height (cm) as affected by compost and chemical fertilizer application

Tillering, is an important trait for grain production with its correlation to rice yield. The number of tillers hill^{-1} counted at various growth stages are illustrated in (Fig. 2). A significant difference in the number of tillers hill^{-1} can be seen for all growth stages at the 1% level. The number of tillers hill^{-1} range from 10.05 to 13.85 and the maximum value was in T4 followed by T2, T3, with these recorded at the 98 DAT. The treatment T1 showed the lowest number of tillers hill^{-1}. Mirza et *al*. (2010) reported that the increased number of tillers hill^{-1} in rice plants is due to the influence of different fertilizer combinations. The more balanced nutrition that the plants can get from organic sources, especially micronutrients, positively affect the number of tillers in plants (Miller, 2007).

The number of productive tillers influences rice productivity rather than the total number of tillers. There were significant differences at the 1% level in the number of panicles hill^{-1} among the treatments (Table. 1). The highest number of panicles hill^{-1} (13.70) occurred in T4, followed by T2 (12.50), T3 (10.80), and the lowest value was in T1 (9.65). This result parallels Miller, (2007), who found that a single application of inorganic fertilizers with a high dose is not necessary to produce effective tillers if supplementation with compost as organic sources is provided, thus helping to supply essential micronutrients to the plants.

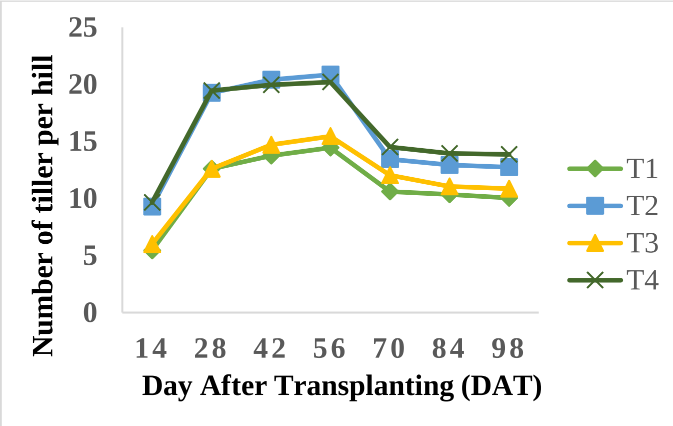

Fig. 2 Number of tillers hill^{-1} as affected by compost and chemical fertilizer application

The panicle lengths range from (22.50 cm) to (23.31cm) and there is a significant difference at the 5% level among the treatments (Table 1). The longest panicle length (23.31cm) was found in T4 which is statically similar to T2 (23.19 cm), while the shortest panicle length (22.50 cm) was in T1. One of the most important factors that affect the rice yield is the number of spikelets per panicle (Yoshida,1981). The mean value of the number of spikelets per panicle indicate no significant difference between treatments (Table. 1). The maximum number of spikelets panicle^{-1} were produced from T4 (165.55), whereas the second-highest number of spikelets panicle^{-1} (161.85) were from T2, followed by T3 (154.15) and the T1 (149.65) treatments. It was observed that the application of organic matter as a supplement can produce more effective tillering in comparison to sole application of inorganic fertilizers, which also help in providing essential micronutrients to the plants (Miller, 2007; Rakshit *et al*., 2008). Mirza *et al*. (2010) also reported similar results in rice. The filled grain % is not significantly different among the treatments (Table 1). The filled grain % range from 70.75 to 83. The highest filled grain % (83) was found in T4, followed by (76.75) the T2. The lowest filled grain % was in T1. According to the results of this study, the application of compost increases the number of filled grain % in comparison to the control.

The maximum number of 1000 grain weight of 22.01g was in T4 treatment, followed by treatment T2 (21.11g). There was a significant difference among the treatments at the 5 % level. The treatments T1 and T3, which has the minimum 1000 grain weight, were statistically similar. These results are similar to the findings of Kuepper (2003) which showed that the organic fertilizer improved the 1000 grain weight. The application of inorganic fertilizers, with the addition of organic manures, shows a positive correlation with 1000 grain weight (Anas *et al*., 2016).

In Figure 3, T4 achieveeds the highest grain yield (7.93 ton ha^{-1}) whereas the lowest grain yield (5.71 ton ha^{-1}) was in T1. The maximum grain yield was followed by (7.03 ton ha^{-1}) T2 and (6.36 ton ha^{-1}) for the T3 treatment. The combined application of compost and chemical fertilizer increased grain yield compared to the control by up to 39% while the increase with the use of chemical fertilizer is 23% compared to the control. The application of compost increases yield by 11% compared to the control. An increase in paddy yield with the use of T4 treatment can be seen in this study and this is similar to that observed by Jagadeeswari and Kumaraswami (2000), and these increases are greater than for treatments with compost alone.

The harvest index of rice as affected by the application compost and chemical fertilizer is not significantly different among the treatments (Table 1). The harvest index ranges from 0.40 to 0.43. The maximum harvest index (0.43) was recorded in T4 and the second highest (0.42) was observed for the T2 treatment. The minimum value (0.40) was found in T1. T4 produced the greatest number of panicles hill^{-1}, the number of spikelets panicle^{-1}, filled grain percent, and a harvest index superior to other treatments. (Table 1). Muhammad *et al*. (2008) observed that the plant height, number of tillers hill^{-1}, spikelet number panicle^{-1}, grain yield, and 1000 grain weight increased due to the application of organic and chemical fertilizers by enhancing the availability of nutrients.

Table 1. Effects of Compost and Chemical Fertilizer Applications on Yield and Yield Components Parameters of Rice during Wet Season, 2020

Treatment	Number of panicle hill^{-1}	Number of spikelet panicle^{-1}	1000 grain weight (g)	Filled grain (%)	Panicle length (cm)	Harvest Index
T1	9.65 d	149.65	20.48 b	70.75	22.50 b	0.40
T2	12.50 b	161.85	21.11 ab	76.75	23.19 a	0.42
T3	10.80 c	154.15	20.47 b	76.50	22.96 ab	0.41
T4	13.70 a	165.55	22.01 a	83.00	23.31 a	0.43
$LSD_{0.05}$	0.93	14.19	1.18	18.46	0.58	0.09
pr≥F	**	ns	*	ns	*	ns
CV%	4.97	5.62	3.52	15.03	1.58	14.12

p<0.01; *p<0.05; ns: no significant

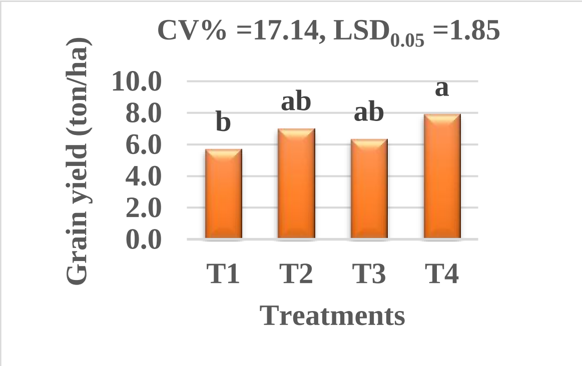

Fig. 3 Grain yields (ton ha^{-1}) with different compost and chemical fertilizer applications

CONCLUSION

The application of chemical fertilizers combined with composted organic matter increases the number of filled grain panicle^{-1}, 1000 grains weight, and rice yield. This combination of compost along with a half dose of chemical fertilizer provides a suitable integrated fertilizer application for the farmers in the study area. According to this study, the integrated application of compost and chemical fertilizer is a good way to achieve optimum growth and yields of rice and this also reduces cost of fertilizers for the farmers when compared to application of chemical fertilizer alone.

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Research article

Production and utilization of crop residues in Cambodia: Rice straw, corn stalk, and cassava stem

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Abstract Rice is the main staple crop, followed by cassava and corn in Cambodia. Annually, million tons of these crops are produced with the particularly need is its grain or root. After harvesting, these crop residues are usually collected for various purposes. Some of them are burned (the easiest option for farmers), which leads to loss nutrients and air and environmental pollution. However, it is limited report on these crop wastes production and utilization, and the crop residues management remain a challenge in Cambodia. Therefore, this study was conducted to assess to what extent that crop residues are available for further processing in Cambodia manufacture. Two hundred eighty eight key informers, were selected purposively to be interviewed through structure-questionnaire interview. The results showed that the crop residues were produced annually approximately 8.6, 0.9, and 2.9 million ton for rice, corn and cassava, respectively. The rice straw was collected for supplementary feed to cattle, vegetable mulch-based and mushroom production. The cassava stem was collected for next year planting and selling to other farmers. In term of quantity, the crop residues collection was just to meet the household's utilizations and the remaining are burned. For better crop waste management and practice, other alternative uses, for instance development of packaging products, construction materials, paper and renewable energy such as biogas and bio-energy using these residues, will change the open-field option and add value chains to the farm owners and rural people.

Keywords: Crop residues; rice paddy; corn stalk; animal feed, mushroom; packaging products

INTRODUCTION

Agriculture is one of the priorities economic activity in Cambodia, which contributed about 21% to GDP in 2019 with the contribution of crops, animal production, fisheries resources, and forestry resources were about 58%, 11%, 24%, and 7%, respectively. Rice is regarded as the main staple crop in Cambodia, approximately 3.328 million hectares planted with the average yield 3.338 ton per hectare (totally 10.885 million tons paddy rice produced in 2019) (MAFF, 2020). Rice straw is a residual by-product of rice at harvest. The total biomass of this residue depends on various factors including: varieties, soils, nutrient management and weather. The ratio of straw to paddy varies, ranging from 0.74 to 0.49 (Nguyen, et al., 2016, Nguyen, Monet, et al. 2020). At harvest, rice straw is piled or spread in the field depending on the harvesting methods, using human labor plus stationary threshers or self-propelled combined harvester. Rice straw that remains in the field after harvest can be collected, burned, or left to decompose (soil incorporation).

The intensification of rice production and rising labor costs have led to the spread of combine harvesters in Asian rice fields. Combine harvesters leave loose rice straw on the ground, making its collection and transportation difficult, laborious, and costly. Farmers choose the quick solution of burning rice straw to quickly remove the biomass and prepare the field for the next crop. In-field burning of rice straw contributes to greenhouse gas emission and poses health and environmental hazards (Tabil, Adapa, & Kashaninejad, 2011).

Unlike rice, corn and cassava are industrial crops, planted on approximately 200 thousand and 656 thousand hectares, respectively in Cambodia. There are two types of corn: white corn (mainly for human food) and yellow/red (mainly for animal feed) in term of grain (MAFF, 2020).

Annually, million tons of crops and its biomass are produced, but it is limited report about the residues. Even though, some amounts of the crop wastes are collected and used for various purposes and literatures showed that the agricultural waste has complex carbohydrate similar to those of wood sources, i.e, percentage of cellulose, hemicellulose and lignin (Theng, 2017), but field burning is still heard a quick solution for farmers to clear the land for next crop. Among several crops in Cambodia, rice straw, corn stalk and cassava stem are seasonal crop residues with widely available and fast growth, compared with wood sources.

OBJECTIVE

The study aimed to assess to what extent that crop residues are available for further processing in Cambodia manufacture.

METHODOLOGY

The results presented in this article are based on quantitative and qualitative methods of primary data collection. The total of 288 households are dealing with rice, corn and cassava production, utilization and supply of the crop residues were subjected for the interview. The study was conducted in six provinces including: Kampong Cham, Kampong Thom, Battambang, Kampong Chhnang, Kampong Speu, and Takeo (Fig. 1). The data collection instrument was a structure-questionnaire (Sa, 2011). The samples are purposively selected (Norng et al., 2011). The collected data was analyzed using SPSS computer software.

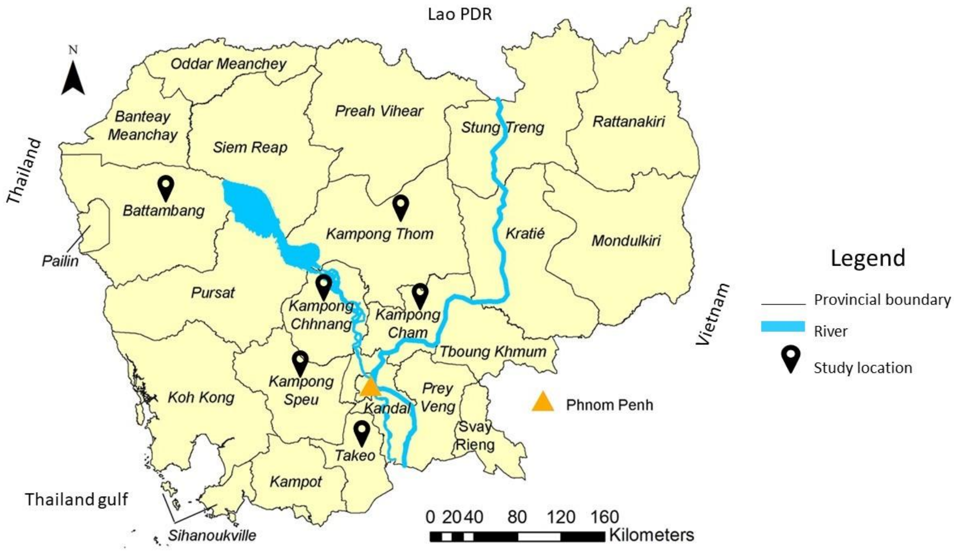

Fig. 1 Map of Cambodia and selected provinces for the data collection

RESULTS AND DISCUSSION

Household demographic for agricultural categories

Table 1 shows the types of agriculture in the study sites. There were 232 (53.2%) rice producer, 36 corn, cassava, and other crops, 15 vegetable growers, 130 cattle producers with 9 cattle farms, and 23 mushroom producers. The household scale cattle are cows or water buffaloes raising at home with the number from 1-13 heads per household (4.22 heads in average) were observed, whereas the farm scale of cattle is raising in a large area of land with more number from 50 to 700 heads (137.77 heads in average) per farm were investigated.

Table 1 Types of agriculture in the studied areas

Agricultural categories	Frequency	Percentage
Rice	232	53.2
- Wet season rice	210	-
- Dry season rice	122	-
Plantation crops (corn, cassava, cashew, bean)	36	8.3
Vegetable	15	3.4
Cattle (farm scale)	130 (9)	29.8
Mushroom	23	5.3

Crops and crop residues production

Rice, corn, and cassava is grown on 0.1 to 300 ha, 0.1 to 10 ha, and 0.5 to 100 ha per household, respectively (Fig. 2). The wet season rice was grown by 210 farmers on the land size range 0.1-50 ha and dry season rice was grown by 122 farmers on the land size from 0.1 to 300 ha. This study found that approximately 50% of the farmers grow 3 times a year for both seasonal rice. But, the majority a household owned between 1 and 2 ha and can grow rice only once a year with few can grow up to 3 times a year depending on irrigation availability and flooding condition. The average yield paddy was 3-6 ton per hectare of grain depend on variety, location, production time, input and water supply, and care. It was in range of the average yield 3.338 tons ha^{-1} (MAFF, 2020). However, there was no investigation and record about rice straw.

Corn and cassava are classified as upland crops, cultivated on smaller area and number of farmers, compared to rice. In this study, the yellow corn variety and cassava are found in Kampong Cham, Kampong Thom and Battambang provinces. The average yield of corn grain was 5-10 tons ha^{-}, higher than the literatures (MAFF, 2020; PPDA, 2012; Net et al., 2013) i.e, about 4.5 tons ha^{-1}, but in the range compared to Belfield et al. (2013) and the average yield of cassava is 20-30 tons ha^{-1}. Corn and cassava can be grown two times per year or diversify together (Net et al., 2013). According to the key informers, the yield of cassava plant or stem was around 1500 bunch per hectare with around 3 kg a bunch.

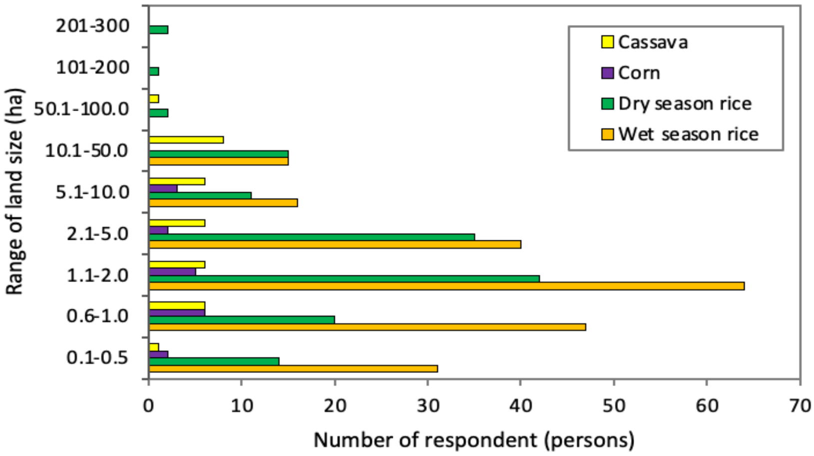

Fig. 2 Land size belong and/or rental by individual household for rice, corn, and cassava

Collection and utilization of crop residues

Fig. 3 showed that about 55%, 0%, and 82% of the respondents collected rice straw, corn stalk, and cassava stem, respectively. The rice straw was collected in quantity ranging from less than 1 ton per year per household to more than 1000 tons and the cassava stem up to 3-5 tons (Fig. 4). Approximately 80%, 8%, and 12% of the collected rice straw was used for cattle feed, mulching and mushroom production, respectively (Fig. 5). The quantity of rice straw needed for household cattle was small, just below 10 tons per year depending on the number of cattle, the available time of household members to collect green grass, and the available free land for cattle feeding with natural green grass. Most of the cattle farm used planted grass or natural grass in orchard of coconut, longan, cashew, and other perennial crops. The more quantity of rice straw was used for mushroom production as the mushroom can be grown 10 to 13 cycles a year. The quantity from 100 to more than 1000 tons per year was collected by collectors or service providers using baler machine. The baler has high collection capacity, make easier to transport the baled rice straw from paddy to cattle farm, mushroom farm and vegetable garden, but the crop growing farmers experienced that the baled rice straw is difficult use, heavier and easier to damage when it is wet. The crop-based mulch using rice straw in vegetable production was commonly in Saang and Koh Thom districts, bordering with Prey Kabas district of Takeo province. Because more farmers live in Saang and Koh Thom selected vegetables growing than rice and other crops, they purchase more rice straw from other neighboring areas including Prey Kabas, Angkor Borey and Bati districts for mulching and animal feed, whereas the other study sites collected and supplied locally. The 45% of respondents did not collected rice straw selected two means including: burning in the paddy field about 20% (IRRI (2019) reported around 3 million tons generated rice straw was burned) and other 25% was left degradation, those farmers or paddy allow once growing per year in rainy season. The cassava plant yield is approximately 10 times over the seedlings need, but generally Cambodian farmers reserved the stem at least double since sometimes experiences of damaged by drought or diseases and required the second planting. In addition, cassava plantation keeps increasing from year to year in Cambodia about 0.66% (MAFF, 2020). Therefore, the result from this study indicated that around 25% of the cassava stem was used for seedlings and the remaining was burned.

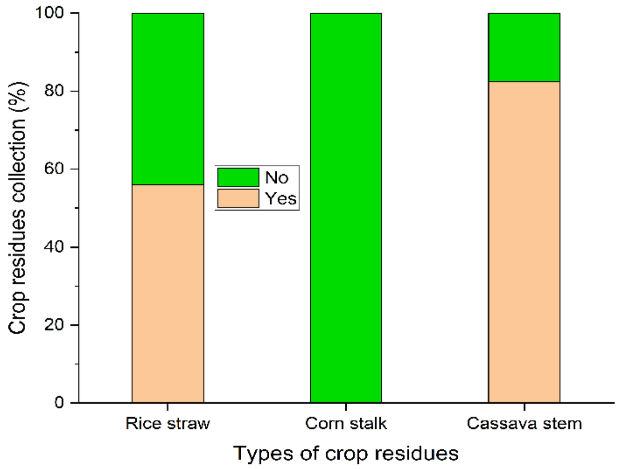

Fig. 3 Collection of crop residues by farmers

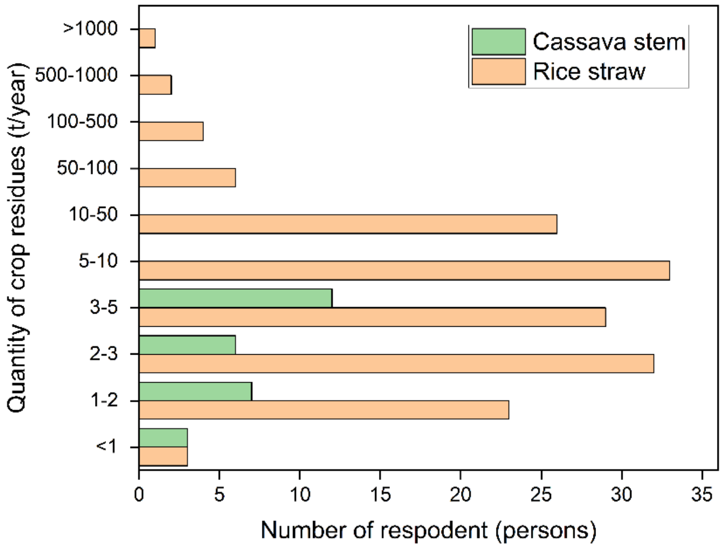

Fig. 4 Quantity of the collected crop residues

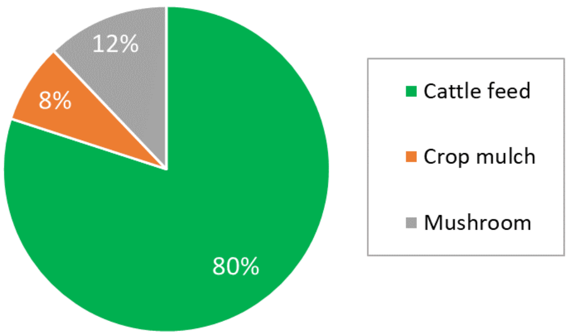

Fig. 5 Proportion of rice straw uses in Cambodia

Cost of crop residues

In this study, the rice straw is not value, except Battambang and Takeo provinces, because the farmers do not care on selling the rice straw as it is widespread on the paddy with possible to collect either from their paddy or neighbors'. There is market in Battambang and Takeo provinces, although, the farmer is paid at lower price around 17 USD per hectare when the collectors collected and sold between 20 and 50 USD per ton, depending on the location of transportation. The cassava stem costs around 1 USD/bunch of 3 kg, excluding transportation cost.

CONCLUSIONS

The by-product of rice, corn, and cassava are produced in lots of quantity with limited use seasonally and annually in Cambodia. The rice straw was used as household cattle feed, mushroom feedstock, and mulch-based vegetable production. Approximately 55% of the rice straw was collected and 45% was burned or left to natural degradation in the paddy field. In term of economic cost-effective, it is a huge lost of money when the biomass can be value added. Regarding, greenhouse gas emission through burning the rice straw, it is a high impact as million ton of rice straw is burned every year. It is similar to corn and cassava crop residues that plenty tons of biomass was produced annually and the matured corn stalk was only burn and cassava stem was only replanting. According to previous studies and literatures, the biomass has similar chemical and physical compositions compared to wood sources fiber, suitable uses for manufacturing various products such as biodegradable packaging materials, paper, construction materials, adding to the current uses for animal feed, mushroom and mulching.

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Research article

Analyzing the water harvesting potential and its maximization by the application of clayey dressing in Qargha Reservoir Watershed, Kabul, Afghanistan

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Abstract The unfavorable impacts of climate change are experienced all over the world. Afghanistan is among the countries that are severely affected by the impacts of climate change. The adverse effect on water resources constitutes one of the most negative effects. Currently, water management authorities and researchers look for improved water management techniques that will reduce the pressure on the already stressed water resources. Surface runoff harvesting is becoming more popular in regions with an arid-semi-arid climate, such as Afghanistan because of the increasing demand for scarce water resources. Therefore, a study was carried out to analyze the water harvesting potential in Qargha Reservoir Watershed, and to evaluate the effectiveness of clayey dressing application in maximizing surface runoff compared to control conditions. Rational method and sorptivity method were used to estimate the potential surface runoff and clayey dressing (silty clay loam and clay loam) was applied as a conservation strategy. A small area of 2 ha was selected in suitable areas of Qargha Reservoir Watershed. Based on 16 rainfall events, the volume of surface runoff estimated by the rational method was 509.40 m^3, which was larger than the 478.34 m^3, estimated by the sorptivity method. After clayey dressing application, the estimated volume of surface runoff based on the rational method increased to 1392.36 m^3. Furthermore, the estimated volume of surface runoff after clayey dressing calculated with the sorptivity method increase to 1608.46 m^3 based on 16 rainfall events. Thus, proper soil surface treatment such as application of clayey dressing is highly recommended for achieving sustainable agriculture.

Keywords water harvesting, Qargha Reservoir, clayey dressing application, silty clay loam, clay loam and sorptivity method

INTRODUCTION

In recent years, the adverse impacts of climate change occur more consistently, and the sector most severely hit by climate change is agriculture sector. The adverse effect of climate crises on water resources constitutes one of the most negative effects. Moreover, excessive use of available irrigation water in the field aggravates the consequences. The most common irrigation method used in the study area is surface irrigation (flood irrigation). Thus, intensive aridity has altered the yield pattern negatively (Parvizi and Sepaskhah, 2015). According to Oweis and Hachum, (2006), rain water harvesting can considerably boost productivity in the drier marginal environments. Water harvesting is among the most promising ways of supplementing the scarce surface water resources in areas to meet demand (Aladenola and Adeboye, 2010). Maximizing surface runoff can be used to provide partial water requirement of rain-fed and irrigation based agriculture (Parvizi and Sepaskhah, 2015).

Currently, water management authorities and researchers look for improved water management techniques that will reduce the pressure on the already stressed water resources. Climate induced changes in precipitation, surface runoff, and soil moisture will possibly have intense impacts on living creatures (Hardy, 2005). Survey conducted by Rahmani and Mihara, (2017), reported that, water shortage was the main problem in the study area farmers face during crop production. Growing season in Qargha Reservoir Watershed of Paghman District, Kabul Province starts in March and ends in October; however, in the latter half from June to October, it hardly rains, which causes crop failure and low productivity. So, collecting and stocking a certain amount of runoff water in the wet season and using it as irrigation water during the latter half of the growing season can reduce water shortage problems (Rahmani et al., 2019 and). Wide range of techniques such as soil compaction, gravel removal, bitumen emulsion and tall oil, less permeable soil, wax and plastic and Sodium dispersants such as sodium carbonate and sodium chloride (Yazar et al., 2014, Parvizi et al., 2015, Short and Lantzke, 2006, Amu-Mensah et al., 2013, Fink et al., 1980 and Frasier et al., 1987) used worldwide for surface runoff maximization. This study aimed to evaluate the effectiveness of clayey dressing application in surface runoff maximization compared to control conditions in the laboratory and in the field.

OBJECTIVE

To analyze the water harvesting potential in Qargha Reservoir Watershed, and to evaluate the effectiveness of clayey dressing application in maximizing surface runoff compared to control conditions.

METHODOLOGY

Study Area

The research 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 carried out 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. According to Rahmani et al, (2018), average precipitation in the watershed is around 280 mm annually and average annual temperature is 11.01 ^oC. Majority of the people living in Paghman District is small subsistence farmers with small plots of agricultural land.

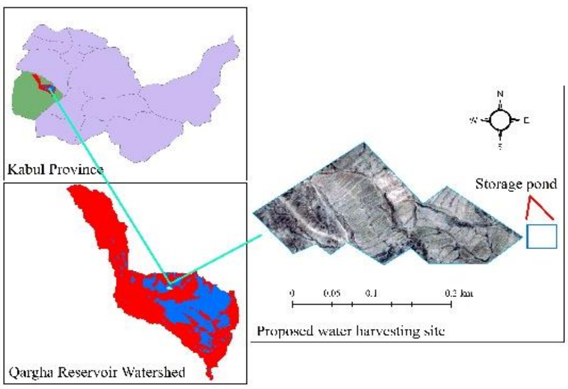

Fig. 1 Location map of proposed water harvesting site (Rahmani et al., 2019).

Surface runoff experiments were conducted in the field and laboratory. Sorptivity method and rational method were used to calculate surface runoff. Soil sorptivity experiments were carried out in the laboratory; several samples from local soil were used in the experiment. The dominant soil particle size distribution (soil texture) in the study area is loam. Thus, surface runoff was calculated with and without clayey dressing application. Clayey dressing application is an economical and environmental friendly runoff enhancement technique. Clayey dressing (less permeable soil) was extracted using sieve sieving and cloth sieving. A clothing was placed on the bucked to remove larger particles from diluted soil (Rahmani, et al., 2018). Cloth sieving was used for clayey dressing extraction in the field and soil sieved (clayey dressing) using sieves of 38 μm and 75 μm were used in the surface runoff experiment in the laboratory. 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.

The rational runoff coefficient for treated condition was calculated based on the runoff plot experiment in the laboratory and in the field. The change in rational coefficient was recorded and then added to rational runoff coefficient for control condition based on ODOT (2014). And then the average runoff coefficient was calculated. The average runoff coefficient for treated conditions calculated was 0.41. Total 16 rainfall events observed from 18 November 2017 to 6 May 2018 for 170 days were selected for runoff volume estimation. Additionally, silty clay loam (SiCL) dressing and clay loam (CL) dressing were used as a surface runoff maximization strategy. For further information refer to the calculation of surface runoff using sorptivity method and rational method in Qargha Reservoir Watershed control condition (Rahmani et al., 2019).

RESULTS AND DISCUSSION

Surface runoff estimation

The amounts of surface runoff generated under different treatments compared to control in the laboratory are shown in Table 1. Silty clay loam dressing with 57%, 53% and 47% concentration increased runoff 1.30x, 1.28x and 1.16x respectively. While, clay loam dressing with 65%, 60% and 53% concentration increased runoff 1.43x 1.41x and 1.27x 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. Shirazi 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 equipment and tools to use. Availability and generation of extra rainfall runoff water can help to revive agriculture in the study area and cultivate large dry uncultivated lands. Statistical analysis showed that there are significant differences between control and clayey dressing applied conditions.

Table 1 Surface runoff water under different treatments

Clayey dressing	Dry density g cm^3	Treatment cg g^{-1}	Water applied (dm^3)	Runoff (dm^3 m^{-2})	Infil. (dm^3 m^{-2})	Runoff (C)	Increase from control (x)
SiCL	1.3	Control	12.96	9.70 ^{a**}	3.20	0.75	
		46.4	12.96	11.24 ^{b**}	1.68	0.87	**1.16**
		52.3	12.96	12.45 ^{b**}	0.50	0.96	**1.28**
		56.9	12.96	12.62 ^{b**}	0.00	0.97	**1.30**
CL	1.5	Control	12.96	8.68 ^{a**}	3.82	0.67	
		52.1	12.96	11.04 ^{c**}	1.55	0.85	**1.27**
		60.1	12.96	12.20 ^{b**}	0.00	0.94	**1.41**
		64.9	12.96	12.38 ^{b**}	0.00	0.95	**1.42**

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

The result of surface runoff experiment conducted in the field showed that, Deh Ponba soil treated with clayey dressing at 57.7 and 64.9 cg g^{-1} increased runoff by 1.41x and 1.42x, and Doda Mast soil increased runoff by 1.55x and 1.58x compared to control shown in Table 2. Statistical analysis also showed that the result of control and treated conditions had signification differences.

Parvizi and Sepaskhah, (2016), examined the effect of gravel removal, rill construction across to slope and applying of baking soda on surface runoff. According to the results, gravel removal technique is nearly as effective in the runoff enhancement as rill construction across to slope and baking soda technique.

Table 2 Surface runoff estimation in the field

Site	Treatment cg g^{-1}	Water applied (dm^3)	Runoff (dm^3 m^{-2})	Runoff (C)	Increase from control (x)
Deh Ponba	Control	45.0	27.7 ^{a**}	0.62	
	SiCL 57.7	45.0	39.2 ^{b**}	0.87	**1.41**
	SiCL 64.9	45.0	39.5 ^{b**}	0.88	**1.42**
Doda Mast	Control	45.0	25.3 ^{a**}	0.56	
	SiCL 57.7	45.0	39.2 ^{b**}	0.87	**1.55**
	SiCL 64.9	45.0	39.5 ^{b**}	0.88	**1.58**

*SiCL = Silty clay loam dressing. **denotes significance difference level at P<0.01*

Results of runoff volume calculation showed that with clayey dressing application of either silty clay loam or clay loam, the runoff volume increased from 509.40 m^3 to 1392.36 m^3 compared to control conditions, which shows 2.73x increase in surface runoff. Similarly, the runoff coefficient value was increased from 0.15 to 0.41. The results of surface runoff calculated based on sorptivity method with clayey dressing application showed that surface runoff volume can be increase to 1608.46 m^3 from 478.34 m^3 control condition, which shows 3.36x increase. Accordingly, both methods confirm that clayey dressing application onto the soil surface can effectively increase surface runoff. The results of surface runoff volume in treated conditions estimated using sorptivity method is shown in Table 3. For the result of surface runoff calculated using rational and Sorptivity method in control conditions please refer to Rahmani et al., (2019). Comparison result of rational and Sorptivity method calculated surface runoff is shown in Table 4.

Table 3 Surface runoff volume estimated using the rational method and sorptivity method treated conditions

Rainfall even	P (mm)	S	Area (ha)	C	Qsp (mm)	Qsp (m^3)	Qra (m^3)
1	14.80	6.70	20000	0.41	9.00	179.70	121.36
2	12.80	6.00	20000	0.41	7.70	153.20	104.96
3	8.00	10.50	20000	0.41	2.10	42.50	65.60
4	14.20	8.60	20000	0.41	7.40	147.90	116.44
5	11.40	7.30	20000	0.41	5.70	114.20	93.48
6	16.80	8.90	20000	0.41	9.40	188.70	137.76
7	3.20	10.80	20000	0.41	0.00	0.00	0.00
8	15.60	9.20	20000	0.41	8.30	165.20	127.92
9	11.20	15.30	20000	0.41	2.80	56.60	91.84
10	22.60	11.80	20000	0.41	12.80	255.50	185.32
11	6.80	7.90	20000	0.41	2.10	41.60	55.76
12	17.40	14.20	20000	0.41	7.40	147.80	142.68
13	8.00	9.40	20000	0.41	2.40	48.30	65.60
14	10.20	11.10	20000	0.41	3.40	67.10	83.64
15	3.80	3.90	20000	0.41	0.00	0.00	0.00
16	2.20	8.90	20000	0.41	0.00	0.00	0.00
Total						**1608.46**	**1392.36**

Amu-Mensah et al., (2013), reported that, possibility of water harvesting to can be created in soils with high infiltration rate by less permeable soil application onto the soils surface. In accordance with the results, it was assumed that the higher effectiveness of clayey dressing in surface runoff inducement (maximization) and reducing infiltration rate of the soil is due to its characteristic of clogging and sealing surface which leads to lower infiltration rate and high runoff production. A study conducted by Rahmani et al., (2018), indicated that, application of less permeable soil (clayey dressing) on soil surface lower the infiltration rate because of clogging soil pores and cracks. 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 take place when the plug flow radius of the soil suspension was bigger than the radius of soil pores. Mihara et al. (1993), also confirm that pore radius smaller than radius of plug flow causes clogging of soil pores, which leads to increased runoff. Mihara and Yasutomi (1992), also reported that clayey suspension flow causes pore clogging.

Table 4 Surface runoff volume change after clayey dressing compared to control

Treatment	Method	Rainfall events	Area (m^2)	Runoff (m^3)	Increase in runoff volume (x)
Control*	Sorptivity method	16	20,000	478.3	
Clayey dressing		16	20,000	1,608.5	**3.36x**
Control*	Rational method	16	20,000	509.4	
Clayey dressing		16	20,000	1,392.4	**2.73x**

Rational method and sorptivity method (control condition) by Rahmani et al.,(2019).

This idea is confirmed and backed by Mihara and Yasutomi (1993) and Mihara et al., (1992), which conclude that clay suspension caused pore clogging and surface sealing. According to Robert (1974), infiltration decreases with increased number of suspended solids in the water. Further, he stated that sediment deposition caused surface sealing.

CONCLUSION

Water harvesting is one of the promising ways of supplementing the surface and underground scarce water resources in areas where existing water supply system is inadequate to meet demand. Water harvesting can substantially increase rainwater productivity in the drier marginal environments. The results of both laboratory and field runoff experiment showed that clayey dressing application (less permeable soil) was highly effective in maximizing surface runoff and to lower infiltration rate even in rainfall events with depth and intensity. Thus, the result of surface runoff calculated using rational method and sorptivity method also indicated that surface runoff can be increased with clayey dressing application onto the soil surface. The statistical analysis also showed that there were significant differences between control and soil treated with clayey dressing. So, maximizing surface runoff can be used to provide water requirement of rain-fed and irrigation based agriculture.

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Research article

Relationship between NDVI and Canopy Cover sensed by small UAV under different ground resolution

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Abstract Canopy Cover (CC) is a significant indicator of crop development and estimation of the evapotranspiration volume of crop leaves within crop simulation models. During the last three decades, monitoring CC for crops using Normalized Difference Vegetation Index (NDVI) obtained from satellite sensors has been studied worldwide. However, a few studies have estimated the CC of crops using NDVI by UAVs. One of UAV imagery's crucial advantages is a high resolution of less than 0.10 m, while the resolution of satellite imagery is usually larger than 10 m. Now that the UAV has become a popular method in agriculture science, it is necessary to prove the interchangeability of UAV and satellite imagery of monitoring CC.

In this study, small UAVs took RGB and multispectral images of the experimental peanuts field in Hokkaido. Orthomosaic and reflectance map of the field were constructed using the UAV imagery and then were obtained CC and NDVI values with GIS software. CC was calculated as the green canopy area ratio, extracted from the orthomosaic using a GIS supervised classification tool. CC was compared with NDVI values under various resolutions of 0.50 m, 1.0 m, 2.5 m, 5.0 m, and 10 m.

The NDVI showed a highly correlated linear relationship with CC under each ground resolution from 0.10 m to 10 m (R^2 led a range of 0.88** to 0.94**). The shapes of NDVI and CC's regression equations closely resembled each other, with the slopes of 1.06 to 1.11 and the intercepts of 0.247 to 0.250, respectively. From the result of ANCOVA, the UAV imagery resolution has no significant impact on NDVI and CC's relationship. Although more irrelevant factors, such as soil and mulching seat, got included within one pixel of the images, the regression equations stayed the same with the increased ground resolution.

Keywords UAV, NDVI, canopy cover, ground resolution

INTRODUCTION

Canopy cover (CC) is a relatively easily measured property that is an indicator of crop growth and an important parameter in crop simulation models, such as the Aqua Crop (FAO, 2012) model. When simulating crop development, Aqua Crop model describes the development expansion of the CC using the percentage area of green canopy cover. According to the Food and Agriculture

Organization (FAO), CC is defined as the ratio between the soil surface covered by the green canopy cover over the ground surface (FAO, 2012). CC value ranges from 0, when there is bare soil, to 1, where the vegetation canopy fully covered the ground. The crop characteristic decides the maximum value of CC. Aqua Crop model describes the development of the canopy between generation and the moment maximum CC is reached through a logistic type equation. Then, at the end of the season, when the senescence starts, the CC value declines (Steduto et al., 2009). Accurate and efficient CC estimation would allow improved scheduling and allocation of irrigation water (Bausch, 1995).

On the other hand, during the last three decades, Vegetation indices (VIs) have been extensively used to trace and monitor vegetation conditions such as health, growth levels, and water or nutrient stress (Silleo et al., 2006). Previous studies have shown that various spectral calculated from visible and near-infrared reflectance data are linearly related to the value of CC (Purevdor et al., 1998). Healthy canopies of green vegetation have a very distinct interaction with certain portions of the electromagnetic spectrum. In the visible region, chlorophyll causes strong absorption of energy, primarily for use in photosynthesis. This absorption peaks in the red and blue region s of the visible spectrum, while the green region is reflected by chlorophyll, thus leading to the green color of most leaves. This strong contrast between the reflectance of red and near-infrared regions of the electromagnet spectrum has been used to develop the Normalized Difference Vegetation Index (NDVI), a VI that has been widely used in the agricultural remote sensing field (Silleos et al., 2006). Region scale NDVI data could be obtained using high-resolution satellite sensors such as NOAA AVHRR, Terra MODIS, Landsat TM. This kind of traditional remote sensing data has been used to make better crop management, monitor the growing stress, and estimate the yield (Hirata, 2009). Furthermore, for the last decade, the research methodology and data analysis techniques from traditional remote sensing have been used to process aerial images with much higher spatial and temporal resolutions taken by Unmanned Aerial Vehicles (UAVs). This rapid development of remote sensing and precision agriculture provide aerial imagery with various resolution.

However, a few studies have estimated CC with UAV-obtained NDVI. It is still unclear if UAV-based NDVI has the same linear regression relationship with CC as satellite-based NDVI. To apply both satellite-sensed and UAV-sensed CC data to crop simulation models such as Aqua Crop, it is necessary to unravel whether the relationship between NDVI and CC remains the same under different ground resolutions. Therefore, This paper processed the UAV-sensed data into different resolutions, and compared the regression relationships between NDVI and CC.

METHODOLOGY

Study site

This study was conducted in the experimental field of the Obihiro University of Agriculture and Veterinary Medicine located in Obihiro City, Hokkaido, Japan (143.1709-143.1747°N, 42.8698-42.8671°E; Fig.1). The experimental field has a total area of 3.2 ha (200 m×160 m), separated into multiple sectors planted with various experimental crops. The peanuts sector inside the experimental field was selected as the study site to compare NDVI with CC. The peanuts usually have relatively spreading forms of about 30-50 cm high with long branches that grow close to the ground. This plant form makes peanut a good objective to study the relationship between NDVI and CC. Previous study shows that the NDVI tends to perform poor correlation to CC when the Leaf Area Index (LAI) value is high. In other words, if the leaf density under the vegetation canopy varies, the NDVI value could be different even though the CC value stays the same (Purevdorj et al., 1998). This kind of variation of LAI is relatively unapparent in peanuts because peanuts tend to grow with a horizonal pattern rather than a vertical pattern. The peanut field area is 1600m^2 (40 m×40 m), with a plant density of 7.7 plant/m^2. The surface of the planting area was covered by white mulch sheets made by plastic films, because insolation was important during the early stage of growth to ensure the basic vegetation growth of peanuts in low temperature region such as Hokkaido.

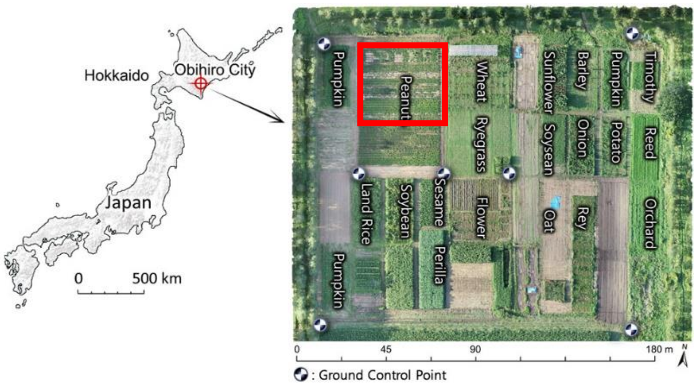

Fig. 1 Location and details of the study site

Investigation and Analyses

The RGB imagery of the experimental field was taken by Phantom 4 Pro (DJI) on 31st July 2019, and the reflectance imagery was made by a portable multispectral camera "Sequoia" (Parrot), which was mounted on Inspire 1(DJI) on 1st August 2019. The flight data is shown in Table 1.

Table 1 Flight conditions

Equipment	Date	Camera height from ground (m)	Speed (m/s)	Overlap (%) Top	Overlap (%) Side	Resolution (cm/pixel)
Phantom 4 Pro	31th July	50	4.8	80	80	1.3
Inspire 1 with Sequoia	1st August	40	3.0	80	80	5.9

NDVI and CC

After obtaining aerial imagery, RGB orthomosaic image and reflectance map of the experimental field were generated with the photogrammetric software, Pix4D Mapper 4.6.4 (Pix4D). The RGB orthomosaic image was used to separate the vegetation, soil and mulch films in ArcGIS Pro 2.3.0 (Esri), with a supervised image classification tool. The result of classification is shown in Fig.3. Based on the classified raster, the CC value of the peanuts field was calculated using Eq.1,

$$CC = \frac{Vegetation}{Vegetation + Soil + Mulch\ film} \quad (1)$$

where "Vegetation," "Soil," and "Mulch film" mean the number of pixels covered by green vegetation canopy, soil, and mulch films, respectively. To obtain the CC and NDVI values under different ground resolutions, we divided the peanut field into squared grids with a side length of 0.5 m, 1.0 m, 2.5 m, 5.0 m, and 10 m. As an example, the 1.0 m grids are shown in Fig.4. Based on the georeferenced reflectance map, the NDVI values were calculated by Eq.2,

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (2)$$

where "NIR" and "Red" mean the reflectance volume of the near-infrared region and the red region. The relationship between NDVI and CC values of each grid's size was determined using a least-squares fitting algorithm with python 3.7. An Analysis of Covariance (ANCOVA) was carried out to testify if there is a significant difference between NDVI and CC relationships under different ground resolutions. Finally, the accuracy of the regression equation was verified using RMSE.

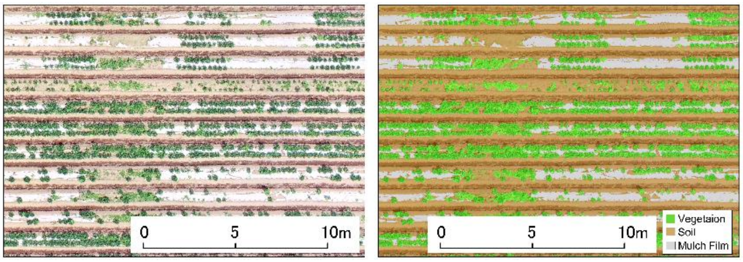

Fig3.Classification result (Left: RGB orthomosaic image; Right: Classified raster)

Fig.4 Example of squared grid dividing the peanuts field (Grid size: 1.0 m)

RESULTS AND DISCUSSION

Fig.5a and Fig.5b shows the spatial distribution of NDVI and vegetation cover under the original resolution of the peanuts field. NDVI tended to be high in the area covered by vegetation and low in the area covered by soil or mulch films. This is because the vegetation surface has a lower reflectance rate in the red region and a higher reflectance in the near-infrared region. In contrast, the soil and the plastic mulch films have similar reflectance in both regions. Besides, the mulch film has a lower NDVI than soil because the PVC material has a relatively higher reflectance of red, and at the meantime, a lower reflectance of near infrared than soil (Corradini et al., 2019). The spatial distribution of NDVI of the other grid sizes (0.5m, 1.0m, 2.5m, 5.0m, and 10m) showed the same tendency. The NDVI value varied from -0.47 to 0.68 under the original resolution, from -0.37 to 0.61 under 0.5 m grid size, from -0.29 to 0.40 under 1.0 m, grid size, from -0.25 to 0.24 under 2.5 m grid size, from -0.10 to 0.13 under 5.0 m grid size, and from -0.05 to 0.08 under 10 m grid size. Unlike the crops or forests with the vertical growth pattern, the maximum NDVI value of peanuts was less than 0.7. This is because peanuts have low-height, wide-expanding, and horizontal-trained canopies, which cause relatively low LAI within the canopies. The CC values varied from 0.00 to 1.00 under the original resolution, from 0.00 to 1.00 under 0.5 m grid size, from 0.00 to 0.74 under 1.0 m grid size, from 0.03 to 0.53 under 2.5 m grid size, from 0.14 to 0.42 under 5.0 m grid size, and from 0.19 to 0.35 under 10 m grid size. The range of both NDVI and CC values decreased with the increase in grid sizes.

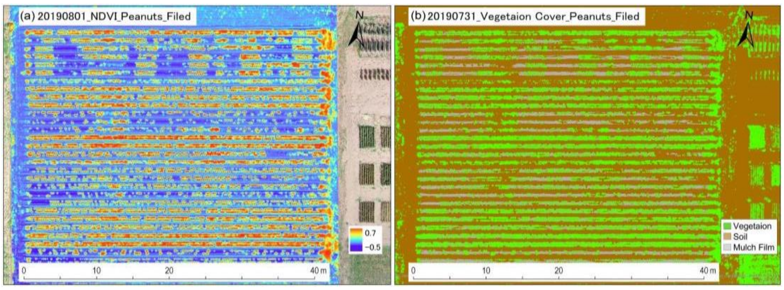

Fig.5 Spatial distribution of NDVI (a) and vegetation cover (b)

Fig.6a to Fig.6e shows the correlation between NDVI and CC under each grid size. NDVI was strongly correlated with CC under the resolution of 0.5m, 1.0m, 2.5m, 5.0m, and10m (R^2=0.88**, 0.92**, 0.94**, 0.89**, and 0.93**, respectively). The shape of the linear regression line ($y=ax+b$) of NDVI and CC closely resembled each other; the slopes (a) such as 1.16, 1.11, 1.09, 1.08, and 1.06, respectively, and the intercepts (b) such as 0.25, 0.25, 0.25, 0.25, and 0.25, respectively. The incept values indicate that a grid with 25 percent of it covered by peanuts canopies has an approximately NDVI value of 0. The slope values slightly decreased with the increasing grid size, resulting in the grid's NDVI values without any vegetation cover varying from 0.5m to 10m (-0.21, -0.22, 0.23, -0.23, and -0.24 respectively). This difference of slopes is considered to be caused by two kinds of abnormal values of NDVI. One was the abnormally high NDVI value due to relatively high LAI. The other one was the abnormally low NDVI value caused by the mulch sheets. These two kinds of abnormal NDVI became outliers when the grid size was small, because there were grids that include only canopies or only plastic. However, they cancelled each out when the grid size was large, so that the regression line was closer to the ideal state where there were simply vegetation and soil.

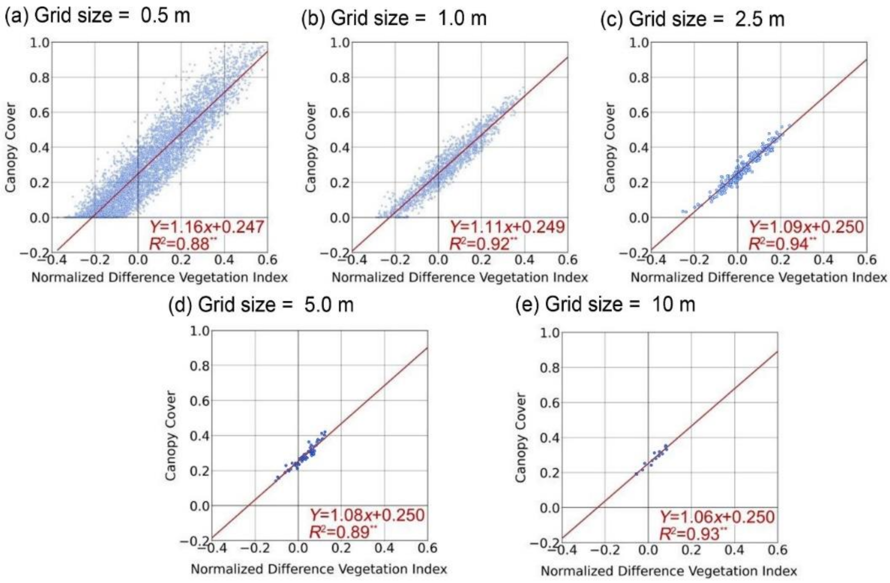

Fig.6 Relationship between NDVI and CC

To testify the significance of each regression equation's differences, an ANCOVA was conducted with an Excel data analysis add-in, XLSTAT (ver 2020.5.1, Addinsoft), where CC as the dependent variable, while NDVI and ground resolution as the explanatory variables. The result is shown in Table 2. The p-value of all kinds of grid sizes except for 10.0 m was near 1.000, indicating that the grid sizes have no significant effect on NDVI and CC's relationship.

Table 2 Model parameters of ANCOVA

Fctor	coefficient	standard deviation	t	Pr > |t|
intercept	24.775	1.980	12.512	**<0.0001**
NDVI	115.735	0.466	248.448	**<0.0001**
Ground Resolution-0.5	-0.021	1.983	-0.011	0.991
Ground Resolution-1	0.004	1.990	0.002	0.998
Ground Resolution-3	0.078	2.072	0.038	0.970
Ground Resolution-5	0.000	2.214	0.000	1.000
Ground Resolution-10	0.000	1.310	0.000	1.000

Therefore, despite the slight difference between the regression equations of the five kinds of grid sizes, it is considered that the NDVI value of peanuts remains the same relationship with CC under different ground resolution. Since the offset effect of two abnormal values of NDVI was most remarkable at the 10 m grids, the equation derived from the data of 10m grid size was used to predict CC using NDVI. The RMSE of CC estimation of each grid size from 0.50 m to 10 m was 0.081, 0.089, 0.048, 0.025, 0.020, 0.014, respectively.

CONCLUSION

Herein, we analyzed the relationships between NDVI and CC values of peanuts in the experimental field using UAV-sensed data under five kinds of ground resolutions. As a result, the NDVI showed a highly correlated linear relationship with CC under each ground resolution. Slight differences of slopes and intercepts were found between the regression equations, however this kind of difference was found not significant due to an ANCOVA. The regression equation of 10 m grid size performed a moderate estimation accuracy of CC with the RMSE less than 0.01. This result demonstrated that CC estimation tend to keep consistent despite of the change of resolution, suggesting the possibility that both UAV-sensed and satellite-sensed NDVI could be used to estimate CC for the usage of crop simulation models such as Aqua Crop.

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Research article

Establishment of Optimized Manufacturing Conditions for Cooked Rice-Part I-Equilibrium Moisture Content and Latent Heat of Vaporization of Cooked Rice

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Abstract The equilibrium moisture contents of cooked milled rice in the desorption process were measured at several temperatures (20-60 °C) and relative humidity levels (10-86 %) by a static method. The equilibrium moisture content of the sample increased with increasing equilibrium relative humidity at a constant temperature and increased with a decrease in temperature at any given equilibrium relative humidity. The Chen-Clayton equation, which is a sorption isotherm, was used to express the relationship between the equilibrium moisture content of the sample, equilibrium relative humidity, and absolute temperature. The latent heat of vaporization of water for the cooked rice was calculated by using the Chen-Clayton equation and thermodynamic theory (Clapeyron equation). At a moisture content of 15-30 % (d.b.) (d.b.: the amount of water per unit mass of dry matter present in the material), the latent heat of vaporization of the sample decreased almost exponentially with an increase in moisture content. For samples at a moisture content above 50 % (d.b.), the values of latent heat of vaporization sufficiently approached that of free water.

Keywords equilibrium moisture content, sorption isotherms, latent heat of vaporization, Chen-Clayton equation, Clapeyron equation, cooked milled rice

INTRODUCTION

The development of processed food made from rice at production location is expected to lead to regional revitalization and increased income for farmers. A simply processed food made from rice is dried cooked rice or pregelatinized rice. A general manufacturing process of dried cooked rice is as follows: 1) washing raw rice, 2) soaking the washed rice in water, 3) cooking or steaming the rice (the raw rice starch is changed to pregelatinized starch), 4) separating the rice kernel from the mass of cooked rice to a single cooked rice, and 5) drying the cooked rice. The dried cooked rice is usually rehydrated with water or hot water and then eaten.

Recently, food that can be kept in case of emergency has been developed and manufactured in Japan to prevent food shortage in the case of natural disasters and infectious diseases. The interest in dried cooked rice has increased as it can be used in preserved food, portable ration food, and emergency provisions. In addition, dried cooked rice has been used as a material in instant food products, for example, an instant pot dried rice similar to an instant pot noodle; thus, the market of dried cooked rice products has continued to increase. The data of the drying characteristics, equilibrium moisture content, latent heat of vaporization for cooked rice, and water absorption (rehydration) characteristics of dried cooked rice are required for optimizing processing operations, designing equipment, and ensuring high quality.

We measured the equilibrium moisture content of the cooked rice, the hot air-drying characteristics of the cooked rice, and the water absorption characteristics of the dried cooked rice. This basic information is needed to establish the optimized manufacturing conditions for cooked rice. The latent heat of vaporization of water for cooked rice was calculated based on the thermodynamic theory by using the equilibrium moisture content data. The moisture transfer kinetics during the drying and the water absorption was analyzed based on the drying theory of the first falling rate period or the first-order reaction rate theory. The equilibrium moisture contents are needed to analyze the hot air-drying characteristics in addition to examining food preservation. Because the changes in moisture content occur during the drying and the water absorption process, kinetic analysis to predict the changes in moisture content are required to optimize the processing conditions. We reported the equilibrium moisture content and the latent heat of vaporization of water in this part I and will report the moisture transfer kinetics in next part II.

To determine the storage conditions and analyze the drying process, it is necessary to know the relationship between the equilibrium moisture content (EMC) in the foodstuffs and the equilibrium relative humidity (ERH) of the drying air or aeration air at a given temperature. This relationship is described by sorption isotherm equations (Sun and Woods, 1993). Knowledge of the moisture sorption isotherms of foodstuffs is valuable in solving food processing and engineering problems such as equipment design, drying, and storage processes as well as predicting shelf life (Arogba, 2001). The latent heat of vaporization (LHV) of water in foodstuffs is important for the design of drying equipment (Chen, 2006). The LHV is neither constant nor equal to the heat of pure water evaporation because the LHV is a function of temperature and moisture content, i.e., the LHV varies throughout the drying process (Rückolda et al., 2003). The LHV can be calculated by using the sorption isotherm equations and Clapeyron thermodynamic theory (Murata et al., 1988; Tagawa et al., 1993). Koide et al. (2016) reported the EMCs for dried cooked rice in the absorption process. However, little research has been reported on the EMC and LHV for cooked rice.

In this study, the EMCs of cooked rice (short grain rice, japonica) in the desorption process were measured at several temperatures and relative humidity levels, and the LHV of water for the cooked rice was calculated by using the measured results of EMC and thermodynamic theory.

OBJECTIVE

The objectives of this study were 1) to evaluate the relationship between the EMC, ERH, and temperature and 2) to estimate the LHV of water by using the thermodynamic theory.

METHODOLOGY

Sample

Non-glutinous rough rice (cv. "Hoshinoyume") was purchased from a Japanese agricultural cooperative in Tohma, Hokkaido, Japan (JA Tohma) and was stored in a refrigerator at approximately 5 °C until the test. The "Hoshinoyume" was widely cultivated in Hokkaido when we conducted this research because this rice had a good eating quality or tasty. This non-glutinous rough rice was first hulled with a roll-type rice huller (THU35B, Satake Co., Ltd.). Brown rice (800 g) was put into an abrasive-type (stir-type) rice-milling machine (SKM-5B (1), Satake Co., Ltd.) and milled for 5.0 min to produce milled rice. The degree of milling (or milling yield) was adjusted to be approximately 92 %.

The milled rice was cooked with commercial rice cookers (NP-FB10, Zojirushi Co., Ltd.) in accordance with the operation manual of the rice cooker. To uniformly gelatinize the rice, the rice was soaked in tap water at room temperature for 1 h before cooking. The cooking time was 45-60 min and the maximum temperature in the rice cooker was around 104 °C. To obtain a single grain of cooked rice from the mass of cooked rice, the cooked rice was rinsed with tap water for 3 s, and the excess water was drained. After the rinse, the surface of the cooked rice was wiped with Kimwipes® (S-200, Nippon Paper Crecia Co., Ltd.) to remove excess water.

Equilibrium moisture content (EMC)

The EMCs of the cooked rice in the desorption process were measured by a static method (Murata et al., 1988; Tagawa et al., 1993) at three temperatures (20, 40, and 60 °C) and ten relative humidity levels ranging from 10 % to 86 %. The temperature was controlled with an incubator (IN802, Yamato Scientific Co., Ltd.). Ten kinds of saturated salt solutions (NaOH, LiCl, CH_3COOK, $MgCl_2$, K_2CO_3, NaBr, $NaNO_2$, $NaNO_3$, NaCl, KCl) were used to maintain the particular relative humidity in each vessel. Each saturated salt solution presents different vapor pressure or relative humidity at each temperature in a closed container. The relative humidity ranges for each saturated salt solution were 4-7 % for NaOH, 10-12 % for LiCl, 19-24 % for CH_3COOK, 29-34 % for $MgCl_2$, 42-45 % for K_2CO_3, 49-60 % for NaBr, 58-66 % for $NaNO_2$, 67-76 % for $NaNO_3$, 74-76 % for NaCl, and 80-86 % for KCl. The relative humidity data of these saturated salt solutions are shown in the references (Arai et al., 1976; Tagawa et al., 1993; Tanaka, 1998). Approximately 10 g of the sample was suspended in a 1 L wide-mouth bottle containing a selected saturated salt solution to maintain a constant humidity at a constant temperature. The sample was weighed on a digital balance (ER-182A, A&D Co., Ltd.) at intervals of 2 or 3 days. Equilibrium was considered to be reached when the change in weight was less than 0.2 mg between two successive measurements. In this method, it took approximately 30 days for a sample to reach the EMC. The EMC of the sample was determined using a forced hot air oven (DX-600, Yamato Scientific Co., Ltd.) at 135 °C for 24 h.

RESULTS AND DISCUSSION

Relationship among the equilibrium moisture content (EMC), equilibrium relative humidity (ERH), and temperature in the desorption process

The relationship between the EMC and ERH is usually expressed by means of a sorption isotherm. The moisture desorption isotherms of the sample at three different temperatures are presented in Fig. 1. As shown in Fig. 1, the EMC increased with increasing ERH at a constant temperature and increased with a decrease in temperature at any given ERH.

Several mathematical descriptions of the sorption data have been developed for different ranges of ERH in regard to different agricultural products (Chakraverty & Singh, 2014). The Chen-Clayton equation (Chen & Clayton, 1971), which is a sorption isotherm, closely fit measured EMC data of the six kinds of grains (Murata et al., 1988; Tagawa et al., 1993). The Chen-Clayton equation is as follows:

$$rh = \exp\left\{-f_1 T^{g_1} \exp\left(-f_2 T^{g_2} M_e\right)\right\} \tag{1}$$

where rh: equilibrium relative humidity (-), T: absolute temperature (K), M_e: equilibrium moisture content (% (d.b.), d.b.: the amount of water per unit mass of dry matter present in the material), and f_1, f_2, g_1, and g_2: parameters.

The measured EMC data of the sample were fitted to Eq. (1) using a nonlinear least squares method (false position method). The goodness of fit was evaluated by the values of the root mean squared error (RMSE). The values of the parameters in Eq. (1) were: f_1 = 50.61, f_2 = 2.577×10^{-7}, g_1

= -0.3675, and g_2 = 2.326. The solid lines in Fig. 1 are the results calculated from Eq. (1). As is evident from Fig. 1, the agreement between the experimental and predicted values of Eq. (1) was found to be satisfactory (RMSE = 0.022). The relationship between the EMC of the sample in the desorption process, ERH, and absolute temperature was expressed by Eq. (1).

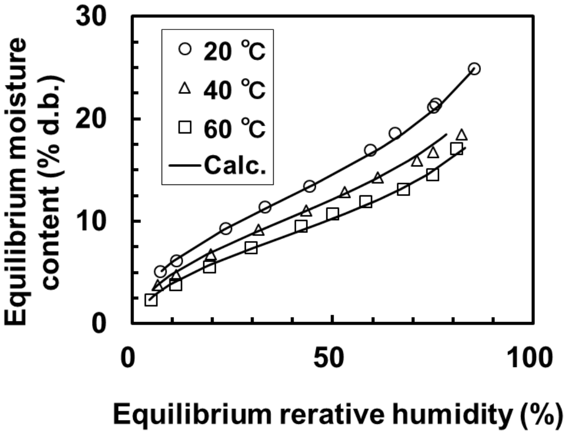

Fig. 1 Moisture desorption isotherms of the sample at three different temperatures

Latent heat of vaporization (LHV) of water

Because Eq. (1) satisfactorily correlated the experimental sorption data of the sample within the range of measurement conditions, Eq. (1) was used to calculate the LHV of water for the sample. The LHV was determined by the same method as Murata et al. (1988) and Tagawa et al. (1993):

The Clapeyron equation for vapor-liquid equilibrium is written as follows:

$$\frac{\mathrm{d}p_{st}}{\mathrm{d}T} = \frac{\Delta h_v}{T\left(v_g - v_l\right)} \tag{2}$$

where p_{st}: the water vapor pressure in the sample (Pa), Δh_v: the latent heat of vaporization (J/kg), v_g: the specific volume of water vapor (m^3/kg), and v_l: the specific volume of liquid water (m^3/kg).
To calculate the LHV (Δh_v), Eq. (3) was rewritten from Eq. (2).

$$\Delta h_v = \left(v_g - v_l\right) \times T \times \frac{\mathrm{d}p_{st}}{\mathrm{d}T} \tag{3}$$

In Eq. (3), the vapor pressure of the moisture in the sample at a given psychrometric condition (p_{st}) was determined from Eqs. (1) and (4).

$$p_{st} = rh \times p_s \tag{4}$$

where p_{st}: the water vapor pressure in the sample (Pa) and p_s: the saturated vapor pressure (Pa). The saturated vapor pressure (p_s) in Eq. (4) is a function of temperature only. The saturated vapor pressure (p_s) in Eq. (4), along with the specific volume of water vapor (v_g) and specific volume of liquid water (v_l) in Eq. (3) were calculated by using the IFC formulation for industrial use (The Japan Society of Mechanical Engineers, 1980) and the equilibrium relative humidity (rh) in Eq. (4) was determined by Eq. (1). The values of $\mathrm{d}p_{st}/\mathrm{d}T$ in Eq. (3) was obtained by differentiating p_{st} in Eq. (4) with respect to the absolute temperature (T).

$$\frac{\mathrm{d}p_{st}}{\mathrm{d}T} = \frac{\mathrm{d}rh}{\mathrm{d}T}p_s + \frac{\mathrm{d}p_s}{\mathrm{d}T}rh \tag{5}$$

The $\mathrm{d}rh/\mathrm{d}T$ value in Eq. (5) was obtained by differentiating rh in Eq. (1) with respect to T as shown by Eq. (6).

$$\frac{\mathrm{d}rh}{\mathrm{d}T} = -rh \times \exp\left(-f_2 T^{g_2} M_e\right) \times \left(f_1 g_1 T^{g_1 - 1} - f_1 f_2 g_2 T^{g_1 + g_2 - 1} M_e\right) \tag{6}$$

In addition, the $\mathrm{d}p_s/\mathrm{d}T$ value in Eq. (5) was calculated by differentiating p_s with respect to T, where p_s was obtained from the IFC formulation (The Japan Society of Mechanical Engineers, 1980).

The LHV isotherms of the sample are shown in Fig. 2, and the LHV values calculated from Eq. (3) for three temperatures is plotted against the moisture content. Though these isotherms were obtained by extrapolating the data at moisture contents above 25 % (d.b.), they showed that the LHV decreased as temperature increased. At a moisture content of 15-30 % (d.b.), the LHV of the sample decreased almost exponentially with an increase in moisture content, and at a moisture content above 50 % (d.b.), the LHV sufficiently approached that of free water. This tendency of LHV versus moisture content is in agreement with the results of Murata et al. (1988) and Tagawa et al. (1993) for grains. The values of LHV for cooked rice were almost the same degree with the grains and beans reported by Murata et al. (1988) and Tagawa et al. (1993). For the sample with a moisture content above 50 % (d.b.), it seemed reasonable to assume that the LHV of the sample was equal to that of free water. Since the LHV is the amount of energy required to remove water from a solid, the higher the LHV, the more tightly bound the water is. The LHV was a function of both temperature and moisture content, i.e., the values varied throughout the drying process. Through the utilization of Eqs. (1) and (2), the LHV of the sample could be estimated as a function of both temperature and moisture content. The LHV of water is the amount of energy (enthalpy) that must be added to a liquid substance, to transform a given quantity of the substance into gas. The energy necessary to add to the drying process can be estimated based on the values of the LHV. This energy calculation leads to the optimization of the manufacturing condition for the cooked rice.

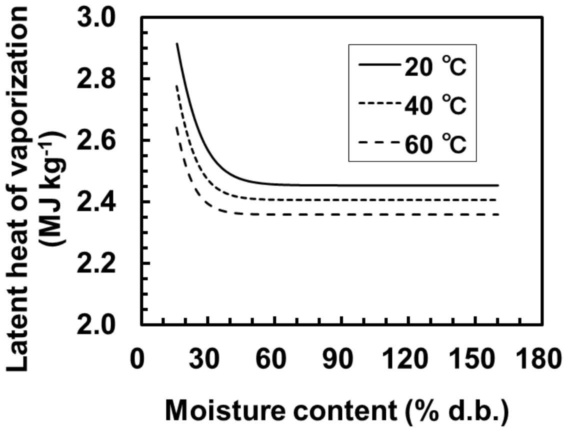

Fig. 2 Latent heat of vaporization of water for the sample calculated from Eq. (3)

CONCLUSION

The equilibrium moisture contents (EMCs) of the cooked rice in the desorption process were measured by a static method at three temperatures (20, 40, and 60 °C) and ten relative humidity levels ranging from 10-86 %. The Chen-Clayton equation was used to express the relationship among the EMC of the sample in the desorption process, equilibrium relative humidity, and absolute temperature. Using the measured results of the EMC, the latent heat of vaporization of water in the sample (LHV) was calculated5 by the Clapeyron thermodynamic theory. The values of LHV decreased almost exponentially with an increase in moisture content from 15-30 % (d.b.) and sufficiently approached that of free water at a moisture content above 50 % (d.b.).

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Research article

Establishment of Optimized Manufacturing Conditions for Cooked Rice-Part II-Moisture Transfer Kinetics of Cooked Rice when Drying and Soaking in Water

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Abstract The thin-layer drying characteristics of cooked milled rice during hot air drying o were measured at four temperatures (30, 40, 50, and 60 °C) and at a relative humidity of 40 %. The hot air-drying process of the sample was composed of the first falling rate, and the exponential model was applied to predict the changes in moisture content of the sample at each temperature. The drying rate constant of the sample increased as temperature increased and was expressed as an Arrhenius-type equation. The water absorption characteristics of dried cooked milled rice when soaking in water were examined at four temperatures (70, 80, 90, and 98 °C). The ratios of the changes in moisture content from 8 to 150 % (d.b.) were converted from the data of changes in moisture content. The first-order reaction rate equation could be applied to explain the water absorption process of samples. The water absorption rate constant had a tendency to increase with increasing soaking temperature and was expressed as a function of soaking temperature by an Arrhenius-type equation.

Keywords cooked milled rice, hot air drying, dried milled rice, water absorption, exponential model, first-order rate constant

INTRODUCTION

The development of processed food made from rice at production location is expected to lead to regional revitalization and increased income for farmers. A simply processed food made from rice is dried cooked rice or pregelatinized rice. A general manufacturing process of dried cooked rice is as follows: 1) washing raw rice, 2) soaking the washed rice in water, 3) cooking or steaming the rice (the raw rice starch is changed to pregelatinized starch), 4) separating the rice kernel from the mass of cooked rice to a single cooked rice, and 5) drying the cooked rice. The dried cooked rice is usually rehydrated with water or hot water and then eaten.

Recently, food that can be kept in case of emergency has been developed and manufactured in Japan to prevent food shortage in the case of natural disasters and infectious diseases. The interest in dried cooked rice has increased as it can be used in preserved food, portable ration food, and emergency provisions. In addition, dried cooked rice has been used as a material in instant food products, for example, an instant pot dried rice similar to an instant pot noodle; thus, the market of dried cooked rice products has continued to increase. The data of the drying characteristics, equilibrium moisture content, latent heat of vaporization for cooked rice, and water absorption (rehydration) characteristics of dried cooked rice are required for optimizing processing operations, designing equipment, and ensuring high quality.

We measured the equilibrium moisture content of the cooked rice, the hot air-drying characteristics of the cooked rice, and the water absorption characteristics of the dried cooked rice. This basic information is needed to establish the optimized manufacturing conditions for cooked rice. The latent heat of vaporization of water for cooked rice was calculated based on the thermodynamic theory by using the equilibrium moisture content data. The moisture transfer kinetics during the drying and the water absorption was analyzed based on the drying theory of the first falling rate period or the first-order reaction rate theory. We had reported the equilibrium moisture content and the latent heat of vaporization of water in part I (Muramatsu et al., 2021. This article was accepted and is continuing the publication process.). The equilibrium moisture contents are needed to analyze the hot air-drying characteristics in addition to examining food preservation. Because the changes in moisture content occur during the drying and the water absorption process, kinetic analysis to predict the changes in moisture content are required to optimize the processing conditions. The moisture transfer kinetics was reported in this Part II. The equilibrium moisture content data reported in Part I was used in the analysis of the moisture transfer kinetics during drying.

Ramesh and Rao (1996) examined the drying of cooked rice (high amylose variety rice) with a vibro-fluidized bed drier. Luangmalawat et al. (2008) reported on the effect of temperature on the drying characteristics and quality of cooked rice (Jasmin rice: long grain rice, indica rice). Jiao et al. (2014) used convective hot air, microwave, and combined microwave-hot air drying techniques for the drying of cooked rice (hybrid indica rice) and evaluated the efficacy of these techniques. Jiao et al. (2014) also investigated the effect of microwave power and air temperature on the drying and rehydration kinetics of dried cooked rice and examined the changes in the color values of the product after drying. Koide et al. (2016) measured the changes in the moisture content of cooked rice during hot air drying and changes in the moisture content of dried cooked rice during water adsorption. Almost all previous papers have reported the drying characteristics of indica rice. Additionally, the drying characteristics of many kinds of food have been measured, and many mathematical models, are used to describe the drying process of food. Optimum drying and water absorption models including the values of parameters, are particularly useful for easily predicting the changes in the moisture content of materials. Therefore, knowing the optimum model is important for practical use.

In this study, we examined the thin-layer hot air-drying characteristics of cooked milled rice (short grain rice, japonica) at four different temperatures. In addition, the water absorption (rehydration) characteristics of dried cooked milled rice were also measured at four different temperatures.

OBJECTIVE

The objectives of this study were 1) to examine the hot air-drying characteristics at several temperatures, 2) to derive a suitable mathematical drying model to describe changes in moisture content, and 3) to evaluate the relationship between the drying rate constant and temperature.

METHODOLOGY

Sample

Non-glutinous rough rice (cv. “Hoshinoyume”) was purchased from a Japanese agricultural cooperative in Tohma, Hokkaido, Japan (JA Tohma) and was stored in a refrigerator at approximately 5 °C until the test. The “Hoshinoyume” was widely cultivated in Hokkaido when we conducted this research because this rice had a good eating quality or tasty. This non-glutinous rough rice was first hulled with a roll-type rice huller (THU35B, Satake Co., Ltd.). Brown rice (800 g) was put into an abrasive-type (stir-type) rice-milling machine (SKM-5B (1), Satake Co., Ltd.) and milled for 5.0 min to produce milled rice. The degree of milling (or milling yield) was adjusted to be approximately 92 %.

The milled rice was cooked with commercial rice cookers (NP-FB10, Zojirushi Co., Ltd.) in accordance with the operation manual of the rice cooker. To uniformly gelatinize the rice, the rice was soaked in tap water at room temperature for 1 h before cooking. The cooking time was 45-60 min and the maximum temperature in the rice cooker was around 104 °C. To obtain a single grain of cooked rice from the mass of cooked rice, the cooked rice was rinsed with tap water for 3 s, and the excess water was drained. After the rinse, the surface of the cooked rice was wiped with Kimwipes® (S-200, Nippon Paper Crecia Co., Ltd.) to remove excess water.

Cooked milled rice was used for measuring the drying characteristics. Dried cooked milled rice was used as a sample for the water absorption test. For the preparation of this dried milled rice, cooked milled rice was dried at a temperature of 40 °C and a drying time of 6 h with a commercial hot air dryer (LH-103D, Satake Co., Ltd.).

Hot air drying test

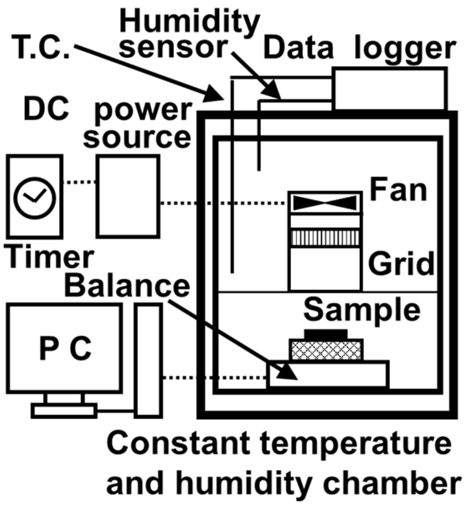

Fig. 1 Schematic of the hot air-drying apparatus

The changes in the moisture content of the cooked rice using the hot air-drying method were measured at four temperatures (30, 40, 50, and 60 °C) and at a relative humidity of 40 %. Fig. 1 shows a schematic of the hot air-drying apparatus used in this study. The apparatus consisted of three units: a drying chamber at constant temperature and humidity, a ventilation unit, and a recording unit. A constant temperature and humidity chamber (IG420, Yamato Scientific Co., Ltd.) was used as the drying chamber. The drying chamber dimensions were a width of 500 mm, a length of 390 mm, and a height of 600 mm. The temperature and relative humidity in the drying chamber were measured with a T-type thermocouple and a relative humidity sensor, and recorded with a data logger (GL200, GRAPHTEC Co., Ltd.). The airflow rate in the chamber was adjusted to 2.0 m/s by a fan (CUDC 12B4, Japan Servo Co., Ltd.) using a DC power source (model 526, Metronix Co., Ltd.). The DC power source was controlled with a timer (ELT-3, AS ONE Co., Ltd.), and the airflow was stopped when the sample mass was measured. A grid screen was fitted below the fan to straighten the air velocity pattern. Changes in mass, i.e., the changes in moisture content, when drying were measured using a digital balance (EK-300i, A&D Co., Ltd.), and the changes in sample mass were automatically recorded on a personal computer. A stainless steel basket with a diameter of 100 mm, a height of 15 mm, and a 3.0 mm aperture, was utilized as a sample tray.

The sample (approximately 10 g) was placed on the tray. The drying test was terminated when the moisture content of the sample was approximately 15 %, on a dry basis (d.b.). The final moisture content of the sample was determined using a forced hot air oven (DX-600, Yamato Scientific Co., Ltd.) at 135 °C for 24 h. Through the use of measured values of final moisture content, the changes in mass when drying were converted to the moisture content of the sample.

Measurement of water absorption characteristics

Moisture content changes of the dried cooked rice when soaking in water were measured at four water temperatures (70, 80, 90, and 98 °C). Approximately 5 g of sample was put into a sample net after weighing the sample mass with a digital balance (FX-300, A&D Co., Ltd.), and soaked in a water bath (SH-12, TAITEC Co., Ltd.). The sample net was removed from the water bath at each preset soaking time (1.0, 2.0, and 5 min intervals), and the surface of the sample was wiped with Kimwipes® (S-200, Nippon Paper Crecia Co., Ltd.) to remove residual liquid. The sample was then reweighed. The increase in sample mass when soaking in water was considered to be an increase in the moisture content of the sample. The moisture content of the sample after soaking was determined from the values of the initial moisture content of the dried cooked rice and the mass changes data when soaking in water.

RESULTS AND DISCUSSION

Hot air-drying characteristics

The moisture content of cooked rice decreased over elapsed time and exhibited a gentle downward curve from the beginning of the drying process at each temperature. The changes in the moisture content of the sample at four different temperatures (30-60 °C) and at a relative humidity of 40 % are shown in Fig. 2. The drying rate (% (d.b.)/h) of the sample was obtained by numerical differentiation (Gregory-Newton forward method) using the moisture content measurements. The drying rate of the sample increased with an increase in temperature. The linear relationship between the drying rate and the free moisture content ($|M\text{-}M_e|$) was found at each temperature. The above result indicates that the hot air-drying process of the sample comprises the first falling rate drying period.

Therefore, the measured drying data were fitted to the following exponential model (Eq. (1)) (Koide et al., 2016) using the least squares method, and the values of the drying rate constant (k_1) were determined at each temperature.

$$\frac{M - M_e}{M_0 - M_e} = \exp\left(-k_1 t\right) \tag{1}$$

where M: the moisture content at each preset time (% (d.b.)), M_0: the initial moisture content (% (d.b.)), M_e: the equilibrium moisture content (% (d.b.)), k_1: the drying rate constant (h^{-1}), and t: the time (h). The values of M_e in Eq. (1) was also calculated from following the equation (Muramatsu et al., 2021. This article was accepted and is continuing the publication process.) at each measurement condition.

$$rh = \exp\left\{-50.61T^{-0.3675}\exp\left(-2.577\times10^{-7}T^{2.326}M_e\right)\right\} \tag{2}$$

The values of k_1 and the root mean squared error (RMSE) of Eq. (1) are given in Table 1. The solid line in Fig. 2 shows the results calculated from Eq. (1). As shown in Fig. 2, the measured results matched well with the calculated results. Under all measurement conditions, the changes in the moisture content of all samples caused by hot air drying could be estimated by Eq. (1).

The temperature dependency of k_1 for grain (Murata, 1982) and beans (Muramatsu et al., 2007) was expressed by the following Arrhenius-type equation:

$$k_1 = a_1 \cdot \exp\left(-\frac{b_1}{T}\right) \quad (3)$$

where a_1 and b_1 are parameters. Eq. (3) shows that the relationship between k_1 and the reciprocal of absolute temperature ($1/T$) is approximately linear in a semilogarithmic plot. The values of k_1 shown in Table 1 were fitted by the least squares method to Eq. (3). The values of the parameters and the RMSE of Eq. (3) were: a_1 = 772.5, b_1 = 1838, and RMSE = 9.081×10^{-2}. Eq. (3) was applicable for examining the relationship between the drying rate constant and the temperature of the sample.

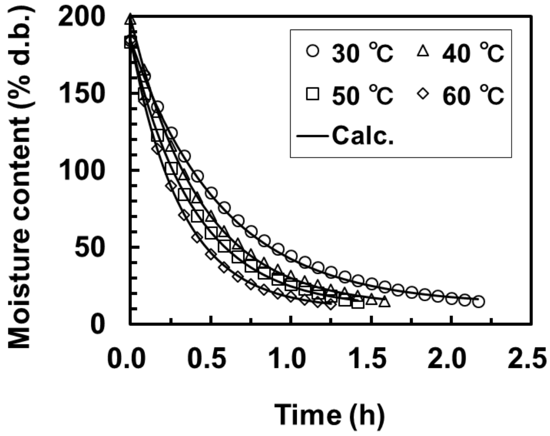

Fig. 2 Changes in the moisture content of the sample when drying

Table 1 Parameters in Eq. (1)

Temperature (°C)	M_0 (% (d.b.))	M_e (% (d.b.))	k_1 (h^{-1})	RMSE (% (d.b.))
30	184.4	12.5	1.746	1.338
40	198.5	11.6	2.311	0.8995
50	183.5	10.7	2.506	1.052
60	184.6	9.89	3.115	0.6286

Water absorption characteristics

The initial moisture contents of the dried cooked rice were approximately 8 % (d.b.). The water absorption curves of the sample are shown in Fig. 3. The moisture content of the sample increased over time, exhibiting a gentle upward curve from the beginning of soaking, and did not approach equilibrium under these measurement conditions. The water absorption rate of the sample increased with an increase in soaking water temperature and on the other hand decreased with an increase in soaking time at each soaking temperature.

The moisture content of cooked rice (nonglutinous japonica rice) is usually approximately 65 % (w.b.), i.e., 150 % (d.b.). In this study, to evaluate the water absorption characteristics of the sample, the ratios of the change in moisture content (Kubota, 1990) from 8 to 150 % (d.b.) (x) were calculated from Eq. (4).

$$x = \frac{M - M_0}{M_T - M_0} = \frac{M - 8}{150 - 8} \quad (4)$$

where x: the ratios of the change in moisture content from 8 to 150 % (d.b.), and M_T: the target or final moisture content (% (d.b.)). The values of x change from 0 to 1, and when “x = 1”, the moisture content of the sample has reached 150 % (d.b.).

The tendency of the changes in the values of x had the same with changes in the water absorption rate. The values of x for the sample increased exponentially with an increase in soaking time.

Therefore, the following first-order reaction rate equation (Kubota, 1990) was applied for analyzing the water absorption characteristics of the sample.

$$\frac{\mathrm{d}x}{\mathrm{d}t} = k_2\left(1 - x\right) \tag{5}$$

where k_2 is the water absorption rate constant (min^{-1}). The unit of time (t) in Eq. (5) is "min". The values of k_2 determined by the least squares method and the RMSE of Eq. (5) for each temperature are shown in Table 2. From the RMSE values, it was confirmed that the measured values agreed well with those calculated from Eq. (5); thus, the ratios of changes in the moisture content of the sample between 8 and 150 % (d.b.) could be estimated by Eq. (5).

The values of k_2 shown in Table 2 increased with an increase in soaking temperature. The values of k_2 were expressed as a function of temperature by using the following Arrhenius-type equation (RMSE = 0.04288).

$$k_2 = 681.0 \cdot \exp\left(-\frac{2606}{T}\right) \tag{6}$$

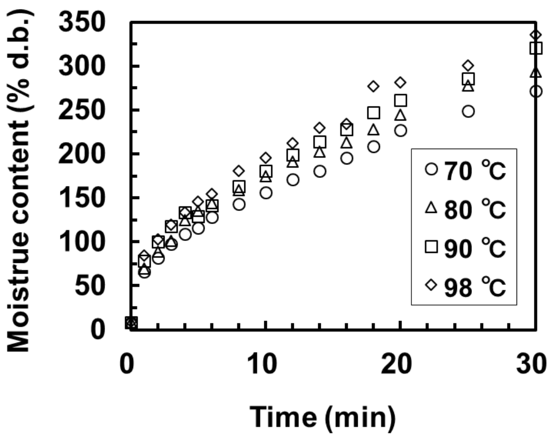

Fig. 3 Changes in the moisture content of the sample during water absorption

Table 2 Parameters in Eq. (4)

Temperature (°C)	k_2 (min^{-1})	RMSE (-)
70	0.3340	0.05893
80	0.4650	0.05416
90	0.4663	0.06033
98	0.6374	0.05380

CONCLUSION

The thin-layer drying characteristics during hot air drying of cooked rice were measured at several temperatures and relative humidity levels. The hot air-drying process of the sample was composed of the first falling rate, and the exponential model was applicable to predict the changes in moisture content of the sample at each temperature. The drying rate constant of the sample increased as temperature increased and was related to temperature by an Arrhenius-type equation.

The water absorption characteristics of dried cooked rice when soaking in water were measured at four temperatures. The first-order reaction rate equation could be applied to explain the water absorption process of samples. The water absorption rate constant was expressed as a function of soaking temperature by an Arrhenius-type equation.

The changes in moisture content of the cooked rice during drying and the dried cooked rice during water absorption can be easily predicted by using the drying model and the water absorption model, respectively. These models will be useful in the determination of the endpoints or treatment time for drying or water absorption. This information saves the input energy and the treatment time and would lead to the establishment of optimized manufacturing conditions for cooked rice.

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Research article

Bamboo charcoal as a lactic acid bacteria carrier for phosphate removal

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Abstract A decline in the demand for using bamboo products has led to abandoned bamboo forests in Japan. To reduce the area of abandoned bamboo forests, the use of bamboo as a construction material and bamboo charcoal as an absorbent have gained considerable attention in recent years. In the literature, many studies have described the formation of biofilms on biochar, leading bamboo charcoal to be considered as a microbial carrier. The aim of this study was to examine the potential of bamboo charcoal as the microbial carrier of lactic acid bacteria (LAB) for phosphate removal. Bamboo charcoal was immersed in a LAB solution for 24 h for LAB to adhere to the bamboo charcoal. Then, the bamboo charcoal was placed in a bamboo fermented solution. Two types of bamboo charcoal, i.e., without pretreatment and dissolved in tap water, were used in the experiments. The experiments were also conducted with and without aeration to determine the effects of oxygenation. The bamboo charcoal without pretreatment displayed an increase in the phosphate concentration, indicating that phosphate was released from the bamboo charcoal. LAB-attached bamboo charcoal demonstrated a much smaller increase in phosphate concentration, suggesting phosphate was removed by LAB. Experiments with dissolved bamboo charcoal also indicated a reduction in the phosphate concentration. The removal rate of phosphate decreased with an increase in the solution pH, suggesting that alkaline conditions limited the activity of the bacteria. Furthermore, the redox potential of the solution became negative in the solution without aeration. Overall, the results demonstrated that bamboo charcoal could be a LAB carrier; however, the bamboo charcoal must be dissolved prior to its use for phosphate removal. Furthermore, aeration and an acidic during phosphate removal are needed to obtain a higher removal rate when using LAB.

Keywords Bamboo charcoal, microbial carrier, lactic acid bacteria, phosphate removal

INTRODUCTION

Although bamboo has been used in many different fields in Japan, a decrease in the demand for bamboo products has led to abandoned bamboo forests. According to a report by the Forestry Agency of Japan, the total bamboo forest area in 2007 was approximately 1600 km^2, which was 10% greater than in 1981. In 2007, the bamboo forest area covered approximately 0.6% of the total forest area in Japan, but up to 66% of the bamboo forest area was left unused. To reduce the area of abandoned bamboo forests, several countermeasures have been proposed to increase the utilization rate of bamboo. Historically, bamboo was primarily used as construction material and for household furniture. In recent years, bamboo has been used as a fertilizer in agriculture (Cui and Wu, 2010; Liu et al., 2014), and bamboo biochar has been used as an absorbent for contaminant removal (Liu et al., 2012; Mohamed et al., 2015).

In previous reports, a large number of negative charges was observed on the surface of biochar (Yigit and Mazlum, 2007). These negative charges generate electrostatic repulsion between the biochar surface and anions, making it difficult to adsorb phosphate ions on the surface. Furthermore, some kinds of biochar can release phosphate in aqueous solutions (Yao et al., 2012). For example, Jung et al. (2015) reported the release of phosphate from bamboo biochar. Therefore, when using biochar for phosphate removal, it is necessary to modify the biochar surface with treatments using acids, alkali, iron oxide, or magnesium ions (Stratful et al., 2001; Tansel et al., 2018). Biochar impregnated with colloidal and nanosized metal oxyhydroxides can enhance the removal rate of phosphate (Zhang and Gao 2013; Zhang et al., 2012). Dai et al. (2020) also reported phosphorus removal in a solution using magnesium-modified biochar from bamboo. Li et al. (2020) reported the enhancement of phosphate adsorption using polyethyleneimine-modified biochar derived from bamboo biomass.

In addition to adsorption, the biological method is one of the various approaches for phosphate removal. As biochar is a porous material, it can serve as a habitat for microorganisms (Egamberdieva et al., 2018). Many studies have examined biofilm formation in biochar and its effect on soil properties (Yang et al., 2019; Ajeng et al., 2020; Gorovtsov et al., 2020). According to the literature, it is believed that organisms-attached biochar can increase the removal rate of phosphate in aqueous solutions. However, to the best of our knowledge, there is a lack of information related to the employment of organisms-attached bamboo charcoal for phosphate removal. In addition, as the efficacy of phosphate removal strongly depends on the properties of the biochar, a study of phosphate removal capabilities is necessary before the widespread use of bamboo charcoal.

OBJECTIVE

This study examines the potential of bamboo charcoal as a microbial carrier for lactic acid bacteria (LAB) and its phosphate removal capabilities. It is believed that LAB-attached bamboo charcoal can increase the removal rate of phosphate in aqueous solutions. Furthermore, this study focuses on deciphering the effects of the pretreatment of bamboo charcoal for phosphate removal. As the release of phosphate from bamboo charcoal has been previously reported in the literature (Yao et al., 2012), and bacteria need oxygen for their activities, the effects of oxygen supply (aeration) and solution pH on the phosphate removal by bamboo charcoal are also examined.

METHODOLOGY

Material Used for the Experiments

Bamboo charcoal (Fig. 1a) and bamboo powder (Fig. 1b) are readily available products. The bamboo charcoal was passed through 3.75 cm and 5.6 mm-mesh sieves. Only the residual on 5.6 mm-mesh sieve was used in experiments, i.e., the diameter range of 0.56-3.75 cm. Two kinds of bamboo charcoal were prepared, i.e., without pretreatment and dissolved in tap water (50 g of bamboo charcoal in 500 mL of water). For the bamboo charcoal dissolved in tap water, the solution was mixed until no further release of phosphate was observed. The bamboo powder was fermented for four days, and then the supernatant (hereafter, called bamboo supernatant) was extracted and used in the experiments.

(a) Bamboo charcoal

(b) Bamboo powder

Fig. 1 Bamboo charcoal and bamboo powder used in the experiments

Experimental Procedures and Measurements

First, approximately 50 g of bamboo charcoal was placed in a LAB solution for 24 h to attach LAB to the bamboo charcoal. Then, the bamboo charcoal was placed in the bamboo supernatant to assess the phosphate removal. The LAB solution was produced by mixing 50 mL of LAB beverage with 1 L of deionized water. The experiments were conducted with and without aeration to examine the effects of oxygen on LAB for phosphate removal. The experiments were conducted in a room with the ambient temperature range of 25-30 ℃.

Temporal measurements of the solution pH, redox potential (ORP), and phosphate concentration were conducted. The pH and ORP were directly measured by placing a pH/ORP meter (Horiba, D-73) into the solution. The solution in the bamboo charcoal layer was extracted using a syringe, and the phosphate concentration in the extracted solution was measured using a digital Packtest (Kyoritsu, DPM2-PO4-D). A summary of these experimental procedures is shown below in Fig. 2. A duplicate measurement was conducted, and the average value was used for discussion. Phosphate concentration, pH and ORP were measured with relative errors of 0.1 mg/L, 0.1, and 1 mV, respectively.

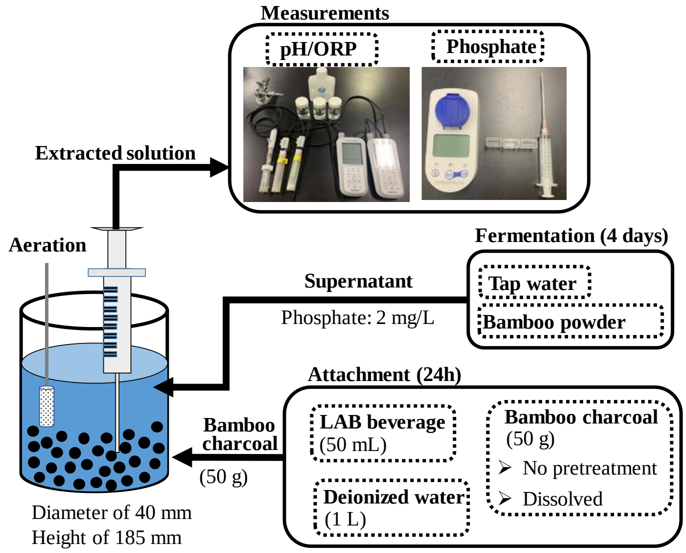


Fig. 2 Summary of experimental procedures

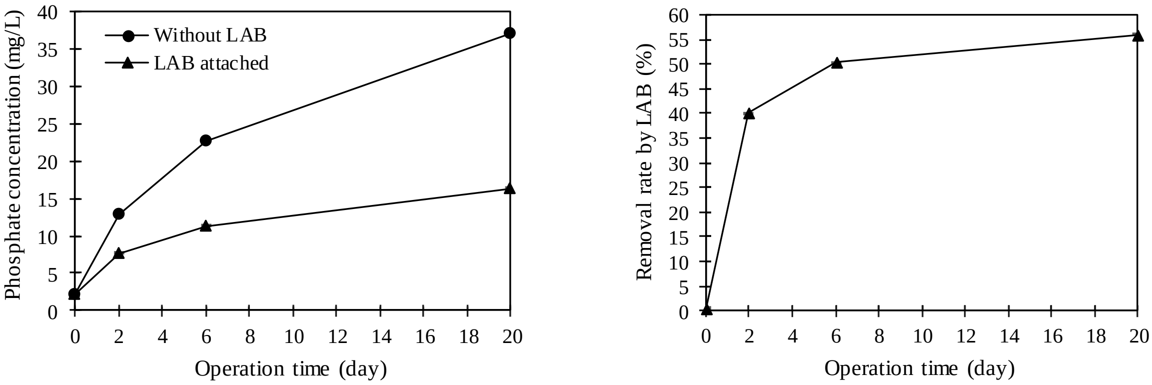
RESULTS AND DISCUSSION

Temporal Changes in Phosphate Concentrations (Bamboo Charcoal Without Pretreatment)

Figure 3 shows the temporal changes of phosphate concentration when using bamboo charcoal (no pretreatment) without aeration. The phosphate concentration in the bamboo supernatant was approximately 2 mg/L, and increased to 37 mg/L at day 20 after the experiment started (Fig. 3a). This increase indicates a release of phosphate from the bamboo charcoal, which is in good agreement with the findings by Jung et al. (2015).

When LAB-attached bamboo charcoal was used, the increase in the phosphate concentration was smaller compared to the bamboo charcoal without LAB. This indicates phosphate removal by LAB. Even though the LAB is attached to the bamboo charcoal, they effectively remove phosphate from the aqueous solution. These results suggest that LAB-attached bamboo charcoal can be an absorbent for phosphate removal.

The removal rate of phosphate by LAB was 40% at day 2, 50% at day 6, and 56% at day 20, see Fig. 3b. These removal rates are on the same scale as conventional biological methods, which remove 20–40% of phosphorus (Ruzhitskaya and Gogina, 2017). Furthermore, it can be inferred from Fig. 3b that the removal capacity rapidly decreased, as it was 40% at day 2, but only increased by 10% from day 2 to day 6 and by 6% from day 6 to day 20. It is likely that the metabolic activity or the bacteria growth was limited due to the lack of oxygen. Without aeration, the ORP decreased significantly at day 20 when using LAB-attached bamboo charcoal to -300 mV vs. Ag/AgCl (no oxygen in water), while the ORP was maintained at 190 mV when using bamboo without LAB. Moreover, the solution pH was 7 when using LAB-attached bamboo charcoal but climbed to 9 when using bamboo charcoal, indicating that the dissolution of bamboo charcoal increases the solution pH. In summary, these results indicated that pretreatment and aeration are necessary when using LAB-attached bamboo charcoal for phosphate removal.



(a) Phosphate concentration (b) Removal rate of phosphate by LAB

Fig. 3 Changes over time of phosphate concentration and removal rate of phosphate by LAB using bamboo charcoal (no pretreatment) without aeration.

Temporal Changes in Phosphate Concentrations (Dissolved Bamboo Charcoal)

Based on the findings shown in Fig. 3, pretreatment of the bamboo charcoal and aeration are both needed for phosphate removal. Figure 4 shows the temporal changes of phosphate concentration when using dissolved bamboo charcoal with aeration. The phosphate concentration of the bamboo supernatant was approximately 2 mg/L and slowly increased to 12 mg/L on day 13 after the experiment began (Fig. 4). In comparison with Fig. 3a, the release of phosphate from the bamboo charcoal was strongly suppressed due to the dissolution of bamboo charcoal before its use in the experiments. This indicates that bamboo charcoal without pretreatment is not an effective absorbent for phosphate removal.

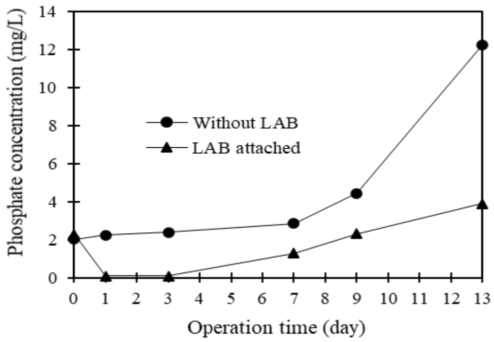


Fig. 4 Temporal changes of phosphate concentration using dissolved bamboo charcoal with aeration

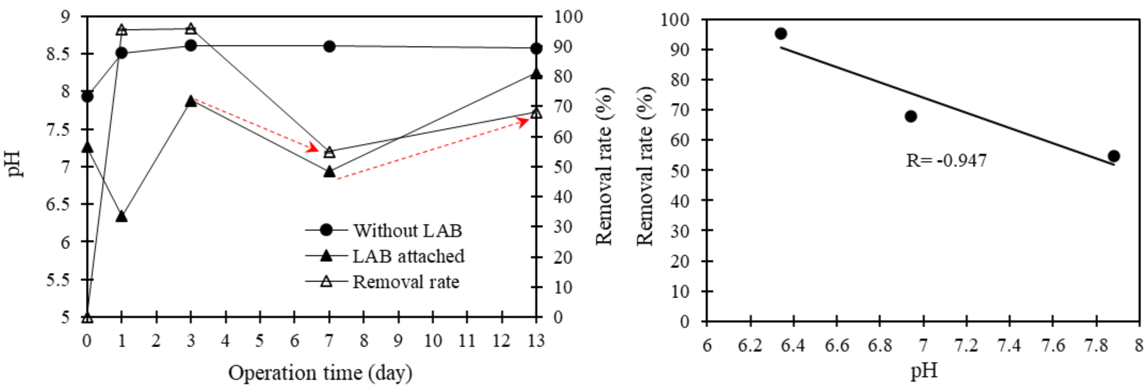
When using LAB-attached bamboo charcoal, a decrease in the phosphate concentration was observed, indicating phosphate removal by LAB. Up to 95% of phosphate was removed during the first 3 days due to a low initial concentration of phosphate. According to Fig. 3a, LAB removed 5 mg/L of phosphate on day 2 and 11.5 mg/L on day 6. Interestingly, according to Fig. 4, LAB could not completely remove the 2.8 mg/L of phosphate produced on day 7; however, it was able to remove 8.3 mg/L of phosphate on day 13. As bacteria are involved in this reaction, it is believed from these results that pH and dissolved oxygen (DO) concentration may also affect phosphate removal.

Effects of DO Concentration and pH on Phosphate Removal

By providing aeration, the ORP was maintained at an oxidizing potential of 275 mV when using bamboo charcoal without LAB, and the ORP was 245 mV with LAB-attached charcoal on day 13. The slightly lower ORP was observed for LAB-attached charcoal, indicating a small oxygen consumption by LAB. In other words, DO was enough for bacteria respiration when aeration was provided, which was considered to be less effect on the bacteria's activity. In addition, it is known that LAB is more active in acidic conditions; however, the dissolution of bamboo charcoal increases the solution pH, potentially influencing the bacteria's activity.

Figure 5 depicts the temporal changes in the solution pH when using dissolved bamboo charcoal with aeration. The dissolution of the bamboo charcoal increased the solution pH with and without LAB; however, the pH was lower with LAB-attached bamboo charcoal (Fig. 5a). This was attributed to the activities of LAB which released lactic acid. The data from Fig. 5a indicate that the solution pH was 6.3 at day, which induced the high phosphate removal rate of 95% on day 3. The solution pH increased from 6.3 on day 1 to 7.9 on day 3, and then decreased to 6.9 on day 7. Although the solution pH decreased from day 3 to 7, the pH value of 7.9 influenced the removal rate from day 3 to 7, i.e., a decrease in the removal rate to 55% was observed on day 7.

Similarly, a pH value of 6.9 on day 7 led to an increase in the removal rate to 68% on day 13. It can be understood from these results that the removal rate is dependent on the solution pH. By plotting the removal rate versus the solution pH (Fig. 5b), it can be observed that the removal rate and pH were strongly correlated (R=-0.947), as expected. These results indicate that the solution pH should be maintained in an acidic state (lower than 6.5) to achieve a higher removal rate.



(a) Temporal changes in pH and removal rate (b) Relationship between pH and removal rate

Fig. 5 Relationship between pH and removal rate.

CONCLUSION

In this study, the potential of bamboo charcoal as a microbial carrier for LAB was evaluated, and its ability to remove phosphate was investigated. The effects of oxygen supply and solution pH on the phosphate removal by bamboo charcoal were also examined. Without aeration, a negative redox potential (ORP) was observed, indicating a large oxygen consumption by LAB. Thus, aeration is needed when using LAB. Even with dissolved bamboo charcoal, the release of phosphate was observed, indicating that bamboo charcoal alone is not an effective absorbent for phosphate removal. When LAB-attached bamboo charcoal was used, a decrease in the phosphate concentration was observed. This suggests that LAB-attached bamboo charcoal is an effective adsorbent for phosphate removal. With aeration, the ORP was maintained in an oxidizing state, which had no impact on phosphate removal. However, the removal rate was found to depend on pH, where the removal rate decreased with an increase in the solution pH. Therefore, the phosphate removal should be conducted under acidic conditions (pH lower than 6.5) to obtain a higher removal rate.

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Research article

Contribution of sustainability rice cultivation practice for farmers according to SRP standard: A case study of Ubon Ratchathani Province, THAILAND

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Abstract: Sustainable rice cultivation is the goal of agricultural development in Thailand. With that in mind, the Thai rice department started the Sustainable Rice Platform (SRP) in Ubon Ratchathani Province, one of the most important jasmine rice production areas of Thailand. Previous studies have shown that most of the paddy fields were in the essential level or "working towards sustainable rice cultivation", the intermediate level of sustainability, while non-paddy fields achieved an overall Sustainable Rice Platform (SRP) score that allowed them to claim to be sustainable rice farms. The purpose of this study was to identify the significant factors that affected sustainability in the group of practices called "SRP theme" and the constraints of rice cultivation development. The study was conducted on 85 farmers in Det Udom district, Ubon Ratchathani Province, Thailand. Questionnaires and in-depth interviews were collected. The results showed that farm size had a significant effect on the Pre-planting theme (a group of pre-plating activities), water management and nutrient management for the SRP score; a larger farm can lead to higher scores. The integrated farming system had a significant effect on farm management, harvest and post-harvest theme. Paddy fields that used the integrated farming system accomplished higher scores. The certified rice program had a highly significant effect on farm management, pre-planting, harvest, and post-harvest theme, including the health and safety theme. Moreover, certified rice programs for farmers (Organic, Good Agricultural Practice-GAP and Sustainable Rice Platform- SRP farmers) enabled higher sustainability rice cultivation scores.

Keywords: Rice, Sustainability, Organic, SRP, GAP, Certification

INTRODUCTION

Rice production plays an important role in Thai economy. Thailand was a top-5 rice exporter in 2019 with about 10.3 million metric tons (Startista, 2020). However, this occupation is currently faced with multiple challenges such as global market competition (USDA. 2020), declining yields, the contamination of agrochemicals, biodiversity losses and greenhouse gas emissions (GHG) (G.S. Bhullar, 2015). Rice cultivation accounts for more than half of Thailand's agricultural GHG emissions (MNRE, 2013). As a result, Thailand is rated 20th of the world in terms of agricultural CO_2 emissions (FAO. 2018). It was found that farmers can reduce GHG emissions and make their paddy fields more sustainable by improving some farm activities. The activities that affect the conditions include changing the way to manage water on a farm, the selection of rice cultivars, nutrient management, and cultivation methods (H. L. Suihawati, 2018) that avoid the burning of rice residue (Noppol, 2017). The Rice Department in Thailand started a sustainable rice cultivation project in Ubon Ratchathani Province, one of the most important jasmine rice production areas of Thailand, by using the Sustainable Rice Platform (SRP). This standard was designed for farm-level impact at the smallholder level and consists of 8 sets of actions called SRP themes, each with several requirements, for a total of 46 types of requirements for sustainable rice production. These include: 1) Farm management, 2) Pre-planting, 3) Water use, 4) Nutrient management, 5) Pest management, 6) Harvest and postharvest, 7) Health and safety, and 8) Labor rights. Farmers who want to implement the program must be trained and improve their farming activities following the SRP standards. Within each theme, sustainability can be shown by a percentage score. To improve the sustainability of rice cultivation according to the SRP standards, there is a strong need to identify the factors that impact the SRP scores in each SRP theme in order to boost the farmer's sustainability in rice cultivation, not only reduce GHG emission but also to improve farming efficiency and economic aspects.

OBJECTIVE

This research aimed to identify the significant factors that affected the sustainability in the group of practices and the constraints of rice cultivation development in Det Udom, Ubon Ratchathani Province, Thailand.

METHODOLOGY

The researchers collected both quantitative and qualitative data by using a questionnaire as an interview guideline to assess the characteristics of farmers and their farms in October 2018. The sustainable scores were calculated by using SRP standard version 1.0 developed by SRP and IRRI. (Wyn, 2015) The sustainable scores came from 46 requirements based on farmer's activities. If the activity belonged to idealistic sustainable rice cultivation, the farmer would receive a high score on that requirement. In contrast, if the farm activities were not sustainable, the farmer would get a low or zero score. Total scores were calculated and presented in percentage to clarify the level of sustainable rice cultivation on farms. Stratified random sampling was used to select farmers from each of four types including SRP, organic, GAP and conventional farmer, according to the farmers' list of extension service centers in Det Udom district, Ubon Ratchathani. The total sample size of 85 farmers comprised 11.3% of the farmers on this list.

This study identified the factors that affected each SRP theme score. Eight regression analysis equations were operated based on the 8 SRP themes mentioned previously. All the dependent variables comprised the total score on each theme, while the independent variables were the characteristics of farms and farmers. All independent variables were entered into the equation at the same time, as shown in the following equation:

$$Y(1,2,..8) = a + b1x1 + b2x2 + b3x3 + b4x4 + b5x5 + b6x6 + b7x7 + b8x8 + b9x9 + e \quad (1)$$

Where: Y1 = farm management scores, Y2= Pre-planting scores, Y3 = Water use scores,
Y4 = Nutrient management scores, Y5 =Pest management scores,
Y6 = Harvest and post-harvest scores, Y7 =Health and safety scores,
Y8 = Labor right scores
X1 = the certified practice of rice farm (dummy variable: certified/ noncertified)
X2 = education period (years)
X3 = Level of integration on farm (dummy: 1 component integration)
X4 = Level of integration on farm (dummy: 2 component integration)
X5 = source of income (dummy: multiple income sources)
X6 = labors on farm (person)
X7 = yield (Kg/Rai)
X8 = farm size (Rai)
X9 = income (Baht)

The data were evaluated and explained in the 8 equations using Statistical package for social science (SPSS) version 23. The demographic features and farming practices of sample respondents were determined using descriptive statistics and content analysis.

RESULTS AND DISCUSSION

Almost all the farmers in this study were descendants of farmers (98%). Over half of them were aged 40-59 years (63.52%). Most of them were full-time farmers and had more than 10 years of experience (88%). They learned agricultural techniques from their parents and grandparents and observed other techniques from neighbors as well as extension agents. A common cropping system in the area is integrated agriculture. They plant food plants such as basil, bananas, and weed grasses in home gardens and various vegetables as commercial field crops. The average rice yield was 352 kilograms/rai (0.16 hectare), while mean annual farm income was 117,936 baht. Moreover, half of the farmers' revenue (58.82%) came from their farms alone. The factors that give effects to the SRP theme scores are provided in Table 1.

Table 1 Effects of farmer and farm characteristics on average SRP scores for each theme

Theme & Constant	Certified Practice (x1)	Education Period (x2)	Integration component		Income Sources (x5)	farm Labor (x6)	Yield (x7)	Farm size (x8)	Income (x9)	R^2 & R^{adj}
			1 (x3)	2 (x4)						
Farm mgt (Y1) 29.36	19.08 (0.00)** (9.99-28.18)	0.30 (0.54) (-0.68-1.28)	3.25 (0.47) (-5.83-12.34)	-11.27 (0.02)* (-21.13-1.40)	2.98 (0.46) (-5.13-11.09)	0.73 (0.74) (-3.74-5.20)	0.10 (0.12) (-0.02-0.23)	0.03 (0.79) (-0.20-0.26)	-0.00 (0.90) (0.00-0.00)	0.27 0.18
Pre-plant (Y2) 43.17	21.66 (0.00)** (11.85-31.48)	-0.45 (0.39) (-1.52-0.60)	1.75 (0.72) (-8.07-11.54)	-5.55 (0.30) (-16.19-5.08)	4.14 (0.34) (-4.62-12.90)	-0.45 (0.85) (-5.28-4.37)	0.03 (0.66) (-0.11-0.17))	0.30 (0.01) * (0.05-0.55)	-0.00 (0.13) (0.00-0.00)	0.29 0.21
Water use (Y3) 60.99	-2.22 (0.62) (-11.18-6.74)	0.20 (0.67) (-0.76-1.17)	-3.51 (0.43) (-12.47-5.44)	-3.38 (0.49) (-13.10-6.33)	-4.42 (0.27) (-12.42-3.57)	-0.01 (0.99) (-4.42-4.39)	0.06 (0.30) (-0.06-0.19)	0.32 (0.00)** (0.98-0.55)	-0.00 (0.39) (0.00-0.00)	0.14 0.03
Nu mgt (Y4) 102.13	2.24 (0.69) (-9.13-13.62)	-1.01 (0.10) (-2.24-0.21)	-7.98 (0.16) (-19.36-3.39)	-8.97 (0.15) (-21.32-3.36)	6.69 (0.19) (-3.46-16.85)	0.04 (0.98) (-5.55-5.64)	-0.04 (0.61) (-0.20-0.12)	-0.31 (0.03)* (-0.06-0.02)	0.00 (0.56) (0.00-0.00)	0.13 0.03
Pest mgt (Y5) 88.72	1.04 (0.76) (-5.83-7.92)	-0.34 (0.35) (-1.09-0.39)	0.79 (0.81) (-6.08-7.67)	-5.37 (0.15) (-12.83-2.08)	-2.78 (0.36) (-8.92-3.35)	2.41 (0.16) (-0.97-5.79)	-0.01 (0.72) (-0.11-0.08)	-0.10 (0.25) (-0.27-0.07)	0.00 (0.24) (0.00-0.00)	0.10 0.00
Harvest (Y6) 55.81	9.23 (0.02)* (1.12-17.34)	-0.25 (0.56) (-1.13-0.62)	-2.76 (0.49) (-10.87-5.33)	-9.99 (0.02)* (-18.78-1.21)	3.70 (0.31) (-3.53-10.94)	1.71 (0.39) (-2.26-5.70)	0.05 (0.37) (-0.06-0.16)	0.00 (0.95) (-0.20-0.21)	-0.00 (0.68) (0.00-0.00)	0.13 0.03
Health (Y7) 57.21	9.61 (0.00)* (3.33-13.90)	0.08 (0.79) (-0.59-0.76)	1.52 (0.62) (-4.75-7.81)	-5.51 (0.11) (-12.33-1.30)	2.86 (0.31) (-2.74-8.47)	1.88 (0.22) (-1.21-4.97)	0.03 (0.46) (-0.05-0.12)	-0.09 (0.26) (-0.25-0.06)	-0.00 (0.71) (0.00-0.00)	0.17 0.07
Labor right (Y8) 91.69	0.10 (0.96) (-4.89-5.10)	0.17 (0.51) (-0.36-0.71)	0.38 (0.87) (-4.61-5.38)	-3.16 (0.24) (-8.58-2.26)	1.43 (0.52) (-3.03-5.90)	1.94 (0.12) (-0.52-4.39)	0.00 (0.83) (-0.06-0.07)	-0.08 (0.18) (-0.21-0.04)	0.00 (0.64) (0.00-0.00)	0.10 0.00

Source: Investigation by the author (2018)
*Note: mgt = management, *p-value >0.05, **p-value >0.01, 95% Confidence Interval*

The group of independent variables (x1-x9) statistically affected 6 of 8 dependent variables (SRP theme scores). All details are explained as follows:

Farm management scores

$$Y1 = 29.36 + 19.08x1 + 0.30x2 + 3.25x3 - 11.27x4 + 2.98x5 + 0.73x6 + 0.10x7 + 0.03x8 - 0.00x9 \quad (2)$$

In terms of farm management scores, farmers were required to update their crop calendar throughout the crop cycle, keep recording of all fertilizers, pesticides, and machinery operations as well as calculated quantities of water use, seed variety, yield, and production cost. They also had to attend training or regularly seek professional advice on farm management. According to the Y1 equation, certified practice of rice farm (x1) and integration component on farm (2 component integration : x4) are the variables that contribute significantly to farm management scores. If farms or farmers use the certified rice practice (Organic, GAP or SRP rice practice), the farm management scores increase because farmers must attain training, report their crop calendar, and detail their agricultural activities (such as cost, yield, profit, timing of machine operation, etc.) to the inspectors of the government extension agent, while conventional farmers are not required to do the same. Furthermore, farmers who used integrated agriculture techniques will achieve higher scores on farm management, more component is more sustainable scores. In contrast, farmers who used a monocrop technique got lower farm management scores when compared to the integrated rice farmers.

Pre-planting score

$$Y2 = 43.17 + 21.66x1 - 0.45x2 + 1.75x3 - 5.55x4 + 4.14x5 - 0.45x6 - 0.03x7 + 0.03x8 - 0.00x9 \quad (3)$$

To achieve high scores in pre-planting, farmers must have the documents to prove that the soil is safe from heavy metal and there is no risk of soil salinity. Their farms must not be in primary forest; the farmland must be flat or be sufficiently leveled. There can be no invasive species and the rice seed must be pure and certified or traceable. Y2 equation shows that the certified practice of rice farm (x1) and farm size (x8) is a statistically significant factor that can increase the sustainability of the pre-planting theme. Certified rice farmers have the condition to check the safety of soil and the quality of rice seed. Further, they are not allowed to cultivate in primary forest areas. This enables certified farms to have higher sustainability scores while conventional farmers have higher risk to achieve lower scores. Additionally, the farmers with bigger farm size (x8) can raise their sustainability in pre-planting of rice farms. If farmers want to develop the sustainability of the pre-planting process, they must check soil quality, adopt land conservation practices such as cover cropping, install erosion barriers or laser land leveling to adjust farm area to fit in the appropriate slope at least every 3 years. This condition increase the production costs on land preparation among smallholder farmers and transform into the constraints of sustainable rice farm development for small scale farmers. Bigger size farm plots will deliver price efficiency compared with smaller farms and provide higher sustainability scores.

Water use score

$$Y3 = 60.99 - 2.22x1 + 0.20x2 - 3.51x3 - 3.38x4 - 4.42x5 - 0.01x6 + 0.06x7 + 0.32x8 - 0.00x9 \quad (4)$$

The sustainability of water use is focused on the efficiency of water management, which is consisted of water quality check, timely and appropriate crop establishment, and sufficient irrigation system and safety water drainage. It was found that farm size (x8) had a significant effect on the water use score of the Y3 equation. According to the geography of Det Udom district, which uses a rain-fed rice production system, one of the most challenging factors is the amount of rain used for rice cultivation. Even though the farmers in this area have a good understanding of the local climate and plan well about timing the operation of rice crops, only the farmers who have larger farm areas have enough space to keep rainwater in a pond or other system for supplementary irrigation. Regarding this factor, the sustainability scores for water use theme increased as the size of rice farms increased.

Nutrient management score

$$Y4 = 102.13 + 2.24x1 - 1.01x2 - 7.98x3 - 8.97x4 + 6.69x5 + 0.04x6 - 0.04x7 - 0.31x8 + 0.00x9 \quad (5)$$

The scores for nutrient management depend on the efficiency of soil fertility enhancement. Farmers should use crop rotation techniques, as well as apply fertilizer based on the result of soil analysis and split the application of nitrogen fertilizers or use slow/controlled release / deep placement fertilizers. Organic fertilizer must be the first choice to improve soil quality and must be applied in the non-flood areas. In the Y4 equation, it was found that a larger farm size (x8) can help farmers achieve higher sustainable scores on nutrient management. Based on the interviews of the farmers, they prefer to apply the organic manure on wetland or flooding periods of their rice farms. They believe that it's easier and more effective than a deep placement fertilizer technique. For the farmers who have a large farm area (and for who have the rainwater storage pond), however, flooding their paddy field only for fertilizer leads to higher production costs. They choose to apply the fertilizers on dry land instead for economic reasons. Even though it is not based on a complete understanding of nutrient management, the action's result is appropriate for the situation. Furthermore, when it comes to fertilizers, a larger farm size provides more economies of scale, both in terms of cost and wage. For all these reasons, large farms achieve higher scores.

Pest management score

$$Y5 = 88.72 + 1.04x1 - 0.34x2 + 0.79x3 - 5.37x4 - 2.78x5 + 2.41x6 - 0.01x7 - 0.01x8 + 0.00x9 \quad (6)$$

On pest management, farmers should understand and adopt the Integrated Pest Management (IPM) technique for principal pest control on their farms. If farmers use a non-chemical methodology to control weed, insect, disease, mollusk, and avoid killing rodents and birds, they achieve high scores. In serious cases, pesticide and chemical substances are allowed to be applied carefully in the target area following the label instructions. Pesticide application equipment should be calibrated and maintained within the current crop cycle. According to the Y5 equation, there is no independent variable on this equation that significantly affects the pest management scores.

Harvest & Post-harvest score

$$Y6 = 55.81 + 9.23x1 + 0.08x2 + 1.52x3 - 5.51x4 + 2.86x5 + 1.88x6 + 0.03x7 - 0.09x8 - 0.00x9 \quad (7)$$

Harvest and post-harvest scores are focused on the timing of the harvest; the rice moisture content should be 21%-24%. All machines and equipment should be cleaned to prevent contamination. Rice should be transported to the drying facilities within 12 hours and stored away from hazardous substances. Rice stubble and rice straw should not be burned to mitigate GHG emissions. On the Y6 equation, the certified practice of rice farm (x1) and level of integration on the farm (2 component with rice: x4) are the independent variables that significantly affected the scores. Farmers that employ organic, GAP, or SRP rice programs must abide with the rules, which include not permitting farmers to burn their rice straw or using contaminated harvesting machines. The conventional farmers in this study burned their rice fields to save their production costs. However, it caused them to achieve lower scores in this sustainable theme. Farmers who use the integrated cropping system will have various kinds of agricultural commodities. To get their products, many activities will happen on their farmland and some of them can cause dirt or contamination in rice products. In that case, farmers become more concerned about the effect on their harvest and post-harvesting activities. This will help to increase the scores as well as the sustainability of the SRP. In contrast, farmers used the monocrop system and there was less concern about contamination, though it may cause lower sustainable scores.

Health & Safety score

$$Y7 = 57.21 + 9.61x1 + 0.08x2 + 1.52x3 - 5.51x4 + 2.86x5 + 1.88x6 + 0.03x7 - 0.09x8 - 0.00x9 \quad (8)$$

To achieve high scores, farmers should prepare safety instructors for all farm laborers, prevent related accidents and disease work. Further, first-aid kits should be available on the farms. Calibration and maintenance of all equipment should be done within the crop cycle. Training for agricultural chemical uses is needed if farmers use chemical elements on the rice farms. According to the Y7 equation, the certified practice of rice farm (x1) was statistically significant to the health & safety scores. Participation in certified rice programs enables farmers to learn the effects of chemicals on human health and to learn how to protect themselves.

Labor rights score

$$Y8 = 91.69 + 0.10x1 + 0.17x2 + 0.38x3 - 3.16x4 + 1.43x5 + 1.94x6 + 0.00x7 - 0.08x8 + 0.00x9 \quad (9)$$

Labor rights scores focus on how farmers address human rights, including the wage and safety conditions for laborers on their farms. Under this theme, no children below the minimum age can work on farms or be around hazardous work. Further, employers must provide education for children. There can be no forced, prison or bonded labor. Laborers must have the right to join or establish an association or organization to negotiate their needs, received wages, and other benefits according to local and national laws. On the Y_8 equation, independent variables on this equation did not have a statistical effect on labor rights scores.

CONCLUSION

The results of the analysis showed that there were three important independent factors that affected the sustainability scores of rice cultivation, consisting of 1) Certified program of the farm, 2) Integrated component of the farm, and 3) farm size. The use of certified rice programs has a substantial impact on 4 SRP themes connected to document certification and training which are the important part to be the certified farmers. Certified farmers have already received extensive training, allowing them to better manage their farms, comprehend the importance of farm preparation, and harvest rice in a sustainable manner. Integrated components affected the management of farms. More farm components would encourage farmers to focus on their management, which will be reflected in their farm management score and harvesting activities. While farm size affected the rice production in pre-planting, water use and nutrient management which is related with farm investment. The larger the farm, the better the chances of being a sustainable rice farm. All significant factors suggested that two major issues need to be addressed to improve the sustainability of rice cultivation, 1) All farmers require adequate knowledge and sustainable rice farming techniques, and the simplest way to achieve this is to urge them to become certified farmers. 2) Farm size cannot be changed easily; therefore, the government should assist farmers in making more profit in the same way, which is through cost reduction. Farmers must participate in the cost-cutting initiative in order to improve their farms sustainable. However, this study was limited in sample size and needed to improve the equation. Future studies should apply this topic with additional budgeting to devise more accurate equations.

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Research article

Organic Agriculture Certification on Thai Agricultural Standard in Upper Northeast Thailand

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Abstract Many countries have controlled measures for imported agricultural commodities. The Department of Agriculture has taken responsibility for the organic agriculture certification, including the quality control of agricultural commodities within the Thai Agricultural Standards (TAS) in the upper-northeast region of Thailand (11 provinces). The objective of this study was to report the factors involved in obtaining and maintaining organic agriculture certification within the entire chain of production. Within our initial year in 2018, there were 73 farms with organic certification (21.92 %) and 260 non-certified farms (78.08 %) from a total population of 333 farms. The 100 % organic certifications consisted of 32 certified farms (86.47 %) and 5 non-certified farms (13.51 %) from a population of 37 farms. A reassessment of 68 farms at the end of 2018 determined that 63 farms (92.65 %) had obtained organic certification versus 5 non-certified farms (7.35 %). In the transition period into 2019, 60 farms (28.17 %) had obtained organic certification, whereas 153 farms were non-certified (71.83 %) from 213 farms. The 100 % organic certification was achieved by 56 farms (94.92 %) with only 3 uncertified farms (5.09 %) from a population of 59 farms. Our re-assessment produced 78 certified farms (98.73 %) and only a single non-certified farm (1.27 %) from 79 farms. The trend of certifications over two years (2018 and 2019) showed that certified organic agriculture production increased from 38.37 to 55.27 %, whereas non-certifications decreased from 61.64 to 44.73 %; from 438 to 351 farms, respectively. We determined that there were six main reasons for non-certification of farms: the inability to sustain organic agricultural production within TAS; the lack of a buffer zone to deter pollution from adjacent plantations; the lack of available recorded data for both traceability and verification; the use of chemicals that did not follow TAS protocols; planting areas within some environments caused the contamination of hazardous substances; and, several farms did not have the proper land-rights documents. Improvements and compliance within these areas will, therefore, result in an environmental ecological balance, as well as increased food safety.

Keywords Thai Agricultural Standard, Certification, and organic agriculture

INTRODUCTION

Several interesting trends have emerged in the global food market, in which consumers have begun to look for safer and better-controlled foods produced in more environmentally friendly, authentic, local systems. Many countries have implemented controlled measures for the importation of agricultural commodities, resulting in the enhanced recognition of food safety and quality for consumption, and further consideration of the environment and the worker's health, safety, and welfare. Organic agriculture production has expanded in Thailand, from 37,684 hectare planting areas in 2014 to 2,791 farm 45,587 hectare areas in 2015; an increase of 20.97 % (2,791 farms) (National Agricultural Development Strategy, 2017). Global food markets demanded that Thailand adhere to various standards in farming, such as the Good Agricultural Practice (GAP) and organic certifications.

The certification body within Thailand's Department of Agriculture is responsible for the inspection and adherence to standards, resulting in organic agriculture certification. The organic agricultural standards cover provisions instituted within the Thai Agricultural Standard (TAS) 9000: Part 1-2009 determines the holistic production management systems which enhance and promote an agro-ecosystem, including biodiversity and biological cycles. It emphasizes the use of natural materials and avoids the use of synthetic materials, plants, animals, or microorganisms derived from genetic modification. An organic production system is designed to handle agricultural products with careful emphasis on processing methods, to maintain the organic integrity and vital qualities of the product at all stages. Accordingly, the organic production requirements for plants shall be used throughout the entire transition period of at least 12 months before the planting of annual crops, and 18 months before the first harvest of organic produce of perennial crops. The producer's transition period occurs at the time organic practice and adherence to the prescribed standards begins, typically when a farmer applies for certification (National Bureau of Agriculture Commodity and Food Standards, Ministry of Agriculture and Cooperatives, 2009). However, farmers often lack their knowledge and understanding of several TAS standards; such as the use of composts, cropping systems, and the control of diseases and pests.

OBJECTIVE

The objective of this study, therefore, was to report upon the situation of organic farming practices within the upper-northeast region of Thailand in the years 2018 and 2019 and to determine the factors involved in obtaining and maintaining the organic agriculture certification within the entire chain of production.

METHODOLOGY

This paper is based on the results from previous reports within this region, as well as the preliminary results from an ongoing study. Our methodology consisted of the following elements:

1. The Organic agriculture certification and the factors related to both obtaining and maintaining certification throughout the entire chain of production, as well as within the 100% certification status.
2. The investigation and possible solutions for the prevention and recurrence of non-certification within the transition from 2018 to 2019.

The area of study, the upper-northeast region of Thailand, included the following 11 provinces: Kalasin, Khon Kean, Chiyaphum, Nakhon Phanom, Loei, Mukdahan, Sakon Nakhon, Nong Khai, Bueng Kan, Nong Bua Lam Phu, and Udon Thani.

RESULTS AND DISCUSSION

Our study identified 73 farms with organic certification (21.92 %) and 260 non-certified farms (78.08 %) from a total population of 333 farms. The 100 % organic certifications consisted of 32 certified farms (86.47 %) and 5 non-certified farms (13.51 %) from a population of 37 farms. A reassessment of 68 farms at the end of 2018 determined that 63 farms (92.65 %) had obtained organic certification versus 5 non-certified farms (7.35 %). In the transition into 2019, 60 farms (28.17 %) had obtained organic certification, whereas 153 farms were non-certified (71.83 %) from 213 farms. The 100% organic certification was achieved by 56 farms (94.92 %) with only 3 uncertified farms (5.09 %) from a population of 59 farms. Our re-assessment produced 78 certified farms (98.73 %) and only a single non-certified farm (1.27 %) from 79 farms. The trend of certifications over the two years (2018 and 2019) showed that certified organic agriculture production increased from 38.37 to 55.27 %, whereas non-certifications decreased from 61.64 to 44.73 %; from 438 to 351 farms, respectively.

Table 1. Inspection within the transitional period, certification and non-certification (2018 to 2019), 100 % organic certification, and re-assessment certification (TAS).

Year/ inspections		Inspection		Certification			Non-certification		
		farms	Area (hectare)	farms	%	Area (hectare)	farms	%	Area (hectare)
2018	**Transition period**	333	161.30	73	21.92	44.85	260	78.08	116.45
	100 % organic certifications	37	32.02	32	86.49	29.74	5	13.51	2.27
	Re-assessment	68	114.69	63	92.65	106.40	5	7.35	8.29
2019	**Transition period**	213	110.54	60	28.17	42.18	153	71.83	68.37
	100 % organic certifications	59	41.06	56	94.92	38.46	3	5.08	2.59
	Re-assessment	79	116.96	78	98.73	116.92	1	1.27	0.04
Total	**Transition period**	546	271.84	133	24.36	87.02	413	75.64	184.82
	100 % organic certifications	96	73.07	88	91.67	68.21	8	8.33	4.86
	Re-assessment	147	231.65	141	95.92	223.32	6	4.08	8.33

The results of our study in 2018 identified several areas of responsibility for organic agricultural non-certification including 19 fruit farms and 42 vegetable farms: the inability to sustain organic agricultural production within TAS: the lack of a buffer zone to deter pollution from adjacent plantations; the absence of any available recorded data for both traceability and verification; the use of chemicals that did not follow TAS protocols; planting areas within some environments caused the contamination of hazardous substances; and, several farms did not have the proper land-rights documents.

In 2019, non-certification farms were present in 108 integrated agricultural farming systems, including four fruit farms, 34 vegetable farms, and 11 herb farms with the same reasons above.

Table 2. Analysis of non-certification farms from 2018 to 2019.

	2018		2019	
	Non-certification	**List**	**Non-certification**	**List**
Integrated system	333	No organic agriculture production according to TAS. No buffer zone to deter from pollution and adjacent plantations. No available recorded data for traceability and verification. Chemical use did not follow TAS standards. Several environments caused the contamination of hazardous substances on produce. Planting areas had no land rights documentation.	108	No organic agriculture production according to TAS. No buffer zone to deter from pollution and adjacent plantations. No available recorded data for traceability and verification. Chemical use did not follow TAS standards. Planting areas had no land rights documentation.
Fruit	19	No organic agriculture production according to TAS. No available recorded data for traceability and verification. No buffer zone to deter from pollution and adjacent plantations. Chemical use did not follow TAS standards. Planting areas had no land rights documentation.	4	No organic agriculture production according to TAS. No buffer zone to deter from pollution and adjacent plantations. No available recorded data for traceability and verification. Planting areas had no land rights documentation.
Vegetable	42	No organic agriculture production according to TAS. No buffer zone to deter from pollution and adjacent plantations. Chemical use did not follow TAS standards. Planting areas had no land rights documentation.	34	No organic agriculture production according to TAS. No buffer zone to deter from pollution and adjacent plantations. No available recorded data for traceability and verification. Chemical use did not follow TAS standards. Several environments caused the contamination of hazardous substances on produce. Planting areas had no land rights documentation.
Herb			11	No organic agriculture production according to TAS. No buffer zone to deter from pollution and adjacent plantations. Several environments caused the contamination of hazardous substances on produce. Planting areas had no land rights documentation.

CONCLUSION

The finding through the transitional period of 2018 to 2019 was farmers' lack of understanding of organic agriculture production (TAS certification). 133 certified farms (24.36 %) encompassing an area of 87.02 hectare and 413 non-certified farms (75.64 %) covering an area of 184.82 hectare from a population of 546 farms (271.84 hectare). Eighty-eight farms were identified for 100 % organic certifications (91.67%) in an area of 68.21 hectare, as well as eight non-certified farms (8.33 %) in an area of 4.86 hectare for a total of 96 farms (73.07 hectare). The non-certifications were due primarily to the framers' conversion back to the use of non-organic chemicals for pest and disease control. Our re-assessment identified 141 farms (95.92 %) in an area of 223.32 hectare and 6 non-certified farms (4.08 %) in an area of 8.33 hectare from a population of 147 farms encompassing 231.65 hectare, due to the farmers' lack of available recorded data for traceability and verification. Further re-assessment resulted in an increase of certifications to 95.92 %, demonstrating the farm's compliance to TAS standards, as well as the farmers' acceptance of the required protocols, with an average score of 4.2, and an average application (TAS) score of 70.79 (Chawit, 2018).

In addition to the six main obstacles to obtaining organic agriculture certification (TAS), Chawit, 2018; determined that two primary obstacles existed in both obtaining and maintain organic certification according to the Thai Agricultural Standard 9000, Part 1-2009. Firstly, organic fertilizers were difficult to obtain; and secondly, farmers lacked the knowledge and experience to create a buffer line for soil, water, and pest control.

Our recommendations to farmers seeking organic agriculture certification and adherence to TAS practices included: 1. Working proactively to obtain the knowledge and understanding of organic agriculture production for TAS certification; 2. Learning to create barriers or ridges (buffer zone) necessary to buffer against contamination through the soil, water, or air from adjacent plantations; 3. Generate the fertility and biological activity of the soil needed to maintain the necessary organic materials according to Jiraschayaporn, 2017; in which a prototype for the production and management of organic fertilizer was capable of producing an increase in organic matter (Surin, Thailand); and 4. Pests, diseases, and weeds shall be controlled by the appropriate species and varieties, including the appropriate rotation programs, mechanical cultivation, conservation of natural enemies of pests by providing favorable habitats, and maintaining the ecosystem. We noted in the above-mentioned research, that the average income per farmer was 193 USD per hectare.

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Research article

Application of APEX Model in Evaluating Streamflow and Sediment Yield in Stung Chinit Catchment

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Abstract Streamflow and sediment yield are important indicators to understand the alterations in hydrological processes as well as the supply and transformation of nutrients and biological productivity in the ecosystem. The main objective of this study was to evaluate the performance and applicability of the APEX model in estimating streamflow, sediment yield, and quantifying the soil erosion in Stung Chinit Catchment. The result indicates that the APEX model performed well in accurately simulating the monthly streamflow and annual sediment yield in the watershed. The overall statistical indicators (NSE, R^2, and PBIAS) of streamflow calibration (1997-2015) were 0.62, 0.60, and 2.25%, respectively. The validation statistical indicators (NSE, R^2, and PBIAS) for streamflow were 0.71, 0.80, and 28.22%, respectively. The mean annual surface runoff was 212.03 mm; varied from 72.56 mm to 435.59 mm. The average annual sediment yield varied from 16.0 tons/ha/year in the lowlands of the Stung Chinit catchment main river channel to 68.2 tons/ha/year in the highlands, with an annual average of 29.2 tons/ha/year. Most of the sediment yield came from the eastern part and near the outlet of the the Stung Chinit catchment.

Keywords: APEX model, sediment yield, streamflow, Stung Chinit Catchment

INTRODUCTION

Soil erosion is a major environmental problem which affects people by degrading water quality, depositing sediment in the channel, decreasing the reservoir effective capacity and increasing the risk of flooding (Umit et al. 2018). Due to some human activities such as forest burning, overgrazing, deforestation, recreation, soil erosion rates have been increased above natural levels, a phenomenon known as accelerated erosion. Accelerated surface erosion is a severe matter that reduces agricultural productivity, finite arable lands, and reservoir capacity. Erosion and sedimentation in a catchment, are closely associated with natural processes which is mainly driven by rainfall and runoff processes. Erosion is the movement and detachment of soil particles by natural forces, primarily caused by water and wind. Sediment yield is the amount of soil that is transported to surface water bodies within a time scale over a specific area (Issaka and Ashraf, 2017).

Sediment yield in a watershed varies spatially, depending on several contributing factors such as topography, soil types, catchment area, climate (i.e., precipitation, wind, temperature, etc.), vegetation cover, human-influenced soil erosion, forest fires, river discharge (Francipane et al. 2015). In a watershed, the amount of sediment transported by a river system depends on the supply of sediment and transport capacity of the flow. Therefore, the accuracy of the estimate of the sediment yield from any watershed relies on understanding and representation of the multiple contributing factors such as rainfall, runoff, and erosion processes. More discussion on sedimentation processes can be found in earlier publications (Wilkinson and McElroy 2007; Francipane et al. 2015). Most physical models normally require hydro-meteorological, topographical, soil, and land use data as the input data for the model. Besides these data, models such as APEX, DSSAT, EPIC, and SWAT (Ayele et al, 2017; Jeong et al. 2010) also require crop management data. APEX is capable of evaluating the effects of various water and land management practices on watershed hydrology, sediment yields and water quality at various environmental issues (Luo and Wang, 2019; Assefa et al. 2018; Van Liew et al., 2017; Ayele et al, 2017; Tuppad et al. 2010)

The Stung Chinit catchment is one of the major tributaries of Tonle Sap Lake. There is an intensified economic activity in the catchment, including major land concessions, infrastructure developments and demographic pressures (CNMC, 2012). As a result, some soil erosion may occur eroded from the upstream to the downstream of the catchment due to agricultural land expansion by encroaching to the forest land. Moreover, farmers suffer abnormal storms, floods and multiple kinds of droughts (meteorological, hydrological and agricultural), making them and their communities highly vulnerable to water scarcity.

OBJECTVIES

The research aims to evaluate the performance and applicability of the APEX model in estimating streamflow and sediment yield as well as identifying the soil erosion in Stung Chinit Catchment, Cambodia.

MATERIALS AND METHODS

Study area

Stung Chinit catchment covers an area of about 8,236 km^2 and composed of the Stung Chinit and Stung Taing Krasaing rivers and other small streams that drain from the north. The mainstream, Stung Chinit, flows 264 km southwestwards to the gentler slopes downstream before discharging into the Tonle Sap Lake (CNMC, 2012). A measuring stream gauge is located in the middle of the river along National Road 6, Kampong Thmar, (Fig. 1).

Rainfall in the catchment increases with elevation, while the spatial distribution of annual average rainfall ranges from 1200 to 1500 mm. Over 90% of the catchment's annual rainfall is received during the wet season, from May to October, and the highest rainfall occurs in August (MOWRAM, 2014). Daily temperatures vary from 20°C in the coolest months of December to January up to 35 °C during the hottest months of April and May (CNMC, 2012). Farmers in Stung Chinit and Taing Krasaing mainly cultivate traditional wet season rice and some dry season rice. A large proportion of the catchment has poor quality soil, Acrisols, which covers 60.75% of the entire catchment (CNMC, 2012). Agricultural land occupies 28.9% of the total catchment area (238,020 ha), located mostly on poor Acrisols. Another 46.3% of the catchment area (381,327 ha) is occupied by forestland, grassland, shrubland, soil and rock, urban settlements and water bodies. Of the total agricultural land, rice takes up 154,014 ha, annual crops 49,197 ha, perennial crops 22,938 ha and village garden crops 7331 ha (CNMC, 2012).

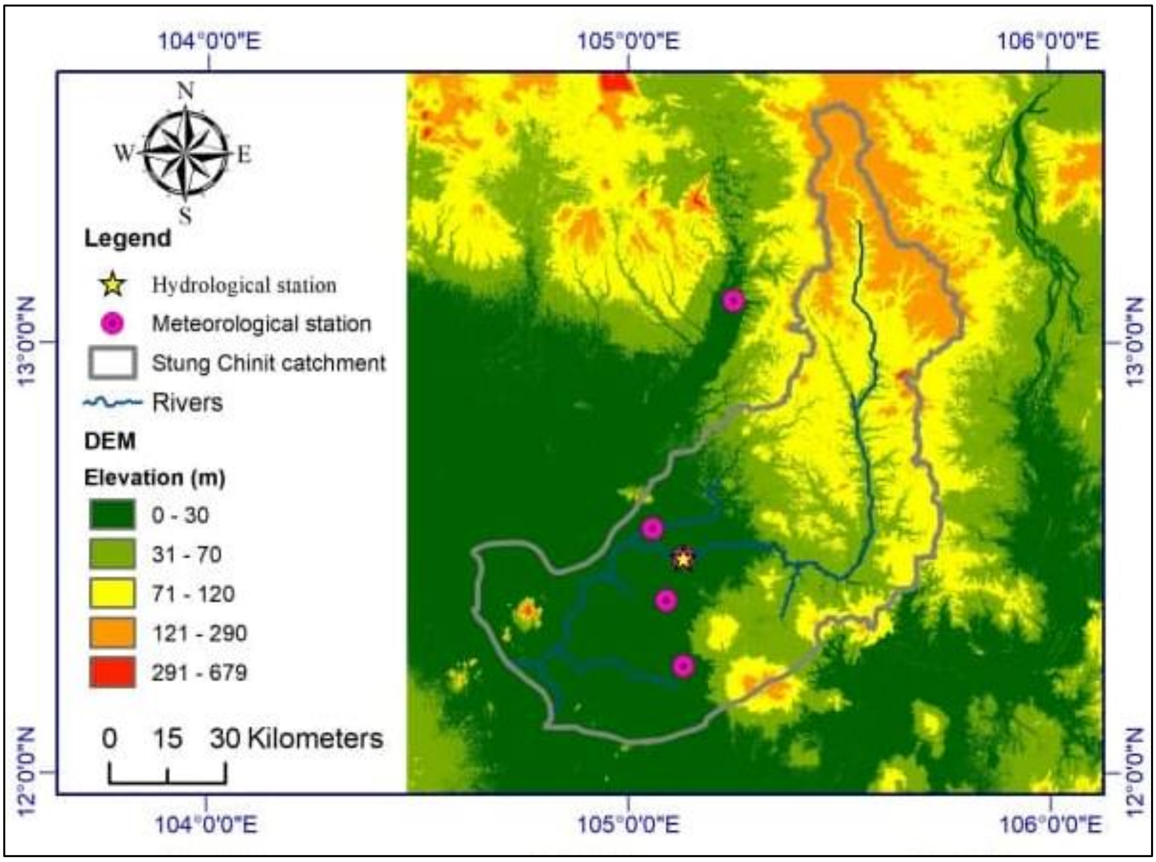


Fig. 1 Topography, hydrological and meteorological stations, and rivers of the study area.

The Apex Model Application, Data Inputs and Model Setup to Predict Hydrology

The APEX model is an extension of the Environmental Policy Integrated Climate (EPIC) model (Williams, 1998), which is capable of evaluating the effects of various soil and water management practices on the hydrology of the system, crop growth, and other environmental factors (Wang et al., 2014; Steglich et al., 2018). The APEX simulates watershed processes based on weather data, soils characteristics, topography, vegetation, and management practices (Wang et al., 2012). Multiple options are available in the APEX model in estimating evapotranspiration, surface runoff, peak runoff rate, and available soil water capacity to derive hydrology of the system (Wang et al., 2012).

The APEX model requires some input data, including Geographic Information System (GIS) data layers, climatic data, and management practices. The GIS data layers are digital elevation model (DEM), soil, and land use or crop covers (Table 1). A 30 m DEM was obtained from the United States Geographical Survey (USGS) website. The land use data was received from the Cambodia National Mekong Committee (CNMC), 2015 (Fig. 2d). A harmonized world soil map prepared by the Food and Agricultural Organization (FAO) with two levels were used for soil database preparation of APEX (Fig. 2b).

During the model setup process, the APEX version 1501, developed by Texas A&M AgriLife Research, Temple, Texas, USA, was used and divided into three steps. The first step was the process of setting up the APEX model and began with the processing of GIS data layers to delineate the watershed boundary, subareas, and derive watershed characteristics from the Digital Elevation Model (DEM). The land use, soil data and slope was overlaid and used the dominant landuse/soil/slope, while the land use of paddy rice was modified in the management file of APEX file based on the schedule of tradition rice cropping system which people mostly cultivate in the catchment (Table 2). The dominant land use in the catchment are evergreen forest (52.94%), paddy rice (26.82%), grassland (6.23%), marsh/swarm (4.56%), shrubland (4.36%), agricultural land (3.6%) and deciduous forest (1.49%) (Fig. 2d), while the dominant soil is Acrisols (55.13%), Gleysols (34.92%) and Vertisols (9.95%) (Fig. 2b). The second step was to integrate weather data of 12 catchments of Stung Chinit provided by WinRock International (Fig. 1) through the Arc-APEX model interface. The third step was the process of performing an initial model run and complete model setup procedures to create APEX model output files for further analysis.

The APEX can simulate all the key water balance components of the system. Precipitation, snow melts, and irrigation are the main inputs to the system, which are then disseminated into various components: surface runoff, subsurface/tile drainage flow, soil water, percolation, and evapotranspiration (Williams, et al. 2006). In APEX, the key landscape processes across hydrological connected units are called subareas. The subareas are the smallest unit in APEX with homogenous watershed characteristics, such as soil types, land use/crop cover, slope, and management. There are two options to estimate the runoff volume (Williams, et al. 2006) which are the modified Soil Conservation Service (SCS) (NRCS, 2004) curve number (CN) and Green and Ampt infiltration (Green and Ampt, 1911) methods used in the APEX model. The SCS-CN runoff estimate method is a function of rainfall and retention parameter. The curve number is a function of land use, hydrologic soil group and management practices. The subsurface flow is a function of the vertical and horizontal flow and simulated as a simultaneous process (Wang et al., 2012). The horizontal flow consists of a lateral flow, whereas the vertical flow (percolation) adds to groundwater storage, which is then subjected to return flow or deep percolation. The vertical component of percolation is calculated as a function of soilwater content, field capacity, and travel time. There are five options available to estimate the potential evapotranspiration such as Penman, Penman–Monteith, Baier and Robertson, Priestly and Taylor, and Hargreaves methods (Williams, et al. 2006). The Hargreaves method is dynamic and requires a lower data, and is a function of solar radiation, latent heat of vaporization, and temperature.

Table 1 Some required input data for APEX model setup

Data	Source
DEM (30×30m) resolution	ASTER-GDEM, USGS
Soil type FAO/UNESCO in 1984	http://www.fao.org/soils-portal/data-hub
Land use and Land Cover	Cambodia National Mekong Committee (CNMC), 2015
Meteorological data (1990 – 2017)	Rainfall data of 12 catchments provided by Soparith Tes from Winrock International.
Stremflow data (1997 – 2017)	

Table 2 Major crop management activity and cropping pattern in Stung Chinit catchment.

Types of crop	Management practices	Date
Medium wet season rice	1st Tillage	25-April
	2nd Tillage	5-May
	3rd Tillage	15-May
	DAP fertilizer application	15-May
	sowing	15-May
	1st stage fertilizer application after planting	30-June
	2nd stage fertilizer application after planting	30-July
	Harvest	10-November

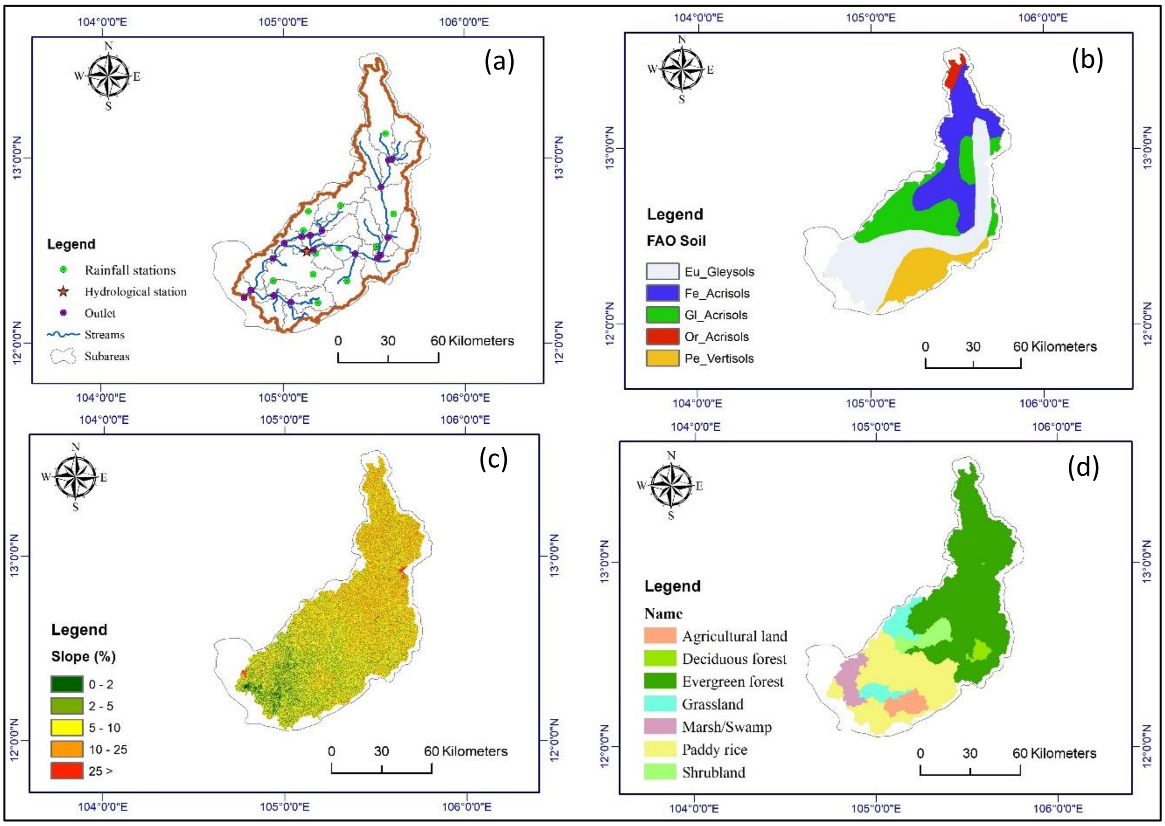


Fig. 2 Model input data in the Stung Chinit catchment: (a) Meteorological and hydrological stations, rivers, outlets, and subareas; (b) Food and Agriculture Organization of the United Nations (FAO) soil; (c) slope classifications; (d) Land use and land cover in 2015 from CNMC.

Sensitivity Analysis, Model Calibration, and Validation

Model sensitivity analysis is a method of identifying key parameters that affect model performance and are essential for model parametrization. The APEX model has huge sets of parameters related to hydrology, sediment, nutrients, crops, and other environmental factors. Sensitivity analysis is the first step for hydrological models, which helps to diagnose and narrow down the enormous sets of parameters for calibration. Model calibration is a process in which model parameters are modified so that a model output mimics observed data, whereas validation is the use of modified parameters to simulate another set of observed data. The APEX auto-calibration and uncertainty estimator (APEX-CUTE) was used to perform sensitivity analysis and auto-calibration for the APEX hydrology model (Wang et al., 2014), followed by manual adjustment of a few parameters. The first step was to examine the APEX hydrology model outputs for modifications. Some default methods and input parameters might need modification to get better simulation prior to sensitivity analysis and calibration (Williams, et al. 2008). The second step included a sensitivity analysis, calibration, and validation of the APEX hydrology model. Streamflow was recorded at Kampong Thmar Station located in the middle of Stung Chinit catchment from 1990 - 2017, while the sediment yield was done in 2005 - 2008. Model warm-up period (1990-1996) was used to initialize model parameters and obtain better predictions. Streamflow records were split into two periods: calibration (1997 - 2015) and validation (2016 - 2017). The APEX hydrology model was verified in monthly basis for the Stung Chinit catchment from the measuring gauge to the upstream of the watershed. Most of the parameters considered during calibration were related to soil properties and climate. The third step includes evaluating the APEX model. The APEX model performance in predicting hydrology of the system was evaluated using commonly used statistical measures such as Nash–Sutcliffe efficiency (NSE), determination of coeffecitnt (R^2), and percent bias (PBIAS). NSE is a normalized statistical measure that was proposed in Reference (Chad et al. 2015). PBIAS measures the deviation of model prediction as an under- or overestimation from observation, while R^2 is a statistic that will give some information about the goodness of fit of a model.

RESULTS AND DISCUSSION

APEX Sensitivity Analysis, Calibration, and Validation for Streamflow

All relevant parameters for APEX hydrology components were included in the sensitivity analysis in accordance with the reference (Wang et al., 2014). The results of the sensitivity analysis in the Stung Chinit catchment illustrated that streamflow was sensitive to the following parameters: Return flow ratio (RFPO), Groundwater residence day (RFTO), Hargreaves potential evapotranspiration (PET) equation exponent (PARM-34), Groundwater residence day (PARM-40), SCS curve number index coefficient (PARM-42), runoff volume adjustment factor (PARM-92), runoff CN initial abstraction (PARM-20) and soil evaporation coefficient (PARM-12), in order of decreasing influence (Table 3). The most sensitive parameters were associated with soil characteristics, groundwater residence day and climatic conditions. The parameter PARM-42 was found to be the most sensitive parameter for streamflow followed by PARM-34, possibly because ET was the second most-dominant hydrological process after rainfall. Feng et al. (2015) showed that ET affecting the water yield of the catchment in their scenario analysis, while Assefa et al. (2018) depicted that ET could be able to impact on hydrology. Variable CN nonlinear CN/SW with depth soil water weighting method (NVCN = 0), which is a function of soil water content and is directly linked with ET, was used. Parameters PARM-92 and PARM-20 were found to be the third and fourth most sensitive parameters for streamflow prediction. Parameters APM and PARM-90 and PARM-92 were less sensitive and thus not used for calibration.

Table 3 APEX sensitive parameters and final calibrated values for streamflow calibration

Parameters	Description	Range	Default Value	Optimal Value
RFPO	Return flow ratio: (Return flow)/(Return flow + Deep percolation)	0.05 – 0.95	0.5	0.85
RFTO	Groundwater residence day	10 – 50	30	60
PARM (12)	Soil evaporation coefficient	1 - 2	2	1.5
PARM (17)	Soil evaporation coefficient	1.5 – 2.5	1.5	2.5
PARM (20)	Runoff CN initial abstraction	0.8 – 1.5	1	1
PARM (34)	Hargreaves PET equation exponent	0.5–0.6	0	0
PARM (40)	Groundwater residence day	10 - 50	30	60
PARM (42)	SCS curve number index coefficient	0.3 -2.5	0.4	0.4
PARM (49)	Groundwater storage threshold	0.001 - 1.0	0.25	0.99
PARM (90)	Subsurface flow factor	1–100	1	1
PARM (92)	Runoff volume adjustment factor	0.1–2.0	1	1

The APEX hydrology model was calibrated by using the 18 years of the measured streamflow data (1997 - 2015) (Fig. 4a) followed by validation (2016 - 2017) using the monthly parameters in Fig. 4b. Model parameter initialization was carried out prior to calibration (warm-up period: 1990-1996). Final calibrated values of sensitive parameters are listed in Table 3. Based on statistical performance measure ratings of Moriasi et al, (2017) as shown in Table 4, the simulation of APEX model in identifying the water discharge showed very good agreement with the observed monthly streamflow both calibration and validation for a monthly time step of NSE = 0.60, R^2 = 0.62 and PBIA = 2.50%, and NSE = 0.71, R^2 = 0.80 and PBIA = 28.22% for model calibration and validation, respectively (Table 5 and Fig. 3).

Table 4 Model performance evaluation rating

Statistic	Evaluation rating			
	Unsatisfactory	Satisfactory	Good	Very good
R^2	< 0.50	0.50 – 0.60	0.60 – 0.70	0.70 – 1
NSE	< 0.50	0.50 – 0.65	0.65 – 0.75	0.75 – 1
PBIAS	> ±25	±15 < PBIAS < ±25	±10 < PBIAS < ±25	< ±10

Table 5 APEX model performance on a monthly basis of observed and simulated streamflow calibration (1997–2015) and validation (2016–2017) in Stung Chinit Catchment

Station Name	Component	NSE	R^2	PBIAS (%)
Kampong Thmar	Calibration	0.60	0.62	2.50
	Validation	0.71	0.80	28.22

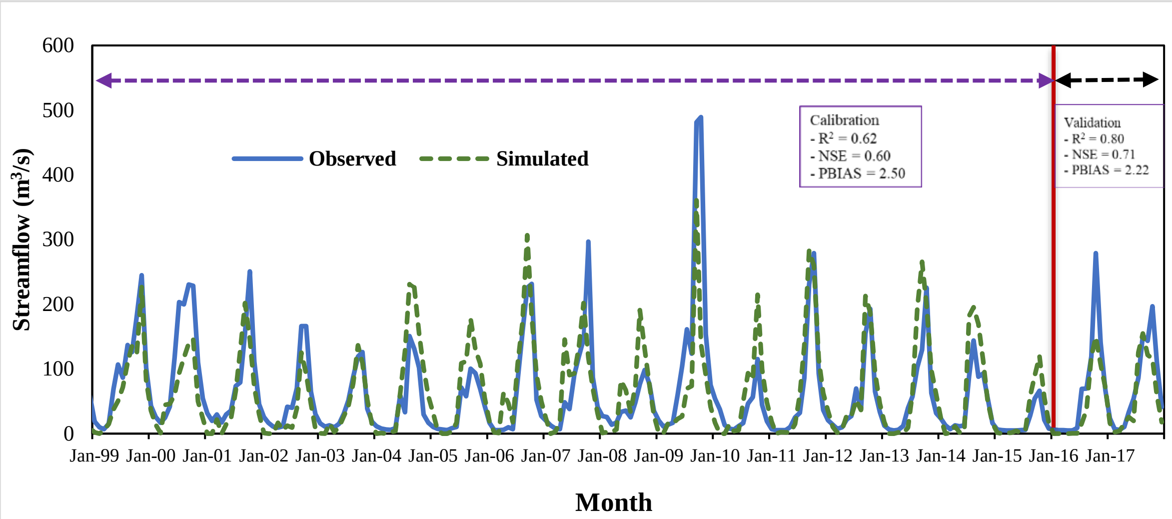
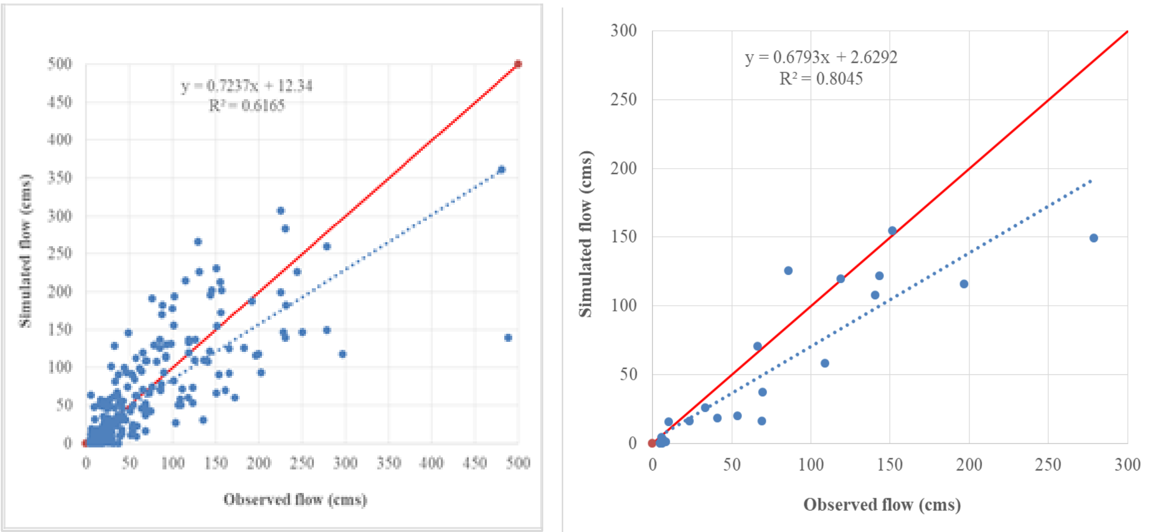


Fig. 3 The monthly comparison of time series measured and simulated stream flow and corresponding precipitation data for the Stung Chinit catchment.



(a) (b)

Fig. 4 The monthly comparison of measured and simulated stream flow for (a) calibration (1997-2015), and (b) validation (2016-2017) periods for the Stung Chinit catchment.

We illustrated a scatter plot with line 1:1 and regression lines to compare the results between the observed and simulated monthly streamflows during calibration and validation (Fig. 4). The model overpredicted the flow when the observed values were less than approximately 320 m^3/s (Fig 4a). The model had a large error of prediction when it predicted a monthly streamflow peak greater than 490 m^3/s. During validation, the low-flow values (<150 m^3/s) were scattered near the 1:1 line, but most of the high-flow values (> 250 m^3/s) were underpredicted (Fig 4b).

APEX Annual Sediment Simulation

Due to the limited data of sediment yield for the model calibration, we could not do the calibration on the sediment yield. The annual suspended sediment load was just estimated as shown in (Table 6). The annual sediment yield is mainly varied with the amount of suface runoff in the catchment. The severe sediment rate of 68.14 ton/ha/year occurred in 1999. This can be the result of forest decline due to the land encroachment and forest-logging in the catchment. Since then, the sediment yield is declining dramatically. The huge erosion occured in 2011 and 2013 because the country experienced the flooding across the country at that time; resulted in severe sediment occurance.

Variability of Surface Runoff and Sediment Yield in the Catchment

The mean annual surface runoff was 212.03 mm (varied from 72.56 mm to 435.59 mm). The sediment yield varied from 10.21 ton/ha/year in the riparian lowlands of the Stung Chinit main river channel to 68.14 ton/ha/year primarily in the mountain highlands from, with an average sediment yield rate of 29.62 ton/ha/year for the entire basin (Table 6).

Table 6 Water balance and sediment components

Year	PRECIP(mm)	QSS(mm)	QSW(mm)	QTS(mm)	YW(t/ha)
1997	1279	176.33	176.28	286.97	16.95
1998	1182	192.46	192.39	306.70	21.88
1999	1910	435.59	435.43	708.31	68.14
2000	1550	243.49	243.36	495.76	37.46
2001	1521	209.23	209.11	439.94	26.88
2002	1196	112.45	112.4	243.95	11.18
2003	1261	126.65	126.59	301.3	16.13
2004	1271	172.61	172.48	489.18	29.90
2005	1019	97.83	97.79	385.16	10.21
2006	1581	313.98	313.76	659.87	40.67
2007	1517	261.03	260.86	566.53	29.34
2008	1412	171.64	171.55	363.78	20.75
2009	1640	284.64	284.47	532.77	40.07
2010	1468	217.74	217.60	446.53	30.06
2011	1592	347.19	346.97	641.92	52.52
2012	1447	234.73	234.61	475.51	26.57
2013	1616	355.71	355.49	652.86	58.56
2014	1352	189.38	189.24	442.01	35.66
2015	931	72.56	72.52	184.78	12.76
2016	1167	134.26	134.19	295.92	16.00
2017	1095	103.16	103.09	257.83	20.25
Mean	**1381**	**212.03**	**211.91**	**437.03**	**29.62**

PRECIP = Precipitation; QSS= Surface runoff; QSW = Watershed outflow; QTS= Total flow from all subarea and YW= Watershed sediment yield

CONCLUSION

Our results showed that the Stung Chinit catchment experienced soil loss during 2011 and 2013 due to the big flooding occurrence in the catchment area. A calibrated and validated APEX model was able to estimate streamflow and sediment yield. The model also provided a good qualitiative description on the the effects of land uses and geographic indicators on streamflow and sediment estimation. The mean annual surface runoff was 212.03 mm varied from 72.56 mm to 435.59 mm, while the sediment yield varied from 16.0 tons/ha/year in the lowlands of the two Stung Chinit catchment main river channel to 68.2 tons/ha/year in the highlands, with an annual sediment yiled of 29.2 tons/ha/year. Most of the sediment yield came from the eastern part and near the outlet of the the Stung Chinit catchment. Land use management in lowlands could be improved while practising some soil erosion control methods in highlands and minimzing inappropriate tillage practices in areas with slopes greater than 25 to prevent soil loss. Due to our data limitations, we did not compare the impact of land use change on streamflow and sediment load in this watershed, but it is important to determine how the drivers of streamflow and sediment load will be changed in response to land use change and climate change in the watershed. Nevertheless, this research should be able to develop a reliable physically-based streamflow model, which is capable of illustratind and defining the critical source areas and conditions of sediment yield.

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Research article

Effects of Chemical Extraction Methods on Physicochemical Properties of Shrimp Chitosan

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Abstract Chitosan extraction methods have not been applied and optimized in Cambodia whose seafood industry produced tons of shrimp shell waste yearly. This study adopted the chemical extraction method and optimized the deacetylation step from chitin to chitosan using different concentrations of sodium hydroxide (NaOH). Shrimp waste (exoskeleton) was sequentially treated with NaOH (3.5%) for deproteination at 80oC; HCl (4%) for demineralization at 80oC; NaClO (0.315%) for decolorization at ambient temperature, and NaOH (40%, 50%, 60%) at 120oC for deacetylation. Chitosan yield, moisture content, total ash, lipid, fiber, solubility, nitrogen content, viscosity, and degree of deacetylation were determined. The commercial chitosan bought from a local market was included for comparison. NaOH at 50% was found to be the optimum concentration for deacetylation based on increased solubility (96.27%), reduced ash content (0.56%) and increased degree of deacetylation (83.23) as compared to that of 40% NaOH (93.61% solubility, 1.25% ash content, and 74.45 degree of deacetylation) though chitosan yield in the former (20.59%) was lower than that in the latter (25.23%). Increasing the NaOH level to 60% had no significant advantage. Lipid and fiber contents were not significantly affected. The characteristics of chitosan extracted with 50% NaOH at deacetylation stage were comparable to that of the commercial chitosan.

Keywords Shrimp shell, Chitin, Chitosan, Deacetylation, NaOH concentration

INTRODUCTION

Cambodia's seafood industry has long been faced with waste disposal problem, mainly shrimp shells from factories producing dried shrimps for local and export markets. Habitually, seafood waste is burned, land filled, dumped at sea or left to get spoiled. This has negative impact on the environment, biodiversity and human health. A sustainable solution is to transform shrimp shell waste into high-value products, particularly chitin and chitosan which have multiple applications in agriculture, food and beverage, medical, pharmaceutical. cosmetics and personal care, textile, environment, health, and water sectors. Global demand for chitin and chitosan is rapidly growing and is projected at 281,700 metric tons in 2027 (https://www.strategyr.com/market-report-chitin-and-chitosan-derivatives-forecasts-global-industry-analysts-inc.asp). However, global supply may remain short by over 50% of demand as in 2022 projections of global demand of 155,500 MT against supply of only 70,000 MT.

Chitin, a crystalline polysaccharide with high molecular weight, is the second most abundant organic compound after cellulose (Rinaudo 2006; Kumari et al., 2015). It is considered as a natural fiber that is found in shells of marine animals, such as shrimps and lobsters, insect shells and in cell walls of several fungi and yeasts. In its structure, chitin is often linked to the other major constituents of the carapace, forming covalent bonds with 30-40% proteins and a complex matrix containing 30-50% calcium and phosphate carbonate and 20-30% of chitin. Extraction of chitin from shrimp shells involves at least two steps: deproteinization which removes proteins and undesired materials such as pigments and is often performed with dilute NaOH solutions, followed by demineralization which removes all minerals (e.g. CaCO3) by using dilute HCl solutions. A decolorization step can be added to remove pigments and produce white product. The chitin produced is further processed by partial deacetylation to produce chitosan. Chitosan is a cationic semi-crystalline linear amino-polysaccharide of 1-4 linked N-acetyl glucosamine and glucosamine units; a white, hard, inelastic and nitrogenous polysaccharide (Cheba, 2011). It has three reactive functional groups, amine, primary and secondary hydroxyls that offer potential for covalent and ionic modifications allowing the improvement of its mechanical and biological properties. In addition, chitosan is a biodegradable, nonallergenic, biocompatible, antimicrobial, renewable, nontoxic product. Both chitosan and chitin have enormous economic value because of their flexible biological properties as well as their high nitrogen content (6.89%) as compared to synthetically substitute cellulose (1.25%). However, the crystallinity and insolubility of chitin demote its commercial applications.

The degree of deacetylation of chitosan ranges from 56% to 99% with an average of 80%, depending on the crustacean species and the preparation methods (No and Lee, 1995; No et al., 2000). Chitin with a degree of deacetylation greater than 50% is generally known as chitosan (Younes et al. 2014). In the deacetylation of chitin, several factors can influence the characteristics of resulting chitosan product. Rege and Block (1999) found that temperature and processing time were the most significant factors having noteworthy impact on degree of deacetylation and molecular weight. Tsaih and Chen (2003) concluded that molecular weight and deacetylation of chitosan are principally influenced by the concentration of NaOH, temperature, duration of reaction and recurrence of alkaline treatment steps.

OBJECTIVE

This study is a first attempt to harness available experience elsewhere on the chemical extraction of chitosan for shrimp shell waste of Cambodia's seafood industry and determined the effects of different NaOH concentrations during the deacetylation step producing chitosan from chitin.

METHODOLOGY

Chitosan Extraction

Figure 1 shows the process flow for chitosan extraction. Shrimp shell waste was collected from a local dried shrimp factory in Sihanoukville province, Cambodia, and brought to the Faculty of Agro-Industry, Royal University of Agriculture, Phnom Penh, Cambodia. The shells were properly washed with clean water prior to chitosan extraction which followed the procedures of Divya et al (2014) and Puvvada and Vankayalapati (2012).

The shrimp shells were deproteinized with 3.5% NaOH at 80oC for 3 hours with constant stirring at a solid to solvent ratio of 1:10 (w/v). Samples were then filtered under vacuum, and the filtrate was washed with tap water for 30 minutes and oven-dried.

Demineralization was performed by washing the deproteinized shells with 4% HCl for 4 hours at ambient temperature with a solid to solvent ratio of 1:10 (w/v), then filtered under vacuum. The filtrate was washed for 30 min with tap water and oven-dried.

The chitin produced was decolorized with 0.315% sodium hypochlorite for 15 min; with a solid to solvent ratio of 1:10 (w/v), followed by washing in tap water and drying under vacuum for 2-3 hours until the powder was crispy.

Deacetylation of chitin to produce chitosan was done using 40, 50 or 60% NaOH for 3 hours at 120oC with a solid to solvent ratio of 1:10 (w/v). The resulting chitosan was washed to neutrality in running tap water, rinsed with distilled water, filtered, and dried at 60oC for 24 hr in the oven.

Chitosan yield was calculated by comparing the weight measurements of the raw material to the chitosan obtained after treatment (Kiruba et al., 2013).

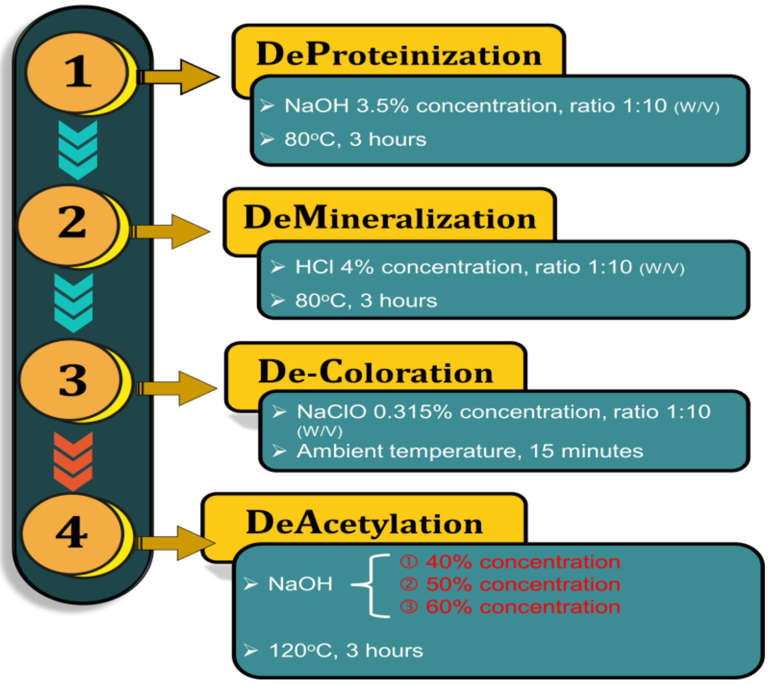

Fig. 1 Process flow for the extraction of Chitosan from shrimp shell waste

Proximate Analysis

Moisture, fiber, fat and nitrogen contents were analyuzed following the AOAC (2001, 2005) methods. Total ash content was determined by the method of the Food Safety and Standards Authority of India (2012). Commercial chitosan (Sigma) was included in all relevant analysis as control.

Degree of deacetylation

The titration method of Czechowska-biskup et al (2012) was followed. Dried chitosan (0.2 g) was dissolved in 20 ml 0.1 M hydrochloric acid and 25 ml deionized water. After 30 minutes continuous stirring, next portion of deionized water (25 ml) was added followed by stirring for 30 minutes. When chitosan was completely dissolved, solution was titrated with a 0.1N sodium hydroxide (NaOH) solution using automatic burette (0.01 ml accuracy). Degree of deacetylation (DA) of chitosan was calculated using formula (1):

$$DA[\%] = 2.03 \times \frac{V_2 - V_1}{m + 0.0042\ (V_2 - V_1)} \qquad (1)$$

m – weight of sample

V_1, V_2 – volumes of 0.1 N NaOH corresponding to the deflection points

2.03 – coefficient resulting from the molecular weight of chitin monomer unit, 0.0042 – coefficient resulting from the difference between molecular weights of chitin and chitosan monomer units.

Solubility

Solubility of chitosan was determined by placing chitosan powder (0.1 g in triplicate) into a centrifuge tube (known weight) then dissolving in 10 ml of 1% acetic acid for 30 min using an incubator shaker operating at 240 rpm and 25°C. The solution was then immersed in a boiling water bath for 10 minutes, cooled to room temperature and centrifuged at 10,000 rpm for 10 min. The supernatant was decanted. The undissolved particles were washed in distilled water (25 ml) then again centrifuged a 10,000 rpm. The supernatant was removed and the undissolved pellets dried at 60°C for 24 hours. The dried pellets were weighed and the percentage solubility was calculated as follows:

(Initial weight of tube + chitosan) **-** *(Final weight of tube + chitosan) x 100* (2)

(Initial weight of tube + chitosan) – (Initial weight of tube) (3)

Viscosity

Viscosity of chitosan was determined with a viscometer. Chitosan solution was prepared in 1% acetic acid at a 1% concentration on a dry basis. Measurement was made in duplicate using a No. 5 spindle at 50 rpm on solutions at 25°C with values reported in centipoises (cPs) unit.

Statistical analysis

A completely randomized design with three replications was used. Data were subjected to analysis of variance and treatment mean comparison by least significant difference (LSD) test using the SPSS Statistical Package.

RESULTS AND DISCUSSION

In general, higher deacetylation degree increases the better solubility and viscosity of chitosan, the better chitosan quality. Deacetylation with 40% NaOH resulted in highest chitosan yield of about 25.2% (Table 1). Increasing the concentration of NaOH to 50-60% significantly decreased chitosan yield to about 20.6%. However, the degree of deacetylation was lower with 40% NaOH (74%) than with 50-60% NaOH (83%), the latter was comparable to that of commercial chitosan. Similarly, deacetylation with 50-60% NaOH significantly increased the solubility and viscosity of chitosan which were comparable to that of the commercial chitosan. Chitosan produced using 40% NaOH had the lowest solubility and viscosity. Chitosan produced with 50% NaOH had moisture, ash, fiber and nitrogen contents which were statistically comparable to that of the commercial chitosan (Table 2). With 40% NaOH, the chitosan produced had significantly higher ash and fiber contents and lower nitrogen content than the commercial control. NaOH at 60% had similar effects as 50% NaOH except that it had the lowest moisture content among treatments. Total fat content did not vary with treatment and ranged from 1.12-1.49%

The results indicate that 50% NaOH was the optimum concentration for deacetylation of chitin to produce chitosan. The chitosan produced had degree of deacetylation, solubility and viscosity of 83.23%, 96.27% and 3.20 log mPa/s, respectively, and proximate composition of 11% moisture content, 0.56% total ash, 1.33% total fat, 1.47% total fiber and 7.29% nitrogen content which were statistically similar to that of commercial chitosan. Previous studies have successfully extracted chitosan from shrimp shell waste (e.g. Kandile et al., 2018; Nacer et al., 2019; Islam et al., 2020; Rasweefali et al., 2021) with similar results as the present study except for the lower chitosan yield obtained (Divya et al., 2014; Puvvada and Vankayalapati, 2012). Using lower NaOH concentration for deacetylation may increase yield of chitosan but other physicochemical properties were compromised. On the other hand, higher NaOH concentration gave no added benefit and may only increase the cost of extraction.

Table 1 Physicochemical characteristics of chitosan extracted from shrimp shells using different NaOCl concentrations for deacetylation.

NaOH Concentration	Yield of chitosan (%)	Degree of Deacetylation	Solubility (%)	Viscosity (log mPa/s)
Commercial chitosan	-	87.38a	95.65a	3.17b
40% NaOH	25.23a	74.45b	93.61b	2.84c
50% NaOH	20.59b	83.23a	96.27a	3.20a
60% NaOH	20.63b	83.35a	96.29a	3.18ab
Probability	**	**	**	**
LSD (5%)	0.882	5.342	0.287	0.022
CV (%)	2.00	3.00	2.00	0.00

Mean separation within columns by LSD, 5%.
a, b, c Duncan's multiple range test

Table 2 Proximate analysis of chitosan extracted from shrimp shells using different NaOCl concentrations for deacetylation.

NaOH concentration	Moisture Content (%)	Total Ash (%)	Total Fat (%)	Fiber (%)	Nitrogen content (%)
Commercial Chitosan	10.53ab	0.59b	1.12	1.33b	7.12%a
40% NaOH	11.78a	1.25a	1.16	1.78a	6.12b
50% NaOH	11.00b	0.56b	1.33	1.47ab	7.29a
60% NaOH	10.14c	0.55b	1.49	1.36b	7.34a
Probability	**	**	ns	**	**
LSD (5%)	0.208	0.132	0.365	1.563	0.287
CV (%)	9.00	10.00	13.00	1.00	0.00

Mean separation within columns by LSD, 5%.
a, b, c Duncan's multiple range test

CONCLUSION

Deacetylation is the final and critical stage to produce chitosan from chitin, both of which were successfully extracted in this research. NaOH at 50% was optimum for the deacetylation step. The physicochemical properties of chitosan extracted with 50% NaOH were comparable to that of the commercial chitosan. Future research could delve into manipulation of other deacetylation conditions (e.g. temperature and duration of deacetylation) that could increase the yield of chitosan without affecting the physicochemical characteristics.

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Research article

Evaluation of Organic Rice Contract Farming Model in Cambodia

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Abstract In Cambodia, since the enactment of government (2012) organic farming under contract farming scheme is considered as one of the measures for better access to markets and poverty reduction. Previous literature revealed that organic rice farmers can generate more profit by engaging in contract farming. But only a few organic farming cases under contract farming succeeded. Since there was a lack of empirical study on current condition and issues of contract farming design and arrangement, this study clarified the effectiveness of organic rice contract farming arrangement and determined the most suitable contract farming model for small-scale farmers to maximize economic benefits. From a total of 5,053 organic rice contract farming households in Preah Vihear province, a total of 90 respondents were randomly selected. In the study area, two different organic rice contract farming models were found, namely intermediary model (Model A) and the multipartite model (Model B). Economic analysis approach revealed that even farmers in model A got a higher price of rice than model B, but there were still model A farmers who did side-selling much more than model B farmers. Thus, third-party in model B seemed to play an essential role in contract farming to make proper arrangements as well as to balance the bargaining of farmers and contractors. In general, model B contract farming (also known as multi-partite model) is recommended for organic rice farmers to maximize their economic benefits as well as profits.

Keywords Contract farming model, Organic rice, Small-scale farmers.

INTRODUCTION

In Cambodia, about 90% of the poor live in rural areas and rely on agriculture for their primary sources of livelihood (NIS, 2008). To promote and improve agricultural productivity and marketing access for agricultural products, the government has been promoting contract farming (CF) and organic farming to remove some constraints on agricultural growth and linkages to input and output markets. (MAFF Cambodia, 2012). However, the advantages of CF can only be achieved if contract arrangements are well managed and are mutually beneficial to both farmers and contractors. For CF overview, various form CFs have been practiced in Cambodia since 1950, mainly through informal arrangements. But this stopped during the civil war 1975-1979 (Couturier, Savun and Ham, 2006). Recently, there have been a few organic rice contract farming reintroduced though some contracts had already failed, and very few have succeed. (Cai et al., 2008; Nou and Heng, 2013). According to Cai et al. (2008); Nou and Heng. (2013) found that serious managerial issues remain, leasing to the poor management. As a result, farmers have often slipped out of the contract before the end of the contract period.

Table 1 Organic Rice Contract Farming in Preah Vihear Province

Year	Agriculture Cooperatives (AC)	Member (HH)	Cultivated area(ha)	Estimate-Production in Contract (tons) (a)	Actual sale	
					Tons (b)	Percentage (b)/(a)
2014	8	891	2,293	1,800	1,466	81
2015	12	1,669	4,185	8,666	2,790	32
2016	25	3,151	8,703	13,795	11,476	83
2017	32	5,162	15,812	26,538	13,984	53
2018	32	5,053	16,052	26,786	1,555	43

Source: Provincial Agriculture department, 2019

Preah Vihear province, located in northern Cambodia, is known as the largest area producing organic rice within contract farming. As shown in table 1, there are 32 Agriculture Cooperatives (ACs) with 5,053 total members. However, the actual sale was low in some years due to natural disasters and some problems in contract farming arrangements.

For this study, CF is defined as arrangements where farmers are the ones who provide land, labor, and capital; and contractors provide technical supports, requirement supports, and market to farmers.

Modalities of Contract Farming and Types of Contracts

According to FAO (2001) there are five contract farming models.
1) Centralized: an agribusiness company buys produce from many small-scale farmers with tight control over quality and quantity. 2) Nucleus estate: an agribusiness company combines CF with direct involvement in plantation production. 3) Multipartite: farmers sign contracts in a joint venture established between an agribusiness company and a local entity. 4) Intermediary: an agribusiness company may have contracts with intermediaries who then sign contracts with a larger number of farmers. 5) Informal: more informal verbal purchase agreements are signed on a seasonal basis, with inputs provided by the company often being restricted to seed and fertilizer.

OBJECTIVE

This study aims to understand the effectiveness of organic rice contract farming (ORCF) arrangement and determine which contract farming model is the most suitable for small-scale farmers with respect to maximizing benefit and farm incomes with specific objectives below:

1. Identify the ORCF models by small-scale farmers in the study area;
2. Determine the effectiveness of each contract farming model on small-scale farmers livelihood in term of income generated, and productivity;
3. Evaluate the difference ORCF models with focus on benefit and contract enforcement.

METHODOLOGY

In this study, both primary and second data were collected. 90 respondents have been randomly selected from 5,053 organic rice contract farming households within 2 different ORCF models in Preah Vihear Province and contractors, agricultural officers, NGOs, and union of agricultural cooperative were interviewed by using questionnaire forms and groups discussions. In this research, qualitative and quantitative data were used.

RESULTS AND DISCUSSION

Organic Rice Contract Farming Models' Characteristic

From field observation, in the study area, there are two different organic rice contract farming models such as:

Intermediary model (Model A): farmers and contractors are directly engaged to each other; farmers who provide land, labors, and capital; and contractors provide technological supports, requirement supports, and market.

Multipartite model (Model B): Union agriculture cooperative is one who links farmers to contractors and technical support; there is support from NGOs to union and farmers; farmers who provide land, labor, and capital and pay for union operation; and contractors provide markets.

Table 2 Arrangement of contract farming models

Categories	Model A	Model B
Farmers	Certified and cooperative agriculture (AC) member	Certified and cooperative member in Union of AC
Contract formulas	Based on market specifications	Based on market specifications
Contract format	Legally formal agreement	Legally formal agreement
Crop schedule	Yes	Yes
Pricing policies	Fixed before harvesting 1-3 weeks by contractors	Fixed before harvesting 1-3 weeks by contractors and Union
Technical assistance	Sometimes	Yes
Loan	No	Yes
Input provision	Limited	Limited
Training provision	Sometimes	Frequently
Communication	Through cooperative	Through union cooperative
Monitoring	Sometimes	Sometimes
Cost of operation	AC	Union + AC

Source: own elaboration based on field survey, 2019

All farmers in both models are certified by the same certification institute. Contract farming format, crop schedule, technical assistance, and input provision are very similar in both contract farming models. However, in contract farming model A did not provide loans to ACs or farmers, while ACs in model B could get loans from union agriculture cooperative. In addition, farmers in model B could get more support than farmers in model A such as during price bargaining, union agriculture cooperatives are with farmers and contractors to set up price of organic rice. Although, farmers in model B must pay the union 30riels/Kg of their organic rice production and another 30riels/Kg to AC operation cost while farmers in model A just have to pay 30 riels/Kg to AC operation cost. Overall, all those support and arrangements affected farmers' productivity, as well as profits.

Organic Rice Farmers' Characteristic in Both Contract Farming Models

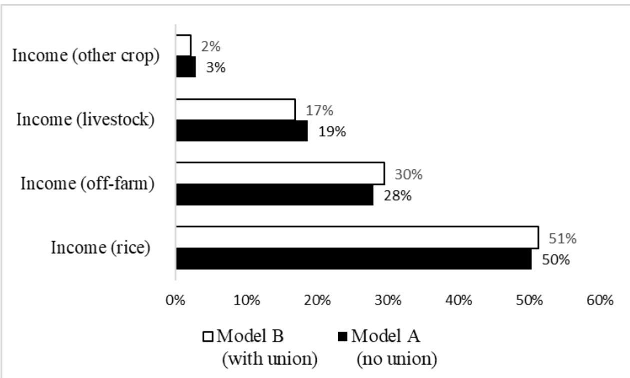


Fig. 1 Income source of farmers in both models

Source: Field survey, 2019

Farmers in both models depend on organic rice cultivation as main income; this is about 50% of total income, followed by off-farm income such as wages, construction name as a few, and livestock breeding on their farms. Beside rice farming, farmers in both models produce other crops such as cassava and cashew nuts. In addition, all farmers could grow organic rice once a year, and most of the farmers do long maturity rice rather than medium maturity. Recently, direct-seeding method is the common practice in organic rice cultivation in the study area while transplanting method is decreasing.

Table 3 Organic rice contract farmers' characteristic

Items	Model A	Model B	A-B	T-Stat	
Number of Household (HH)	45	45			
Family size (person)	4.36	4.76	(0.40)	(1.36)	*
Age (years)	44.29	40.22	4.07	1.80	**
Farming experiences (years)	25.16	21.80	3.36	1.46	*
Education (years)	6.22	4.49	1.73	2.65	**
Planted rice land size (ha)	4.25	3.44	0.81	1.86	**
Income (rice) per HH	8,671,311	8,608,900	62,411	0.07	
Income (rice) per ha (riels/year)	2,101,846	2,611,896	(510,050)	(4.28)	*

Source: Field survey, 2019 *Note: *Signification at level 0.06 to 0.10 **Signification at level less than 0.05*

Farmers in model A are 4 years older and use 0.81ha of rice cultivation land more than farmers in model B. Moreover, income from organic rice per HH are very similar in both models, but income from organic rice per ha in model B is higher than farmers in model A meaning there are some differences in each productivity.

Productivity of Organic Rice Farming in Both Models

As shown in table 4, farmers in model A spent more on labor cost due to a lower use of combine harvester services while farmers in model B got more support from the union to get more combine services during harvesting. Overall, farmers in model B spent less in production cost than farmers in model A. Moreover, Family labor and exchange labor is considered as noncash cost because farmers did not pay in cash. However, farmers in model B Still use more exchange labor than farmers in model A; this affected the cash income in both models. The study found that when there were differences in cash incomes, farmers' decisions were also different.

Table 4 Total production cost of organic rice production

Unit: '000 riels /ha

Items	Model A				Model B			
	Direct seeding		Transplanting		Direct seeding		Transplanting	
	Medium	Late	Medium	Late	Medium	Late	Medium	Late
Variable cost	**485.1**	**515.7**	**282.9**	**258.1**	**569.7**	**515.2**	**587.1**	**353.9**
Fuel consumption of								
Land preparation	55.9	53.5	56.0	54.3	57.8	57.9	58.7	58.6
Transportation	18.1	18.0	19.6	18.8	18.5	18.0	20.7	20.0
Seed	303.8	197.5	126.0	105.0	305.8	179.4	139.8	113.8
Threshing	70.0	64.1	81.3	80.0	83.9	75.2	105.1	105.3
Combine harvester	**37.3**	**182.6**	**-**	**-**	**103.7**	**184.6**	**262.7**	**56.3**
Fixed cost	259.2	288.2	259.2	296.4	254.9	273.2	246.9	274.6
Total labor cost	**600.1**	**532.0**	**983.5**	**966.6**	**511.6**	**457.1**	**665.1**	**850.0**
Family labor	234.0	224.7	356.8	343.3	217.5	213.1	206.6	350.0
Hired labors	292.1	237.9	506.7	570.0	208.2	153.9	251.2	287.5
Exchange labors	74.0	69.4	120.0	53.3	85.9	90.0	207.3	212.5
Total Production Cost	**1,344.4**	**1,335.9**	**1,525.6**	**1,521.1**	**1,336.2**	**1,245.4**	**1,499.1**	**1,478.5**

Source: Field survey, 2019 *Note: Labors cost is 20,000 riels per 8 hours per person. 4050 riels= 1USD (2019/10/01)*

Table 5 Total productivity of organic rice production in both contract farming models

Unit: '000 riels/ha

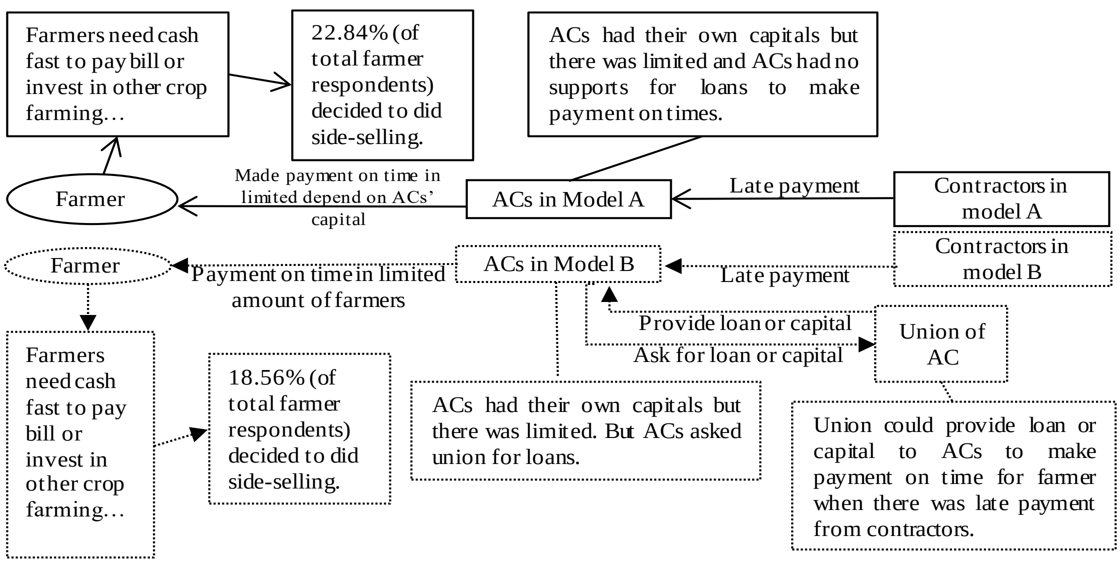
Items	Model A				Model B			
Cultivation method	**Direct seeding**		**Transplanting**		**Direct seeding**		**Transplanting**	
Rice type	Medium	Late	Medium	Late	Medium	Late	Medium	Late
Yield (Tons/ha)	**1.74**	**1.64**	**2.05**	**2.00**	**1.96**	**1.87**	**2.30**	**2.15**
Price (Riels/kg)	1,407	1,117	1,510	1,130	1,384	1,087	1,405	1,108
A. Gross revenues	**2,448.6**	**1,831.9**	**3,095.5**	**2,260.0**	**2,712.7**	**2,027.7**	**3,231.5**	**2,382.2**
a.Total Variable cost	485.1	515.7	282.9	258.1	569.7	515.2	587.1	353.9
b.Total Fixed cost	259.2	288.2	259.2	296.4	254.9	273.2	246.9	274.6
c.Total Labor cost	600.1	532.0	983.5	966.6	511.6	457.1	665.1	850.0
B.Total noncash cost	308.0	294.1	476.8	396.6	303.4	303.2	413.9	562.5
C.Total Production cost (a+b+c)	1,344.4	1,335.9	1,525.6	1,521.1	1,336.2	1,245.4	1,499.1	1,478.5
D.Total Cash income (A-C+B)	1,412.2	790.1	2,046.7	1,135.5	1,679.9	1,085.4	2,146.3	1,466.2
E.Total profit (A-C)	**1,104.2**	**496.0**	**1,569.9**	**738.9**	**1,376.5**	**782.2**	**1,732.4**	**903.7**

Source: Field survey, 2019 Noted: 4050 riels= 1USD (2019/10/01)

In table 5, all organic rice prices were already deducted from the cost of union and AC. Therefore, contract farming model A provided higher price of rice than model B but yield in contract farming model B was a higher in each category. From field observation, farmers in model B used combine harvester services during harvesting that could keep the high volume and quality of rice (saving from grain losing), while almost farmers in model A had done the harvesting by hand. Therefore, farmers in model B could generate more profit than farmers in model A, especially on cash income. In addition, medium rice maturity usually could provide higher yield but during that time, there was drought in the middle of the cultivation season which affected the yield of medium maturity. After all, farmers in model B could generate more profit and cash income than farmers in model A even though farmers in model A got higher price.

Key Challenges and Main Concern in Both Organic Rice Contract Farming Models

From field observation in 2019, contractors in both contract farming models made late payment to farmers which cause some problems in contract farming arrangement such as side-selling. Side



selling referred to farmers who sold some or all their contracted productions to other sellers beside the contractors. Since those farmers needed cash in hand fast, they decided to do side selling. Therefore, farmers who did the side selling received lower unit price compared to unit price in contract farming. In addition, there were about 22.84% of farmer respondents in model A who did side-selling while model B had about 18.56%.

Fig. 2 Reasons of farmers did side selling in both contract Farming models
Source: Author's compilation base on field survey, 2019

As shown in fig.2 farmers in model B did side selling less than farmers in model A because farmers in ACs in model B could get some loans from union to make the payments on time instead of the late payment from contractors, while ACs in model A used their own capital to make payments on time. So, it seems that union in model B has played an important role to keep good contract arrangement.

Table 6 General benefits and main concern in both contract farming models

Categories	Model A	%	Model B	%	Total	%
NHH	**45**	***100***	**45**	***100***	**90**	***100***
Concerns						
Limited access to credit	31	*69*	15	*33*	46	*51*
Price bargain	31	*69*	20	*44*	51	*57*
Noncompliance	33	*73*	26	*58*	59	*66*
Poor infrastructure	37	*82*	38	*84*	75	*83*

Source: Field survey, 2019

Table 6 showed that farmers in model A had more concerns than farmers in model B in each category because farmers in model A did not have any third party (e.g. union) to balance the power of contractors and farmers as well as good arrangement. However, both contract farming model farmers still have concerns; thus, both contract farming models need to improve those conditions. Moreover, farmers in model B also complained about the high interest rates from the union and operation costs. In addition, poor infrastructure leads to higher spending on production cost of farmers and union operation.

CONCLUSION

Two different organic rice contract farming models were found in the study area, namely the intermediary model (Model A) and the multi-partite model (Model B). Model B farmers paid more on third-party (union) operation and resulted in more support (e.g. training, loan) than model A farmers. As results, model A farmers could get a higher price of organic rice than model B farmers. However, with the current situation, that of having supports from the union which allowed model B farmers to generate more profit and cash income than farmers in model A. Moreover, there were still model A farmers who did side-selling more than model B farmers. Thus, union in model B seemed to play an essential role in contract farming to make proper arrangements while ensuring the farmers' profits and balancing the power of farmers and contractors. Overall, with the current condition, contract farming model B (also known as multi-partite model) is recommended for organic rice farmers to maximize their economic benefits and profits.

Part of the limitations of this study was time constraints. Thus, further study should focus on the key challenges in contract farming relationship within the supply chain in order to propose and critically evaluate options for improving contract farming conditions for organic rice farmers and introducing more efficient and sustainable contract design based on all actors in contract farming by using both qualitative and quantitative approaches.

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Research article

The distance learning model on cross-cultural agriculture: A case study of Thai and American 4-H club

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Abstract: Learning in the digital age of the 21st century and globalization era, a knowledge-based society, expects students to master the 21st century skills or global competencies rather than being excelled in their academic performance. The cross-cultural learning concept supports learning in this era that focuses on the learning of diverse people and cultural differences by organizing mutual learning on issues of mutual interests to create wide and varied learning in line with the needs of the learners and the current trend of global change. This learning is also in accordance with the needs of 4-H club members that has a variety of learning needs as well as having a variety of learning styles. The objectives of this research were to develop and evaluate a learning model on cross-cultural distance education in agriculture. The research and development model were used. The populations were 1) 162 4-H club members from Thailand and the United States. Quantitative data were collected from the sample size of 75 using a questionnaire and analyzed using descriptive statistics. 2) educational experts in Thailand and the United States. 15 experts was determined by using purposive sampling method. Qualitative data was collected using focus group and analyzed by content analysis. The results showed that developing a learning model according to the 4-H needs included learning interest, expectation, experiences, and knowledge. The development of a model of distance learning management in cross-cultural agriculture for 4-H is divided into 4 phases as follows: seminar defining the learning model, implementation of learning model, evaluation of learning Model, and conducting seminar and summarizing the learning model. From the evaluation of learning model regarding learning characteristics, learning methods, learning channels and tools, learning period, learning style and learning support, 4-H revealed that they were appropriate usefulness and satisfaction at high level and highest level.

Keywords: Learning model, Cross-cultural, Distance education, Agriculture, 4-H club

INTRODUCTION

Learning in the digital age of the 21st century and the globalization era is a knowledge-based affair. Students are expected to master 21st-century skills as well as global competencies apart from excelling in their academic performance (Turiman, 2011; OECD, 2018), which is driven by creative power and involves the potential of knowledge and wisdom combined with the advancement of information and communications technology (Sanguankaew, 2008). The curriculum in the 21st century focuses on critique attributes, interdisciplinary project-based activities, and research-driven coursework that can connect local communities, countries and the world. Occasionally, students can collaborate with various projects around the world using a curriculum that emphasizes advanced thinking skills, multiple intelligence, technology and multimedia (Sangkhaphan, 2013, p. 14)

The goal of Thailand and the United States' 4-H operations is to develop and empower agricultural youth. This was done by establishing a 4-H groups in schools to promote and encourage 4-H members to gain knowledge and technology related to agriculture, strengthen their agricultural skills and create attitudes to passion and interest in agriculture and agricultural professions. Furthermore, the goal is also to develop leadership, thinking, and problems solving skills that can be applied in their life in the future, especially in globalization and in the 21^{st} century.

The cross-cultural learning concept supports learning in the digital age, focusing on the learning of diverse groups of people and cultural differences by organizing mutual learning on issues of mutual interests in order to create wide and varied learning in line with the needs of learners and the current trends of global advancement. This learning is also in line with the needs of 4-H club members that have a variety of learning needs as well as having a wider variety of learning styles with the use of modern technology for learning. Consequently, there is a need for novel forms of communication through social media, chat platforms, and bulletin boards (Weeranakin et al., 2013; Weeranakin et al., 2014).

Distance learning can transcend geographical boundaries, differences in socio-cultural contexts, values, and expectations of diverse educational systems, though learners may prove to be its greatest challenge (Gunawardena, 2014). Distance education is consistent with learning management in the 21st century that focuses on self-directed learning through the use of a variety of media. Therefore, the application of distance education concepts in cross-cultural learning management between Thai and American 4-H clubs involves the transfer of knowledge to and between learners in each country through various types of media, thus allowing learners to have the opportunity to continuously learn by themselves broadly and with cost-effectiveness.

For the reasons mentioned above, the researchers developed this study. It concerns the development of learning styles that are in line with the needs of young people in the 21^{st} century who want to learn from a variety of media and be able to connect local communities in their country with the world through collaboration with global projects. Moreover, the information can be synthesized as a guideline for the development of a model for managing distance learning across cultures, in line with the needs of young people in the 21^{st} century.

OBJECTIVES

The objectives of this research were to develop and evaluate a learning model on cross-cultural distance education in agriculture of 4-H clubs in Prachamonkol School and Purdue Extension.

METHODOLOGY

This research used the research and development model. Data was collected in both quantitative and qualitative research (Creswell, 2012). The populations were 1) 112 members of the 4-H club at Prachamongkol School, Kanchanaburi Province in Thailand and 50 members of the 4-H club of the Legacy Learning Center from Marion County under the extension services of Purdue Extension of Purdue University, Indiana, USA., totaling 162 persons. Quantitative data were collected from the sample size of 75 using a questionnaire containing questions on a five-point Likert scale and analyzed using descriptive statistics. The questionnaire was divided into 4 parts including general information, the context and operating conditions of 4-H, agricultural learning management, and the need of 4-H for cross-cultural distance learning. 2) Educational experts in Thailand and the United States. 15 experts was determined by using purposive sampling method. Qualitative data was collected using focus group and analyzed by content analysis. The research conceptual framework as shown in Fig. 1.

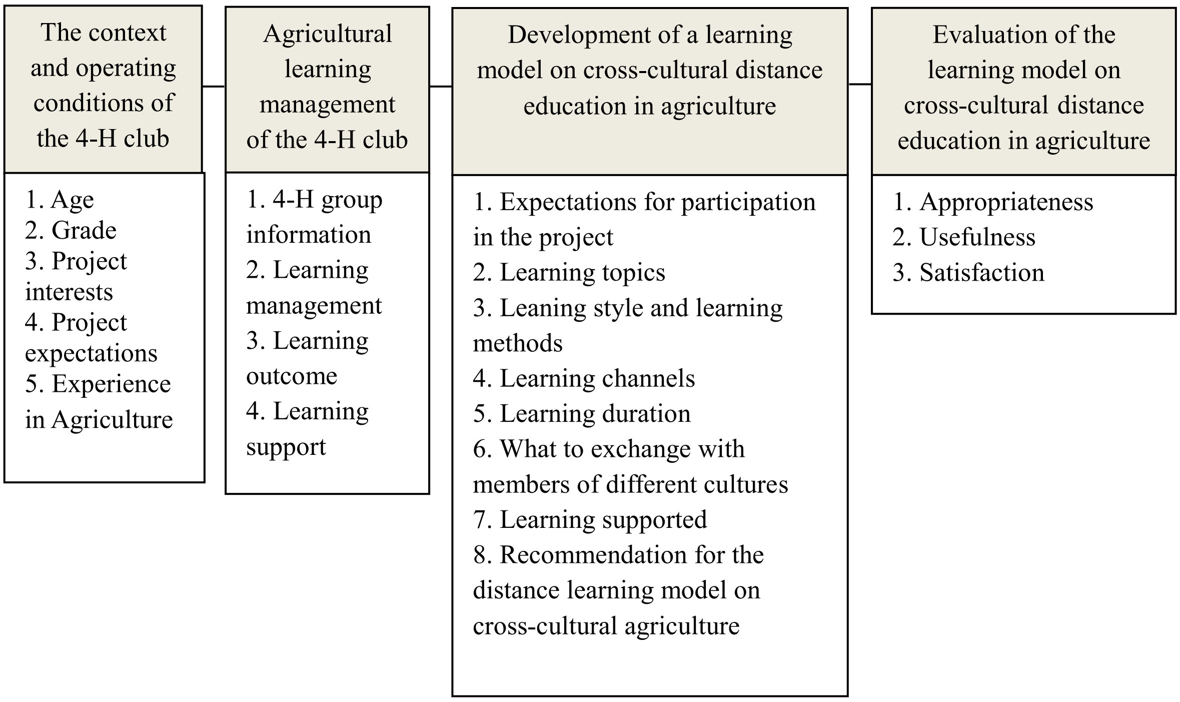

Fig. 1 The conceptual framework of the research

RESULTS AND DISCUSSION

The context and operating conditions of 4-H club in Prachamonkol School and Purdue Extension

Thai and American 4-H club context and operating conditions are as follows: 70.0% of Thai 4-H were females with an average age of 15.02 years old, 36.0% of whom were studying in 7th grade, while 64.0% of American 4-H were females with an average age of 13.56 years with 52.0% studying in 6th grade. Most of them were interested in joining the project to exchange cross-cultural learning. In terms of culture, agriculture and food in foreign countries, most of the expectations of 4-H members in the project were to get to know and talk to new friends, speak languages, and learn about the culture of foreign life. Based on the findings, there can be a discussion that in term of new generation in the 21st century, 4-H club members who want to connect the world has a variety of learning needs, learning styles with the use of modern technology for learning such as social media. The school should provide opportunities for student growth through exploring the global through collaboration with projects.

Agricultural learning management of 4-H club in Prachamonkol School and Purdue Extension

Agricultural learning management of 4-H club in Prachamonkol School consisted of learning by doing, constructivism learning, cooperative learning, learning by technology. Agricultural learning management of 4-H club in Purdue Extension School consisted of school enrichment, special interest programs, after school, camps and conferences. Based on the findings, there can be a discussion that the learning management for 4-H club should get in line with the curriculum in the

21st century that focuses on the critique attributes, interdisciplinary project-based, research-driven, and connecting local communities with countries and the world.

Development of learning model on cross-cultural distance education in agriculture of 4-H club in Prachamonkol School and Purdue Extension

Development of learning model on cross-cultural distance education in agriculture was conducted in 4 phases as follows: 1) seminar defining the learning model on cross-cultural distance education in agriculture, 2) implementation of learning model on cross-cultural distance education in agriculture, 3) evaluation of learning model on cross-cultural distance education in agriculture, and 4) conducting seminars and summarizing the learning model on cross-cultural distance education in agriculture as shown in Fig. 2.

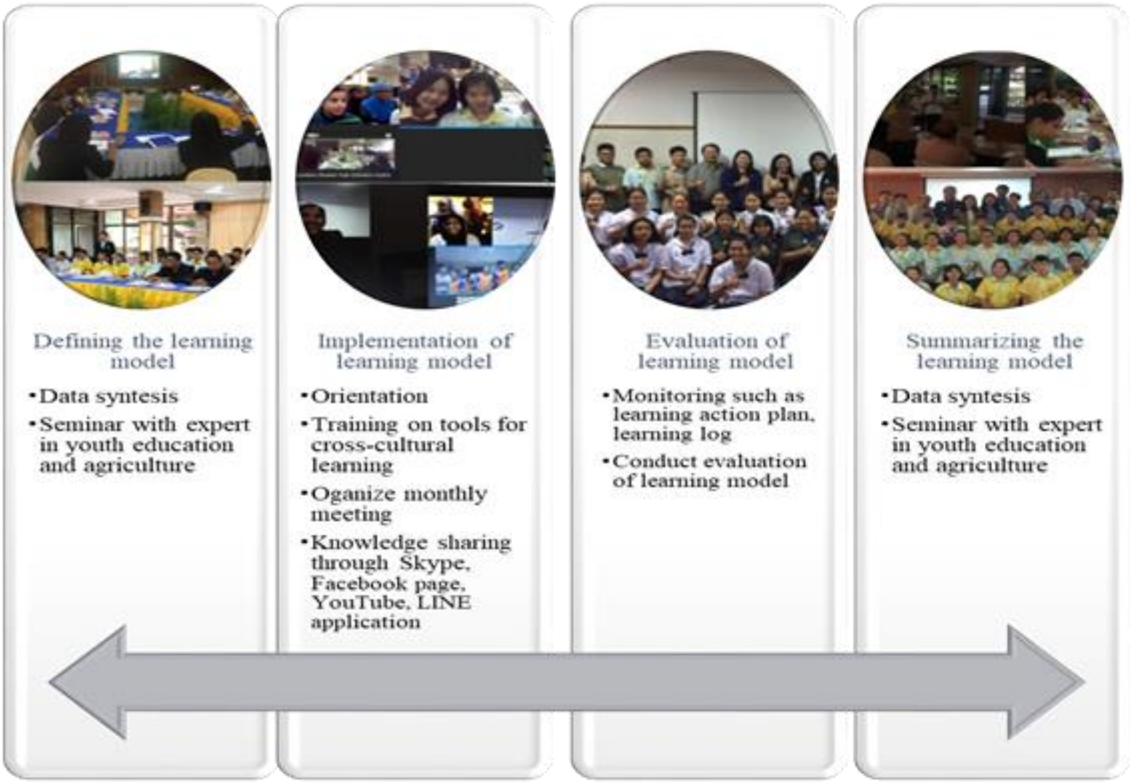

Fig. 2 Development of learning model on cross-cultural distance education in agriculture of 4-H club

The learning model on cross-cultural distance education in agriculture of 4-H club was designed based on student needs such as learning topics, learning time and learning channels. Many social media were used for this learning model including 1) Facebook page; Thai-American 4-H, https://www.facebook.com/thaiamerican4H, 2) YouTube; for examples, https://youtu.be/4p1yguMWvlI, https://youtu.be/GMGP1qA8tsY, and 3) LINE application. This learning model are in line with the needs of 4-H who want to learn from a variety of media to be able to connect local communities to the country and the world through collaboration with projects.

Evaluating of the learning model on cross-cultural distance education in agriculture of 4-H club in Prachamonkol School and Purdue Extension.

The evaluation of learning management model on cross-cultural distance education was to assess the learning styles and learning methods in 3 areas which are suitability, usefulness and satisfaction.

Each area will evaluate in 6 aspects including learning characteristics, learning methods, learning channels and tools used in learning, learning duration, learning style, and learning support. It was found that the evaluation of learning styles and learning methods in all 6 aspects, Thai and American 4-H club considered its appropriate usefulness and satisfaction at the high to highest level (Mean ranged from 3.64-4.74) as shown in Table 1.

Table 1 Evaluation of 6 aspects of learning styles and learning methods in appropriate usefulness and satisfaction

Issue	Appropriate		Usefulness		Satisfaction	
	Thai 4H ($\bar{X}$)	American 4-H ($\bar{X}$)	Thai 4H ($\bar{X}$)	American 4-H ($\bar{X}$)	Thai 4H ($\bar{X}$)	American 4-H ($\bar{X}$)
1. Learning style						
1) Student-centered learning	4.18	4.36	4.18	4.20	4.16	4.12
2) Project Based learning	4.02	4.24	4.16	4.24	4.06	4.08
3) Learning by doing	4.30	4.12	4.38	4.16	4.42	4.32
2. Learning tools						
1) Discussion	4.04	4.04	4.02	4.00	3.94	4.00
2) Training	4.16	4.16	4.28	4.20	4.02	3.96
3) Demonstration	4.32	4.52	4.34	4.36	4.14	4.24
4) Group activities	4.26	4.40	4.12	3.88	4.02	3.96
5) Video	4.06	4.12	4.06	4.12	4.20	4.40
3. Learning Channels						
1) Facebook	4.52	4.48	4.64	4.56	4.44	4.36
2) Skype	4.28	4.16	4.46	4.32	4.38	4.36
4. Learning time						
1) Duration of learning throughout 4 months	4.16	4.16	4.18	3.96	4.24	4.24
2) Time to exchange						
2.1) Sunday (6.00-8.00 p.m.)	4.24	4.24	4.28	4.20	4.00	4.08
2.2) Monday (6.00-8.00 p.m.)	3.94	3.76	4.00	3.72	3.96	3.64
5. Learning methods						
1) Large group exchange once a month.	4.52	4.52	4.30	4.40	4.26	4.32
1.1) Between 4H Thai-American						
1.2) In each school	4.42	4.60	4.34	4.40	4.22	4.16
2) exchange subgroups						
2.1) Between 4H Thai-American	4.56	4.60	4.16	4.20	4.38	4.40
2.2) In each school	4.48	4.60	4.18	4.32	4.26	4.20
3) exchange subgroups on issues of interest	4.18	4.12	4.14	4.00	4.20	4.16
4) Learning from Project Implementation	4.36	4.36	4.36	4.00	4.16	4.12
5) Exchange using video	4.32	4.36	4.34	4.28	4.32	4.40
6) Exchange of learning through Skype	4.46	4.44	4.34	4.20	4.18	4.00
7) Sharing Learning through Facebook	4.46	4.44	4.42	4.48	4.38	4.60
6. Learning Supported	4.74	4.60	4.62	4.60	4.48	4.32
1) Teacher Consultant						
2) School administrators	4.12	4.04	4.18	4.20	4.20	4.20
3) Parents	4.34	4.28	4.28	4.20	4.20	4.08
4) Operators from Sukhothai Thammathirat Open University	4.32	4.32	4.28	4.28	4.40	4.36
5) Operators from Purdue Extension	4.54	4.56	4.40	4.40	4.46	4.44
6) Related Agencies	4.24	4.20	4.16	4.04	4.12	4.04

Based on the findings, there can be a discussion that the implications of this study are for teacher and school to provide opportunities for student growth through exploring the global through collaboration with projects around the world and to engage in the advancement of information and communication technology in learning. The learning model for cross-cultural distance education in agriculture between the 4-H club should be flexible and fit to students needs such as learning topics, learning styles, learning methods, learning tools, learning channels, learning time and learning supported. In order to prepare 4-H club and youth for an inclusive and sustainable world, it should be done by preparing them with the global competencies which is the capacity to be able to examine local, global and intercultural issues, to understand and appreciate the perspectives and world views of others, to engage in open, appropriate and effective interactions with people from different cultures, and to act for collective well-being and sustainable development (OECD, 2018). Furthermore, student should engage in the cross cultural learning to see the world and explore the different cultures to be fully engaged in the experience.

CONCLUSION

The results show that in terms of the context and operating conditions of Thai and American 4-H club, most of them were interested in joining the project to exchange cross-cultural learning. In terms of culture, agriculture and food in foreign countries, most of the expectations of 4-H members in the project were to get to know and talk to new friends, speak languages, and learn about the culture of foreign life. Agricultural learning management of 4-H club included learning by doing, constructivism, cooperative learning, learning by technology, school enrichment, special interest programs, after school, camps and conferences. Development of learning model on cross-cultural distance education in agriculture was conducted in 4 phases as follows: 1) seminar defining the learning model on cross-cultural distance education in agriculture, 2) implementation of learning model on cross-cultural distance education in agriculture, 3) evaluation of learning model on cross-cultural distance education in agriculture, and 4) conducting seminars and summarizing the learning model on cross-cultural distance education in agriculture. The evaluation of learning management model on cross-cultural distance education was to assess the learning styles and learning methods in 3 areas which are appropriate, usefulness, and satisfaction. Each area was evaluated in 6 aspects including learning characteristics, learning methods, learning channels and tools used in learning, learning duration, learning style, and learning support. It was found that Thai and American 4-H club considered its appropriate, usefulness, and satisfaction at the high to highest level (Mean ranged from 3.64-4.74)

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Research article

A Case Study on Postharvest Handling Practices of Mango Fruits in Selected Areas of Myanmar

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Abstract Mango (*Mangifera indica* L.*)* is one of the most popular fruits in tropical countries. The postharvest losses of mango fruits in developing countries are still high and facing the economic loss. Myanmar mango is harvested only once a year, there is often an oversupply which leads to low prices and product losses at harvest time. This study was conducted to investigate the existing handling practices and to identify the losses concerned with the major problems facing the handling of mango in selected areas during mango season of May 2017. A total of 120 respondents from mango growers of Mandalay and Sagaing regions were randomly selected and interviewed using structured questionnaires. The total loss of 32%-52% of mango fruits were observed during postharvest handling and transportation due to poor transportation infrastructure and bad road conditions in production sites. The temporary transportation was used trailer which is driven by motorbike for local market and ten-wheeled truck without cooling system was used for export market. The loss in harvesting stage was 10-20% responded by the growers due to the harvesting tool and which was picking the fruit with a long bamboo-hook or ladder to reach the high plant. Thus, postharvest losses of mango fruit were the highest percent in study areas. Currently, mango growers were directly sent to local wholesale and China border markets by non-refrigerated truck. No collective bargaining takes place on the price and each farmer interacts individually with the brokers or buyers by receiving market price. The 79 % of mango growers were commonly practiced for temporary bulk package of bamboo basket followed by the use of plastic crate of 15% from the farm site to destined markets All growers mostly and currently used the packaging style of individual fruit wrapping by paper in plastic crate for export market. One of the major constraints is the scarcity of labor in mango season by the results of 73 % responded by the mango growers. Regarding the perception of growers, more than 50% of respondents have knowledge and experiences on postharvest handling managements, however, trainings on systematic handling practices among the stakeholders were still needed to reduce the losses.

Keywords: Handling Practices, Harvesting, Packaging, Transportation and Mango Supply Chain

INTRODUCTION

Mango (*Mangifera indica* L.) is an important tropical fruit around the world and it belongs to the family Anacardiaceae. The origin of mango is Indo-Burma region and it is one of the most important exportable fruits in Myanmar. Myanmar is the sixth largest country in mango production in Asia. The mango production areas in Myanmar are over 104,000 hectares with the average yield of 6.83 MT/ha (MOALI, 2018). More than one hundred varieties of mango are cultivated throughout Myanmar. Major mango production areas in Myanmar are Mandalay Region, Sagaing Region and Southern Shan State. Twenty kinds of mango species and more than 300 varieties are cultivated throughout Myanmar (VFRDC, 2003). Among these varieties, the exportable cultivars are Sein Ta Lone, Mya Kyauk and Shwe Hin Thar. Out of them, Sein Ta Lone is very popular in both domestic consumption and export markets of China, Taiwan, Russia and Singapore. Mango is one of the most perishable fruits and have a short postharvest life of 4-8 days at room temperature (Carrillo et al., 2000). It is facing high postharvest losses in Myanmar and it is estimated in the range of 25-40% from harvest to consumption stage (FAO, 2011). In order to increase food security, it is not enough to increase the productivity in agriculture but there is also a great need to reduce the losses (Parfitt et al., 2010). The mango postharvest handling practices include series of operations such as harvesting, precooling, cleaning, selection, grading, washing, ventilation, grading, bagging, packaging and distant transportation before they reach the market (Kader, 2005). Awareness and adoption of postharvest handling technology of mango fruits by growers, producers and traders along the supply chain are still weak in Myanmar. There is paucity of information on postharvest handling practices and losses of mango concerned with the problems in commercial mango production. Therefore, this study was carried out to investigate the existing handling practices and postharvest losses by identifying the major problems facing by the mango growers.

RESEARCH METHODOLOGY

This study was conducted in major mango producing areas of Mandalay and Sagaing Regions in the central part of Myanmar. A total of 120 respondents from mango orchards in 6 villages of these regions were randomly selected and interviewed using structural questionnaires. The survey was conducted in May 2017 using random sampling procedure. The questionnaires were composed of total 40 questions concerned with cultivation practices and postharvest handling practices of mango fruit and demographic facts of gender, age, education level, employment, land holding size and income. The problems encountering during harvesting, postharvest handling and growers' perception, suggestions were also collected in this study. The collected data were transferred and analyzed by using Statistical Package of the Social Science (SPSS) version 23.0 software.

RESULTS AND DISCUSSION

Assessment on Socio- demographic characteristics of the respondents

Socioeconomics factors of mango growers include age, educational status and land holding size. It reveals that the farm size of mango growers ranged from one to 14 hectares and about 40 % of mango growers possessed 1-2 hectares, another 40 % possessed 3-4 hectares. The growers who possessed more than 10 hectares were recorded as 10% in study areas (Fig.1). The most cultivated and demandable mango varieties were Sein Ta Lone and Shwe Hinn Thar observing about 50% followed by 24% of these two varieties and Yin Kwe mango (Fig. 2). It can be assumed that Sein Ta Lone and Shwe Hin Thar mangoes are the most market demand by the consumers and other cultivars of Mathe and Nga Mout were growing together with Sein Ta Lone and Shwe Hinn Thar mangoes. According to survey, the age of mango respondents with the range of both 31-40 year and 41-50 years belonged to 36% respectively whereas the rest of 28% were older than 50 years showing 18% and 10% belonged to age group of 20-30 years in both study areas. The majority of household heads were within the middle age and mainly males whereas the females were served as household workers in the orchard. It is evident that the educational status of respondents ranged from primary to graduate level. Most growers were graduate level of 29% followed by the 27% of high school level. The rest of 27% and 19% were secondary level and primary education level, respectively.

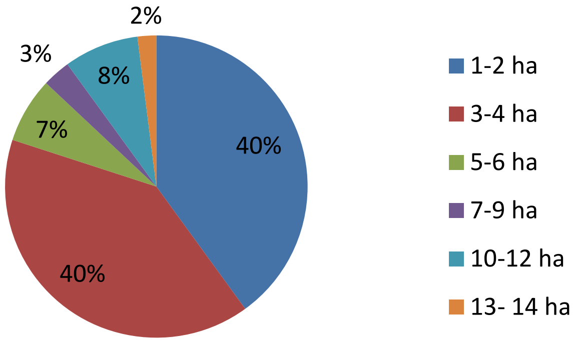

Fig. 1 Distribution of mango farm size in study areas

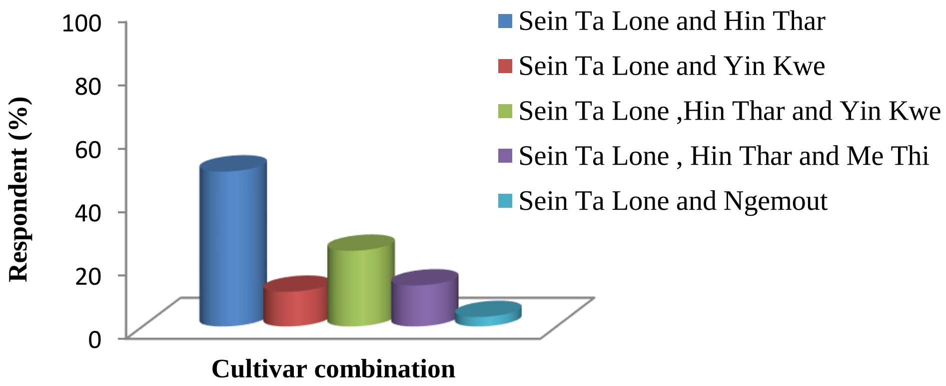

Fig. 2 Distribution Percent of different mango varieties among the respondents Handling practices of mango in study area

Handling practices of mango fruits include the stages of precooling, cleaning, sorting, grading, packaging and transportation from farm site to consumers. Individual fruit wrapping was commonly practiced for local and distant markets. The bulk packaging items for mango fruits were bamboo basket, plastic crate and wooden box. Among them, about 80% of bamboo basket was used for local market followed by the 14 % for plastic crate for export market. The rest of 4 % was wooden box and 2% was carton box used in locally (Table 1). It can be assumed that bamboo basket is easily available with low cost in Myanmar. It was agreed with the report of FAO (2011) and that packaging generally provides protection for the product to reduce losses and to maintain fruit quality with the enhancement of product value.

Table 1 Access to handling practices by packaging materials by mango growers

Item	Respondents (%)
Bulk Packaging Type	
1.Wooden crate	4.00 (n =100)
2.Plastic crate	14,25 (n =95)
3.Bamboo basket	79 .75 (n=110)

4. Carton box	2.00 (n= 80)
Total	**100**
Individual Packaging item	
1.Paper	100 (n =110)
2.Net sac	0
Total	**100**

Table 2 Losses of mango fruits by the sample respondents in study areas

Item	Losses (%)	Respondents (%)	Reasons
Preharvest	0		Falling the small fruits due to wind
Harvest time	10-20	32 (n=100)	Due to harvesting tool a) using a long stick or scissors to cut the fruit from the tree b) climbing the tree or using a ladder to reach high plant
Postharvest	21-30	65 (n=100)	during handling practices and transportation
Others	1- 2	3 (n=72)	Pest, disease infestation and climatic condition
Total	**32- 52**	100	

Losses of mango during handling practices in study area

The survey was conducted to examine the main reasons of mango losses during the pre-harvest, harvest and postharvest periods. There was no respondent for pre-harvest loss. However, postharvest loss of mango during handling and transportation was higher than those of the harvest loss. About 65 % of postharvest loss was recorded during handling practices and transportation followed by the harvest time loss of 32% was due to higher plants by the use of long bamboo pole and ladder. The other losses of 1-2% were identified as wind condition, pest and disease infestation. Thus, total losses of 32-52% were observed due to improper handling practices, transportation system and harvesting practices (table-2). Most respondents reported that the mango fruits were mostly and temporarily transported by 86% of trailers which was driven by motorbike from farm to local market. The bad nature of road networks at the farm site and unfavorable factors during transportation resulted in great postharvest losses. The following (Figs. 3 & 4) show knowledge background on handling practices and growers′ perception on training requirement. More than 50% of respondents had their own sets of criteria for postharvest handling managements and knowledge. However, half of growers and labors had no knowledge concerned it and they still used traditional harvesting method and handling practices that means mango directly piled on the ground with no paper, sheet or straw with stack and also harvested mangoes with stalk which caused dropping the latex that resulted in negative effects on fruit quality and increase in postharvest losses. Thus, about 80 % of respondents answered to give trainings on postharvest handling managements for labors and growers. Therefore, educational training on postharvest managements such as biological pest control, advanced harvesting technique, systematic handling and packaging practices would greatly help in reducing the postharvest losses of mango fruit.

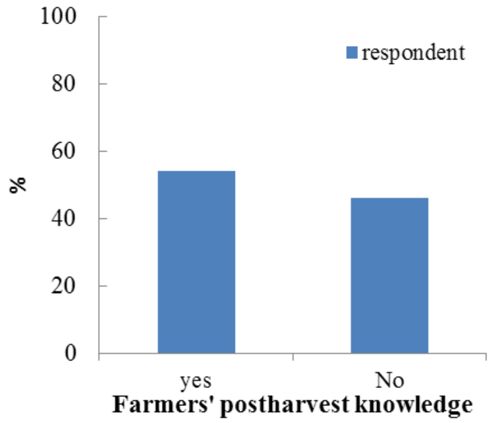

Fig. 3 Postharvest knowledge by the mango growers in study areas

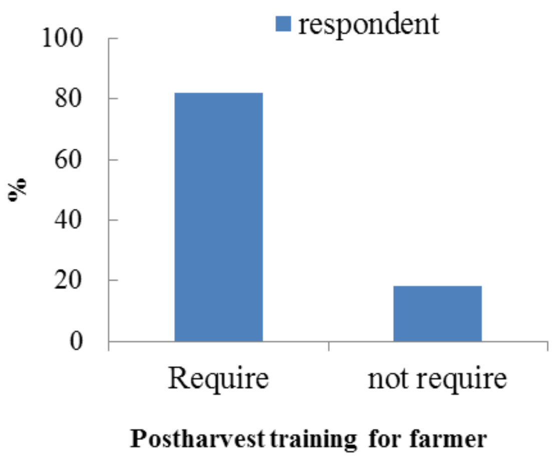

Fig. 4 Farmers' perceptions on postharvest training in study areas

CONCLUSION

Almost 100% of the respondents were commonly practiced by paper packaging to individual fruit for distant transportation along the sale process. Therefore, handling and packaging practices should be systematically managed to reduce postharvest losses and to maintain the quality of the products. It is suggested that the use of enough labors (pickers and packers) and they should be trained to reduce losses at harvest time and postharvest losses. It is needed to change the attitudes of growers to adopt innovation in farming cultivation practices and community among the growers. Moreover, to be modernized orchard and easy to manage for harvest, changing the attitude of the growers is one of the constraints and transportation as a result of undulations on roads are one of the major causes of postharvest losses. Furthermore, farmers do not have good storage facilities at the farm level, and this forces them to sell their fruits immediately after harvest. And also, no collective bargaining takes place on the price of mango. According to the study, some respondents in study areas were practicing on sizing and grading of mango fruit for export market by the use of machinery and this may be regarded as quality criteria. Although growers have the knowledge and awareness on postharvest handling practices and managements for mango export market, they have not tried to carry out practically and systematically these practices. Therefore, trainings and awareness program on postharvest technologies in fruit production is needed to train the mango growers and stakeholders for the advancement of postharvest handling practices. Moreover, cooperation with public and private partnership should support them to take these actions.

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Research article

Evaluation of Water Quality and Vegetable Production in Cheung Ek Lake, Cambodia

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Abstract Wastewater management in Phnom Penh is always a concern for the Royal Government of Cambodia as well as citizens of the capital. All wastewater and sewage from the households and the industries are untreated discharges into the city's wetlands, such as Cheung Ek, Tompun, Trabek Lakes. Cheung Ek Lake is the biggest and terminal lake in the chain of water systems before discharging into Bassac and Mekong River. Apart from the purification of the wastewater, the lake ecosystem also has an important economic function. Local people use the lake for fishing and to cultivate aquatic plants such as water morning glory (*Ipomoea aquatica*) and water mimosa (*Neptunia oleracea*). Considering these aspects, the objectives of this study are to (i) analyze water quality in Cheung Ek Lake during the rainy season; (ii) study the economic balance and the price-chain of water morning glory production. The water samples were collected on three different days at three points in the lake (inlet, middle and outlet) and analyzed for pH, EC, Fe, DO, PO_4^{3-} and NO_3^-. Semi-structured questionnaires were designed for the economic analysis, and a total of 20 farmers were interviewed for social characteristics, input and output costs, and the water morning glory market channel of water morning glory production. Except for phosphate concentrations which was higher at the inlet site, the other nutrient content poses no threat to environmental pollution. Additionally, the lake's chemical load were lower at the outlet than at the inlet. In terms of economic benefit, the net profit from the production was 23.77 USD per day/ha. Despite the fact that the farmers spent a lot of money on hiring the manpower, the profits from the sale was sufficient. The production's economic efficiency was 1.80. The result of water quality and economic showed lake perform a role in removing pollutants and provide economic benefits to the farmers.

Keywords Phnom Penh, Cheung Ek Lake, water quality, water morning glory

INTRODUCTION

The explosive urban expansion throughout Asia has resulted in severe environmental problems, including air and water quality issues and inadequate infrastructure (Varis et al., 2005). In the process of urbanization, economic development and the natural environment are linked by a series of positive and negative effects. Wastewater management has become a concern for the Royal Government of Cambodia since Phnom Penh city's population has grown from 1.4 million in 2008 to 2.1 million in 2018 (NIS, 2019). Until now the city still doesn't have proper wastewater treatment plan while its population continue to grow as well as the expand of city. In the past, the wastewater from the urban are discharged into 3 wetlands namely Tumpon Lake, Trabek Lake, and Cheung Ek Lake (Tharith et al., 2008). The wastewater is serviced by a combined sewer system, and flow is pumped to Cheung Ek Lake (natural wetland) for treatment before it discharges to the Bassac River system (Visoth et al., 2010). However, the urbanization keeps intrude the wetlands area result in only Cheung Ek Lake remained.

Cheung Ek Lake, the largest wastewater Lake in the city, knows as the production area for water morning glory (WG) for almost four decades. The lake's surface area changes from 1,300 to 3,000 ha during the dry and rainy seasons (Nara et al., 2015), given the potential for plant cultivation. This wetland system can potentially provide adequate wastewater treatment, environmental and economic benefits (Brix et al., 2007; Koottatep et al., 2010; known). However, those study were conducted a decade ago and even before the starting of intrusion into the lake area. The uncontrolled human occupation on the lake’s bank has led to encroachment of the lake's surface area every year, especially from 2013 when the satellite cities project started (Sahmakum Teang Tnaut, 2019). Cheung Ek Lake was proven to be effective in treating treated wastewater for bacterial contaminants, nutrients, detergents, and metals (Irivine et al., 2008; Sovann et al., 2011; Visoth et al., 2010; Vuong et al., 2007). However, as the lake's surface area gets smaller, its potential for wastewater treatment reduce as well. High concentration of phosphorus and deplete level of DO were reported at the point where wastewater from the city discharge into the Mekong rivers (Chea et al., 2016). These could be the result of direct municipal discharges and urban storm water runoff in densely populated areas. Therefore, the question remained whether the lake could still offer ecosystem services to the city.

The purpose of this paper is to investigate the potential of Cheung Ek Lake in ecosystem services in aspect of wastewater treatment and economic benefit. This paper consists of two specific objectives: (i) analyze water quality in Cheung Ek Lake during the rainy season; (ii) study the economic balance and the price-chain of water morning glory (*Ipomoea aquatic*) production.

METHODOLOGY

Study Area

The study was conducted on Cheung Ek Lake located at the south of Phnom Penh city (104°90’–104°94’E and 11°46’–11°53’N). It is the catchment area where 80% of total wastewater from this catchment is drained into the lake (Van der Hoek et al., 2005). The lake’s surface area changes from 1,300 to 3,000 ha approximately from dry to rainy seasons, with an average depth of 0.5-1.5 m in the dry season and 7–9 m in the rainy season. The average annual rainfall is 1,440 mm and elevation is around 10 m above sea level (Nara et al., 2015).

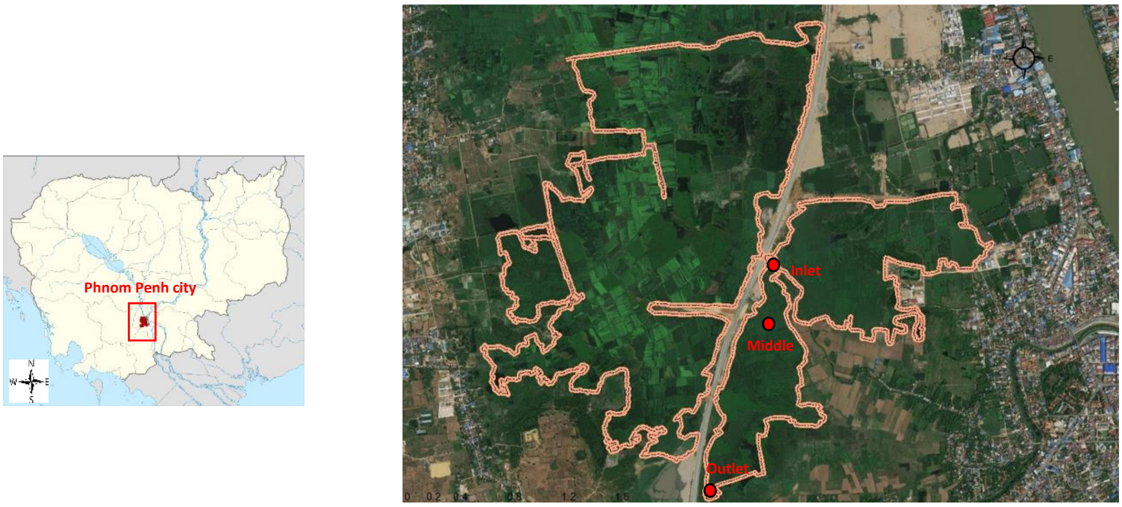

Fig. 1 Map of Cambodia and sampling point in Cheung Ek Lake (Google map)

Water Sampling and Analysis

Water sampling was conducted during the rainy season of September 2019 by using Heyroth Water

Sampler. Sampled water was kept in the plastic containers at 5 ^{0}C and transported to the laboratory within 3 h of collection for analysis. The water samples were collected on three different days at the inlet, middle and outlet. Totally 27 water's samples were analyzed for pH, electrical conductivity (EC), iron (Fe), dissolved oxygen (DO), phosphate (PO_4^{3-}) and nitrate (NO_3^-) using DR 900 portable data-logging colorimeter instrument.

Field Survey and Interview

The semi-structured questionnaires were created, and 35 respondents were surveyed. Among 35 respondents are include 20 farmers, 5 middlemen, 5 wholesalers, and 5 retailers whose involved in the production and selling of water morning glory. Social characteristics of the farmers, economic returns and efficiency of the production of water morning glory were analyzed based on semi-questionnaire survey.

RESULTS AND DISCUSSION

The analysis of physical and chemical parameters of water samples are given in Table 1. The result of pH indicates moderately alkaline water in Cheung Ek Lake. The mean pH of Cheung Ek varied from 6.98 to 7.15 at the different sampling sites. Lower pH in the middle point indicates the acidity in the water and could be due to a high concentration of positive hydrogen ion in the water. Electrical Conductivity of Cheung Ek Lake water were not significantly different among sampling sites, varying from 0.66 to 0.75 mS/cm. High conductivity in the lake indicates the mixing of sewage and the rainfall during raining season. Nitrate contents were slightly different from each site, ranging from 0.11 to 0.66 mg L^{-1}. The high concentration in the outlet point, which could be due to the release of the nutrients from sediment where there is no plantation cultivated. The result of PO_4^{3-} varied drastically among different sampling sites in the lake, ranging from 1.42 to 5.29 mg L^{-1}. PO_4^{3-} were maximum at the inlet and become lower in the middle and outlet. The high concentration of PO_4^{3-} in the inlet suggests urban runoff, industrial wastewater and chemicals used in the water for agriculture activities. The low concentration of Iron (Fe) were observed in the outlet of the lake and ranged from 0.03 to 0.05 mg L^{-1}. DO of the lake ranged from 3.55 to 6.06 mg L^{-1}. The maximum concentration of DO were at the inlet and lower at the outlet. This further indicated the flow rate of the lake at different sites and the process of dissolved solid breakdown through self-pollution regulating mechanisms of the lotic water system.

Table 1 Discharge and chemical properties of inlet, middle and outlet of the lake

Location	Discharge (m^3/s)	pH	EC (mS/cm)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	Fe (mg/L)	DO (mg/L)
Inlet	42.12	7.06 ± 0.30	0.75 ± 0.04	0.66 ± 0.29	5.29 ± 2.26 a*	0.03 ± 0.03	5.14 ± 2.24
Middle	-	6.98 ± 0.27	0.72 ± 0.01	0.11 ± 0.16	1.42 ± 0.59 b*	0.05 ± 0.05	6.06 ± 1.99
Outlet	33.91	7.15 ± 0.36	0.66 ± 0.02	0.55 ± 0.18	1.90 ± 0.50 b*	0.06 ± 0.03	3.55 ± 0.66

*Note: Values are mean ± SD (n=3), * $p < 0.1$*

Correlation matrix between different physical and chemical parameters are shown in Table 2. A correlation matric was observed between some important water quality parameters of the lake, which further indicates the interactions between water chemical constituents. The result showed that, pH had a positive correlation with dissolved oxygen (DO) and nitrate (NO_3^-). According to Battas et al. (2019) pH greatly affects the adsorption rate of nitrate. It also affects the charge on the surface of the adsorbent during the ion exchange process. Also, Electrical conductivity (EC) had a correlation with phosphate (PO_4^{3-}) because the contamination of inorganic compounds in the solution of phosphate ions contribute to electrical conductivity.

Table 2 Correlation matric of water quality in the lake

	pH	EC	NO_3^-	PO_4^{3-}	Fe	DO
pH	1					
EC	-0.137	1				
NO_3^-	**0.628	-0.247	1			
PO_4^{3-}	-0.157	**0.646	-0.148	1		
Fe	-0.042	-0.275	-0.126	-0.186	1	
DO	*0.480	0.036	0.083	-0.221	-0.087	1

*Significant difference at **p<0.01, * p< 0.05*

The water quality of the lake can be defined by two indicators such as concentration and load. The concentration indicated in Table 1 and Table 3 shows the load of four parameters in Cheung Ek Lake between the inlet and outlet site. The result for PO_4^{3-} , NO_3^- and DO showed a decreasing trend. Iron (Fe) increased in both sites. As the outlet's load was reduced compared to the inlet's load it can be said that the lake can remove inflow pollutants. In contrast to the JICA report, 2016 has stated that the lake has been encroached by houses, factories, agricultural and other activities, and they are no longer effective in performing their natural purification function. The reason could be due to in rainy season the inverse flow direction of water coming from the Mekong River at the southeast part of the lake (outlet), colliding this water moving in the opposite direction (Sovann et al., 2011) pushed the wastewater back to the upper part of the lake which then made the concentration and load of the parameters high in the lake (Nara et al., 2015).

Table 3 Nutrient load of the inlet and outlet

Parameter	Inlet	Outlet
NO_3^- (g/m^3)	28.08	18.65
PO_4^{3-} (g/m^3)	222.81	64.42
Fe (g/m^3)	1.26	2.03
DO (g/m^3)	216.50	120.38

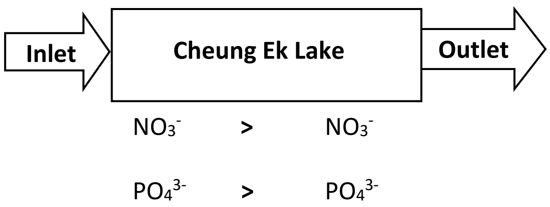

Fig. 5 Function of the Cheung Ek Lake

Socio-Economic Aspects of Water Morning Glory Production

Table 4 shows the socio-economic characteristics of 20 respondents. The average household size was 6.1 people per household, which is higher than the national average of 5.3 people for the urban areas (NIS, 2019). On average, experience in farming water morning glory was 10.4 years and the cultivated area per household was 2.15 ha. The average harvest per day per ha was 164.5 bunch and the average price was 0.37 USD per bunch.

Table 4 Socio-economic characteristics of water morning glory (WG) producers

Number of household (HH)	20
Average family size (person)	6.1
Average age of farmer (year)	37.8
Average year of experience in WG production (year)	10.4
Average planted area per HH (ha)	2.15
Average harvest per day per ha (bunch)	164.5
Average price per bunch (USD)	0.37

Source: Field survey, 2019

Total Production Cost and Economic Return of Water Morning Glory

Table 5 showed the result of the production cost (per day/ha) of water morning glory. The result revealed that the total production cost was 29.58 USD per day/ha. The result also showed that most of the expense during the production was on labor.

Table 5 Total production cost of water morning glory

Item	Price (USD)
Total variable cost (a+b)	**28.43**
-Variable cost (a)	**5.85**
Pesticide	3.57
Gasoline	1.55
Plastic	0.22
Boat reparations	0.16
Rope	0.34
-Total labor (b)	**22.58**
Family labor	7.98
Rent labor	14.59

Item	Price (USD)
Total fix cost (c)	**1.15**
Land rent	0.68
Bamboo	0.29
Boat	0.15
Sprayer	0.01
Container	0.01
Total production cost (a+b+c)	**29.58**

Regarding economic return from production, this study examined several indicators, like gross revenue, total cash income and net profit. The results show that the income from the production was 53.35 USD per day/ha (Table 6). The cash income is referring to the income that the farmers received without deducting labor of family involve in the production. In the water morning glory production, the cash income that the farmers received was 32.90 USD per day/ha. Although the farmers spent a lot on labor, the return from the sale was good enough. The economic efficiency for the production was 1.80 (Table 6), suggested that the business with this product is profitable. The value 1.80 of economic efficiency could be interpreted as follows: if 1 USD is spent on the production, 1.80 USD will be received from the sale of products. So, net profit was 0.80 USD per unit of expense.

Table 6 Economic efficiency of water morning glory

Income (USD)	Cash income (USD)	Net Profit (USD)	Production cost (USD)	Economic Efficiency
53.35	32.90	23.77	29.58	1.80

Figure 6 shows the price chain in water morning glory production between farmers, middlemen, wholesalers and retailers. The price of the water morning glory product varies from month to month according to its availability and demand. The result of the questionnaire survey showed that the price of water morning glory is lower in the dry season compared to the rainy season. The average market price range for farmers and retailers were between 0.22 to1.38 USD per bunch. The difference in the prices can be seen between the first and final supplier.

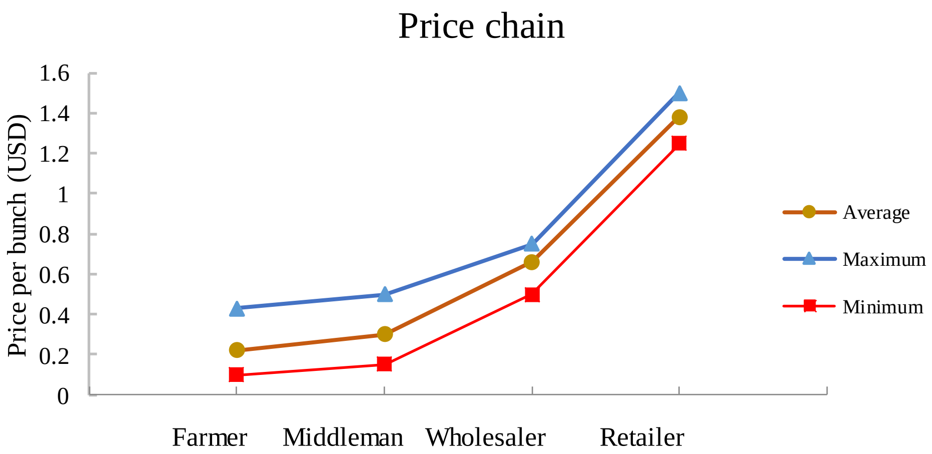

Fig. 6 The price chain in the water morning glory production

Water quality in Cheung Ek Lake affect to the economics of the farmers

Cheung Ek Lake plays an essential role in nutrient supply for the farmers during the cultivation of vegetables. According to the questionnaire survey, fertilizer is not necessary for plant production in the lake. Comparing to the amount of fertilizer needed in land cultivation of water morning glory production is around 200-300 kg in 1 hector, costing around 105-157 in one production cycle. Therefore, the farmers from the lake can earn more by spending less on the extra cost of fertilizer application. However, to think only the benefit, the other point of view also concerning to the quality of the vegetable that product in the wastewater lake.

However, faecal and protozoan parasite contamination were detected in the lake's water morning glory (Anh et al., 2008). According to Van der Hoek et al. (2009), people who were exposed to wastewater at Cheung Ek Lake developed dermatitis. While low concentrations of potential toxic element concentrations were identified in water spinach and fish created in Cheung Ek Lake wastewater systems, indicating that these components pose a minor food safety risk (Marcussen et al., 2009; Chea et al., 2010).

CONCLUSION

Cheung Ek Lake is an important wetland, which used to be an efficient natural treatment plant for wastewater and production of water morning glory in Phnom Penh. In this study, we emphasized on understanding the role of the lake as purify of wastewater. The results on the water quality of the lake indicate that it is becoming less polluted. The result of the chemical load during the rainy season showed that the lake is taking part of purification as well. Nonetheless, the result with the economic analysis from the farmers who cultivated water morning glory in Cheung Ek Lake shows a profitable sign with economic efficiency 1.80.

Overall, Cheung Ek Lake is an essential part of urban ecosystem. This lake performs significant role in removing pollutants from the water and provide economic benefits to the farmers. Additionally, research on the quality during the dry season is required to continue monitoring the lake's water quality. The amount of heavy metal and parasite contamination will also be examined for health assessment.

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Research article

The Possibility of Producing and Distributing Healthy Cassava Seeds in Cambodia

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Abstract This study discussed the possibility of producing and distributing healthy cassava seeds in Cambodia. Since 2015, there has been no official healthy seed certification and distribution system in Cambodia despite the rapid spread of the Sri Lankan Cassava Mosaic Disease in Southeast Asia. To improve cassava production and its sustainability, we conducted interviews using a structured questionnaire in Battambang and Pailin Provinces from April to November 2017 and received responses from 205 cassava producers. The results showed that most producers reused seeds from the previous years' harvest and indicated considerable market interest for healthy cassava seeds in Cambodia. Finally, we found that training and information on healthy seed production combined with stringent pest and disease monitoring efforts are essential. This study suggests that a market-based, healthy cassava seed distribution system can be established in Cambodia.

Keywords cassava, seed production and distribution, Cambodia, sustainable, market-based solution

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is one of the largest staple crops in the world and one of the most important cash crops in Cambodia (FAO, 2020; MAFF, 2018). Although there are many uses for cassava starch, from food to cosmetics, its utilization as a source of biofuel has increased its demand in recent years. Cassava propagates from the cuttings of the remaining cassava stems after its tuber is harvested (Tokunaga et al., 2018). Although propagation makes cassava grow faster compared to plant growth from seed germination, once contaminated with a virus or a phytoplasma, this propagation method has a negative impact. It could easily spread diseases like witches' broom (Alvarez et al., 2013) and harmful pests, such as mealybugs, red mites, and scale insects. Furthermore, recently, Sri Lankan Cassava Mosaic Disease (SLCMD), which severely affects cassava and spreads through whitefly and human factors, has spread rapidly in Southeast Asia (Wang et al., 2016; Uke et al., 2018).

In Cambodia, the government-led cassava extension system has been limited (MAFF, 2015; Tokunaga et al., 2018). The Department of Agricultural Extension of the Ministry of Agriculture, Forestry, and Fisheries (MAFF) was established in 1995. However, their activities are limited due to a lack of funding, technical expertise, extension materials; an inadequate production and distribution system; and human resources to support extension processes. As a result, an official system for producing and distributing cassava seeds has yet to be established.

In Ratanakiri and Battambang Provinces of Cambodia and Dak Lak and Tay Ninh Provinces of Vietnam, cassava seeds are informally distributed and self-regulated, without any active quality certification schemes (Delaquis et al., 2018). Thus, traders play an important role in the long-distance seed movement. The use of farm-saved seed and exchanges among acquaintances within the community are most common. However, given the spread of SLCMD, this informal and self-regulated method of seed distribution has increased the chances of humans spreading the disease.

To remedy this situation and promote the country's economic growth, the Royal Government of Cambodia (RGC) recently announced its "National Policy on Cassava 2020-2025," which declared cassava as one of the potential crops for agro-industrial development in Cambodia (RGC, 2020). Therefore, MAFF and its allied universities are required to "promote and encourage propagation farms and private cassava stem suppliers to sell and distribute healthy and disease-free cassava stems." (RGC, 2020). However, even though this policy is relatively new, there have not been any detailed discussions about the possibility of enabling the production of healthy cassava seeds.

Prior to the current policy discussion, since 2016, we have been conducting a project titled "Development and Dissemination of a Sustainable Production System Based on Invasive Pest Management of Cassava in Vietnam, Cambodia, and Thailand" supported by the Japan Science and Technology Agency and the Japan International Cooperation Agency. The project aims to establish a sustainable production system that utilizes healthy seeds by developing a market-based dissemination model that supports the private sector, producers, and the government, with a management system for invasive cassava diseases and pests. For this project, it was essential first to identify the producers' cassava seed preferences, distribution, propagation methods, and demand for healthy cassava seeds. Our projects contribute to creating a certified production and distribution system for healthy cassava seeds, in line with the one envisioned by the Royal Government of Cambodia.

OBJECTIVE

This study aims to discuss the potential for healthy cassava seed production and distribution in the Cambodian market by characterizing the present status of cassava seeds, including producers' preferences for cassava varieties and their demand for healthy cassava seeds based on a structured questionnaire interview. Finally, the project mentioned above focusing on the production system of healthy seeds was used as a case study.

METHODOLOGY

We interviewed producers about the 2016-2017 cassava production cycle in two Districts of Pailin Province and six Districts of Battambang Province, northwest of Phnom Penh, the capital of Cambodia, from April to November 2017 using a structured questionnaire. The total planted area of 134,385 ha in Battambang is the largest cassava production land area among all Provinces and produces 3,769,266 tons of cassava per year. Pailin Province has the fifth largest cassava planted area of 59,067 ha in Cambodia, producing 1,477,175 tons, the third-largest in terms of quantity (MAFF, 2018).

A stratified random sample based on the cassava planted area was applied to select the respondents. The total respondents included 205 cassava producers: 144 from Battambang Province and 61 from Pailin Province. All the questionnaires were valid. Then, qualitative and quantitative analyses were applied.

RESULTS AND DISCUSSION

Some characteristics of the respondents are profiled below (Table 1). In the survey, only the primary cassava producers in the household were considered, comprising 93% males and 7% females. Their average age, cassava planting times, and cultivated area was 49 years for males and females, 4.08. and 3.73 ha, respectively. As discussed below, 40% of producers purchased seeds for the 2016-2017 cycle. While currently there is no healthy seed distribution system, approximately 68% of respondents showed a willingness to buy healthy seeds, and 72% showed a willingness to become healthy seed producers.

Table 1 Descriptive summary of survey respondents

Variables	Mean	Std. Dev.	Min.	Max.
Gender (1=male, 0=female)	0.93	0.26	0	1
Age (years)	49.00	13.29	21	78
Province (dummy)	0.70	0.46	0	1
Cassava planting times before the 2016-2017 cycle (times)	4.08	3.03	0	16
Total cassava cultivated area (ha)	3.73	4.65	0.09	40
Purchased seeds for the 2016-2017 cycle or not (1=yes, 0=no)	0.40	0.49	0	1
Want to buy healthy seeds (1=yes, 0=no)	0.68	0.47	0	1
Want to be a healthy seed producer (1=yes, 0=no)	0.72	0.45	0	1

(N=205)

First, the survey inquired about the cassava varieties used by the producers (Table 2). While 78.9% of answers included "Unknown" or nicknames in Khmer, such as "Kor Teul" (long neck) and "Masao" (starch), others provided a variety name. Although we cannot confirm the accuracy of the provided variety names, our survey reveals that they mostly use Thai varieties such as Rayong 9, Rayong 90, and Houybong. Based on visual checks done by a descriptor created by our project, the varieties called "Unknown," "Kor Teul," and "Masao" include KU50 and Rayong 7, which are also from Thailand. The name "Masao" implies that producers care about the starch contents of the variety; Masao varieties often have a reputation of containing a high starch content. We find that Cassava producers prefer high starch content varieties. However, they do not have a very strong preference over the specific variety and can accept the variants distributed in the market.

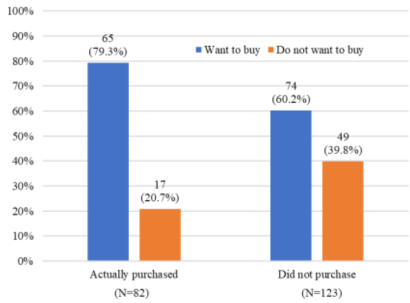
Table 2 Cassava varieties used by the surveyed producers

Unknown			Thai varieties		
Variety	Number of answers	%	Variety	Number of answers	%
Unknown	71	33.3%	Rayong 2	1	0.5%
Kor Teul	61	28.6%	Rayong 3	1	0.5%
Masao	25	11.7%	Rayong 4	2	0.9%
Malay	3	1.4%	Rayong 5	1	0.5%
Meyong	1	0.5%	Rayong 9	9	4.2%
Namdeng	1	0.5%	Rayong 11	1	0.5%
Red Petiole (Kandeng, Kanteng)	6	2.8%	Rayong 90	9	4.2%
			81	6	2.8%
			85	1	0.5%
			89	1	0.5%
			Houybong	13	6.1%

(N=213)

Second, the results showed that 40.0% of those surveyed did not buy cassava seeds because they reused the seeds harvested from their fields in the previous cycle. Further, 76.9% of those who purchased seeds bought them in their neighborhood, while 11.5% bought seeds imported from Thailand, and the remaining 11.5% bought seeds brought by road from Vietnam. This result complements the results of the previous study by Delaquis et al. (2018). These results show that seeds can easily be imported and transported across different regions; diseases and pests could easily spread.

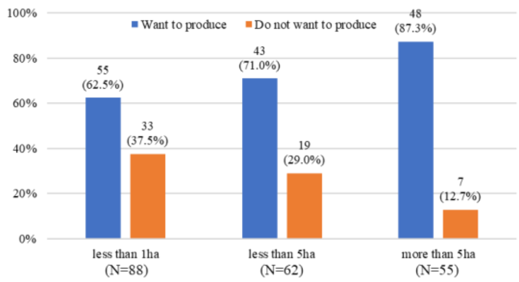
Third, we asked producers, "Do you want to purchase healthy seeds if they are available on the market?" To this, 139 (67.8%) producers answered affirmatively, and of those, 48.8% bought seeds in the 2016-2017 cycle. It implies 33.1% (=48.8% x 67.8%) of producers might purchase healthy seeds in the future. Further, the average percentages of producers who want to buy healthy seeds in each "Actually purchased group" and "Not purchased group" are significantly different at a x^2statistic of 8.227 (p-value<0.01) (Fig. 1).



Pearson chi2(1) = 8.227 Pr = 0.004

Fig. 1 Producers who want to purchase healthy seeds based on the 2016-2017 purchase record

Fourth, 71.7% of producers answered yes to the question, "Do you want to produce healthy seeds as a business?" Furthermore, the producers with a large cassava cultivation area were more interested in healthy seed production than smaller ones (Fig. 2). Additionally, this is statistically significantly different at a x^2statistic of 10.262 (p-value<0.01). It implies that the larger the cassava area producers have, the higher the willingness to be healthy cassava producers. Thus, larger land area producers recognize the business opportunities present in the production of healthy seeds.



Pearson chi2(2) = 10.262 Pr = 0.006

Fig. 2 Producers who want to produce healthy seeds by cassava cultivation area

Thus, we find that producers can accept new varieties, and those who purchased stem seeds for the 2016-2017 cycle are interested in purchasing healthy seeds. Additionally, those with a production area of 1 ha or more are more interested in producing healthy seeds than those with less than 1 ha of cassava production area. These results suggest that there is a potential market for healthy seed cassava in Cambodia. Further, since the existing seed distribution method could spread pests and diseases across Cambodia, establishing a market-based certified healthy seed production system could prevent the spread of pests and diseases like SLCMD.

Based on the results above, our project started a healthy seed production system in Cambodia on a trial basis (Fig. 3). In Cambodia, the National University of Battambang (NUBB) has a Cassava Propagation and Distribution Center. In 2018, the project selected two varieties, KU 50 and Rayong

7, and started producing healthy seeds through careful monitoring and Polymerase Chain Reaction (PCR) testing. Then, the varieties were sold to three producers who wanted to be healthy seed producers in Battambang Province (Producer A: 1,351 healthy seeds), Banteay Meanchey Province (Producer B: 599 healthy seeds and 400 additional healthy seeds in 2019), and the other producer in Banteay Meanchey Province, who stopped production immediately because of weather conditions. We found these producers interested in the project through the survey and personal communications in our pursuit to find healthy seed producers, and we also introduced them to the NUBB. The price is 1$ per 1 bunch (20 seeds), which was the market cassava price at the time of the study. Two producers in Banteay Meanchey Province were also supported by Deutsche Gesellschaft für Internationale Zusammenarbeit. In 2019, in addition to these three producers, two more producers in Battambang and Oodar Meanchey Provinces and the General Directorate of Agriculture (GDA) field in Battambang Province started to be healthy seed producers. With the prevalence of the spread of SLCMD, gradually more producers became interested in becoming healthy seed producers.

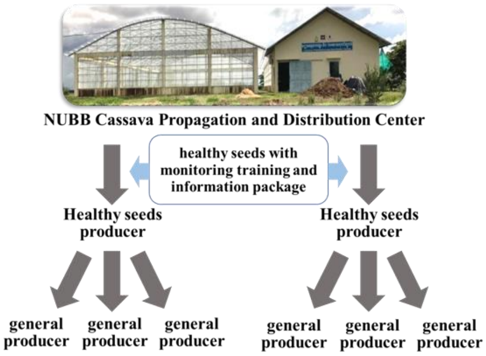


Fig. 3 The healthy cassava seed distribution system at NUBB

These producers were trained periodically to monitor cassava fields and could independently execute such monitoring techniques. They also received information packages and training on pests and diseases and how to treat them. The monitoring system recommended by the project is as follows. 1. When the cassava plants start producing leaves, check each border and the middle of the field carefully to find abnormal plants shorter than other plants or those that are yellow. 2. Check the stem from the bottom to the bud and the surface of the leaves to find pests, such as whitefly, mealybug, red mite, and scale insect, diseases such as witches' broom, and SLCMD; and 3. Remove pests by hand, in case there are few. If the pest infestation is severe, use recommended chemicals to control whitefly, a Sri Lankan cassava mosaic virus vector. 4. Finally, and most importantly, remove infected or suspicious SLCMD plants from the field, bury or burn them, and replace them with healthy cuttings.

At the time of harvest, and if the PCR test result of their samples at NUBB is negative, Producer A and Producer B can sell these healthy seeds to the general producers who value such seeds. After multiplying healthy seeds, the producers sold them in 2019 (Producer A: 2,000 stems (1 GDA field)) and 2020 (Producer A: 2,400 stems (1 general producer and 1 GDA field); Producer B: 1,095 stems (11 general cassava producers)), while other healthy seed producers did not sell because they were under multiplying their stems. Some of these general producers have become interested in producing healthy seeds. They have joined our monitoring training to sell such seeds to other producers as a business.

These findings show that NUBB and healthy seed producers can become sources of trusted cassava seeds for producers in Cambodia. While Cambodia has no official seed distribution system, our system (including NUBB and the cassava producers) can be a pioneer model. However, the healthy seeds produced in this trial are not free from the risk of disease. Therefore, monitoring is an essential part of healthy seed production. Nevertheless, the results show that a healthy seed production system centered on NUBB with well-trained healthy seed producers can positively affect the cassava sector in Cambodia.

CONCLUSION

The study clarified that cassava producers in Cambodia could accept and produce healthy cassava seeds. Producers care about the starch contents of the variety, though they do not have a very strong preference for the specific variety and can accept variants distributed in the market. Those who purchased seeds in the 2016-2017 cycle are still interested in purchasing healthy seeds. Additionally, those with a cassava production area of 1 ha or more are more interested in producing healthy seeds than those with less than 1 ha. Further, we demonstrated that the pilot project in Battambang Province had created a healthy production system for cassava seeds in Battambang and Banteay Meanchey Provinces, which has seen positive results. We emphasize that monitoring is an integral part of the healthy seeds production system. While SLCMD has been spreading, producers have a high demand for a healthy seed market. Therefore, our market-based production system can contribute toward creating sustainable cassava production to help producers increase their income and improve the country's economic growth while meeting the policy aims of the Royal Government of Cambodia.

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Research article

The Current Status of Cassava Producers and Healthy Cassava Seed Production and Distribution Trial in Vietnam

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Abstract This study discusses the current status of cassava producers in Vietnam, the demand for healthy cassava seeds, and the potential for a healthy seed production and distribution system. Owing to the recent spread of Sri Lankan Cassava Mosaic Disease in South East Asia, the government-led agricultural extension system and the informal cassava production and distribution system in Vietnam have sought a "health" seed production system. To improve the existing system and contribute to sustainable cassava production in Vietnam, we conducted interviews using a structured questionnaire in Dong Nai, Gia Lai, and Tay Ninh provinces from April to December 2017 and received responses from 182 cassava producers. The results show that the majority of cassava producers rely on this crop for their income. Therefore, they are interested in purchasing healthy seeds, and their willingness to pay is statistically significantly higher than the purchasing price in all three provinces. Based on the results and the existing cassava production and distribution system in Dong Nai, this project instituted a monitoring system, polymerase chain reaction testing, and a healthy seed certification system. This study found that seed producers face several difficulties, including implementing a monitoring and management system. Thus, there is potential for establishing a healthy cassava seed production and distribution system in Vietnam.

Keywords cassava, seed production and distribution, Vietnam, willingness to pay

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is one of Vietnam's three most important food crops, with 532,600 ha of cultivated area, an annual average yield of 18.8 tons per ha, and fresh root production exceeding 10.27 million tons (GSO, 2018). Cassava is grown in as many as 40 of the country's 63 provinces. Vietnam ranks seventh in cassava production in the world (FAO, 2020).

The Sri Lankan Cassava Mosaic Disease (SLCMD) was first reported in Cambodia in 2015 (Wang et al., 2016) and was then found in Tay Ninh in 2018 (Uke et al., 2018). Since then, Vietnamese cassava producers have faced substantial challenges, as the disease drastically decreases cassava yields (Fargette et al., 1988; Fauquet and Fargette, 1990; Makeshkumar, 2016). According to Vietnam's Plant Protection Research Institute, the estimated annual cassava yield loss will be between 12.7 percent and 34.6 percent. The starch content is expected to decrease by 1.02 percent to 18.97 percent. SLCMD has spread rapidly using whiteflies as a vector; it is also spread through infected stem distribution as cassava can be quickly propagated from stems, which are transported as "seed" to multiple locations.

In Ratanakiri and Battambang provinces in Cambodia and Dak Lak and Tay Ninh provinces in Vietnam, informal and self-regulated seed distribution systems are managed by private producers and traders (Delaquis et al., 2018). Although these systems appear to work well in normal situations, once the stems are infected with SLCMD, the disease can rapidly spread through human factors, such as traders and transporters, who distribute cassava seeds over a wide range.

In Vietnam, it is essential to understand the current production and stem movement situation, including the socio-economic condition of cassava producers, to discuss the possibility of healthy seeds. The seeds are considered healthy if they are not detected positive for SLCMD in the polymerase chain reaction (PCR) testing. Thus, production and distribution should be carried out through the market mechanism.

Vietnam has a public extension system founded in 1993, organized into five levels—central, provincial, district, commune, and village or hamlet. All 63 provinces have their own extension centers (Tokunaga et al., 2018). Furthermore, an official cassava seed production and distribution system exist in addition to the informal, self-regulated distribution system. As part of the official system, the Hung Loc Agricultural Research Center (HLARC) in Dong Nai province in southern Vietnam breeds, produces and distributes cassava varieties. Private producers under HLARC propagate and distribute these stems among "general producers" who primarily cultivate cassava for its roots and potential buyers of healthy cassava seeds in the province. This system, however, has no monitoring methods, nor does it employ PCR testing or have any certification. Hence, there is a potential risk of the distributed stems becoming contaminated with viruses or phytoplasma, further spreading the disease.

Therefore, since 2016, we have been executing a project titled "Development and Dissemination of a Sustainable Production System Based on Invasive Pest Management of Cassava in Vietnam, Cambodia, and Thailand," supported by the Japan Science and Technology Agency and the Japan International Cooperation Agency. This project aims to improve the current cassava seed production and distribution system centered at HLARC and establish a sustainable production system that uses healthy seeds. This system can be established by developing a market-based dissemination model that supports the private sector, producers, and the government and devising a management system for invasive cassava diseases and pests. To improve the system, it is essential to first identify cassava producers' seed preferences, their demand for healthy cassava seeds, and the current situation of cassava production. However, sufficient information is not yet available.

OBJECTIVE

This study aims to discuss the current status of cassava producers and stem distribution in southern Vietnam, including their cassava seed preferences. Further, the potentiality of a healthy cassava seed production and distribution system is also discussed, and producers' willingness to pay (WTP) for healthy seeds is estimated. Finally, the improved cassava seed production and distribution system developed by the project is explained, and challenges are discussed.

MATERIAL AND METHODS

Study Site

A series of semi-structured interviews based on a questionnaire was conducted in southern Vietnam's Dong Nai, Gia Lai, and Tay Ninh provinces (Fig. 1) from April to December 2017. First, we checked the government census database and contacted local government offices to determine the cassava producer population of the provinces; however, we discovered it to be fluctuating. However, the purpose of the study was to capture the potential for seed production, the selection of seed farmers, and willingness to pay. Thus, we used purposive sampling with equal selection based on cassava plantation area to categorize the respondents into three groups: less than 1 ha, between 1 ha and less than 5 ha, and more than 5 ha. As a result, the total number of respondents was 182—60 in Dong Nai, 61 in Gia Lai, and 61 in Tay Ninh.

The three provinces mentioned above are the primary cassava cultivation areas in Vietnam (GSO, 2018). Tay Ninh and Gia Lai have the largest (64,800 ha) and second-largest (61,600 ha) cassava production areas among all provinces and produce 2,024,000 tons and 1,207,100 tons, respectively. Dong Nai stands at the 10th position among the country's 58 provinces and contains five municipalities with 15,700 ha of cassava production area and 399,700 tons of production. The main cassava production center in Dong Nai is the Xuan Loc district, and in Tay Ninh, it is the Tan Chau district. In Gia Lai, the Dak Po and Krong Pa districts are the two leading cassava production centers. Therefore, these locations were chosen for surveying.

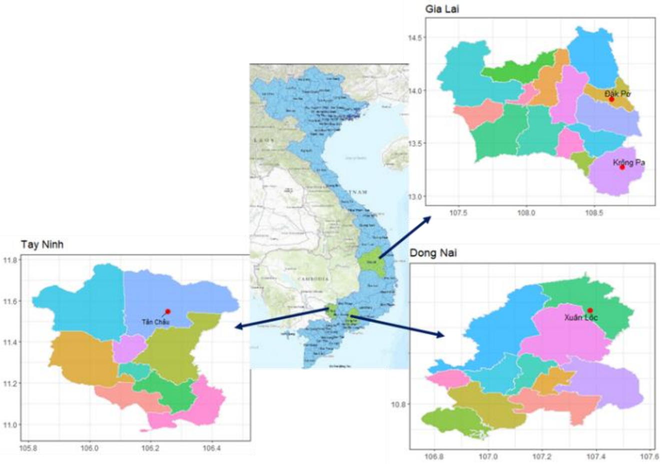

Fig. 1 Survey areas in Vietnam

Theoretical Model

The concept of WTP is derived from the Hicksian welfare measure of compensating variation (CV). The CV measure asks what compensating payment or offsetting change in income is necessary to make an individual indifferent to an increase in price. This is often interpreted as the new price set. The concept can be illustrated by following the standard economic theory of indirect utility function (Bateman et al., 2002), which can be written in the general form:

$$V = (Y, P, Q) \qquad (1)$$

where (V) describes the economic wellbeing or maximum amount of utility a respondent can derive from their income (Y), given the prices of goods they face (P) and the level of environmental quality (in this case, getting healthy, clean seeds not infected by pests or disease $[Q]$). WTP is defined as the amount that must be taken away from a person's income while keeping this utility constant:

$$V\ (Y - WTP, P, Q_1) = V(Y, P, Q_0) \qquad (2)$$

where (Q_0) and (Q_1) are the alternative levels of the good or quality indexes ($Q_1 > Q_0$, indicating that (Q_1) refers to improved environmental quality).

The WTP was estimated following Mitchell and Carson (1981, 1984), and the payment card method of contingent valuation was used to estimate the WTP for healthy seeds. Producers were asked how much they would be willing to pay to obtain a certified healthy cassava seed.

However, an open-ended payment card CVM question can generate a high number of zero responses (Green et al., 1998). In that case, the distribution of WTP could be censored by the left to a zero value. To address this, Halstead et al. (1991) recommended using the Tobit regression model as the more theoretically correct econometric model for the open-ended CVM format.

The Tobit regression model considers both the censored and continuous observations in the process of estimation. Following Kim and Cho (2002), the Tobit regression model can be expressed by:

$$WTP_i^{Tobit} = X_i'\beta + e_i \quad (3)$$

where WTP_i^{Tobit} is the unobserved continuous dependent variable; $X_i^{'}$ is a vector of explanatory variables; β is a vector of coefficients; e_i is an independently distributed error term, assumed to be normal with zero mean and constant variance σ^2; and $i = 1, 2, \ldots, n$ denotes individuals in the sample. The observed WTP variable is given by:

$$WTP_i = \begin{cases} X_i'\beta + e_{i.} & if\ WTP_i^{Tobit} > 0 \\ 0 & if\ WTP_i^{Tobit} \leq 0 \end{cases} \quad (4)$$

Empirical Model and Hypothesis

The Tobit regression model can be expanded to include the socio-economic variables being hypothesized to influence producers' willingness to pay for healthy cassava seeds ($WTP_{healthyseedling}$). The empirical model is presented in the following:

$$WTP_{healthyseedling}^{Tobit} = \beta_0 + \beta_1 gender + \beta_2 TayNinh + \beta_3 GiaLai + \beta_4 tocaha + \beta_5 fulltime + \beta_6 experience + \beta_7 catimes + \beta_8 camain + \beta_9 labor + \beta_{10} dactualpurchase + \beta_{11} dwillingness + \beta_{12} dstemsupplier + e_i \quad (5)$$

where the dependent and independent variables are defined in Table 1, $\beta_0\ to\ \beta_{12}$ are coefficients, and e_i is the error term $\sim N\ (0, \sigma^2)$.

The study hypothesizes that older producers, experienced producers, producers with larger land areas devoted to cassava, producers with more family members engaged in cassava production, and producers who would like to be healthy seed producers will have higher $WTP_{healthyseedling}$.

RESULTS AND DISCUSSION

Status of Cassava Producers in Southern Vietnam

Table 1 shows the socio-economic situation of the respondents. Among the cassava producers surveyed, 86 percent were men and the rest were women; the average age of the respondents was 48.63 years. Their total cassava plantation area was 2.90 ha. Sixty percent of the respondents were full-time producers and had an average of 23.82 years of general farming experience. They had planted cassava 11.43 times on average, and 63 percent of them cited cassava production as their main source of income. The average family consisted of 4.51 members, of which 2.10 were engaged in cassava farming. This information shows that our respondents were introduced to cassava production recently, and for some of them, it has become an important cash source, making it a sort of family business. In other words, they depend on cassava production for a living. In addition, 27 percent of the respondents purchased seeds for the 2016/2017 farming cycle, and 66 percent of them were interested in purchasing healthy seeds if they were available in the market; moreover, 35 percent of the producers wanted to make a business of producing healthy seeds.

Table 1 Descriptive summary

Variables		Mean	Std. dev.	Min.	Max.
gender	(1=male, 0=female)	0.86	0.35	0	1
age	(years)	48.63	10.48	23	70
DonNai	Province (Don Nai=1, otherwise=0)	2.01	0.82	1	3
TayNin	Province (Tay Nin=1, otherwise=0)				
GiaLai	Province (Gia Lai=1, otherwise=0)				
tocaha	Total cassava cultivated area (ha)	2.90	2.55	0.4	17
fulltime	General farm working status (1=full time, 0=part time)	0.60	0.49	0	1
experience	Years of farming experience (years)	23.82	9.67	2	50
catimes	Number of cassava plantings done before 2016/2017 cycle (times)	11.43	6.38	0	31
camain	Cassava as main income source (1=yes, 0=no)	0.63	0.49	0	1
labor	Number of family members engaged in cassava farming	2.10	0.97	1	7
dactualpurchase	Purchased seeds for the 2016/2017 cycle (1=yes, 0=no)	0.27	0.44	0	1
dwillingness	Want to buy healthy seeds (1=yes, 0=no)	0.66	0.48	0	1
dstemsupplier	Want to be a producer of healthy seed (1=yes, 0=no)	0.35	0.48	0	1

(N=182)

Cassava Varieties

The cassava varieties used by the producers are shown in Table 2. Since these producers can cultivate different varieties simultaneously, the total number is not equal to the number of respondents. Whereas 17.4 percent of the respondents mentioned the variety of cassava they cultivated as "Unknown," others answered with specific variety names. In Dong Nai, KM325 (21 cases) and KM140 (20 cases) were preferred. In Tay Ninh and Gia Lai, KM419 and KM94 were the major cassava varieties. Although this study could not confirm their claimed variety, it was found that the KM series was the most popular choice in southern Vietnam.

Table 2 Cassava varieties used by producers

Varieties	Dong Nai	Tay Ninh	Gia Lai	Total	Percent
KM419	5	48	13	66	35.9
KM94	7	8	9	24	13.0
KM325	21	1	1	23	12.5
KM140	20	1	1	22	12.0
KM98-5	1	2	6	9	4.9
KM95	0	0	4	4	2.2
KM98	0	0	2	2	1.1
KM505	0	1	0	1	0.5
KM96	1	0	2	1	0.5
Unknown	5	2	25	32	17.4

(N=184)

Among the respondents, 72.5 percent did not purchase cassava seeds for planting or replanting and instead used stems from the previous cycle. Of the remaining producers, 52.0 percent bought stems from their neighbors or relatives. These community-level stem exchanges are dominant in Vietnam and Cambodia (Delaquis et al., 2018). Another 46.0 percent bought stems from seed dealers because they wanted to explore new varieties with higher starch content. In Dong Nai, one cassava producer bought stems from the HLARC. Based on our interviews, most seed dealers were from the Tay Ninh province. This fact is consistent with a previous study's finding that Tay Ninh is "the highly commercialized 'cassava seed basket' of Southern Vietnam" (Delaquis et al., 2018).

Healthy Cassava Seed and Distribution System

We also asked the respondents whether they would purchase healthy stems if they were available in the market, and 65.9 percent of the producers answered yes, of which the percentages for Dong Nai, Tay Ninh, and Gia Lai were 23.08, 18.68, and 24.18, respectively. In contrast, 28.03 percent of producers would not purchase healthy stems, of which the percentages in Dong Nai, Tay Ninh, and Gia Lai were 4.95, 14.84, and 8.24, respectively. Another 6.05 percent of producers would like to have more information about the growth status, yield, and starch content of healthy varieties before making a decision.

Further, we found that the respondents' WTP for healthy cassava seeds was significantly higher than the actual purchasing seed price in all three provinces (Table 3). Thus, we confirmed that there is a potential market for healthy cassava seeds.

Table 3 Purchase, seed price, and WTP for healthy cassava seeds by province

Province	Purchase for cassava seed % (producers)			Mean of seed price (95% C.I.)	Mean of WTP (95% C.I.)	t statistic
	Yes	No	Other			
Dong Nai	23.08 (42)	4.95 (9)	4.95 (9)	18546 (16837-20255)	24091 (19630-28552)	2.61
Tay Ninh	18.68 (34)	14.84 (27)	0.00 (0)	11528 (8418-14637)	22875 (17140.45-28609.55)	4.2
Gia Lai	24.18 (44)	8.24 (15)	1.10 (2)	12593 (10578-14607)	17500 (15841-19159)	3.64

Price in VND, 22500 VND ~ 1 USD

Table 4 presents the factors that influence producers' $WTP_{healthyseedling}$. The results show that the number of cassava plantings done before the 2016/2017 cycle influences $WTP_{healthyseedling}$. When we run the pair-wise regression, older producers, producers with larger cassava land area, producers with more family members engaged in cassava production, and producers who would like to be healthy seed producers had higher $WTP_{healthyseedling}$ at the statistically significance level of $p<0.10$. However, the effects of these individual factors diminish with the number of times they had previously planted cassava. There was a strong correlation between number of years planting cassava and age, so we excluded age. Apart from that there were no other strong correlations. Thus, we can conclude that when producers are experienced with cassava cultivation, they understand the importance of purchasing healthy seeds and perhaps the high risk of purchasing unknown seeds that could spread pests and disease. You may as well say that older people prefer to purchase healthy certified seeds.

Table 4 Determining factors that influence producers' WTP

VARIABLES	$WTP_{healthyseedling}$	
gender	2,551	
	(3,153)	
TayNinh	2,008	
	(2,632)	
GiaLai	-2,364	
	(2,463)	
tocaha	464.4	
	(362.3)	
fulltime	-392.7	
	(2,071)	
experience	10.84	
	(106.7)	
catimes	313.8	*
	(161.6)	
camain	-395.5	
	(1,975)	
labor	-710.3	
	(907.2)	
dactualpurchase	-1,541	
	(2,158)	
dwillingness	7,635	
	(7,407)	
dstemsupplier	2,659	
	(1,979)	
var(e.willprice)	9.803e+07	***
	(1.298e+07)	
Constant	9,355	
	(9,918)	
Observations	114	114

*Note: *** p<0.01, ** p<0.05, and * p<0.10, respectively.*

Thus, following the current situation and the existing cassava production system centered at the HLARC, our project tested the healthy seed production system. We did so because the organization has played an important role as a cassava center, and producers and traders in Dong Nai and Tay Ninh provinces buy cassava seeds from the HLARC (Fig. 2). As a "stock seed production field," the HLARC produce healthy seeds after careful field monitoring and PCR testing, and it sold seeds to three producers in Dong Nai province in 2018 (Producer A, Producer B, and Producer C). These producers found business prospects in healthy cassava seed production and were trained periodically on how to monitor cassava fields and to execute such monitoring by themselves. They also received pest and disease information packages and were expected to become proficient at healthy seed production.

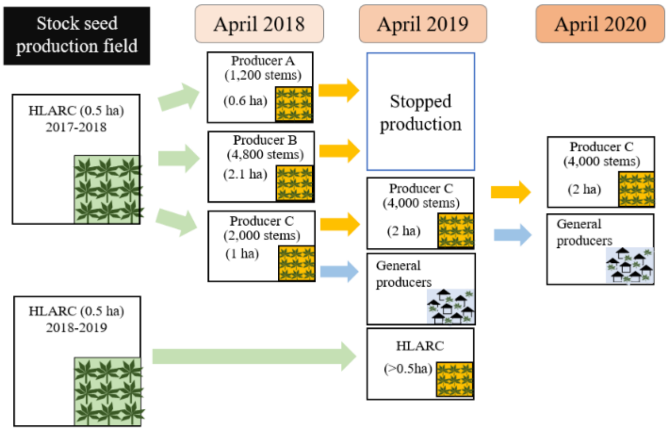

Fig. 2 Healthy cassava seed distribution system centered at HLARC

The project faced several challenges. In the existing system, the HLARC issues seeds to producers for free, along with necessary tools such as production techniques, fertilizers, and chemicals, because it does not have enough fields to test new varieties and wants producers to propagate and test them. Although, as part of our project, we wanted the HLARC to "sell" seeds to producers so that our system could work in a market-based manner in future, the producers who used to get seeds for free from the HLARC did not want to "purchase" them. In addition, producers were more interested in "higher starch content" than "healthy" seeds. It was complicated to make them understand how healthy seeds are essential for sustainable production.

Furthermore, the monitoring system needed to produce healthy seeds had not been properly implemented by the seed producers from the beginning. Our project provided them with information packages and training on pests and diseases, including how to treat them, and tried to train them to monitor cassava fields to avoid infections, pests, and their spread. As cassava has grown well for a long time without monitoring, seed producers were averse to the idea of monitoring their fields. This prevented the early mitigation of infected seeds when SLCMD spread in Dong Nai province in 2018. Consequently, although the HLARC and seed producers inspected their fields and removed suspicious seeds about two months after the planting in which the infection was detected, its spread became worse in the province. Even the higher level of monitoring afterwards failed to completely contain the spread of the infection.

Facing these challenges, however, Producer C produced healthy seeds for at least three cycles and sold them to general producers, whereas Producers A and B stopped production. The reason for this was that they were both producers in Dong Nai. Producers A and B were not following the monitoring protocol because the disease was not found in Dong Nai in the same year as in Tay Ninh. Consequently, when the producers found their cassava infested, they could not continue harvesting healthy cassava as the disease rapidly spread to other provinces, including Dong Nai. In contrast, Producer C had predicted the status of SLCMD. Therefore, he followed the protocol and his cassava production remained healthy. Although there is room for improvement in the monitoring done by Producer C, the current findings show that our healthy seed production and distribution system following the existing system could work. To develop the system, it is essential for HLARC and the project to provide every possible assistance to seed producers, teach them the importance of monitoring and management of healthy seeds for sustainable cassava production, and effectively implement a monitoring and management system.

CONCLUSION

This study analyzed the current status of cassava producers, their demand for healthy cassava seeds, and the potential of a healthy seed production and distribution system in Vietnam. Cassava producers depend on cassava production for their livelihood and tend to use varieties that are predominant in their communities. In addition, they have a preference for the KM series, which indicates that the variety is well-accepted as a healthy seed in the area. A production and distribution system of healthy seeds has a potential market because the respondents in all three provinces were interested in purchasing healthy seeds, and their WTP was statistically higher than their actual seed purchasing price. Our project created a healthy seed production system in Dong Nai province. Although there were many challenges, such as low awareness among seed producers about the importance of following the monitoring protocol and the rapid spread of SLCMD, one seed producer succeeded in propagating healthy seeds by monitoring their production. Considering the existing system and producers' preferences, we continue to explore ways to implement an efficient monitoring and management system to mitigate the impact of SLCMD and distribute healthy seeds.

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Research article

Measurement of Postharvest Losses of Sesame (*Sesamum indicum* L.) from Harvesting to Storage at Farm Level

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Abstract During a crop's transition from farm to consumer, much of the crop is lost due to several factors, including improper handling, inefficient processing facilities, and biodegradation due to microorganisms and insects. This study was conducted with two objectives: to measure the extent of postharvest losses of pre-monsoon and post-monsoon sesame in field operations, i.e. in the harvesting, stacking, drying of stalks, threshing and winnowing processes, and also to determine the quantity lost with the use of different types of packaging materials used for storage. The research was conducted in Pwintphyu and Pakokku Townships, Magway Region, Myanmar in July and December 2016. The postharvest losses were measured at harvesting, stacking, stalk drying, threshing and the winnowing stages on the farms. When comparing postharvest losses, losses were higher in pre-monsoon sesame than post-monsoon sesame, except at the harvesting stage. The total losses were found to be more in the pre-monsoon crop (21.34%) compared to the post-monsoon crop (11.88%). In regard to contribution to total losses, the storage loss accounted for the major part (71.42%) of the total postharvest losses in pre-monsoon sesame. For the remaining losses, 22.35% occurred during stalks drying and threshing process, 3.47% when stacking, with 1.45% of loss during harvest and 1.31% at winnowing. For post-monsoon sesame, storage losses comprised 91.08% of total losses, followed by harvest loss (6.48%), stalks drying and threshing (1.68%), winnowing (0.59%) and stacking (0.17%). To assess the storage losses resulting from the use of different packaging materials, two types of packaging materials were tested. The harvested sesame seed was stored in pioneer superbags and woven polypropylene bag for eight months at farmers' houses. At the end of this period, weight losses for the pre-monsoon sesame occurred in sesame stored in both superbags and woven polypropylene bags. However, losses for the post-monsoon sesame occurred only the woven polypropylene bag.

Keywords sesame, postharvest, losses, stacking, stalks drying, storage

INTRODUCTION

Reducing postharvest losses, especially in developing countries, could be a sustainable solution to increase food availability, reduce pressure on natural resources, eliminate hunger and improve farmers' livelihoods (Hodges et al., 2011). During the crop transition from farm to consumer, it undergoes several operations such as harvesting, threshing, cleaning, drying, storage, processing and transportation. During these processes, crop is lost due to several factors. These include improper handling, inefficient processing facilities, biodegradation due to microorganisms and insects, etc. (Kumar and Kalita, 2017). Postharvest losses increase with an increase in area under crop and with increased time of storage, while they decrease with improvements in the type of storage and method of storage (Nag et al., 2000).

Postharvest losses in less developed countries have been subject to a relatively small number of studies, and are mostly guesstimates derived from questionnaires rather than actual measurements. However, this approach may be misleading because postharvest losses may be due to a variety of factors which varies from commodity to commodity, from season to season, and to the variety of circumstances under which commodities are grown, harvested, stored, processed and marketed (Tyler, 1982). Therefore, it is important not only to work with figures that are good estimates related to a particular crop, time and place, but also to be aware that there will be variations at other times and in other situations.

OBJECTIVES

The study was conducted with two objectives: to measure the extent of postharvest losses of pre-monsoon and post-monsoon sesame in field operations and to determine the quantity losses associated with the use of different types of packaging materials used during storage.

METHODOLOGY

Field experiment

The research was conducted in Pwintphyu and Pakokku Townships which are situated in the Magway Region of Myanmar, in July 2016 and December 2016. The experiments were carried out in six farmers' fields in Pwintphyu Township for the pre-monsoon sesame crop and in six farmers' fields in Pakokku Township for the post-monsoon sesame. The plot size was 15m x 15m with two plots in each farmer's field. The variety of sesame grown in this study was black sesame (Samou Nei). The postharvest losses were measured at the harvesting, stacking, stalks drying, threshing and the winnowing stages on the farms.

Determination of quantity losses

Harvest losses

The sesame plants in the experimental plots were harvested according to normal practice (using a sickle). Left over sesame pods on the harvested plots (both on the ground and on unharvested standing plants) were thoroughly collected, cleaned, dried, weighed and stored separately in paper bags. Losses for each plot are determined by the following equation (Appiah et.al., 2011).

Harvesting losses = Weight of left over grains / Total weight of harvested grains × 100

Stacking losses

The harvested sesame stalks are placed on plastic nets. Stalks were separately piled for each plot, and this method was used in the field stacking. After removing the stalks for drying, all the grains remaining on plastic nets were collected, cleaned, dried and kept in paper bags for each plot. If farmers used a threshing floor, the stalks were piled on the floor directly and the grains on the floor were collected by the farmers. After the farmers' had finished the stacking stage, the grains remained on threshing floor were collected to determine losses (Appiah et.al., 2011).

Stacking losses = Weight of left over grains / Total weight of harvested grains × 100

Stalk drying and threshing losses

The ground was covered with canvas and the stalks were placed upright and dried on these canvases. This method was used for in-field processing but not for those dried on a threshing floor. After drying, stalks were moved and threshed on another canvas ground cover. The sesame grains for each plot that remained on all canvases were collected, cleaned, dried and kept in paper bags. Where farmers did their drying on a threshing floor, the stalks were dried on the floor directly and the grains on the floor were then collected by farmers. After they had completed this process, the grains remaining on the threshing floor were collected to determine losses (Appiah et.al., 2011).

Drying and threshing losses = Weight of left over grains / Total weight of collected grains × 100

Winnowing losses

Two canvasses were spread on the floor, one for the winnowed grain and the other for the discarded chaff. Grains from the discarded chaff were collected, cleaned, dried and weighed the grain to determine losses (Appiah et.al., 2011).

Winnowing losses = Weight of grains collected from chaff / Total weight of collected grains × 100

Storage losses

Two different packaging materials were used to store the grain; woven polypropylene bag and pioneer superbags, with storage in six farmers' houses for a period of eight months. The quantity loss was determined at two-month intervals during this storage period. Quantity losses is calculated using the formula (Appiah et.al., 2011).

Storage losses = (Initial weight of grains - Final weight of grains) / Initial weight of grains × 100

RESULTS AND DISCUSSION

Total postharvest losses for pre-monsoon and post-monsoon sesame

When comparing postharvest losses, the losses were higher in pre-monsoon sesame than post-monsoon sesame except in regards to harvesting losses. The losses that occurred on farm before storage were found to be at a maximum in the stalks drying and threshing stage (4.77%) followed by stacking losses (0.74%), harvest losses (0.31%) and winnowing losses (0.28%) for the pre-monsoon crop. In post-monsoon sesame, the maximum quantity losses were found at the harvest stage (0.77%) followed by the stalks drying and threshing process (0.2%), winnowing (0.07%) and stacking (0.02%). The total losses were greater in the pre-monsoon crop (21.34%) than the post-monsoon crop (11.88%) (Table 1). The losses during harvesting and stacking showed a highly significant difference between the two different crops. Also, stalks drying and threshing losses, winnowing losses and total losses showed a significant difference, but storage losses were non-significant between the pre and post-monsoon crops (Table 1).

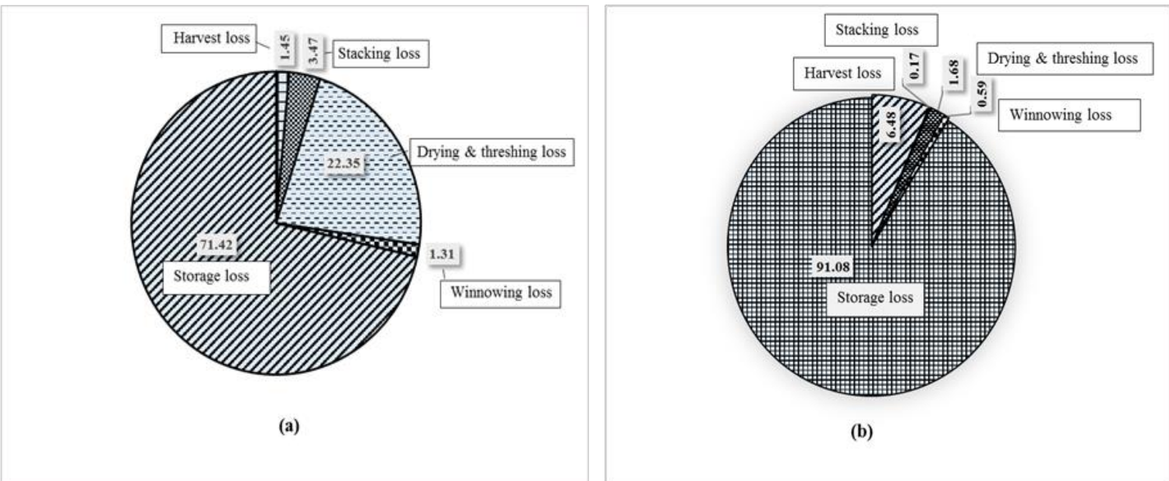

Fig. 1. Proportion of postharvest losses of (a) pre-monsoon (b) post-monsoon sesame

In regard to total losses, storage loss comprised the major part with 71.42% of the total postharvest losses for pre-monsoon sesame. The remaining losses consist of, 22.35% in stalks drying and threshing process, 3.47% during stacking, 1.45% at harvest loss and 1.31% of during winnowing (Fig. 1 a). In post-monsoon sesame, storage losses represented 91.08% of total losses, followed by harvest loss at 6.48%, stalks drying and threshing loss with 1.68%, and winnowing loss at 0.59% of total losses. The loss during the stacking process was only 0.17% of total losses (Fig. 1 b). The losses during storage are a result of several factors, both biotic (insects, pests, rodents, fungi) and abiotic (temperature, humidity, rain) (Abedin et al., 2012). In India, the postharvest losses of sesame were estimated at different stages across four different marketing channels. The total losses at farm level were 46.75%, 37.58%, 35.85% and 51.84% respectively as part of the total losses in supply chain. Harvest losses of sesame in four different marketing channels were 10.57%, 9.32%, 6.72% and 16.54% of total losses. Collection losses were 4.88%, 4.66%, 5.88% and 9.93% of total losses; while 8.94%, 5.59%, 6.16% and 8.46% of total losses occurred at the threshing stage. Winnowing losses of sesame, 8.13%, 7.45%, 6.72% and 4.78% were found in these four marketing channels, and a considerably high amount of losses occurred in drying/packaging with these being 8.94%, 7.45%,7% and 8.09% respectively. The storage losses at the processing level in the four marketing channels were 15.04%, 8.07%, 8.12% and 12.13% of total losses in the supply chain (Kumarasamy and Sekar, 2014).

Table 1. Postharvest losses of pre-monsoon and post-monsoon sesame

Activity	Pre-monsoon	Post-monsoon
	Percentage of losses	Percentage of losses
Harvest losses		
Average	0.31	0.77
Range	0.11 to 0.71	0.58 to 1.17
	$t = -3.788, P = 0.004^{**}, df = 10$	
Stacking losses		
Average	0.74	0.02
Range	0.24 to 1.11	0.01 to 0.06
	$t = 4.195, P = 0.008^{**}, df = 5.021$	
Stalks drying and threshing losses		
Average	4.77	0.20
Range	1.91 to 10.09	0.04 to 0.37
	$t = 3.582, P = 0.016^{*}, df = 5.021$	
Winnowing losses		
Average	0.28	0.07
Range	0.09 to 0.56	0.03 to 0.09
	$t = 3.148, P = 0.024^{*}, df = 5.225$	
Storage losses		
Average	15.24	10.82
Range	7.63 to 21.93	3.19 to 23.43
	$t = 1.235, P = 0.245^{ns}, df = 10$	
Total losses		
Average	21.34	11.88
Range	11.18 to 29.99	4.42 to 24.41
	$t = 2.27, P = 0.047^{*}, df = 10$	

*Note: **significant at 1% level; *significant at 5% level; ns = non-significant*

Effects of packaging materials and storage durations on total weight of stored sesame

The harvested sesame seed/grain was dried, weighed and stored in two types of packaging materials, pioneer superbags and woven polypropylene bag, for eight months at the farmers' houses. Every two months during this period, samples were taken, cleaned and weighed. Pests were found in the stored sesame, therefore, one of the main factors causing reduction in weight may be pest infestations during the storage period. Insects alone can cause 36 to 43 percent storage loss (Bala et al., 1990). Sufficiently airtight storage systems, although allowing insects and other aerobic organisms to initially survive, oxygen concentrations are decreased below those permitting further insect development (Chanda, 2013). In pre-monsoon sesame, the weight of stored seed/grain (500 g) decreased significantly in two months (482.88 g) a trend that continued until four months (477.96 g), and which then again significantly decreased by six months, with a loss of 464.97 g and on into the eighth month, when sesame weight decreased to 446 g. In post-monsoon sesame, the initial stored weight (500 g) was not significantly reduced in the first two months (497.19 g), or for the periods following (in four months (494.45 g), in six months (494.24 g), but it then decreased significantly in the six to eight month period to 469.84 g. Therefore, it can be seen that storage losses of pre-monsoon sesame (10.8%) was higher than post-monsoon sesame (6.03%) in the eight months of storage (Table 2).

Table 2. Mean effects of packaging materials and durations on total weight of stored sesame

Treatment	Stored weight (g)	
	Pre-monsoon sesame	Post-monsoon sesame
Packaging materials (P)		
Superbag	484.01 a	497.12 a
Woven polypropylene bag	464.72 b	485.17 b
$LSD_{0.05}$	6.46	5.93
Storage duration (D)		
Initial storage	500.00 a	500.00 a
2 months	482.88 b	497.19 a
4 months	477.96 b	494.45 a
6 months	464.97 c	494.24 a
8 months	446.00 d	469.84 b
$LSD_{0.05}$	10.22	9.38
Pr > F		
P	0.0000	0.0002
D	0.0000	0.0000
P × D	0.0003	0.0000
CV (%)	2.62	2.32

Note: In each column, means with the same letter are not significantly different at 5 % level.

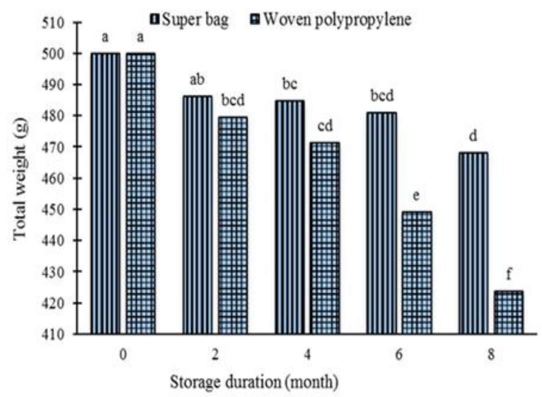

Fig. 2. Combination effect of packaging materials and storage duration on total weight of pre-monsoon sesame

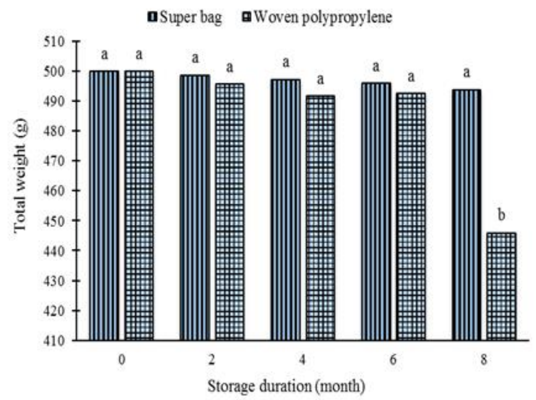

Fig. 3. Combination effect of packaging materials and storage duration on total weight of post-monsoon sesame

The combination effect of packaging materials and storage durations on the total weight of stored pre-monsoon sesame is shown in Figure 2. In the first two months of storage, the weight of seed/grain stored in the superbags did not fall, whereas seed stored in the woven polypropylene bags was significantly reduced. After four months storage, the weight of sesame stored in the superbags was significantly different to the weight at initial storage. The weight of stored sesame in the woven polypropylene bags was also not significantly different than the weight of stored seed/grain weight for two months, however, it was significantly different to the weight of sesame after six months storage. From six months to eight months storage, the weight of sesame stored in superbags did not significantly decrease, while the weight of sesame stored in woven polypropylene bag had decreased significantly by eight months from the weight at six months (Figure 2). By the end of the storage period measured (eight months), the weight loss of pre-monsoon sesame stored in superbags was 6.36%, while for sesame in woven polypropylene bag there was a loss of 15.24%.

The combination effect of packaging materials and storage durations on the total weight of stored post-monsoon sesame is shown in Figure 3. The weight of stored sesame in superbags did not significantly decrease over eight months storage, while the weight of sesame stored in woven polypropylene bag maintained similar weights for the first six months and then decreased significantly at eight months storage with a 10.82% weight loss (Figure 3). As the packaging materials are airtight, insects and aerobic microorganisms creates an inhibitory environment over time by increasing carbon dioxide concentration and decreasing oxygen due to their respiratory metabolism (Adler et al., 2000). If the weight loss of pre-monsoon and post-monsoon sesame during storage is compared, losses of pre-monsoon sesame occurred in both the superbags and woven polypropylene bags, however, losses of the post-monsoon sesame were found only in the woven polypropylene bags. This might be due to the initial seed moisture content at time of storage, as the initial moisture content of pre-monsoon sesame was higher than that of post-monsoon sesame. When using airtight storage methods, it is important to have a very well dried product at the beginning of the storage period (Hayma, 2003). Also Ben et al. (2009) reported that one of the main challenges of using hermetic bags is that the grain to be stored should be thoroughly dried to avoid mold and the rotting of grains.

CONCLUSION

The range of the total postharvest losses of pre-monsoon sesame and post-monsoon sesame were (11.18% to 29.99%) and (4.42% to 24.41%). Storage losses were the highest contributor to losses among all the postharvest processes for sesame in both seasons. Storage losses can be mitigated by use of efficient storage technology, and upgrading both infrastructure and storage practices. When comparing postharvest losses, the losses were higher in pre-monsoon sesame than for post-monsoon sesame, except for harvest losses. Although the losses in harvesting, stacking, stalk drying and threshing, winnowing and total post-harvest losses were significantly different, the difference in the amount lost during the storage stage for pre and post-monsoon crops were non-significant. The differences of losses that occurred during stacking, stalk drying and threshing and winnowing were due to the different handling practices of farmers. Therefore, if farmers had a good threshing floor, post-harvest losses would be reduced and a better quality product produced. In regard to the packaging materials, a significant difference of total weight of stored sesame that was lost can be seen for the different packaging materials surveyed. Storage in superbags resulted in far less sesame weight loss than storage in woven polypropylene bags.

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