Research article

Review on Causes, Effects, and Management of Soil Salinity on Irrigated Rice Fields in Tanzania

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Received 22 May 2023 Accepted 2 August 2023 (*Corresponding Author)

Abstract Salinization is a process of increasing concentrations of salts in soil and water. Soil salinity is the most serious agricultural problem in irrigation agriculture in Tanzania. Severe salinity can cause significantly lower yields, food insecurity, and environmental degradation. If not properly addressed, soil salinization can accelerate and potentially expand to currently unaffected irrigated agricultural land. Despite the efforts made by the government and other stakeholders, rice production in irrigated rice fields in Tanzania is still experiencing low yields. Current rice yields are between 2.5 and 4 tons/ha, which is low compared to the average rice yields reported in other countries. Salinity problems are caused by the prevailing climate characterized by high evapotranspiration, geological and geographical characteristics of the area, quality of irrigation water, and inadequate land use practices. This paper aims to review available information on the causes and effects of soil salinity on irrigated rice fields in Tanzania and to provide information on management strategies to adjust soil salinity and improve soil fertility. References from books, papers, journals, online readings, and dissertation papers from different universities and institutions were used to get information for this paper review. In this review, the various reasons that cause soil salinity in irrigated fields in Tanzania have been identified, which are the nature of rocks, poor irrigation management, and non-compliance with established irrigation regulations. Also, the effects of soil salinity in Tanzania have resulted in a decrease in yields, an increase in costs of production, poor quality of products, and water shortages for irrigation. Lastly, some recommendations identified to solve the challenges of soil salinity include setting up a local drainage system on affected land, renovating some irrigation facilities, reclaiming the affected soil with gypsum and manure, and flushing all salt-affected water with non-salt water.

Keywords review, soil salinity, causes and effects, irrigated rice field, Tanzania,

INTRODUCTION

Globally, the challenge of soil salinity in areas that practice irrigation agriculture has been increasing day after day, resulting in crop production decreasing while also causing land environmental problems such as degradation, erosion, and siltation. Salinity affects about 800 million ha of arable lands worldwide and approximately 33 % of irrigated areas (about 74.25 million ha) are currently considered threatened by soil salinization by various degrees (Shrivastava and Kumar, 2015). According to Jamil et al. (2011), it's projected that by the year 2050, there will be more than 50 % of the farmland worldwide, which would become salt affected. Rice is the most sensitive cereal crop while barley is the most tolerant cereal crop (Munns and Tester, 2008; Karan et al., 2012). Salinity has serious effects on the percentage of filled spikelet, and grain weight, and can also hinder the uptake of essential nutrients in rice (Clermont-Dauphin et al., 2010). Most irrigation schemes, which are especially within arid and semiarid environments, are already experiencing increasing levels of salt-affected soil, solely due to the mismanagement of the soils, the use of poor-quality irrigation water, poor drainage systems, poorly designed and managed irrigation infrastructures, excessive use of irrigation water and climate change (Kashenge-Killenga, 2010). Most irrigation water qualities have adverse effects on the physical properties of soil because it is mostly connected with the buildup of sodium ions on the soil exchange complex. The quality of water can impact the volatility of the soil aggregates which eventually leads to the dispersion of the clay particles and the clogging of soil pores. When underground water is made to move to the soil surface by evapotranspiration, the soluble salts condense on the soil particles on the surface and form a white crust.

Irrigation practices affect land by increasing the rates of leakage and groundwater recharge which results in the rise in the water table. The water tables when it rises bring salts into the plant root zone which affects both plant growth and soil structure; then the salt remains behind in the soil surface after the water has been taken up by plants or lost due to evaporation (Popay et al., 2009). Soil salinity is generally measured by electrical conductivity (EC) (Allison and Richards, 1954; Sonmez et al., 2008; Scudiero et al., 2017). A soil is considered saline if the EC of a saturation extract exceeds 4 dS m^{-1} at 25°C (Sonmez et al., 2008). Soil salinity or EC may be measured on the bulk soil (ECa), in the saturation paste extract (ECe), in soil: water ratio suspensions of 1:1 to 1:5 such as 1:1, 1:2, 1:2.5 and 1:5 or directly on soil water extracted from the soil in the field (ECw) (Allison and Richards, 1954; Sonmez et al., 2008; Kargas et al., 2018). Like other countries in Africa, soil salinity in Tanzania contributes to one of the most serious ecological and environmental problems in most of the irrigation schemes, so understanding the causes and effects of soil salinity in various irrigation schemes in Tanzania, will provide an opportunity for the government to come up with enabling policies to solve this challenge help farmers to practice irrigation agriculture that will specifically eliminate and reduce the problem of soil salinity in their respective areas. This is because among the factors that contribute to the increase in soil salinity are methods that are used by farmers in irrigation agriculture, like the use of fertilizers application and improper uses of irrigation facilities. The objective of this paper is to review the information on the causes and effects of soil salinity on irrigated fields and to come up with information on management strategies to control the problem.

OBJECTIVE

This review study tries to sum up and review available information on the causes and effects of soil salinity on irrigated rice fields in Tanzania. And it provides information on management strategies to adjust to deal with this challenge of soil salinity on rice irrigated fields in Tanzania to strengthen Irrigation Agriculture so that it can bring productivity and income to farmers in Tanzania.

METHODOLOGY

The methodology used to get information for this paper are references from papers, journals, online, and dissertation papers from different Universities and Institutions.

Causes of Soil Salinity on Rice Irrigated Fields in Tanzania

The main source of salt in arid and semi-arid areas includes rainfall (Rengasamy and Olsson, 1991), mineral weathering (Gunn and Richardson, 1979), irrigation and various surface water (Mehanni and Chalmers, 1986; Rengasamy and Olsson, 1993), groundwater which redistributes accumulated salts during evaporation, chemical applications (Rengasamy and Olsson, 1993) and man activities (Dregne, 1976). These sources, coupled with environmental modifications, lead to three different classes of salinization and sodicification that are grouped so for management purposes. These classes include Saline soils that have $EC_e > 4$ dS m^{-1} at 25° C and ESP < 15 (high soluble salts and low exchangeable Na^+). Sodic soils have $EC_e < 4$ dS m^{-1} and ESP > 15 (low soluble salts and high exchangeable Na^+). Saline-sodic soils are characterized by $EC_e > 4$ dS m^{-1} and ESP > 15 (both salts and exchangeable sodium are high), pH15%, and pH>8.5) (Allison and Richards, 1954). In Tanzania, some studies have been done to determine the sources of soil salinity in irrigation schemes, those studies identify various reasons from different areas that do irrigation farming, and some of those reasons are as follows.

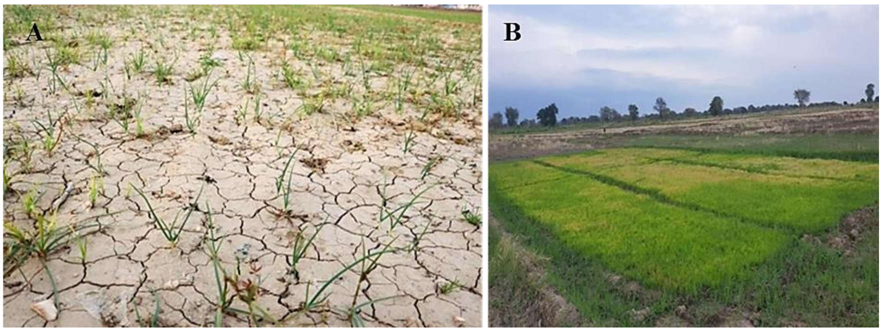
Table 1 Case papers used for gathering information used in this study

Researcher and year of publication	Research title	Journal name and published date	Causes of soil salinity	Effects of soil salinity	Management of soil salinity
Meliyo et al. (2017)	Evaluation of Salt Affected Soils for Rice (Oryza Sativa) Production in Ndungu Irrigation Scheme Same District, Tanzania	Sustainable Agriculture Research, 6 (526-2017-2656)	Nature location of the Irrigation area Poor Irrigation Management	Decrease in yields. Decrease in cultivation area.	Manure and limestone application The local drainage system infarms
Makoi et al. (2007)	Reclamation of sodic soils in northern Tanzania, using locally available organic and inorganic resources	African Journal of Biotechnology 6, no. 16.	Non-compliance Poor Irrigation Management	Increase in costs of productions	The local drainage system in farms Extension to farmers on irrigation management
Kashenge et al. (2012)	Soil characterization for salt problems in selected rice irrigation schemes	Journal of Advances in Developmental Research, 3(1).	Poor Irrigation Management	Water Shortages High costsof production	Application of drainagesystem Renovation facilities
Omar et al. (2022)	Exploring farmers' perception, knowledge, and management techniques of salt-affected soils to enhance rice production on small land holdings.in Tanzania	Cogent Food & Agriculture, 8(1), 2140470	Fertilizer application Poor drainage system	Decrease in yields. Decrease in cultivation Area.	Flashing salt water Extension services to farmers
Kashenge-Killenga et al. (2016)	Extent of Salt-Affected Soils and Their Effects in Irrigated and Lowland Rain-Fed Rice Growing Areas. of Southwestern Tanzania	Climate Change and Sustainability in Agriculture, 97-126	Poor Irrigation management	Increase incosts of production.	Proper Irrigation management

Firstly, the cause of soil salinity in irrigated fields in Tanzania is the Natural location of an area, most schemes which are experienced soil salinity due to the nature of rocks in their respective areas, and this normally happens to the water source which is the source of water is from Spring or aquifer. Irrigation salinity occurs due to increased rates of leakage and groundwater recharge causing the water table to rise. Rising water tables can bring salts into the plant root zone which affects both plant growth and soil structure. This is common in an area surrounded by a mountain like in the Kilimanjaro region irrigation scheme as the Ndungu source of its irrigation water has salinity due to the nature of the rock (sedimentary rock) which causes the soil salinity.

According to Makoi, J. H. (2007), the strong reason for the soil salinity in areas where they are doing Irrigation Agriculture in Tanzania is poor irrigation management, which is often contributed to the farmers themselves not knowing the methods and principles of Irrigation Agriculture. This is muchly related to knowing when and how to irrigate (irrigation schedule), application of fertilizer, and poor drainage system which causes accumulation of water which in the end results in soil salinity irrigating with saline water adds salt to the soil and increases the need for applying more irrigation water to leach salts past the plant root zone.

Another source of soil salinity is non-compliance with various laws and guidelines set under the irrigation laws in the country, which states that before starting an irrigation scheme, the source of water must be measured and tested to see if its water complies with the required quality for irrigation, including measuring the level of salt and consider the installation of salt control infrastructure as a drainage system in the scheme. Some people do not follow the guidelines set by the Irrigation Commission responsible for Irrigation Agriculture in the country.



Source: NIRC

Fig. 1 Soil affected by salt (A); yields of paddy affected by salt (B) at irrigation schemes in Tanzania due to poor irrigation management

Effects of Soil Salinity on Rice Irrigated Fields in Tanzania

Soil salinity is an environmental stress affecting agriculture globally, substantially reducing cultivated land area, crop productivity, and quality. Farmers can keep salinity problems in check by using fertilizer. It is widely recognized by soil scientists that soil salinity reduces crop yield. Salinity not only decreases the agricultural production of most crops, but also, affects soil physicochemical properties, and the ecological balance of the area. The impacts of salinity include—low agricultural productivity, low economic returns, and soil erosion (Hu and Schmidhalter, 2005). In Tanzania, soil salinity has caused various challenges, but the biggest one is the decrease in yields production, as statistics show that almost five percent (5%) of the area suitable for agriculture in many irrigation schemes in Tanzania is not cultivated due to soil salinity problem also there are some cases in some Irrigation scheme where they usually produce 3-4 t/ha now they are producing 1-1.5 t/ha due to problem of soil salinity (Luzi-Kihupi et al., 2015). Being not cultivated and abandoned automatically leads to a decrease in Production yields in a particular area and affects farmers' income incomes. Also, soil salinity, causes production costs to increase for farmers in Tanzania. as many of them use various methods to reduce salt, including using a lot of fertilizer so that their plants are healthy remaining, others also use gypsum to improve the soil structure damaged by salts. By doing all of this it leads to an increase in the cost of production (Kashenge, 2016). Another effect of soil salinity in Tanzania is irrigation water shortages, this is because in Tanzania most of the farmers reduce the salinity in their fields by applying much water to fields to flush out the water affected by salts and also to balance salt-affected soil, so a lot of water is used to flush out and by doing that it leads to shortages of water for irrigation on downstream. Water shortages downstream lead to conflicts among the farmers in most of the irrigation schemes in Tanzania (NIRC).

DISCUSSION

Management to Control Soil Salinity

There have been various efforts taken by farmers to control soil salinity in their irrigated fields to eliminate or reduce the problem, also governments, stakeholders, and research institutions are continuing to come up with a different approach to controlling soil salinity.

Provision of drainage system to the area affected, this method is mostly used by most farmers, they create local drainage systems on farms to remove water with salinity from the soil, and therefore the amount of soil salinity automatically is reduced and the drained water is removed through the outlet. The other suggested ways of removing soil salinity recommended by researchers are such to renovate and close supervision of water inlet and outlet canals to prevent leakage of water between blocks, affected fields require reclamation by the use of gypsum, farm-yard manure, good drainage and flushing using good quality water, It is essential that drainage water, with its salt load from the affected soil, be removed from the scheme, the use of farmyard manure at a rate of 3 to 8 tons/ha is recommended to boost soil organic matter and improved soil infiltration to facilitate washing of salts to minimize the effect of salts (Meliyo, 2016). The farmyard manure will also supply some nutrients (N, P, and K) that were limiting in some soils and therefore need to be added to improve rice productivity andSoil reclamation will probably need to be a continuing practice in the most affected areas. The most economical solution to maintain productivity will probably be a combination of salt-tolerant variety selection and soil amelioration practices (Mdemu, M.L., 2020).

CONCLUSION

Controlling soil salinity, sustainable soil, and irrigation water management practices have a vital role in the production of rice at irrigation schemes in Tanzania country. Many approaches are available to rehabilitate salt-affected soils. These include physical methods (irrigation and drainage management); chemical amendments (gypsum, H_2SO_4, combined application gypsum with other organic amendments); and biological approaches (screening salt-tolerant genotype, growing ameliorating crop species, crop species in rotation, etc.). The agro-ecological conditions in Tanzania are comparable to many other countries where these approaches have successfully been tested. Therefore, there is a good potential for adopting these practices that will increase economic benefits to farmers.

ACKNOWLEDGEMENTS

First, I thank God for his blessing to me, special thanks to research fellows in the laboratory of Tokyo University of Agriculture for his supervision, mentorship, guidance, and advice. Lastly Many thanks to JICA for the financial support of my research.

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Research article

Evaluation of the Effect of Lactic Acid Bacteria on Histamine-producing Bacteria Isolated from Cambodian Prahok

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Received 2 June 2023 Accepted 5 August 2023 (*Corresponding Author)

Abstract Prahok (fermented fish paste) is commonly used as a side dish or condiment in Cambodian cuisine. Because of the condition of the raw material and inadequate hygiene during processing, this type of fermented fish is frequently loaded with histamine toxicity. The purpose of this study was to examine the potential histamine-producing bacteria (HPB) isolated from prahok collected from three provinces in Cambodia and to evaluate the efficacy of local lactic acid bacteria (LAB) in controlling those HPB. For HPB isolation, a modified Niven's agar was used and the bacteria species were identified using the Biolog GEN III Semi-automatic system, while histamine concentration was quantified using a colorimetric enzyme assay. Ten LAB strains from the stock collection of Laboratory Food Biotechnology, Faculty of Agro-Industry, were used to evaluate their antibacterial activities against HPB using the well diffusion method and the co-culture method, and compared to the control which involved growing HPB without LAB. As a result, five identified HPBs isolated from prahok, including *Enterobacter aerogenes*, *Klebsiella oxytoca*, *Morganella morganii*, *Proteus penneri*, and *Staphylococcus xylosus*, were found to produce histamine at levels of more than 200 ppm in vitro. A well diffusion and co-culture examination demonstrated that the growth of all potential HPB cultured with three LABs (*Lactobacillus plantarum, Lactobacillus gasseri,* and *Lactococcus lactis*) of a total of 10 LAB strains was inhibited compared to the control. In conclusion, because the three LABs listed above cannot create histamine, they are promising candidate LABs to apply in prahok processing to control HPB as well as histamine levels in the final product.

Keywords prahok, histamine producing bacteria, histamine, lactic acid bacteria, antimicrobial activity

INTRODUCTION

Fish is a vital source of food for millions of Cambodians, who live in a country where bodies of water abound. The Mekong River, Sap River, Bassac River, and Tonle Sap Lake, Southeast Asia's largest freshwater lake, are home to hundreds of thousands of fish species, which locals harvest and process into a variety of fermented dishes such as Prahok, Pa ork, and many others, moreover, a technique that has been around since ancient times and continues to this day (Chuon et al., 2014). However, the majority of the production of these fermented fish is still traditionally produced by local families, where knowledge of hygiene is limited (Ly et al., 2018). Otherwise, the outbreak of foodborne disease caused by bacteria in Cambodia is not publicly reported or taken seriously by the authority, which ultimately becomes normal in people's livelihoods, obviously, this can cause serious harm to human health (Chrun et al., 2017).

One of the key chemicals that contributes to food-borne intoxication is histamine ($C_5H_9N_3$), a biogenic amine that will cause significant health effects such as diarrhea, rash, nausea, vomiting, fever, abdominal pain, and a variety of other symptoms similar to allergic reactions when consumed at high levels by humans (Shimoji et al., 2019; Surya et al., 2019). Foods with high histamine content can lead to histamine intoxication, also known as scombroid fish poisoning. Histidine is decarboxylated into this biogenic amine by bacterial decarboxylases (Madejska et al., 2022). The maximum level of histamine content should be 100 mg/L and not exceed 200 mg/L, according to trustworthy food regulators like the European Commission (regulation No. 2073/2005/EC), Australia-New Zealand Food Standards (ANZFS), the Food Safety and Standards Authority (FSSAI), and CODEX (Surya et al., 2019; CODEX.,2015). Histamine has been found in raw fish, salted or fermented fish and smoked fish, and other fish products (Kuda et.al., 2007; Madejska et.al., 2022; Moon et.al., 2013; Pawul-Gruba and Osek, 2021; Sokvibol et.al., Tao et.al., 2022).

A popular strategy to combat these bacteria recently is known as biocontrol, in which lactic acid bacteria (LAB) are used to produce amine oxidase enzymes, which are used to de-structure the biogenic amine. LAB has been widely accepted as a safe (GARS) biocontrol in food processing by many food producers due to its potency as an anti-pathogen (Lim, 2016). The main purpose of this study was to examine the potential histamine-producing bacteria (HPB) isolated from Prahok collected from three provinces in Cambodia and to evaluate the efficacy of local lactic acid bacteria (LAB) in controlling those HPB.

OBJECTIVE

The objectives of this study are to examine the potential histamine-producing bacteria isolated from Prahoks collected from three provinces of Cambodia and to evaluate the efficacy of local lactic acid bacteria (LAB) in controlling those histamine-producing bacteria (HPB).

METHODOLOGY

Sample Selection

The sampling for the analysis is collected randomly from three separate provinces' local markets such as Kampong Thom, Kampong Cham, and Siem Reap. A total of 15 samples were gathered, which were then sealed in polyethylene bags in an ice box and delivered right away to the microbiology Laboratory, Faculty of Agro-Industry, Royal University of Agriculture, Phnom Penh.

Isolation and Identification of HPB

The samples were accurately weighed out at 1.0 g, added to 10 mL of sterile TSB, supplemented with TSB (3.0%), histidine monohydrochloride (0.1%), and pyridoxal hydrochloride (0.5%), cultured for 24 h at 30 °C (Lim, 2016). The presence of histamine was demonstrated by streaking on Niven's agar (Niven et al., 1981), which was incubated at 35 °C for 24 hrs. By monitoring how well the isolates grew in Niven's medium, supplemented with Tryptone (0.5%), Yeast extract (0.5%), L-Histidine 2HCl (2.0%), NaCl (0.5%), $CaCO_3$ (0.1%), Agar (3.0%), and Bromecresol purple (0.006%), it was determined that the isolates produced histamine. A doubt colony with a purple halo surrounding it and a yellowish backdrop were found (Joosten and Northolt, 1989; Mavromatis and Quantick, 2002; Refai et al., 2020). The HPB species have been identified by using the Biolog Semi-automatic MicroStation with Microlog Software System (Model: MicroStation Brand: BIOLOG) (Al-Dhabaan and Bakhali, 2017).

Colorimetric Enzyme Assay

To measure the level of PHB, a single colony was chosen and grown in 5 ml of TSB-Histidine broth for 24h at 35°C and then the result was read by Spectrophotometer (Model: DNM-9602G, Brand: Nanjing Perlove Medical) using the formula of Histamine (Karami et al., 2021) (Eq. 1).

$$Concentration\ (ppm) = [(Es - Eb) \div (Ed - Ec) \times 40 \qquad \text{Eq. 1}$$

Antimicrobial Activity Testing by Applying Well Diffusion and Co-Culture Method

Well diffusion method: Ten LAB kept in the microbiology laboratory at the Faculty of Agro-Industry, Royal University of Agriculture were cultured in 2 ml of De Man, Rogosa, and Sharpe broth (MRS broth) for 24 hrs. at 30 °C, and then separated using a centrifuge engine (Model: Z 326, Brand: HERMLE - Germany) running at 6,000 rpm for 15min. HPB is disseminated on Mueller-Hinton agar (MHA), measured at 90% equal to 10^{-8} (% transmittance) using a Biolog Turbidimeter (model: MicroStation, brand: BIOLOG), and then holes with a 6 mm diameter are made. The perforated hole was filled with 100 microliters of LAB, which was incubated for 24 h at 35±2 °C (Cotton et al., 2019; Jahangirian et al., 2013).
Co-culture method: 10% of LABs suspension 9 Log CFU/ml were inoculated with 6 Log CFU/ml of HPB in mixed broth (MRS broth + TSB) in each tube. This experiment was performed under aerobic conditions at 30 °C in the water bath for 72 hrs. Every 24 h, the mixed broths have been streaked on selective agar to observe the presence of HPB (Mellefont et al., 2008).

RESULTS AND DISCUSSION

Isolation and Identification of HPB

HPBs were investigated in Prahok from 3 provinces, Kampong Thom, Kampong Cham, and Siem Reap. After incubating at 30°C for 24 hrs., 15 homogenate Prahok samples were determined to be histamine positive. In the overall 15 Prahok samples, 8 (53%) had histamine levels from 0<100 ppm which is the level allowed by USFDA (2001), and 6 (40%) were detected with histamine 100<200 ppm had histamine levels beyond Cambodian regulation standards (CS, 2015), and 1 (7%) was the highest amount of histamine found in Prahok Trey Sandaiy purchased from Kampong Cham province which was contained 228 ppm of histamine concentration over Cambodian regulation standards >200 ppm (Table 1). Similar to Sokvibol (2022) research on the Assessment of biogenic amine levels from Cambodia fermented fish products showed in the three samples of Prahok products brought from Kampot, Phnom Penh, and Kampong Chhnang had histamine levels were over the Cambodian guideline of 200 ppm, while those in 11 samples (Prahok and Teuk Trey) met the FDA's recommended level of 50 ppm (Sokvibol et al., 2022).

The identification of HPB by the Biolog GEN III Semi-automatic system analysis detected 7 species. 5 of 7 species that can produce histamine over 1000ppm were chosen to evaluate the effect of LAB on HPB (Table 2) including *Enterobacter aerogenes* (1610 ppm), *Proteus penneri* (1576 ppm), *Staphylococcus xylosus* (1420 ppm), *Morganella moganii* (1507 ppm), and Klebsiella oxytoca (1520 ppm). In contrast, 2 more species, *Enterococcus faecalis* (67 ppm) and *Citrobacter youngae* (153ppm) also generate histamine, although at levels that were beyond 200 ppm (Table 1). As research of Moon (2013) investigated the Isolation and Characterization of Histamine- Producing Bacteria in Fermented Products and found bacteria that could produce histamine such as *Morganella moganii* and *Enterobacter aerogenes* by rRNA testing. (Moon et al., 2013). According to researcher Tao (2022) studied on Prevalence of Histamine-Forming Bacteria in Two Kinds of Salted Fish at Town Markets of Guangdong Province of South China was identified six bacteria species in the samples of salted fish pickled overnight, there are *Vibrio alginolyticus*, *Vibrio rumoiensis* (360 to 363 mg/kg), *Staphylococcus saprophyticus* (95 to 113 mg/kg), *Staphylococcus xylosus* (65 to 96 mg/kg), *Lactococcus lactis* (3 mg/kg), and *Morganella morganii* (2,000 mg/kg) and 1 specie from dry salted fish, *Enterobacter aerogenes* (351 to 352 mg/kg). (Tao et al., 2022).

The presence of histamine found in prahok products may be caused by several variables, including the type of fish used, the species of fish used, the location of the fish, and producer processing techniques. However, histamine is heat stable, and if it was there before automated processing began, it can be detected in the final products (Madejska et al., 2022). As a result, it is not surprising that foodborne outbreaks are common in Cambodia because in Cambodian food, people use prahok as an ingredient in many dishes, and it can be eaten raw by mixing it with lemon and chili. (Ly et al., 2020; Norng et al., 2011).

Table 1 Histamine level and HPB identification from prahok products in the three different provinces

Province	Type of Prahok Trey	Scientific name	Histamine level* (ppm)	Identification bacteria species	Histamine level** (ppm)
Kampong Thom	Prahok Trey Chomrus	-	144	ND	-
	Prahok Trey Chomrus	-	87	*Klebsiella oxytoca*	1520
	Prahok Trey Kampleanh	*Osphronemidae*	157	ND	-
	Prahok Trey Chdor	*Channa micropeltes*	1	*Enterococcus faecalis* *Citrobacter youngae*	- 67 153
	Prahok Trey Sanday	*Wallagonia attu*	228	*Enterobacter aerogenes*	- 1610
	Prahok Trey Riel	*Cyprinidae*	13	ND	-
Kampong Cham	Prahok Trey Chongva	*Rasbora tornieri*	157	ND	-
	Prahok Trey Lait	-	52	ND	-
	Prahok Trey Riel	*Cyprinidae*	157	ND	-
Siem Reap	Prahok Trey Kampleanh	*Osphronemidae*	47	ND	-
	Prahok Trey Kampleanh	*Osphronemidae*	124	*Staphylococcus xylosus* *Proteus penneri* *Morganella moganii*	1422 1576 1507
	Prahok Trey Kampleanh	*Osphronemidae*	18	ND	-
	Prahok Trey Ros	*Channa striata*	118	ND	-
	Prahok Trey Ros	*Channa striata*	53	ND	-
	Prahok Trey Pra	*Pangasiidae*	36	ND	-

Histamine level= Histamine level in Prahok samples Histamine,*
*Histamine level**= Histamine level produced by HPB*

Antimicrobial Activity Testing by Applying Well Diffusion and Co-culture Method

Table 2 displays the results of the inhibition zone measurements for 10 LAB against *Enterobacter aerogenes*, *Proteus penneri*, *Staphylococcus xylosus*, *Morganella moganii*, and *Klebsiella oxytoca*. These substances have significant antibacterial activity against both Gram-positive (*Staphylococcus xylosus*) and Gram-negative (*Enterobacter aerogenes*, *Proteus penneri*, *Morganella moganii*, and *Klebsiella oxytoca*) bacteria. According to Table 2, all 10 LAB showed increased antibacterial activity when compared to the five HPB, however, *Lactobacillus plantarum*, *Lactococcus lactis*, and *Lactobacillus gasseri* had greater zone values. According to the five LAB strains found in Myeolchi-jeot, the research of the Inhibitory Effect of bacteriocin-producing lactic acid bacteria against histamine-forming bacteria isolated from Myeolchi-jeot shared 98.3–100% sequence identity with the following bacteria: *Pediococcus acidilactici*, *Leuconostoc mesenteroides*, *Enterococcus faecium*, *Lactobacillus sakei*, and *Lactobacillus acidophilus* produced an antibiotic substance that inhibited the growth of HPB like *B. licheniformis, S. marcescens*, *S. xylosus*, *A. hydrophila*, or *M. morganii* (Lim, 2016).

Table 2 Growth inhibition of HPB by 10 LABs using well diffusion method

LAB	Time (hrs.)	HPB [Zone value (mm)]				
		Staphylococcus xylosus	*Enterobacter aerogenes*	*Proteus penneri*	*Morganella morganii*	*Klebsiella oxytoca*
Lactobacillus mali	24	0	0.0	0.0	0.0	0.0
	48	0	0.0	0.0	0.0	0.0
	72	0	0.0	10.0	10.5	0.0
Lactococcus garvieae	24	0	0.0	0.0	0.0	0.0
	48	0	0.0	0.0	12.0	0.0
	72	0	12.4	10.5	14.0	8.6
Lactobacillus plantarum	24	0	0.0	0.0	0.0	0.0
	48	0	10.5	8.6	12.0	0.0
	72	0	10.5	10.5	13.6	11.0
Lactococcus lactis	24	0	0.0	0.0	0.0	0.0
	48	0	10.6	0.0	12.4	0.0
	72	0	13.9	11.0	15.8	0.0
Lactobacillus gasseri	24	0	0.0	0.0	0.0	0.0
	48	8	0.0	0.0	12.0	0.0
	72	0	13.9	11.0	17.0	0.0
Leuconostoc gelidum	24	0	0.0	0.0	0.0	0.0
	48	0	0.0	0.0	11.5	0.0
	72	0	0.0	0.0	12.4	0.0
Tetragenococcus solitarius	24	0	0.0	0.0	0.0	0.0
	48	0	12.4	0.0	12.0	0.0
	72	0	0.0	0.0	13.0	11.0
Pediococcus parvulus	24	0	0.0	0.0	0.0	0.0
	48	0	0.0	0.0	9.6	0.0
	72	0	00.0	0.0	10.5	0.0
Lactobacillus curvatus	24	0	00.0	0.0	0.0	0.0
	48	0	00.0	0.0	10.0	0.0
	72	0	00.0	9.0	10.5	0.0
Leuconotoc citrerum	24	0	00.0	0.0	0.0	0.0
	48	0	00.0	0.0	10.0	0.0
	72	0	00.0	10.5	10.5	0.0

Table 3 Three effective LABs performed co-culture analysis to find the presence of HPB

LAB	N	Time (hrs.)	HPB				
			Staphylococcus xylosus	*Enterobacter aerogenes*	*Proteus penneri*	*Morganella morganii*	*Klebsiella oxytoca*
Lactobacillus plantarum	3	24	(-)	(-)	(-)	(-)	(-)
		48	(-)	(-)	(-)	(-)	(-)
		72	(-)	(-)	(-)	(-)	(-)
Lactococcus lactis	3	24	(-)	(-)	(-)	(-)	(-)
		48	(-)	(-)	(-)	(-)	(-)
		72	(-)	(-)	(-)	(-)	(-)
Lactobacillus gasseri	3	24	(+)	(+)	(+)	(+)	(+)
		48	(+)	(-)	(-)	(-)	(+)
		72	(-)	(-)	(-)	(-)	(-)
Mixed LAB	3	24	(-)	(+)	(+)	(+)	(+)
		48	(-)	(+)	(-)	(-)	(-)
		72	(-)	(-)	(-)	(-)	(-)

Since they produced better results in good diffusion, *Lactobacillus plantarum*, *Lactococcus lactis*, and *Lactobacillus gasseri* were chosen to examine the co-culture strategy to find HPB. According to Table 3, 2 LAB, which included *Lactobacillus plantarum* and *Lactococcus lactis*, could not be detected when co-cultured for 24 hours at 30 °C with the five HPBs. In contrast, *Lactobacillus gasseri* proved effective against *Enterobacter aerogenes*, *Proteus penneri*, and *Morganella moganii* for 48 hours at 30 °C, whereas *Proteus penneri*, *Morganella moganii*, and *Klebsiella oxytoca* were examined for after 48 hrs and *Staphylococcus xylosus* after 24 hrs in mixed LABs.

In research of the Control of tyramine and histamine accumulation by lactic acid bacteria using bacteriocin-forming lactococci showed that *L. lactis subsp. lactis* produced nisin Z induced the death of the histamine-producing strain *S. thermophilus*. However, *L. lactis subsp. lactis* EG46- produced lacticin 481 was able to reduce its growth extent and histamine accumulation (Tabanelli et al., 2014)

CONCLUSION

This study showed that the seven different bacterial species, including *Enterobacter aerogenes*, *Proteus penneri*, *Staphylococcus xylosus*, *Morganella moganii*, *Klebsiella oxytoca*, *Citrobacter freundii*, and *Citrobacter youngae*, were found in Prahok products, according to this study. Five of these seven are known histamine makers since samples show levels of histamine that are higher than the 200ppm threshold set by Cambodian regulations. Therefore, Prahok producers must follow the regulatory limitations on histamine that have been defined by international and national standards to maintain adequate hygiene procedures to prevent cross-contamination and proper handling methods to control the bacterial development dependent on the fermented fish products. Antibacterial activity of *Lactobacillus plantarum*, *Lactococcus lactis*, and *Lactobacillus gasseri* was stronger than other 7 LAB by using well diffusion method to evaluate the effeteness of grate zone values, whereas in co-culture the antibacterial activity of *Lactobacillus plantarum* and *Lactococcus lactis* were stronger than *Lactobacillus gasseri* in inhibited Enterobacter aerogenes, Proteus penneri, Staphylococcus xylosus, Morganella moganii, Klebsiella oxytoca, Citrobacter freundii, and *Citrobacter youngae*. Therefore, *Lactobacillus plantarum* and *Lactococcus lactis* can be used as potential antibacterial agents in Prahok products. In a study performed in Sweden, bacteria on samples were reduced by cleaning with water (Uhlig et al., 2017). Therefore, to rid the prahok product of bacteria and histamine, the prahok manufacturer should clean the fish multiple times with water.

ACKNOWLEDGEMENTS

This work was funded by Cambodia Higher Education Improvement Project (Credit No. 6221-KH).

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Research article

Influence of Native Trees on Soil Fertility at Rainforestation Sites in Mailhi, Baybay City, Leyte, Philippines

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Received 23 May 2023 Accepted 20 August 2023 (*Corresponding Author)

Abstract The Philippines is one of the few countries in the world which was originally and thoroughly covered by rain forest. The conversion of natural forests to agricultural land uses has led to land degradation. Soil is a vital resource for human survival in that it is the medium in which most plants grow, it cleans and stores water, detoxifies pollutants, and plays a key role in the regulation of the Earth's temperature. One of the intentions of rainforestation farming (planting of native tree species) is to regenerate soil fertility. However, the effect of native forest trees on soil fertility is still poorly understood. Hence, this study was conducted to evaluate the influence of native trees on the fertility status of the soil in Mailhi, Baybay City, Leyte, Philippines. Two adjacent sites were evaluated and sampled. These were the 22-year-old rainforestation farm and the nearby coconut plantation. At each site, a 20 m x 20 m plot for sampling purposes was established which was divided into four parts. In each part, four (4) composite soil surface samples were collected from a soil depth of 0-20 cm using a soil auger. Each of the four composite samples came from three (3) subsamples. The subsamples were mixed, and one-half kilogram was placed in properly labelled plastic bags and brought for processing and laboratory analysis. Results revealed that the rainforestation farm did not have an effect on water holding capacity and soil pH but significantly increased the organic matter and total N contents of the soil, when compared with the nearby coconut plantation. On the other hand, available P and exchangeable K were lower in the soil under native tree species compared to the coconut plantation. The results indicate that indeed, the native trees in the rainforestation site have caused important changes to the fertility status of the soils.

Keywords rainforestation, native trees, soil fertility

INTRODUCTION

The Philippines is one of the few countries in the world that was originally and thoroughly covered by rainforests (Schulte, 2002). In the past decades, forests were considered one of the most important resources of Leyte Island. But after the conversion of part of Leyte's original forest vegetation to secondary forest due to logging operations, kaingin or slash-and-burn cultivation, forest fire, and other natural phenomena such as pest diseases, and natural calamities, large parts of the upland areas were colonized by farmers (Contreras-Hermosilla, 2000). The conversion of natural forests to agricultural land uses has led to land degradation.

Asio et al. (2009) explained that soil is a vital resource for human survival in that it is the medium in which most plants grow, it cleans and stores water, detoxifies pollutants, and plays a key role in the regulation of the Earth's temperature. Soil is also the habitat of a multitude of soil organisms necessary for the cycling of elements and for keeping a healthy environment for human beings (Blum, 2007). Worldwide, soil resources are degraded at an unprecedented rate due to various human activities. Soil degradation means the deterioration of soil properties to the extent that the soil is no longer productive (Fullen and Catt, 2004).

The Philippines as one of the most severely deforested countries worldwide (Kummer and Turner, 994 as cited by Marohn, 2007), has officially adopted Rainforest Farming for its natural governing program. As defined in the Memorandum Circular No. 2004-06 issued by the Department of Environmental and Natural Resources (DENR), rainforestation farming is a concept in forest restoration, wherein only indigenous and endemic tree species are used as planting materials which include but are not limited to dipterocarp species, premium tree species, etc. It is a kind of reforestation whose aim is to preserve biodiversity expand Philippine forests and simultaneously sustain human food production. One of the intentions of rainforestation farming is to regenerate soil fertility. Asio and Milan (2002) reported that rainforestation farming is a helpful strategy to improve soil quality.

Therefore, this study was conducted to focus on the effects of native trees as rainforestation species on the nutrient status of the soil. Likewise, the study validated the hypothesis that rainforestation farming improves the soil nutrient status.

OBJECTIVE

The objective of this study is to evaluate the influence of native trees as rainforestation species on the fertility status of the soil and to determine the soil properties affected by planting native trees in the marginal upland site in Mailhi, Baybay City, Leyte, Philippines.

METHODOLOGY

Sampling Site Selection

The field study was conducted in 2016 in the Rainforestation site in Mailhi, Baybay City, Leyte (Fig. 1) about 23 km southwest of Baybay at 351 m asl elevation. A preliminary field survey was done to assess and select the sampling area. The rainforestation site was established twenty-two (22) years ago in 1995.

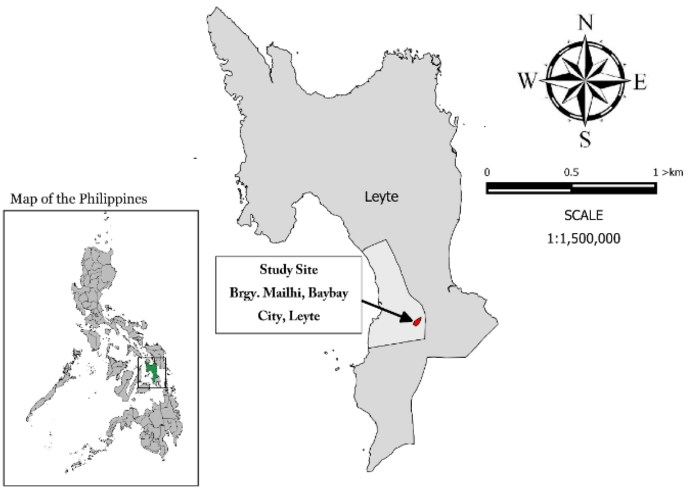


Fig. 1 Location of the sampling site in Mailhi, Baybay City, Leyte, Philippines

Note: the location was a marginal upland under the coconut plantation before the rainforestation site was established.

Soil Collection and Preparation

Two adjacent sites were selected. One is inside the rainforestation farm, and the other is under the coconut plantation which is typical of the area. A 20 m x 20 m plot was measured and then divided into four parts. In each part, four (4) composite soil surface samples were collected from the 0-20 cm soil depth using a soil auger. Each of the four composite samples came from three (3) subsamples. The subsamples were mixed, and one-half kilogram was placed in properly labelled plastic bags and brought for processing and laboratory analysis.

Laboratory analysis includes soil physical properties such as particle size distribution using the hydrometer method (ISRIC, 1995), water holding capacity (Alef and Nannipieri, 1995), and soil chemical properties such as soil pH analyzed potentiometrically using the soil-to-water ratio of 1:2.5 (ISRIC, 1995), soil organic matter obtained using Loss of Weight on Ignition (Schlichting et. al, (1995), total nitrogen using Micro-Kjeldahl method (ISRIC, 1995), available phosphorus analyzed using Bray 2 method (Bray and Kurtz, 1945) and exchangeable potassium using Metson method (Metson, 1956).

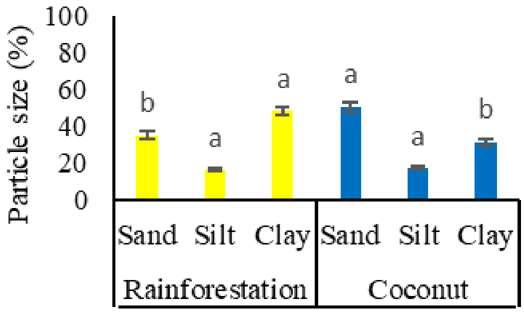
Data Encoding and Statistical Analysis

All data gathered were collated, encoded, and summarized using an electronic spreadsheet editor, Microsoft Excel 2013. The data were analysed using the Statistical Package for Social Science (SPSS version 20). The variability of the mean of soil properties was analysed using the one-way analysis of variance (ANOVA). Moreover, in a case where significant variations at $p \leq 0.05$ were identified, Tukey and Least Squares Differences (LSD) were carried out to compare means.

RESULTS AND DISCUSSION

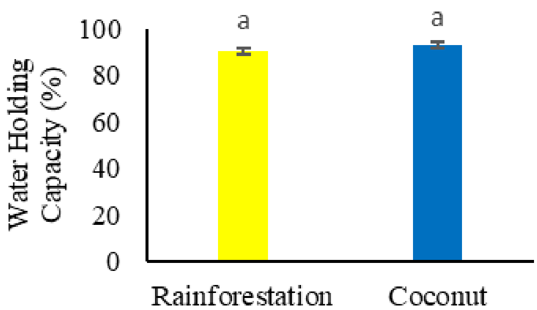
Soil Physical Properties

Figure 2 shows the particle size distribution of the two sampling sites. Results revealed that in terms of particle size distribution, the soil in the rainforestation had clay and sand contents of 48.3 ±1.98 % and 35.2 ±1.40 %, respectively, while the soil in the coconut plantation had 31.61 ±1.98 % and 50.78 ±1.40 %, respectively (Fig. 2). The soil textural class was clay and sandy clay loam, respectively. Based on the results of the statistical analysis, there was a significant difference ($p \leq 0.05$) between the soils in the rainforestation and coconut plantation in terms of the sand and clay contents but no significant difference in the silt.



Note: Values with different superscript letters(a-b) of particle size within the site are Significantly different at $p \leq 0.05$; N=32

Fig. 2 Particle size distribution of soil rainforestation farm and coconut plantation



Note: Values with a different superscript letter (a-b) of particle WHC within the site are significantly different at $p \leq 0.05$; N=32

Fig. 3 Water holding capacity in the soil in the rainforestation farm and coconut plantation

Clays have a large specific surface, often predominantly negatively charged, that retains water and nutrients. The clay itself may be a source of plant nutrients when it degrades. On the results, rainforestation soil had higher clay content which indicates good water and nutrient retention.

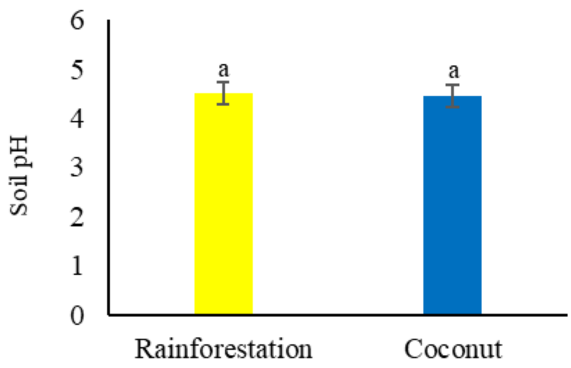
On the other hand, Fig. 3 reveals that the water holding capacity in the coconut plantation and the rainforestation farm had average values of 93.19 ±3.02 % and 90.21 ±3.02 %, respectively. This result suggests that the kind of land use has not yet influenced the water-holding capacity of the soil.

Soil Chemical Properties

Figure 4 shows slight variations in the pH of the soil. Results showed that the soils in the rainforestation site and the coconut plantation had comparable pH values. This indicates that the kind of land use has not yet caused a significant change in the soil reaction.

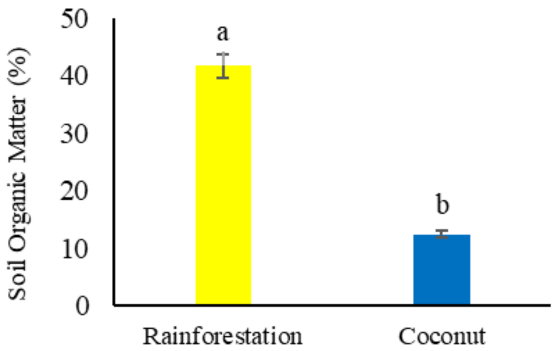
Soil properties are usually improved when trees are grown due to the increase in surface soil organic matter (Huxley, 1999). Organic matter refers to all decomposed, partly decomposed, and undecomposed materials of plant and animal origin (FAO, 2006).

Figure 5 shows that the soil in the rainforestation farm had higher organic matter content than the soil in the coconut plantation ($p \leq 0.05$). The higher amount of OM of the rainforestation farm could be due to its higher organic material addition in the form of litterfall than in the coconut plantation. The amount of OM in the soil depends on the litter fall (leaves, twigs, bark, etc.) contributed by trees as the primary vegetation in the area and the consequent losses through the decomposition of these materials.



Note: Values with different superscript letters (a-b) of soil pH s within the site are significantly different at p≤0.05; N=32

Fig. 4 Soil pH values of rainforestation farm and coconut plantation



Note: Values with a different superscript letters (a-b) OM within the site are significantly different at p≤0.05; N=32

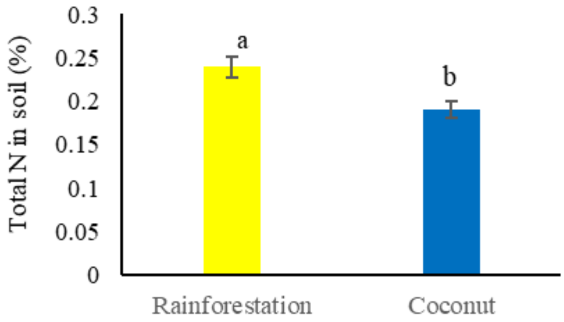
Fig. 5 Soil organic matter contents of the soils under rainforestation farm and coconut plantation

Soil Nutrient Status

Figure 6 shows higher soil nitrogen content in the rainforestation farm than in the coconut plantation ($p \leq 0.05$). It agrees with the study of Atup (2016) where total N contents of the soils under coconut plantation were low. Bande (2004) reported that during his study the soil in the rainforestation had 0.17% nitrogen content according to Landon (1991) the sufficiency ranges in soil, soils with values within the range between 0.1-.20 classified as low, while the nitrogen content in the current study had 0.24 ±.01 % classified as medium in sufficiency ranges in soil. The nitrogen content in the soil of rainforestation significantly improves. Apart from the application of N fertilizers, the main source of N in soils is the breakdown and humification of organic matter. The results on total N can therefore be attributed to the higher OM content of the rainforestation farm compared to the coconut plantation.

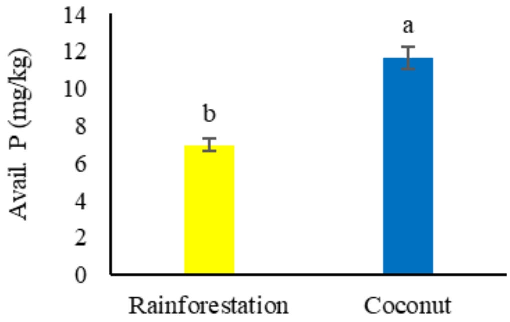
The soil in the coconut plantation had a higher available P level compared to the soil in the rainforestation farm (Fig. 7). The difference is significant at $p \leq 0.05$. This level of available P cannot easily be explained since P fertilizer application is not being practiced by the coconut owner (Fig. 7). This may be explained by the periodic burning that occurs in the coconut plantation. It is also possible that the cycling of P is faster in the coconut plantation. As coconut is burned, it produces ash which is a residual material produced when it is burned for energy production. According to Erich (1991), ashes were found to be more similar to conventional P fertilizer materials and the addition of coconut ashes to the surface soil in the coconut can increase the availability of P.

As can be seen in Figure 7, available phosphorus in rainforestation farms is 6.97 ±1.08 mg kg^{-1} while, in coconut plantations, it is 11.66 ±1.08 mg kg^{-1}. According to Landon (1991), the sufficiency ranges in soil, soils with values within the range between 5-9 mg kg^{-1} are classified as low. However, the presently available phosphorus in the soil of the rainforestation is higher than the previous result reported by Bande (2004) 3.4 mg kg^{-1} values range <5 classified as very low. This indicates an improvement in the availability of P due to the native trees.



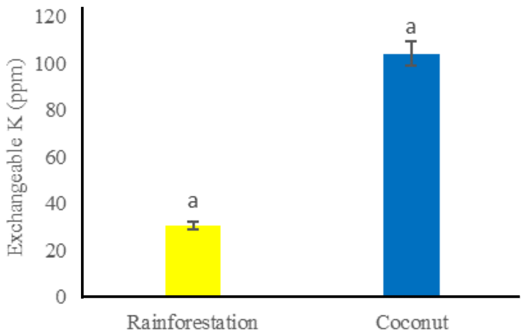
Note: Values with different superscript letters (a-b) of N within the site are significantly different at p≤0.05; N=32

Fig. 6 Total N (%) of soils in the rainforestation farm and under coconut plantation



Note: Values with a different superscript letter (a-b) of P within the site are significantly different at p≤0.05; N=32

Fig. 7 Available P of the soil in the rainforestation farm and under coconut plantation



Note: Values with the different superscript letter a of K within the site are significantly different at p≤0.05; N=32

Fig. 8 Exchangeable K of soils in the rainforestation farm and under coconut plantation

Figure 8 shows the average value of exchangeable potassium in the soils in the rainforestation farm which is 30.57 ±36.74 mg kg^{-1}. It is classified as very low available potassium in the soil based on Landon (1991). On the other hand, the average value of exchangeable K in the soil under coconut which is 104.16 ±36.74 mg kg^{-1} classified as medium in the sufficiency ranges in soil according to Landon (1991). In addition, Bande (2004) reported that the soil in the rainforestation during his study had 130.5 mg kg^{-1} which is higher than the current available potassium. This may be explained that during the current study, some potassium is still in the leaves and the uptake of the potassium is slow, while in the soil in the coconut plantation, the possible reason could be the periodic burning of the coconut husk. Coconut husk ash will never totally replace K fertilizer; however, it can recycle a substantial proportion of nutrients in a coconut plantation.

CONCLUSION

Planting native trees as rainforestation species has changed the fertility status of the soil after twenty-two (22) years from its establishment.

The results also revealed that the rainforestation farm when compared with the nearby coconut plantation did not have an effect on water holding capacity and soil pH but significantly increased the organic matter and total N contents of the soil. On the other hand, available P and exchangeable K were lower in the soil under native tree species compared to the coconut plantation. However, based on the previous results of Bande (2004) rainforestation increased total nitrogen and available P but decreased the exchangeable K of the soil.

ACKNOWLEDGEMENTS

We extend our gratitude to the Institute of Tropical Ecology and Environmental Management and the Department of Soil Science, Visayas State University, Baybay City, Leyte, for the support for this study. The authors would also express their sincere thanks to Professor Dr. Barry Noller and the Institute of Environmental Rehabilitation and Conservation (ERECON) for financial support to this study.

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Research article

Evaluation of the Effect of Alternate Wetting and Drying Irrigation on the Growth of Paddy Rice Plant Height Using a Logistic Model

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Received 21 June 2023 Accepted 10 September 2023 (*Corresponding Author)

Abstract Climate change poses a challenge to irrigation water supply, especially in the case of the continuous flood irrigation method (CF). Alternate wetting and drying irrigation (AWD) is a method of rice cultivation widely used as a mitigation measure for water consumption, without reducing yields. To better promote AWD in areas where water scarcity occurs in the future, it is necessary to quantify the impact of AWD on growth. The objective of this study was to evaluate the impact of AWD on rice growth under AWD irrigation using logistic curves. Subsequent analysis demonstrated that by using AWD, irrigation capacity was reduced by approximately 19%. Additionally, multiple regression analysis indicated that temperature, sunshine hours, and relative humidity had significant effects on plant growth. A growth model (RMSE = 2.98 cm to 3.82 cm) was generated by applying a logistic curve where the daily mean integrated values of meteorological data as explanatory variables and plant growth as the objective variable. Using the model, it was found that AWD increased the growth rate of the rice plant; however, rice plant growth in the initial period was lower compared to CF.

Keywords alternate wetting and drying, logistic model, plant growth model, climatic parameter, water management

INTRODUCTION

Rice is a staple food for more than half of the world's population. According to FAOSTAT (2021), rice is produced in more than 100 countries, mostly in Asia. Rice is usually grown in flooded fields until 7-10 days before harvest, which requires large amounts of water. Irrigation water for growing rice accounts for 34-43% of the world's total irrigation water (IRRI, 2014). Currently, climate change is increasing the intensity and frequency of extreme weather events. This is expected to change rainfall patterns, significantly affecting the hydrological cycle, and increasing the number of rice-growing regions that suffer from water scarcity (IPCC, 2021). In addition, rapid population growth and competing demands for water in Asian developing countries are causing irrigation water shortages. To ensure stable rice yields in water-scarce regions, more accurate and efficient water use in all areas of agriculture is required. More efficient water management methods, or water-saving technologies, are needed to meet the food demands of a rapidly growing population in an increasingly water-scarce world. One of the water-saving technologies developed for rice cultivation in Asia is alternating wet-dry (AWD) irrigation. This method was developed by the International Rice Research

Institute (IRRI) to reduce irrigation water use in paddy fields without reducing yield compared to continuous flooding (CF) irrigation. AWD, as recommended by IRRI, is an irrigation method in which the water level is lowered to 15 cm below the ground surface, then irrigated to the normal water level, and then the irrigation is stopped, and the water level is lowered to below the ground surface repeatedly. AWD is recommended to start a few weeks after transplanting rice plants and to keep them flooded from one week before to one week after flowering, but to continue until maturity. In various environments, AWD irrigation has been shown to save water by reducing evaporation due to soil drying, reducing reactive discharge due to pouring, and reducing subsurface infiltration without significantly affecting yield (Pandey et al., 2010; Taminato et al., 2016). Many studies have compared growth under AWD with that of CF, but the effects of AWD irrigation on the growth of paddy rice grasses have been reported to be different for different nitrogen application rates and growing environments (Yakubu et al., 2019; Zheng et al., 2020). Therefore, it is important to quantitatively evaluate the effect of AWD irrigation on the growth of rice plants to assess its impact more accurately on the growth of rice crops.

OBJECTIVE

The objective of this study is to quantitatively evaluate the impact of climatic factors on rice growth in AWD irrigation by using a logistic curves equation.

MATERIALS AND METHODS

Conditions of the Plant Growth Experiment

The experiments in this study were conducted from June to September 2022 in an experimental net room of the Setagaya Campus, Tokyo University of Agriculture in Japan, using 1/1400 pots (Fig. 1). The soil used for the experiment was loam soil, which was sampled at paddy fields in Nagano Prefecture, Japan. "Koshihikari" a cultivar of *Japonica* was used as a rice variety for the experiments. Rice was grown in two test plots: a CF plot irrigated with continuous waterlogging, which is a conventional irrigation method, and an AWD plot irrigated using the AWD method. Base fertilizer was applied at 4 kg/10a, 8 kg/10a, and 8 kg/10a of nitrogen (N), phosphorus (P), and potassium (K), respectively (the fertilizer standard for the "Koshihikari" variety), and additional fertilizer was applied at 3 kg/10a of both N and K, except P. The base fertilizer was applied after the first day of planting (June 1st), and the additional fertilizer was applied 15 to 20 days before the first day of ear emergence (July 23rd). Fertilizer was applied to the test soil, and three seedlings were transplanted into each pot. The pots were transplanted on 1st June 2022, and the transplanted pots were placed randomly in an experimental net room and rearranged every week to avoid differences in growth among locations. Drying was completed when cracks appeared on the soil surface and a gap between the pot and the soil could be seen.

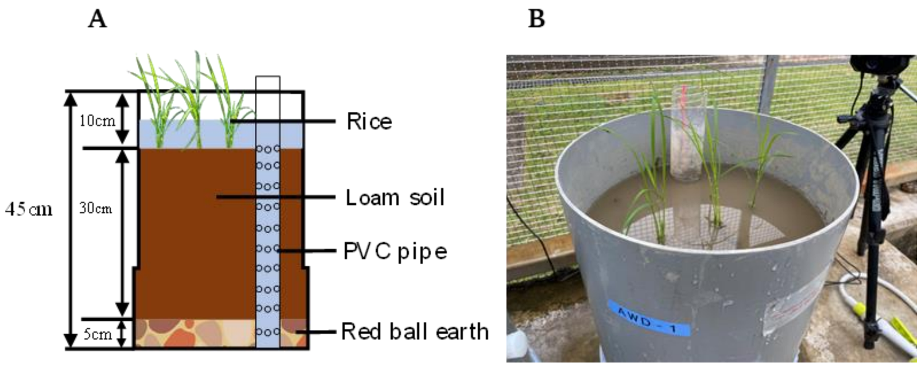


Fig. 1 Schematic diagram of experimental pot used in this study (A); rice plant pot (B)

Water Management During the Experiment

A 50 cm height polyvinyl chloride pipe having many holes on all sides was inserted into the soil to check the water level in the pot. In CF, the water level was checked twice daily, in the morning and evening, and irrigated when the water level reached 15 cm below the soil surface to maintain a waterlogging depth of 3 to 5 cm. In AWD, irrigation was continued from 2 weeks after transplanting until maturity, except during the mid-drying period and around the flowering period.

Collection of Growth and Climate Data

Plant growth data were collected weekly from 1st June to 15th September (106 days after transplanting). The growth-related parameters measured were rice plant height. Plant height was measured from the base of the stem at the soil surface to the tip of the extended leaves using a measuring tape. Meteorological data were measured using a weather station (U30-NRC Logger, Onset) in the net room for temperature, solar radiation, relative humidity, rainfall, and wind speed. The measurement period was 122 days from 1st June to 30th September after transplanting. The weather station was designed to record an average value for every hour.

Fitting a Logistic Curve

The logistic curve is an idealized curve that describes the pattern of population growth or growth of an organism with an upper bound such as resources (food) and is expressed by Eq. (1).

$$y = \frac{K}{1+b\cdot exp^{-ax}} \tag{1}$$

where *y* is the objective variable, *x* is the explanatory variable, *K* is the coefficient (Limit values of plant height), *and a* and *b* are coefficients of the logistic curve.

For each combination of explanatory variable (*x*) and objective variable (*y*), the coefficients *a* and *b* and the marginal value K were estimated. Fig. 2 shows a graph in which the marginal values are set to *K* = 1 and *a* and *b* are varied.

In a logistic curve, *a* is a constant that expresses the rate of increase of the curve on the rise with respect to the explanatory variables, and *b* is a constant that varies the period until the curve rises. The larger the value of *a* in the growth curve, the faster the growth rate increases, and the smaller the value of *b*, the earlier the growth starts. The combination of coefficients *a* and *b* makes it possible to estimate and evaluate the growth pattern.

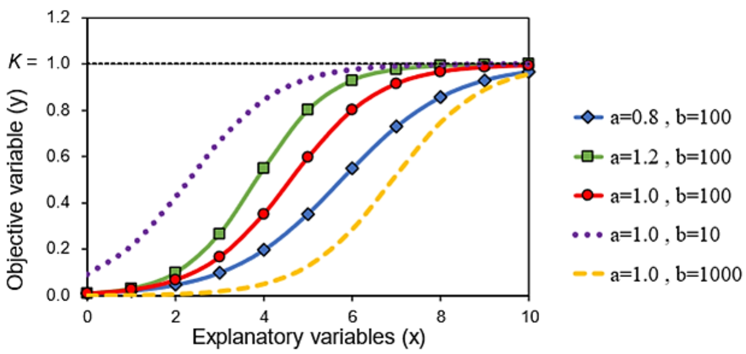


Fig. 2 Graph of logistic curves

Selection of Explanatory Variables

In this study, plant height growth (cm) in each test plot was used as the objective variable (*y*), and the daily mean integrated values in temperature (°C), sunshine hours (hr), relative humidity (%), and wind speed (m/s), which are generally considered to influence plant growth, were used as explanatory variables (x). Sunshine hours were calculated from the time when the direct solar radiation was 0.12 kW/m² based on the definition by Japan Meteorological Agency (2014). Multiple regression analysis was performed to select the explanatory variable (x) by normalizing the integrated values for temperature, sunshine duration, relative humidity, and wind speed, and standard partial regression coefficients were calculated. To evaluate the effect of AWD irrigation on the growth of plants, a model with a single explanatory variable was created to avoid complicating the equation, and the values of the coefficients a and b were compared. The evaluation was conducted by comparing the values of the coefficients a and b. To evaluate the accuracy of the logistic model, the Root Mean Square Error (RMSE) between the estimated and measured rice height.

RESULTS AND DISCUSSION

Comparison of Water Usage in CF and AWD

Figure 3 shows the average daily temperature and solar radiation in the net room during the growing period. The temperatures measured in the net room were higher than normal during the growing period, except in early June. Solar radiation was below the annual average value during the experiment (Fig. 3). The daily average wind speed was less than 1.0 m/s on most of the days, although a maximum instantaneous wind speed of 8 m/s was recorded during the typhoon.

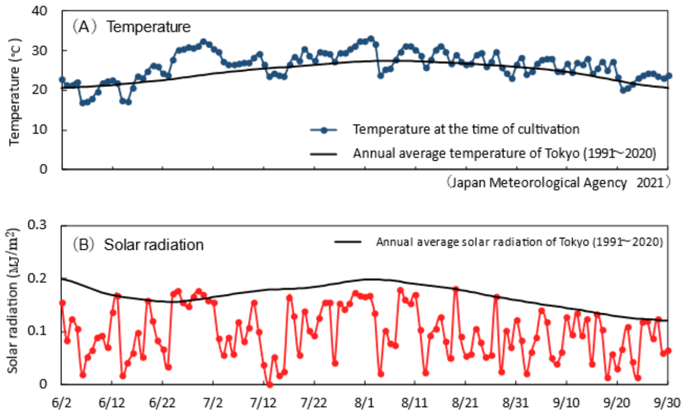


Fig. 3 Periodic change in average daily temperature and solar radiation

During the growing period, 116.5 L of water was used in CF and 94.2 L was used in AWD. The amount of water saving rate (%) using AWD was calculated such as [(116.5 L - 94.2 L) ×100] /116.5 L. This gives 19% water saved when the AWD method was used. The amount of irrigation and water applied to the pots from rainfall and irrigation during the trial is shown in Fig. 4. Comparing the AWD and CF treatments, the number of irrigations was reduced by half, and the irrigation rate was reduced by about 19%. There were large differences in irrigation rates during the vegetative growth stage (2nd June to 8th July) and ripening stage (2nd to 14th in September), but little difference was observed during the reproductive growth stage (21st July to 15th August).

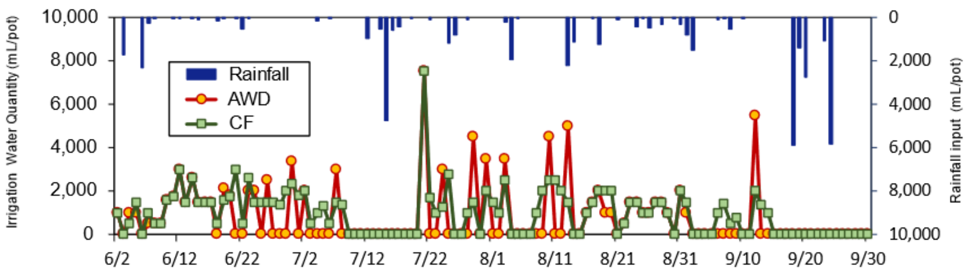


Fig. 4 Irrigation water and rainfall during the growing trial period

Plant Height Growth and Yield

The result of plant height and yield for CF and AWD irrigation methods is shown in Table 1. It was observed that the height of the plant at various stages of growth and yield was almost same for the both methods. However, from the obtained results it can be said that AWD is an efficient method of irrigation as it can produce the same results with respect to CF with less irrigation water.

Table 1 Plant height (cm) and yield (g/plant) as influenced by water management

Experimental plot	Days after transplanting			
	14	22	46	58
CF	27.3 ±1.2	47.5 ±1.6	91.0 ±4.4	95.6 ±2.8
AWD	27.6 ±0.6	44.9 ±2.9	92.7 ±3.3	94.6 ±3.0
	79	92	AH	Yield (g/plant)
CF	104.3 ±0.4*	105.6 ±2.1*	105.7 ±2.0*	17.9 ±0.5
AWD	101.0 ±0.8	101.7 ±1.1	101.9 ±1.1	17.5 ±1.8

The data are presented as mean ± standard deviation., AH: at harvest
** Indicates significant difference (p>0.05, Mann-Whitney's U test)*

Selection of Explanatory Climatic Parameter Variables for the Logistic Model

The results of the multiple regression analysis are shown in Tables 2 and 3. The absolute values of the standard partial regression coefficients were large for integrated temperature, integrated sunshine duration, and integrated relative humidity, while the value of integrated wind speed was small compared to other weather factors. Therefore, integrated wind speed was excluded, and integrated temperature, integrated sunshine duration, and integrated relative humidity were used as explanatory variables.

Table 2 Results of multiple regression analysis (I)
Based on cumulative temperature, cumulative sunshine hours, cumulative relative humidity, and cumulative wind speed as explanatory variables for grass growth in CF

Explanatory variable	Partial regression coefficient	Standard partial regression coefficient	*t*-value	Significance
Cumulative temperature	-0.3441	-9.7759	-5.7916	**
Cumulative sunshine hours	0.6915	4.7667	4.2914	**
Cumulative relative humidity	0.0543	4.5151	2.8732	**
Cumulative wind speed	9.2612	1.4098	2.4472	*

** Indicates significant difference (p<0.05) ** (p<0.01)*

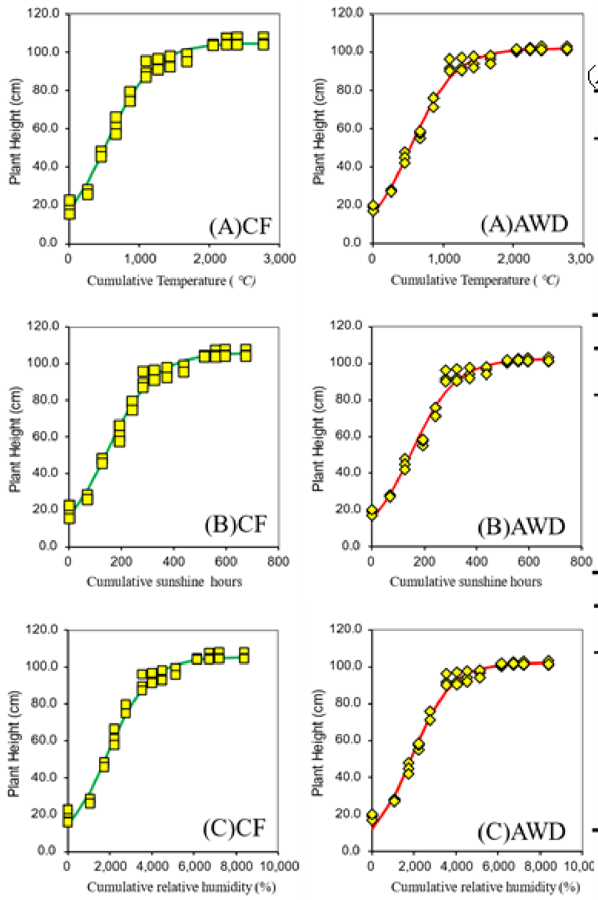
Table 3 Results of multiple regression analysis (II)
Based on cumulative temperature, sunshine hours, humidity, and wind speed as explanatory variables for plant height in AWD

Explanatory variable	Partial regression coefficient	Standard partial regression coefficient	*t*-value	Significance
Cumulative temperature	-0.3682	-10.6270	-5.6352	**
Cumulative sunshine hours	0.5908	4.1372	3.3338	**
Cumulative relative humidity	0.0667	5.6310	3.2073	**
Cumulative wind speed	11.4116	1.7645	2.7414	**

** Indicates significant difference (p<0.05) ** (p<0.01)*

Assessment of Plant Growth Patterns by Fitting Climatic Parameters in the Logistic Model

The values of each coefficient and its logistic curves are shown in Fig. 5. The logistic model with rice plant height as the objective variable and integrated temperature, integrated sunshine hours, and integrated relative humidity as explanatory variables had an accuracy of 2.98-3.82 cm RMSE. Comparing the value of *a* with that of CF, the growth rate is marginally better for AWD. However, the values of *K* and *b* indicate a smaller growth maximum and a longer period before growth begins compared to CF. Temperature, sunshine hours, and relative humidity were also almost the same. In other words, higher values of temperature and sunshine hours after transplanting would lead to faster growth and a longer growth initiation period, leading to differences in final plant height under AWD irrigation. In the study by Zheng et al. where final plant height was reported as similar results of this study, the temperature and sunlight hours after transplanting were probably low. On the other hand, Yakubu et al. reported that the final plant height was significantly higher than that of CF may be due to higher temperatures and sunshine hours after transplanting.



	CF	AWD
(A) Cumulative temperature		
K	104.8	101.8
a	3.03×10^{-3}	3.20×10^{-3}
b	5.06	5.61
RMSE	3.14	2.98
(B) Cumulative sunshine hours		
K	105.6	102.5
a	11.2×10^{-3}	11.8×10^{-3}
b	5.34	5.87
RMSE	3.37	3.82
(C) Cumulative relative humidity		
K	105.3	102.2
a	1.00×10^{-3}	1.06×10^{-3}
b	6.49	7.46
RMSE	3.53	3.34

Fig. 5 Fitting logistic curves (left: CF, right: AWD)

(A) cumulative temperature, (B)cumulative sunshine hours, and (C) cumulative relative humidity

CONCLUSION

This study was conducted to clarify the effects of climatic parameters on rice plant growth and yield using the AWD irrigation method. Based on the results of this study, the plant height and yield were similar to CF, however, AWD saved approximately 19% water compared to CF. A study of weather factors affecting paddy rice growth revealed that cumulative temperature, cumulative sunshine hours, and cumulative relative humidity have a significant impact on paddy rice growth. A logistic model was fitted with the objective variable as paddy plant height and the explanatory variables as integrated temperature, integrated sunshine hours, and integrated relative humidity. A logistic model created was accurate from 2.98 cm to 3.82 cm by RMSE. The results showed that AWD had a slightly better growth rate than CF, however, the initial growth of the rice plant was slower compared to CF.

ACKNOWLEDGEMENTS

We would like to thank Ms. Hiyori ISEKI and other undergraduate students who belong to the Department of Bio-production and Environment Engineering at the Tokyo University of Agriculture for their cooperation in the research. We also thank Dr. Eiji Matsubara of JIRCAS for introducing and explaining AWD irrigation in detail.

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Research article

Key Factors Influencing Education Disparity in the Low-Grown Tea Cultivation Community of Sri Lanka

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Received 12 July 2023 Accepted 20 September 2023 (*Corresponding Author)

Abstract Education indicators in Sri Lanka compare well with other South Asian countries relative to economic standards. However, educational disparities between living sectors (urban, rural, individual farming, and estate) remain, and children in the estate sector face the greatest challenges in improving educational attainment. Tea is a prominent industry in the estate sector, with several common types of tea plantation management, and the educational attainments of children whose parents work in this sector have been previously found to vary depending on the plantation management type in which their parents are involved. This study aimed to investigate the factors that contribute to children's educational disparities, specifically by focusing on the different management types within the low-grown tea cultivation community. This study adopted a two-step mixed-method analysis. The first step examined children's educational disparity among four living sectors across 9 tea-growing districts, using data from the Child Activity Survey 2008/09. The second step investigated educational disparities within three management types (plantation companies, private estates, and individual farming) of the tea cultivation community. Quantitative analysis employed cross-tabulation, while qualitative analysis relied on questionnaires and interviews. Six indicators of the children's environment were considered factors influencing educational disparities, with school enrollment status as an indicator of educational attainment. The quantitative analysis revealed that children in the estate sector had the lowest school enrollment rates, particularly those belonging to private estate communities. Contrary to the widely-held belief that household income is a significant factor in educational disparities, it was not found to be statistically significant within either the estate sector or the tea cultivation community. The qualitative analysis indicated that relocation is one of the factors contributing to the low enrollment status of private estate children. It also suggested that other indicators, such as household income, are interconnected factors contributing to educational disparities.

Keywords Sri Lanka, children, educational disparity, tea cultivation community

INTRODUCTION

Tea cultivation was introduced as an alternative to coffee during the colonial period in the 19th century. The laborer houses, known as "line houses," were originally built for seasonal workers migrating from South India for coffee harvesting. However, these houses continue to be used even after transitioning to tea cultivation, lacking adequate facilities and sanitation. This has raised concerns regarding children's development (SOMO 2006). In the 1970s, significant changes in the management structure of the tea cultivation community (referred to as "tea community") occurred due to land reforms, leading to a diversification of management types. Furthermore, economic reforms during the same period brought about overall economic and social development, which impacted the living conditions of those involved in tea cultivation[1].

Previous studies have focused on examining the impact of living environments on educational

[1] In the 1970s, the existing large-scale estates were nationalized and later bundled into 22 Regional Plantation Companies (RPC). In 1995, management was handed over to the private sector. Concurrently, Private Estates (PE) expanded the tea cultivation area and the number of Individual Farmers (IF) increased.

attainment in various fields, with household income considered a crucial factor influencing educational disparities. However, an interesting finding has been reported: despite a higher prevalence of low-income households among tea farmers, all children achieve good educational attainment within the tea community (Fukuda, 2023). This suggests that there may be additional factors beyond household income that are associated with educational disparities. Thus, based on the management types in the tea community, this study attempted to identify factors that affect education disparities among children and explored relations between "the living environments surrounding children" and "their educational attainment" by using quantitative and qualitative methods.

MATERIALS AND METHODS

Methods

This study employed a two-step mixed-method analysis to investigate factors contributing to educational disparities. In the first step, disparities among children in four living sectors across 9 tea-growing districts[2] were examined. The second step focused on disparities among three management types within the tea community. Quantitative and qualitative methods were employed. The quantitative analysis examined educational attainment differences among the living sectors and the tea community. The qualitative analysis was conducted to identify key factors contributing to education disparities and explore the relations between these factors, based on the different management types of tea cultivation in the low-grown tea areas. Six indicators of the living environment are "household income, house-head's education level, housing condition, the safety of living space, and child economic and housework", with "school enrollment" as an indicator of educational attainment.

Data Collection

In the first step, descriptive analysis was conducted using data from the Child Activity Survey 2008/09 (CAS 08/09), which represented all of Sri Lanka except the Northern Districts. For this study, 3,683 households and 6,119 children were extracted from the 9 districts where tea estates are concentrated. Three living sectors were originally defined: urban, rural, and estate. However, due to the significant increase in individual farming, the classification scheme was expanded to include urban, rural, individual farming, and estate. In the second step, questionnaires based on CAS 08/09 were distributed, and interviews were conducted between 2013 and 2015 in the Kotapola division of the Matara district. This area is known for tea cultivation conducted by regional plantation companies (referred to as "plantation companies" or "RPC"), private estates (referred to as "PE"), and individual farming (referred to as "farming" or "IF"). The sample included 302 housing units, with 103 from RPCs, 100 from PEs, and 99 from IFs across 11 villages. Additionally, interviews were conducted with school teachers, estate owners and managers, and local government officers.

RESULT AND DISCUSSION

Educational Disparity Among Living Sectors in Tea-Growing Districts

Despite Sri Lanka's focus on social policies, the estate sector in the country struggles with low educational attainment and quality of education (UNICEF 2014). Sri Lanka, formerly Ceylon, is a geographically diverse and naturally abundant island. Within the nine targeted districts of the CAS 08/09, the sample distribution was as follows: 473 children (7.9%) in urban areas, 3,352 children (54.8%) in rural areas,1,289 children (21.1%) in farming communities, and 1,005 children (16.4%) in the estate sector.

Table 1 presents the enrollment status and grade repetition/dropout experience of children. Out

[2] 9 districts include Kalutara, Kandy, Matale, Nuwara eliya, Galle, Matara, Badulla, Ratnapula and Kegalle.

of 6,119 children, 5,147 were attending school, 633 were not attending, and the status of 339 children was unknown. Notably, the estate sector had the highest percentage (15.5%) of children not attending school, compared to approximately 10% in other sectors.

Upon completing primary education, some students face challenges in continuing their education. When examining enrollment status based on the level of education, there were 4,562 children belonging to the compulsory education age group, 97% of whom attended school overall, while only 93% were in the estate sector. For children aged 15-17, 66% overall progressed to senior secondary education, but the rate dropped significantly to 27% in the estate sector.

Table 1 Enrollment status and grade repetition/dropout experience

Living sectors	Enrollment status			Grade repetition / Dropout experience		
	Attend	Non-Attend	Total	Non-experience	Experience	Total
Urban	401 (89.3%)	48 (10.7%)	499	408 (88.9%)	51 (11.1%)	459
Rural	2,855 (90.0%)	317 (10.0%)	3,172	2,823 (87.4%)	407 (12.6%)	3,230
Farming	788 (89.9%)	144 (10.1%)	932	692 (89.9%)	692 (10.2%)	971
Estate	1,103 (84.5%)	124 (15.5%)	1,227	113 (71.3%)	1,133 (28.7%)	1,262
Total	5,147 (89.0%)	633 (11.0%)	5780	5,056 (85.4%)	866 (14.6%)	5,922

Furthermore, 5,056 children had no experience of grade repetition or dropping out, while 866 children had such experiences. The proportion of children with these experiences varied across sectors, with 11% in urban, 13% in rural, 10% in farming, and a significantly higher 29% in the estate sector. These findings highlight significant differences in the educational attainments of children between the estate sector and other sectors.

Impact of Household Income on Educational Attainment

Past studies have often mentioned that out-of-school attendance is deeply rooted in structural inequalities and disparities. Extensive research has been conducted in various fields to investigate the impact of the family environment on educational attainment, with household income identified as one of the key factors affecting educational disparity (Harsh and Paul 2007).

The average monthly income for all 3,682 households is approximately Rs. 16,000, with urban Rs. 25,595, rural Rs. 17,075, farming Rs. 20,765, and estate Rs. 10,585. In terms of income groups, approximately 50% of households in urban areas belonged to the high-income group, while in rural and farming areas, it ranged from 30% to 40%. However, in the estate, only 4% of households belonged to the high-income group, and a significant 59% lived under 10K, indicating that estate children are much more likely to face poverty than those who live in other sectors.

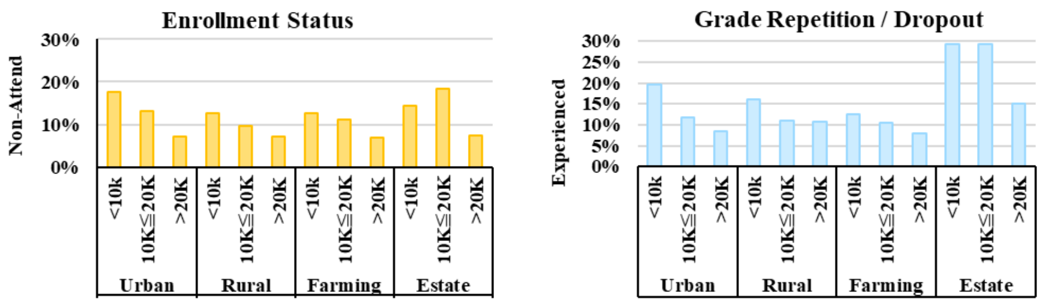

Fig. 1 Educational attainment within living sectors

Figure 1 shows the relationship between household income and educational attainment. In non-estate sectors, higher household income is associated with improved enrollment and reduced grade repetition/dropout rates. However, this pattern is not observed in the estate sector. Further analysis reveals that while enrollment status and grade repetition/dropout status are statistically significant overall, they are not significant within the estate sector. This suggests that factors other than income are related to the educational disparities within estates.

Educational Disparity within Tea Cultivation Communities

Sri Lanka is divided into 25 districts and 9 provinces, with 331 divisions and 14,021 GN divisions. The study focuses on the Kotapola division in the Matara District, which consists of 37 GN divisions. Data collection and interviews were conducted in four selected divisions characterized by low living conditions. This area is known for its low-grown tea, with diverse management types due to historical backgrounds. In contrast to the upcountry, where large tea plantations were established on hillsides during the colonial era, tea cultivation in the low-grown tea areas has evolved on land adjacent to the villages (Wenzlhuemer, 2008).

Table 2 provides an overview of households and children categorized by management types, including the enrollment status of children. The cross-tabulation analysis revealed a statistically significant difference among the three types of management communities. It is noteworthy that children living on private estates had lower enrollment rates compared to the other management types, with 22.4% of children in the private estate community not attending school. In contrast, only 6.9% of children in the RPC community and none in the IF community were not attending. (Fukuda, 2023)

Table 2 Family overview and enrollment status by management types

Management types	Enrollment status	Boy	Girl	Total	Enrollment status	
					Attend	Non-attend
Plantation company (RPC)	103	106	90	196	175 (93.1%)	13 (6.9%)
Private estate (PE)	100	117	88	205	149 (77.6%)	43 (22.4%)
Individual farming (IF)	99	72	61	133	131 (100.0%)	-
Total	302	295	239	534	455 (89.0%)	56 (11.0%)

Living Environments and Their Impact on Educational Attainment

Figure 2 illustrates the relationship between six living environment indicators and children's educational attainment. The data indicates an overall trend where lower attendance is linked to factors such as low household income, lower education levels of the household head, lack of ownership or residing in a line-house, reduced security of living space, and extended hours of activities.

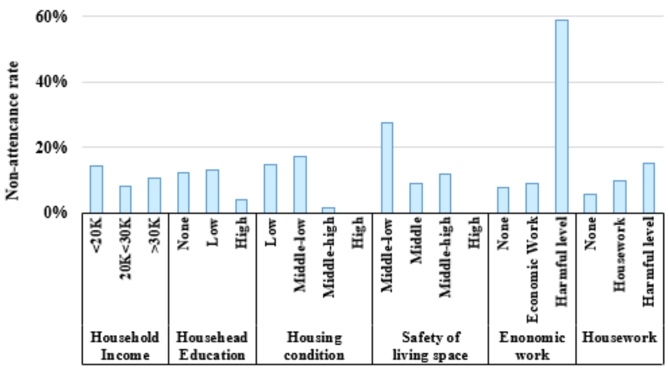

Fig. 2 Impact of living environments on educational attainments

Table 3 presents the statistical results of the cross-tabulation analysis, investigating the relationship between the living environments and children's enrollment status within the tea community. The findings indicate that within tea communities, household income alone does not significantly impact educational disparities. Instead, factors such as the education level of the household head, housing condition, safety of the living space, and children's economic activities show a significant association with educational disparities. These findings suggest that some of these factors may play more influential roles in shaping educational disparities.

Table 3 Relationship between living environments and enrollment status

Family environments		Living conditions		Child activities	
Household Income	Head Education	Housing	Safety	Economic work	Housework
No-significant	Significant	Significant	Significant	-	No significant

χ-square test (p=0.05): Significant = Different, No significant =No different
**Economic work: Due to the sample size, statical analysis could not be conducted.*

Factors Behind Educational Disparity

Table 4 provides the comparisons of the six environmental factors. It indicates that children living in the IF community engaged in economic and housework to some extent, but they had favorable housing conditions and living conditions. Children living in the RPC community had a lower household income and housing conditions, but they fared relatively better in the other four environmental factors. Children living in the PE community had moderate household income and housing conditions, but they experienced poorer levels in the remaining four environmental factors. This discrepancy within the tea community can be attributed to the social structure of each management type.

Table 4 Quality of living environments within tea cultivation communities

Management type	Family environments		Living conditions		Child activities	
	Household income	Head education	Housing	Safety	Economic work	Housework
Plantation company (PC)	Low	Middle	Low	Middle	No	Low
Private estate (PE)	Middle	Low	Middle	Low	High	High
Individual farming (IF)	High	High	High	High	Middle	Middle

The social structure varies according to management type. Individual farmers (IFs) are self-employed and rely on income from tea harvesting and side jobs. They have higher average incomes, but a significant number of them fall below the poverty line. In contrast, wages for workers in RPCs are determined through wage board discussions involving the RPCs, trade unions, and the government. In contrast, PE workers' salaries are decided individually by each estate, potentially resulting in lower wages and fewer benefits, particularly in medium and small PEs. The higher average household income on PEs compared to RPCs can be attributed to multiple-income earners

Housing types also differ. IF households typically own their housing, while most children in the estate community live in line houses provided by the estate. A notable difference between the RPC and PE households is their right to residency. Those in the RPCs can stay in line houses after retirement, even if their family members are not working. In contrast, PE residents can only stay if they or their family members are employed, except for some large estates. The better housing arrangement in PEs compared to RPCs can be partly attributed to some PE workers commuting from outside the estate and owning their own homes. Additionally, the education environments also vary. Children from the IF community have more opportunities to access education and attend relatively large schools in town. Conversely, children in the RPC and PE communities have fewer opportunities to access education. Children in the RPC community primarily attend estate schools (with school buses for distant homes). Similarly, children in the PE community typically attend schools located nearby (Fukuda, 2023).

Reasons for School Non-attendance

As shown in Table 2, all of the IF children were attending school, while 13 RPC and 43 PE children were not attending. Table 5 provides the main reasons explained by the families of 39 non-attending children. The most common reasons were 'financial difficulty' (10 children), 'relocation between estates' (9), and 'child dislikes school/study' (7). Other reasons included 'child labor' (5), 'inadequate documents and procedures' (4), and 'disability' (4).

Table 5 Reasons for school non-attendance

	Financial difficulty	Relocation	Adjustment to school	Economic activities	Inadequate paperwork	Disable	Others	No answer
RPC	3	2	3	2	-	3	-	1
PE	7	7	4	3	4	1	4	16

Table 6 Enrollment status: impact of housing ownership and relocation

	RPC	PE	Total		RPC	PE	Total
Attend	174 (100.0%)	148 (100.0%)	45 (100.0%)	Attend	90 (100.0%)	84 (100.0%)	174 (100.0%)
Doesn't own house	154 (85.5%)	110 (74.3%)	264 (58.3%)	Relocated	1 (1.1%)	42 (50.0%)	43 (24.7%)
Owns house	20 (11.5%)	38 (25.7%)	189 (41.7%)	No relocation	89 (98.9%)	42 (50.0%)	158 (75.3%)
Non-Attend	13 (100.0%)	43 (100.0%)	56 (100.0%)	Non-Attend	9 (100.0%)	24 (100.0%)	33 (100.0%)
Doesn't own house	9 (69.2%)	40 (93.0%)	49 (87.5%)	Relocated	2 (22.2%)	18 (75.0%)	20 (87.5%)
Owns house	4 (30.8%)	3 (7.0%)	7 (12.5%)	No relocation	7 (77.8%)	6 (25.0%)	13 (12.5%)
Total	187	191	509	Total	99	108	207

Furthermore, six estates managers, five school teachers, and five GN officers described the challenges faced by the children. They mentioned that children growing up on the estates face economic disadvantages, as their families have limited awareness of education due to their education level. Consequently, workers, particularly those employed in PEs, often move from one estate to another in search of a better salary, which is an obstacle to children's education. In some cases, children stop attending school due to various factors, such as incomplete procedures by parents, financial constraints within their families, or difficulties in adapting to new schools. These findings suggest that the family's economic status and migration between estates impact children's enrollment status. As shown in Table 2, there was no significant difference between household income and school attendance status, but there was a significant relationship between housing conditions and school attendance status. Table 6 presents the relationship between housing ownership and enrollment status, as well as the relationship between relocation and enrollment status. The cross-tabulation analysis revealed statistically significant findings within the tea community overall. It is noteworthy that there is an observed educational gap based on residence rights and relocation experiences. Specifically, 58.3% of the school-attending children lived in line houses, while 87.5% of the non-attending children did. Among non-attending children on PEs, only 7.0% belonged to families who owned their housing, while 93.0% lived in line houses. As for relocation, overall, 24.7% of school-attending children had experienced relocation, while 60.6% among non-attending children. Among non-attending children in PEs, 25.0% had not experienced relocation, but 75.0% had.

Exploring the Process of Educational Disparity by Interrelated Living Environments

The cross-tabulation analysis conducted in this study revealed that household income was not directly associated with educational disparity in the estate sector or the tea community. However, insights from interviews highlighted the link between household income and residential mobility.

Figure 3 illustrates the process of educational disparities by the living environments surrounding children, with a focus on residency rights, which were found to be statistically significant and emphasized in the interviews. Families without residency right tend to move from one estate to another, influenced by their lower income. That is families with lower incomes frequently relocate between estates in search of better employment conditions. These relocations may require children to change schools, which negatively impacts their educational attainments because of inadequate paperwork, additional cost, or difficulty adjusting to a new school environment.

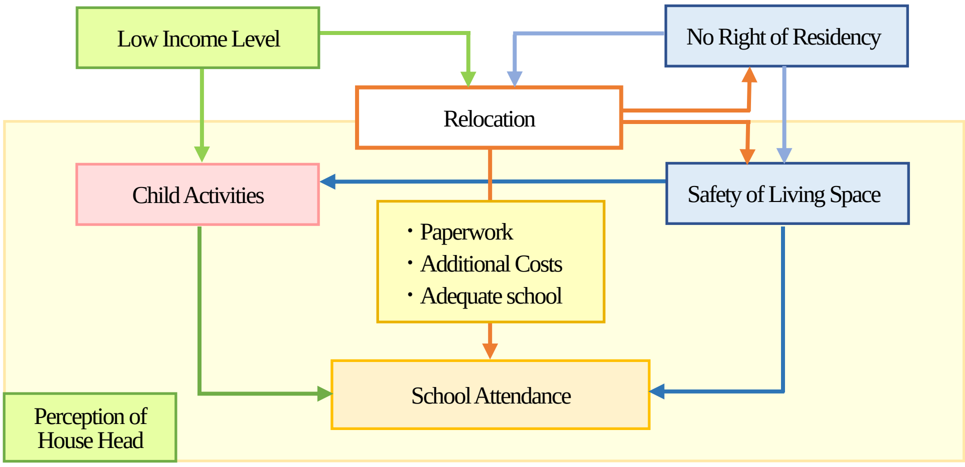

Fig. 3 Process of educational disparities in private estate communities

Furthermore, families without a residential right may be less willing to invest in housing and necessary facilities, which is potentially leading to unsafe living spaces and an increase in the time the children spend helping with housework, in turn negatively affecting their education attainment. Moreover, children often play an important role in low-income families, not only as income providers but also as chore providers. Long hours of engagement in these activities can affect their learning time and is one of the factors that widen the educational gap. families with low educational backgrounds often lack a concrete understanding of the importance of education or a knowledge of proper sanitation or are unaware of the adverse consequences of child labor, which give a negative impact on children's education attainment. By exploring the influence of these interrelated living environments on educational disparity, we gain valuable insights into the challenges that hinder equitable access to education.

CONCLUSION

This study employed a mixed-method analysis, combining quantitative and qualitative approaches, to examine the factors contributing to educational disparities. The quantitative analysis revealed that children in the estate sector, particularly those on private estates, had the lowest school enrollment rates.

Contrary to the prevailing belief that household income is a significant factor in educational disparities, the findings indicated no statistically significant relationship between household income and educational disparities within the estate sector or the tea community. However, the qualitative analysis suggested that relocation is one of the factors influencing the low enrollment status among children in private estates. Furthermore, it revealed the presence of other interrelated factors, including household income, which collectively contribute to the differences in enrollment status among the three management types.

One limitation of this study was the absence of questions about relocation in the initial questionnaires. Further research could focus on comparing the factors that contribute to education disparities between the high-grown and low-grown tea areas of Sri Lanka.

ACKNOWLEDGEMENTS

I would like to express my heartfelt gratitude to all the interviewees who generously dedicated their valuable time to participate in this study. I am deeply grateful for the support, assistance, and valuable advice provided by the individuals who contributed to this research.

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Research article

Growth and Mineral Uptake of *Moringa oleifera* Lam. in Low-Permeability Soils at Different Salinity Levels

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Received 24 July 2023 Accepted 1 October 2023 (*Corresponding Author)

Abstract This study investigated the uptake of minerals by moringa (*Moringa oleifera* Lam.) and examined the salt tolerance of moringa under different salinity treatments (0, 4, 8, and 16 dS/m). The effect of root growth on soil permeability at different salinity levels was also examined. Moringa showed significant negative effects of salinity on growth parameters at 8 dS/m. Significant growth inhibition was observed for moringa at 16 dS/m. The higher C/F ratios, calculated as (assimilated organ mass)/ (non-assimilated organ mass), in moringa in the 16 dS/m treatment may be due to the inhibition of nitrogen uptake by the roots, causing photosynthesis in the leaves to produce assimilates to sustain the body of the tree. In each moringa organ, the Na concentration increased as salinity increased. Significant differences in concentration were observed for Ca and K in leaves and Fe in stems at different salinity levels. The correlation analysis showed that only Mg and P in the branches and Fe and Mg in the stems were significantly negatively correlated with Na concentration, suggesting that increases in Na concentration cause limited inhibition of mineral uptake by moringa. A significant positive correlation was found between Na and P in the roots. It was suggested that moringa roots may have promoted growth by increasing P uptake in response to increased Na. There was a positive correlation between the length of moringa main roots and saturated hydraulic conductivity. The saturated hydraulic conductivity of the soil without moringa cultivation was 1.1×10^{-6} cm/s, and moringa root growth increased the saturated hydraulic conductivity by two orders of magnitude (10^{-4} cm/s) at 0 and 4 dS/m and by one order of magnitude (10^{-5} cm/s) at 8 and 16 dS/m.

Keywords moringa, soil salinity, root growth, mineral uptake, soil permeability

INTRODUCTION

Soil salinity is a major threat to land globally, and 833 million ha of soil is affected by salt (FAO, 2021). Coastal paddy fields in the Tohoku region were salinized by the tsunami caused by the Great East Japan Earthquake. In addition to natural disasters, coastal areas are also said to be widely affected by salt damage due to sea level rise caused by climate change. In addition, it has been calculated that the saline front will move up to 20 km upstream of the Mekong Delta in the 2030s due to climate change (Khang et al., 2008).

Saline soils need to be amended by improving soil permeability to discharge salts from soil layers. It is known that tree roots, such as *Alnus* Mill. roots, enhance soil permeability (Vergani and Graf, 2015). However, other studies suggest that the effect of trees and roots on soil permeability depends on soil type, soil and land use history, and vegetation cover type (Bonell et al., 2010). Therefore, the effect of each plant on the improvement of soil permeability should be investigated.

Moringa (*Moringa oleifera* Lam.) is highly salt tolerant, and all parts of moringa can be used for multiple purposes (Horn et al., 2022). Moringa seedlings survived up to 8 dS/m with a slight reduction in biomass chlorophyll a, crude protein, and mineral concentrations with increasing salinity (Nouman et al., 2012). Two-month-old moringa transplants might be NaCl tolerant up to 8 dS/m (Elhag and Abdalla, 2014). Farooq et al. (2022) investigated the impact of various salinity levels on the root attributes of moringa and revealed higher salinity levels (7.5 dS/m and 11.5 dS/m) significantly minimized the root surface area compared to 1.5 dS/m and 3.5 dS/m. These results show that salt tolerance has been studied, but a comprehensive assessment of mineral concentrations of moringa under saline conditions has not been completed. Research on root growth parameters has been conducted; however, the effect of moringa root growth on the improvement of soils has not been examined.

OBJECTIVE

This study investigates the growth and mineral uptake of moringa and the salt tolerance of moringa at different salinity levels. Root growth and its effect on soil permeability in soils with different salinity levels were also examined.

METHODOLOGY

A cultivation experiment was conducted in a greenhouse for two months. Root boxes (width: 60 cm, height: 40 cm, depth: 10 cm) made of acrylic plates were used for the cultivation experiments. The root boxes were filled with a 20-cm-deep plow layer and a 10-cm-deep plow layer, as shown in Table 1. The soil texture of paddy soil was CL (Clay Loam) and the soil hydraulic conductivity of two layers of soil as shown in Table 1 was 1.1×10^{-6} cm/s.

Table 1 Physical properties of soils in the cultivation experiment

	Dry bulk density (Mg/m^3)	Particle density (Mg/m^3)	A mixing ratio of experimental soil	
			Paddy soil (CL)	Gravel
Plow layer	1.2	2.53	100%	0%
Plow sole layer	1.7	2.59	75%	25%

The soils were subjected to four salinity treatments: one without NaCl (0 dS/m) and three with NaCl added to the soil to adjust the soil salinity to EC_e = 4, 8, and 16 dS/m. Indian moringa seeds were used, and a total of 24 sample trees were grown, with six moringa tree replications in each salinity treatment. 10 mm irrigation water was supplied when the soil surface was dried, and no fertilizer was used.

Growth parameters (tree height and dry matter (DM) weight of leaves, branches, stems, and roots) were measured. Dry matter weights were determined after samples were oven-dried at 80 °C for 48 hours. The C/F ratio was calculated as the (assimilated organ mass) ÷ (non-assimilated organ mass), and the aerial C/F ratio was calculated as (assimilated organ mass) ÷ (aboveground non-assimilated organ mass); these ratios were used as indices to describe the structure of material production systems (Nomoto and Yokoi, 1981).

The mineral concentrations in each organ of the harvested moringa were determined by ICP optical emission spectrometry (Varian, Vista-MPX). A soil permeability experiment was performed after harvesting the aboveground portions of the moringa plants, with the roots remaining in the root box. The root box was placed in a bucket filled with water and it was capillary saturated, then water was ponded to a depth of 10 cm, and changes in water level over time were recorded. The measured data were substituted into Darcy's equation to obtain the saturated soil hydraulic conductivity. ANOVA was performed at the 5% significance level for the height, dry matter, and mineral concentration of each part of moringa grown under each salinity condition. When the ANOVA showed significant differences, multiple comparisons (Tukey test) were used to test between samples.

RESULTS AND DISCUSSION

Effect of Salinity Treatments on Growth Parameters

Significant differences were found in tree height, root dry matter weight, total dry matter weight, and the C/F ratio under different salinity levels (Table 2). There were no significant differences between 0 dS/m and 4 dS/m in any of the parameters. All the parameters except the CF/ratio at 8 dS/m had significantly smaller values than those at 0 and 4 dS/m. All the parameters except the C/F ratio at 16 dS/m had significantly smaller values than those at the other salinity levels. The C/F ratio at 16 dS/m (0.346) was significantly larger than that at 4 dS/m (0.164). Noumen et al. (2012) showed that moringa was able to survive under 8 dS/m conditions with little reduction in nutritional value. Elhag and Abdalla (2014) showed that moringa is salt tolerant up to 8 dS/m, with significantly lower values for tree height and leaf dry weight at 16 dS/m. Farooq et al. (2022) also concluded from their experiment results that germination rate, root surface area, and aboveground growth are largely unaffected at salinity levels up to 3.5 dS/m. Our results were similar to those of previous studies.

Table 2 Effects of salinity treatments on growth parameters

Different letters indicate significant difference at $p < 0.05$ (DM: dry matter)

Salinity treatment	Tree height (cm)	Leaf DM (g)	Branch DM (g)	Stem DM (g)	Root DM (g)	Total DM (g)	C/F ratio	Aerial C/F ratio
0 dS/m	53.5±7.9ab	2.020±0.35	0.977±0.20	2.470±0.62	9.45±2.20ab	14.9±2.6ab	0.164±0.02a	0.711±0.10
4 dS/m	63.5±7.1a	2.390±0.49	1.110±0.28	2.960±0.73	10.20±1.40a	16.7±2.1b	0.164±0.01a	0.650±0.10
8 dS/m	52.5±8.5ab	1.890±0.70	1.030±0.40	2.760±1.20	4.15±0.88b	9.78±2.5a	0.199±0.04ab	0.555±0.04
16 dS/m	27.5±3.9b	0.812±0.20	0.307±0.12	0.650±0.24	1.42±0.40c	3.18±0.1c	0.346±0.09b	0.925±0.20

Mean ± standard deviation (Data adopted from Kume et al., 2023)

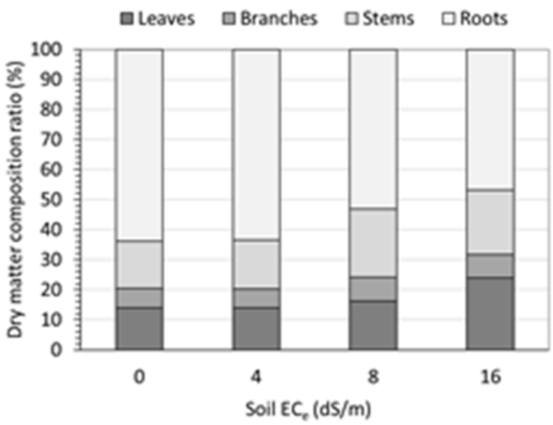

Fig. 1 Composition of dry matter weight by the organ of moringa grown at different salinity levels

The compositions of moringa organs at 0 dS/m and 4 dS/m were similar, while the percentages of moringa organ dry matter weights at 8 dS/m were approximately the same as those at 0 dS/m, with a 7% increase in stem dry matter weight and a 10% decrease in root dry matter weight (Fig. 1). Moringa in the 16 dS/m treatment had 10% greater leaf dry matter weight, 2% greater branch dry matter weight, 5% greater stem dry matter weight, and 17% lower root dry matter weight than moringa in the 0 dS/m treatment, with a significant difference in the C/F ratio (0.164 at 0 and 4 dS/m compared to 0.346 at 16 dS/m). The aerial C/F ratios were not significantly different among the salinity levels. Carbon is acquired by aboveground plant parts, and nitrogen is acquired by belowground plant parts (Hirose, 1988). Individuals showing abnormally high C/F ratios are thought to die due to an imbalance between assimilated and non-assimilated organs (Higo, 1987). Moringa in the 16 dS/m soil, where growth inhibition was observed, showed a significantly higher C/F ratio than moringa in the other treatments, and that photosynthesis in the leaves produces assimilates to sustain the body of the tree.

Mineral Uptake by Moringa

The Na concentrations in the organs were significantly different among the different salinity levels (Table 3). In each moringa organ, the Na concentration increased as salinity increased. Tukey's test showed no significant differences in Na concentration between the 0 dS/m treatment and 4 dS/m treatment for all organs. In leaves, branches, and stems, the Na concentrations at 8 dS/m and 16 dS/m were significantly different from those at 0 dS/m. For roots, the Na concentration at 8 dS/m was significantly different from that at 0 dS/m and 4 dS/m, and the Na concentration at 16 dS/m was significantly different from those at the other salinity levels.

Table 3 Mean values of mineral concentrations in each organ of moringa grown at various salinity levels

*Different letters indicate significant difference at $p < 0.05$ (*DM*: dry matter)*

	Salinity treatment	Na mg/g DM	K mg/g DM	Ca mg/g DM	Fe mg/g DM	P mg/g DM	Mg mg/g DM	Cu µg/g DM	Zn µg/g DM
Leaves	0 dS/m	1.110±0.21a	24.9±1.4a	8.69±0.89ab	0.166±0.05	7.72±0.86	3.18±0.25	11.3±2.7	50.1±17.0
	4 dS/m	0.958±0.13a	21.7±1.9a	10.10±1.20a	0.122±0.09	6.24±0.70	2.58±0.35	10.3±0.9	44.8±8.8
	8 dS/m	2.410±0.30b	18.5±0.7ab	7.90±0.36ab	0.183±0.05	5.79±0.91	2.66±0.40	13.8±4.2	82.7±25.0
	16 dS/m	1.890±0.35ab	14.2±2.1b	6.10±0.50b	0.120±0.02	5.42±0.87	2.61±0.36	8.03±0.7	34.9±4.3
Stems	0 dS/m	0.574±0.08a	24.2±2.3	11.10±1.4	0.538±0.08a	7.21±0.86	3.21±0.50	9.82±0.9	55.8±6.6
	4 dS/m	1.570±0.16a	18.9±1.3	9.95±1.10	0.479±0.01a	6.58±0.60	3.12±0.31	10.3±1.4	57.8±13.0
	8 dS/m	3.930±0.68b	19.5±2.8	10.90±1.10	0.115±0.05b	5.02±0.10	2.14±0.21	11.3±1.7	69.3±20.0
	16 dS/m	4.670±0.62b	25.5±7.0	10.10±0.67	0.142±0.02b	6.38±1.20	1.94±0.21	14.1±2.2	73.3±13.0
Branches	0 dS/m	0.499±0.10a	30.2±1.8	10.50±1.20	0.171±0.04	9.13±0.35	1.73±0.28	13.2±1.7	80.0±18.0
	4 dS/m	1.240±0.15a	25.9±1.3	11.80±1.20	0.109±0.01	8.66±0.43	1.68±0.21	9.11±2.5	56.4±21.0
	8 dS/m	3.870±0.80b	31.6±3.7	8.33±0.52	0.114±0.04	6.66±0.80	1.07±0.10	6.02±0.7	41.0±4.6
	16 dS/m	4.680±0.62b	24.5±3.0	10.60±2.60	0.172±0.08	8.04±1.30	1.23±0.12	8.83±2.5	48.6±8.9
Roots	0 dS/m	0.768±0.11a	13.7±1.1	6.23±0.95	0.716±0.03	4.38±0.32	3.25±0.24	14.7±1.2	91.3±17.0
	4 dS/m	1.550±0.12a	12.4±0.7	5.30±0.59	0.560±0.01	5.00±0.27	2.31±0.15	12.6±1.6	63.2±14.0
	8 dS/m	5.650±0.75b	13.8±1.3	5.36±0.74	0.714±0.07	5.02±0.47	2.38±0.13	12.4±0.1	75.9±11.0
	16 dS/m	9.070±0.84c	13.3±2.0	5.58±0.48	1.040±0.20	6.68±1.00	2.89±0.33	15.5±1.8	78.9±15.0

Apart from Na, significant differences in concentration were observed for Ca and K in leaves and Fe in stems. For these values, the concentration decreased with increasing salinity. Cu, Mg, P, and Zn did not show significant differences among organs or salinity levels. In leaves, the Na concentration increased and the K concentration decreased with increasing soil salinity. Mg and P in the branches and Fe and Mg in the stems showed a decreasing trend in response to increasing Na (Table 4). The P concentration increased with increasing Na concentration in the roots. There was no correlation between Na and other minerals. The P concentration was significantly correlated with various ion concentrations in all organs. The P concentration was significantly positively correlated with Ca, Cu, Fe, and K in leaves; with Ca, Cu, Fe, Na, and Zn in branches; with Fe, K, and Mg in stems; and with K, Mg, and Na in roots. In branches, the Ca concentration was significantly positively correlated with Cu, Fe, Mg, P, and Zn, and the Cu concentration was significantly positively correlated with Fe, Mg, P, and Zn.

Table 4 Correlation matrix of mineral concentrations in each organ

		Ca	Cu	Fe	K	Mg	Na	P	Zn
	Ca	-	0.28	0.19	0.57	0.15	-0.20	0.46	0.16
	Cu		-	0.85	0.10	0.15	0.05	0.44	0.96
	Fe		*	-	0.10	0.19	0.05	0.67	0.83
Leaves	K	*			-	0.33	-0.06	0.67	0.05
	Mg					-	0.06	0.23	0.10
	Na						-	-0.02	0.22
	P	*	*	*	*			-	0.35
	Zn		*	*					-
		Ca	Cu	Fe	K	Mg	Na	P	Zn
	Ca	-	0.71	0.78	-0.36	0.66	-0.11	0.54	0.57
	Cu	*	-	0.75	-0.08	0.80	-0.35	0.55	0.89
	Fe	*	*	-	-0.18	0.59	-0.05	0.42	0.52
Branches	K				-	-0.10	-0.21	0.00	0.06
	Mg	*	*	*		-	-0.47	0.48	0.78
	Na					*	-	-0.45	-0.30
	P	*	*	*		*	*	-	0.43
	Zn	*	*	*		*		*	-
		Ca	Cu	Fe	K	Mg	Na	P	Zn
	Ca	-	-0.31	0.24	-0.17	0.67	0.11	0.19	-0.32
	Cu		-	-0.22	0.56	-0.22	0.31	0.27	0.91
	Fe			-	0.05	0.58	-0.57	0.42	-0.21
Stems	K		*		-	-0.01	-0.05	0.68	0.31
	Mg	*		*		-	-0.42	0.56	-0.15
	Na			*		*	-	-0.25	0.19
	P			*	*	*		-	0.09
	Zn		*						-
		Ca	Cu	Fe	K	Mg	Na	P	Zn
	Ca	-	0.13	-0.07	0.42	0.50	-0.11	0.20	0.06
	Cu		-	0.37	0.07	0.28	0.17	0.09	0.74
	Fe			-	-0.12	0.12	0.32	-0.02	0.40
Roots	K	*	*		-	0.58	0.14	0.65	-0.13
	Mg	*			*	-	0.08	0.45	0.16
	Na						-	0.63	-0.01
	P				*	*	*	-	-0.25
	Zn		*						-

** Indicates a significant correlation coefficient at $p < 0.05$.*

In the study by Elhag and Abdalla (2014), leaf Ca and K in moringa also decreased with increasing Na concentration. Increases in Na have been found to decrease K in triticale, barley, and rice (Flowers and Hjibagheri, 2001; Naidoo, 2007). There were no significant differences in the concentrations of P, Cu, Mg, and Zn. Matsumaru (1990) found no clear relationship between Fe, Mn, and Zn concentrations and increasing salinity in a cucumber salt tolerance experiment. The results of the correlation analysis in this study also showed that only Mg and P in the branches and Fe and Mg in the stems were significantly negatively correlated with Na concentration, suggesting that increases in Na concentration cause limited inhabitation of mineral uptake by moringa. A significant positive correlation was found between Na and P in the roots. The same results were obtained by Elhag and Abdalla (2014) and Nouman (2012). It was suggested that moringa roots may have functioned to promote growth by increasing P uptake in response to increased Na.

Root Growth and Soil Permeability

There was a positive correlation between the length of moringa main roots and saturated hydraulic conductivity in the salinity-treated soils (Fig. 2). The relationship between the circumference of the main root and saturated hydraulic conductivity was highly positive (Fig. 3). The saturated hydraulic conductivity of the soil without moringa was 1.1 × 10^{-6} cm/s, and moringa root growth increased the saturated hydraulic conductivity by two orders of magnitude (10^{-4} cm/s) at 0 and 4 dS/m and by one order of magnitude (10^{-5} cm/s) at 8 and 16 dS/m. *Sophora japonica* has tap roots, which grow relatively deep and vertically; these roots loosen the soil more deeply and greatly increase soil infiltration rates (Zhang et al., 2019). *Alunus incana* roots were shown to improve soil permeability (Vergani and Graf, 2015). The length and circumference of the main root were greatest at 0 dS/m and 4 dS/m. The circumference was 13.1 cm and 13.9 cm at 0 and 4 dS/m, respectively, and 6.8 cm at 16 dS/m, approximately half of that at 4 dS/m. There was a strong positive correlation between root dry weight and the length and circumference of the main root in each treatment (length: $r = 0.99$, $p = 0.0006$; circumference: $r = 0.98$, $p = 0.001$).

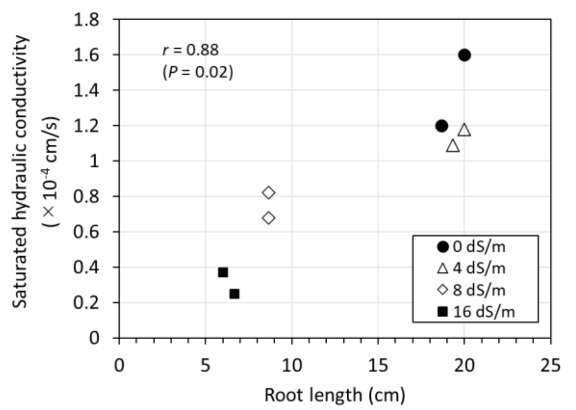

Fig. 2 Relationship between root length and saturated hydraulic conductivity

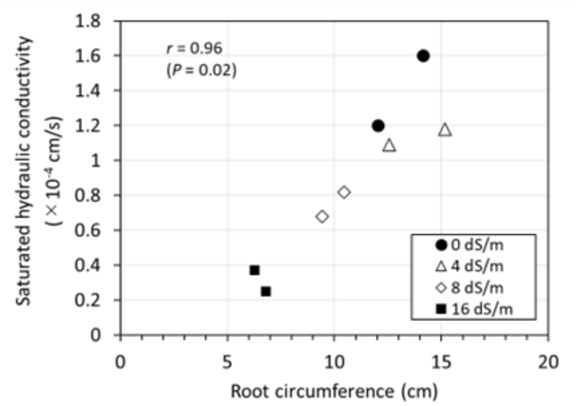

Fig. 3 Relationship between root circumference and saturated hydraulic conductivity

CONCLUSION

Moringa has high salt tolerance and can be grown in paddy soils up to 8 dS/m with almost no growth inhibition. As soil salinity increased, Na concentrations in each moringa organ also increased. The results of the correlation analysis in this study also showed that only Mg and P in the branches and Fe and Mg in the stems were significantly negatively correlated with Na concentration, suggesting that increases in Na concentration cause limited inhabitation of mineral uptake by moringa. There was a strong positive correlation between the length of moringa main roots and saturated hydraulic conductivity, the results showed that moringa root growth increased the soil permeability.

ACKNOWLEDGEMENTS

This research was financially supported by The Mitsui & Co. Environment Fund and JSPS KAKENHI 21H03692.

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Research article

Environmental Impact Assessment of Air Emission from Fertilizer Utilization and Rice Straw Burning from Rice Production in Cambodia

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Received 1 August 2023 Accepted 10 November 2023 (*Corresponding Author)

Abstract Rice is the most important staple food for feeding nearly half of the world's population, and almost the entirety of the population of Asia. An increase in food demand leads to an increase in agricultural residues, resulting in impacts on human health and environmental consequences. The current study aimed to estimate the emission of primary and secondary fine particulate matter attributable to fertilizer from the open burning or rice straw in Cambodia in terms of country-specific characterization factors (CFs), and to estimate the human health and ecosystem impact of particulate matter formation and terrestrial acidification. Additionally, the study aimed to propose an alternative scenario to reduce the negative impact on human health and the ecosystem. Three scenarios were set to conduct the study's assessment, including a baseline scenario representing current farmer practices, including typical fertilizer application rates and open burning of rice straw after harvest (S0); a scenario reducing fertilizer use to 60% while still allowing open rice straw burning (S1); and a scenario with no open rice straw burning and a 60% reduction in fertilizer use (S2). Human health damage was calculated in units of Disability Adjusted Life Year (DALY), and ecosystem impact was expressed in the units of Potentially Disappeared Fraction of species (PDF/m^2/yr) presented under the scenarios. The total human health impact of S0 was 5.35E+01 DALY, S1 was 5.27E+01 DALY, and S2 was 3.75E-01 DALY, while the total ecosystem impact of S0 was 4.38E-02 (PDF/m^2/yr), S1 was 3.60E-02 (PDF/m^2/yr), and S2 was 4.85E-03 (PDF/m^2/yr). The results of this study indicated that minimizing the use of chemical fertilizer and zero open burning of agricultural waste can reduce the number of pollutants that affects human health and ecosystem soil acidification. It showed that reducing burning straw waste can reduce the toxins that affect human health by 99% and reduce the increase of soil acidity by 94%.

Keywords air pollution, DALY, LCA, particulate matter ($PM_{2.5}$), rice production

INTRODUCTION

Rice has now become a foreign exchange earner for several countries and plays an important role in their economies (Kumar et al., 2017). In the case of Cambodia, rice production has increased significantly in the last decades, particularly since the major economic reforms in 1989. The planted areas of rice increased from 1.9 million hectares (ha) in 1990–1991 to about 2.6 million hectares in 2009–2010 (ASEAN Development Bank, 2012). Favorable weather conditions, an increase in the availability of rural credit and private investment, technology improvement, new high-yield rice varieties, application of chemical fertilizer and other inputs are the factors of the increasing rice yield (The World Bank, 2015). Excessive fertilization and mindless use, obviously caused soil salinity, heavy metal accumulation, water eutrophication, and accumulation of nitrate, considered in terms of air pollution in the air of gases containing nitrogen and sulfur, which can lead to problems such as the greenhouse effect (Savci, 2012; Chandini et al., 2019). In the United States, uncontrolled agricultural emissions will influence states' ability to satisfy global environmental impacts. Despite recent progress to reduce sulfur oxide (SO_x) and nitrogen oxide (NO_x) emissions, NH_3 plays a substantial role in $PM_{2.5}$ formation, and increasing ammonia may increase $PM_{2.5}$ (aerosols with aerodynamic diameters less than or equal to 2.5 µm) concentrations (Clappier et al., 2021). The compound of these pollutants such as criteria pollutants of known tropospheric O_3, SO_2, and $PM_{2.5}$ affects human health and the environment. Animal production, chemical fertilizer application, land use land changes, biomass burning, and other agricultural practice is a primary producer of increased gases and particulate matter (Clappier et al., 2021). Particulate Matter of air pollution is an air-suspended mixture of solid and liquid particles that vary in number, size, shape, surface area, chemical composition, solubility, and origin. The size distribution of total suspended particles (TSPs) in the ambient air is tri-modal, including coarse particles, fine particles, and ultrafine particles (Chow, 1995). Agricultural residue open burning in Southeast Asia accounts is up to 43% of the total open biomass burning (BB) which contributes significantly to air pollution. BB is a source of global air pollution that typically contains $PM_{2.5}$ sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO_2), ammonia (NH_3), methane (CH_4), and other air pollutants (Le et al., 2020). It is estimated that in developing countries approximately 300,000 to 700,000 people can be saved from premature death if aerosol levels are reduced to a safe level (an Air Quality Index (AQI) under 100 signifies good or acceptable air quality) (Seinfeld and Pandis, 2016). Thus, this study aims to investigate the impact assessment of air pollutants emitted from chemical fertilizer and rice straw open burning from rice production in Cambodia and to analyze human health impact assessment and ecosystem impact terrestrial acidification using an analytical tool called Life Cycle Assessment (LCA). Also, to provide a recommendation on negative impact reduction under three scenarios are set to conduct the study's assessment.

METHODOLOGY

Data Collection

The chemical fertilizer application data was collected from the survey questionnaires of three provinces known as Prey Veng, Svay Reing, and Kampong Thom province. The practical application of chemical fertilizer (Urea; DPA; KCl) from the farmers is 27 kg/1ton of rice production; it was considered as scenario S0 and from a lab-scale experiment at Cambodia Agriculture Research Development Institute (CARDI) which was carried out by the plantation in the column-based experiment of a known diameter by Lai et al. (2022) based on the soil type used in the experiment with the application of 11kg chemical fertilizer/1ton of rice production (Chemical fertilizer application was recommended by CARDI); represent the scenario S1, and the scenario S2 is the condition of combination chemical fertilizer application recommendation by CARDI with Zero burning after harvesting.

Emission Inventory Assessment

Emission of NH_3 and NO_x from chemical fertilizer and $PM_{2.5}$, NO_X, NH_3, and SO_2 from rice straw open burning were estimated according to the methodology of the EMEP guidelines 2016 (EEA (European Environment Agency) 2016) and Tier1 of the EMEP/EEA guidebook 2019, respectively.

Emission from fertilizer:

$$NH_3 = 17/14 \sum_{m-1}^{M} (\mathrm{EF}a_m \times P + EFb_m \times (1-P))N_{min,m} \quad (1)$$

where NH_3 is ammonia emission after mineral fertilizer application [kg NH_3]; m is fertilizer type; M is the number of fertilizer types; $\mathrm{EF}a_m$ is the emission factor on soil with pH ≤ 7 [kg NH_3-N/kg N]; $\mathrm{EF}b_m$ is the emission factor on soils with pH > 7 [kg NH_3-N/kg N]; P is the fraction of soils with pH ≤ 7 [%/100]; N_{min} is mineral fertilizer application [kg N]; 17/14 is the conversion factor from N to NH_3 (NH_3 = 17 g/mol and N = 14 g/mol).

Emission from rice straw open burning:

$$E = Activity\ data \times Emission\ factor\ (EF) \quad (2)$$

where E is the emission of the pollutant; EF is the emission factor obtained from EMEP/EEA tier 1 The EF of $PM_{2.5}$ 140 g/GJ, NOx 91 kg/GJ, SO2 11 g/GJ table 3.5 page 17 in 1.A.2 EMEP/EEA 2019; Activity data is the amount of burnt source categories.

Where the total amount of rice straw from rice production was calculated following the formula developed by (Shrestha et al., 2013).

Life Cycle Impact Assessment

The human health impact assessment was estimated from particulate matter formation ($PM_{2.5}$, NOx, NH_3, and SO_2), while the Ecosystem impact assessment was estimated from the terrestrial acidification (NH_3, SO_2, and NOx).

Human Health Impact Assessment

The human health impact is expressed as DALYs (disability-adjusted life years), the years of life lost due to death + years of lived with disability, was calculated by applying the ReCiPe 2016 v1.1 (A harmonized life cycle impact assessment method at midpoint and endpoint level by (Huijbregts et al., 2017).

$$HI = E \times CFs \quad (3)$$

where HI is human health impact expressed in DALYs; E is the emission of pollutants; CFs is endpoint characterization factors of human health (yr. $kton^{-1}$) level in Cambodia.

Ecosystem Impact Assessment (Terrestrial Acidification)

$$Ecosystem\ impact = E \times CF \quad (4)$$

where E is the emission of the pollutant; Ecosystem impact is the potentially disappeared fraction of species ($PDF/m^2/yr$); CF is the endpoint characterization factors of an ecosystem (species/kg) level in Cambodia.

To propose a scenario to reduce air pollution that affects human health and ecosystem impact, the estimation was carried out under three scenarios. First scenario S0; the baseline is the condition of using chemical fertilizer (Urea, DAP, KCl) and rice straw open burning by farmers practiced from the survey. The second scenario (S1), is the application of chemical fertilizer (Urea, DAP, KCl) recommended by CARDI with the practice of rice straw open burning by column based-experimental (Lai et al., 2022). The third scenario (S2); the optimization is the application of chemical fertilizer NPK recommendation by CARDI with zero burning of rice straw.

RESULTS AND DISCUSSION

Emission Inventory

The estimation of air pollutants NH_3, NOx, $PM_{2.5}$, NO_x, and SO_2 from chemical fertilizer and rice straw open burning is expressed as kg/1ton of rice production. Figure 1 reveals the concentration of emissions released from chemical fertilizer and rice straw open burning under the three studied scenarios. It is noticed that the pollutants released from the application of fertilizer by farmers practiced (S0) are higher than the pollutants emitted from the reducing fertilizer application recommended (S1) by 76%. In addition, the result showed that rice straw open burning is the majority of source of $PM_{2.5}$ and SO_2 (Fig. 1) of scenario S2. The study by (Lorn et al., 2022) investigating $PM_{2.5}$ from fertilizer usage, fuel combustion, and straw residue burning revealed that 51.56% of the total emission in the study is generated by rice straw open burning and 24.10% generated from fertilizer.

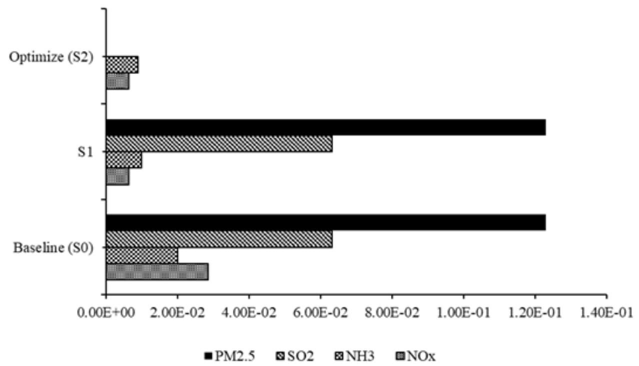

Fig. 1 Emission of pollutants of the studied scenarios from 1 ton of rice production

Life Cycle Impact Assessment

Life cycle impact assessment from two endpoint categories, human health impact (the particulate matter formation) and ecosystem impact (terrestrial acidification) are estimated from the emission of chemical fertilizer and rice straw open burning, is represented as kg/1ton of rice production, are expressed as DALYs and PDF/m^2/yr, respectively. The human health impact estimation revealed the highest value in scenario S0 (5.35E+01 DALYs) if compared to scenario S1 (5.27E+01DALYs) and S2 (3.75E-01DALYs) (

In Asia, managing rice straw remains a challenging matter. The available information and knowledge are scattered and either cannot reach the target practiced (farmers, and rural people) (Van Hung et al., 2020). The common management practice of rice straw is to leave straw to integrate into the soil known as rice straw incorporation. The incorporation practice can improve soil fertility yet adequate time must be allowed to ensure the effectiveness of the decomposition, thus it may not be considered by a short cycle of crop growing practice (Zhang et al., 2021). Cattle feed and mushroom cultivating are other alternatives to rice straw management (Gummert et al., 2020), and recommended rice straw used in biochar studies is suggested (Ly et al., 2015; Chandra and Bhattacharya, 2019). However, positive and effective results can be obtained unless all parties must involve (farmers and government) and recognize the serious effect of the uncertain method of managing rice straw.

Fig. 2 Human health impact from particulate matter formation

). Figure 2 showed that the human health impact is contributed majority from $PM_{2.5}$ and SO_2 which contributed from rice straw open burning, following by NOx, and NH_3. It is also noticed that the highest value of ecosystem impact estimation is found in scenario S0 (4.38E-02 PDF/m^2/yr), while S1 and S2 are 3.60E-02 PDF/m^2/yr and 4.85E-03 PDF/m^2/yr, respectively (

Fig. 3). Based on the finding result, SO_2 is the most contributor to ecosystem impact following by NH_3, and NOx, respectively. As can be seen in the result, a great negative impact on both human health impact and the ecosystem impact happened under scenario S0. The particulate matter formation from both primary and secondary sources of rice straw open burning practiced and excessive application of chemical fertilizer are seriously affecting both human health and the ecosystem. In the case of eastern and north-central China, regions with large population densities and high levels of $PM_{2.5}$, approximately 4% of all-cause mortality in the country can be avoided (95% confidence interval: 1–7%) by reducing emissions of primary particulate matter and gaseous particulate matter precursors, and thus lower ambient concentrations of $PM_{2.5}$ (Zhao et al., 2011). Mahmood and Gheewala, (2020) stated that rice straw open burning which emitted the majority of $PM_{2.5}$, exhibited significant impacts on the environment, terrestrial acidification, freshwater eutrophication, and human damage to ozone formation. To reduce the amount of particulate matter formation and terrestrial acidification emitted to the environment which affects greatly human health and the ecosystem, it is suggested to stop the activity of open burning and excessive use of chemical fertilizer so it can prevent damage to human health by 99% and to the ecosystem by 94%.

In Asia, managing rice straw remains a challenging matter. The available information and knowledge are scattered and either cannot reach the target practiced (farmers, and rural people) (Van Hung et al., 2020). The common management practice of rice straw is to leave straw to integrate into the soil known as rice straw incorporation. The incorporation practice can improve soil fertility yet adequate time must be allowed to ensure the effectiveness of the decomposition, thus it may not be considered by a short cycle of crop growing practice (Zhang et al., 2021). Cattle feed and mushroom cultivating are other alternatives to rice straw management (Gummert et al., 2020), and recommended rice straw used in biochar studies is suggested (Ly et al., 2015; Chandra and Bhattacharya, 2019). However, positive and effective results can be obtained unless all parties must involve (farmers and government) and recognize the serious effect of the uncertain method of managing rice straw.

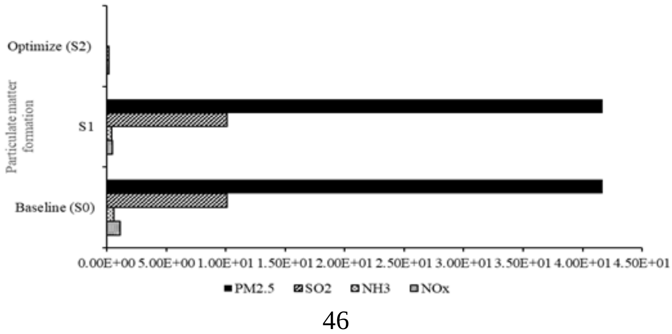

Fig. 2 Human health impact from particulate matter formation

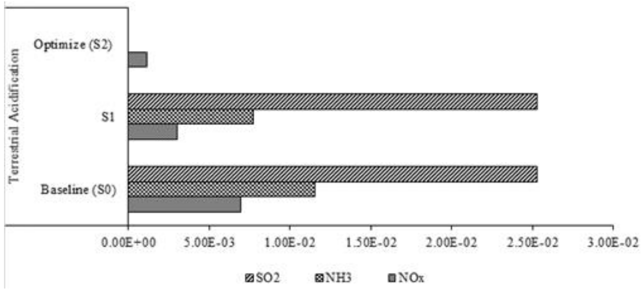

Fig. 3 Ecosystem impact from terrestrial acidification

CONCLUSION

Chemical fertilizer and rice straw open-burning activity emitted pollutants that are harmful to both human health and the ecosystem. Rice straw open burning released the majority of $PM_{2.5}$ and SO_2 while the most pollutant emitted from chemical fertilizer is NOx. Emissions released from rice straw open burning alone cause great effects on both human health and the ecosystem. It is suggested to stop the activity of open burning and the excessive practice of applying chemical fertilizer, therefore it can reduce 99% of human health impact and 94% of ecosystem impact.

To tackle this issue, educating people about the harmful effects of burning rice straw and other agricultural waste is crucial. Additionally, implementing improvements in straw utilization rates and minimizing open-field burning are vital steps towards establishing a circular bio-economy that utilizes agricultural straw as a valuable resource. Moreover, it is important to invest in improving technology for mushroom and ruminant farming. Lastly, promoting the elimination of agricultural waste and open burning is crucial for a sustainable future.

ACKNOWLEDGEMENTS

This paper was funded by Cambodia Higher Educational Improvement Project (credit No.6221-KH). The author would like to thank the Institute of Technology of Cambodia for all its facilities.

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Research article

Seasonal Changes of Water Quality in Cheung Ek Lake, Cambodia

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Received 15 September 2023 Accepted 15 November 2023 (*Corresponding Author)

Abstract Cheung Ek Lake is the biggest wastewater lake inside Phnom Penh City and has massive water and nutrient inflow. Around 70% of rain runoff and wastewater in Phnom Penh flows into Cheung Ek Lake through three main canals: Trabek Canal, Stung Meanchey Canal, and Lou Pram Canal, before discharging into the Bassac River. Since 2008, the rapid urbanization of the satellite city in Phnom Penh has decreased the area of the lake and contributed to the degradation of the lake's water quality. Cheung Ek Lake performs many functions such as flood control, natural wastewater treatment, and provision of water for vegetable production. Previous studies identified the positive and negative impact of lake water on the local ecosystem and human livelihoods. The aim of the current study was to monitor seasonal changes in water quality in Cheung Ek Lake, Cambodia. Additionally, the objectives of this study were to (i) analyze the changes in water quality parameters in the rainy season and the dry season and (ii) describe daily and hourly changes in phosphate (PO_4^{3-}) concentration in the lake. For that, selected chemical parameters such as pH, electroconductivity (EC), phosphate, nitrate (NO_3^-), iron (Fe^{2+}), and dissolved oxygen (DO) were measured in the rainy and dry seasons. In addition, phosphate (PO_4^{3-}) was analyzed hourly for a week in the dry season. The water samples were collected at 3 points: inlet, middle, and outlet of the lake, at a depth of 0.5 m. Water samples were analyzed in situ using a spectrophotometer. The decreased values of EC, NO_3^-, PO_4^{3-}, and Fe^{2+} from inlet to outlet show that the lake has the potential to reduce the nutrient level in both seasons. Phosphate increases at 10 am, 1 pm, and 7 pm indicated that water quality was remarkably affected by daily rush hours of household activities. This further suggested that household activities could be the main sources of the presence of a high concentration of PO_4^{3-} in the lake.

Keywords Cheung Ek Lake, water quality, seasonal change

INTRODUCTION

Scarce freshwater resources are increasingly being used to satisfy the demands of a rapidly increasing population and a growing global economy. The increasing rate of uncontrolled and unplanned urbanization in developing countries in Asia, Africa, and South America is likely one of the most important factors in the decline of the quality of urban water bodies and the increasing health and other associated risks for urban residents (Pankaj et al., 2019).

The major cities in Southeast Asia have millions of inhabitants and a great number of small- and large-scale industries. Often these cities have no formal wastewater treatment facility, and the wastewater is discharged into a drainage system whose main purpose is to prevent flooding of the city. This is also the case for Phnom Penh city. The city of Phnom Penh had a population of 2.3 million people in 2019 (NIS, 2019) and a demographic growth of 3.2% in the period 2008-2019. In 2014, Phnom Penh boasted a total of 97,200 established enterprises, reflecting a 1.4 percent increase compared to 2011 (NIS, 2015). Moreover, only 9 percent of discharged water in Cambodia is properly treated before being released into the main water bodies, making Cambodia the second-lowest capacity after Lao PDR in Southeast Asia (Buth et al., 2019). Until now, there have been no public sewage treatment plants in Phnom Penh and the majority of the industries have been constructed without wastewater treatment facilities. Domestic and industrial wastewater as well as storm water is drained out of the city into Cheung Ek Lake (Takahashi et al., 2002).

Cheung Ek Lake is essential in the treatment of Phnom Penh's sewage and the prevention of devastating floods both in the city center and the southern border town of the city. Acting as a large natural wastewater treatment area, this lake has been found to be semi-effective through the use of plants such as water morning glory and water mimosa, both of which are planted by local aquatic farmers, which assist in cleansing the water of harmful pollutants (Irvine et al., 2015). As the city's wastewater, including sewage, drains directly into the lake through three major canals, the presence of this lake is a natural barrier protecting pollutants from entering the Bassac River downstream. However, the uncontrolled human occupation on the lake's bank has led to encroachment of the lake's surface area every year, especially since 2013 when the satellite cities project started (Sahmakum Teang Tnaut, 2019). As the lake's surface area gets smaller, its potential for wastewater treatment reduces as well. Even though several studies have examined the water quality in Cheung Ek Lake (Irvine et al., 2008; Nara et al., 2015), the study on the changes in the water quality related to seasons is still not being examined yet. Thus, this study aims to address the gaps seen.

OBJECTIVE

The purpose of this study is to monitor the seasonal changes of water quality in Cheung Ek Lake, Cambodia. Accordingly, the objectives of this study are to (i) analyze the changes in water quality in the rainy season and the dry season and (ii) describe daily and hourly changes in phosphate (PO_4^{3-}) concentration in the lake.

METHODOLOGY

The study was conducted on Cheung Ek Lake located south of Phnom Penh city (104°90'–104°94'E and 11°46'-11°53'N). It is the catchment area where 80% of the 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 the elevation is around 10 m above sea level (Nara et al., 2015). The rainy season is from May to September and the dry season starts from October to May.

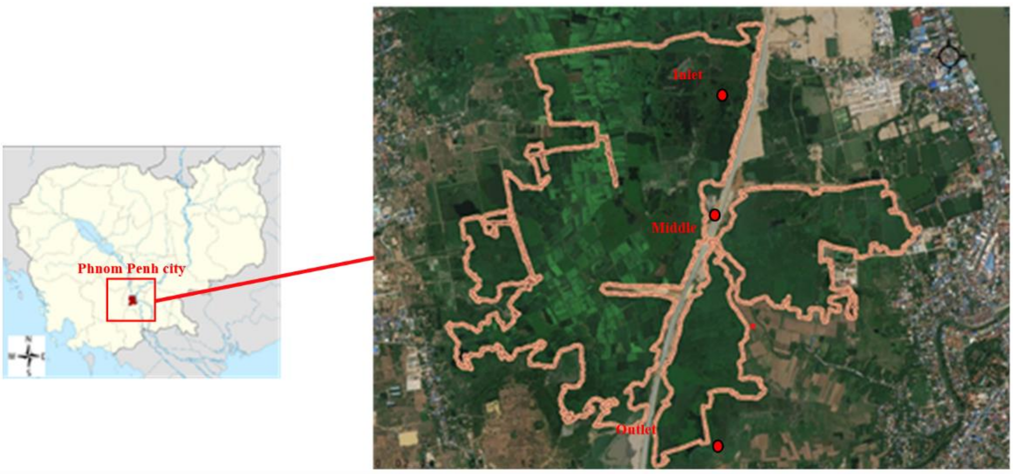

Fig. 1 Map of Cambodia and sampling point in Cheung Ek Lake (Google map)

Water Sampling and Analysis

To analyze the changes in water quality parameters, water sampling was conducted for the rainy season in 2019 and 2020 for dry seasons. Water samples were taken at 0.5 m depth by using Heyroth Water Sampler. Sampled water was kept in the plastic containers at 5°C and transported to the laboratory within 3 h of collection for analysis.

Water samples were analyzed for pH, electrical conductivity (EC), iron (Fe), dissolved oxygen (DO), phosphate (PO_4^{3-}), and nitrate (NO_3^-) using a pH meter, EC meter, and DR 900 portable data-logging colorimeter instrument. The water samples were collected at the inlet, middle, and outlet for 3 days in the rainy season (9th -11th Sep 2019) and 7 days in the dry season (19th -25th Dec 2020).

To analyze the daily changes of PO_4^{3-} concentration in the lake, the water sample was taken hourly in the lake from 5 am until 7 pm for 7 days in the dry season (19th - 25th Dec 2020). During this date range, no rainfall was recorded, and the average daily air temperature ranged from 23-30°C. Totally 107 water samples were analyzed for PO_4^{3-} in the inlet point of the lake to determine its possible sources.

RESULTS AND DISCUSSION

The results from Table 1 and Table 2 for pH in both seasons range from 7.06 to 7.7 indicating it base state of the lake's water. The electrical conductivity (EC) decreased from the rainy to the dry season, and one of the primary factors influencing this change in EC levels in the water body could be rainwater. Iron (Fe^{2+}) concentrations ranged from 0.03 to 0.08 mg L^{-1}, which, based on the water pollution control standard in Cambodia for public water areas (20 mg L^{-1}), indicated no sign of Fe contamination (RGC, 2009).

Table 1 Chemical water parameters of the inlet, middle, and outlet of the lake in rainy season

Sampling location	pH	EC (mS/cm)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	Fe^{2+} (mg/L)	DO (mg/L)
Inlet	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	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, Source: Data from analysis in Sep 2019*

Table 2 Chemical water parameters of the inlet, middle, and outlet of the lake in the dry season

Sampling location	pH	EC (mS/cm)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	Fe^{2+} (mg/L)	DO (mg/L)
Inlet	7.7±0.18	0.37±0.04 a*	0.4±0.05	4.64±0.91 a*	0.08±0.04	3.25±0.96 a*
Middle	7.7±0.28	0.36±0.01 a*	0.3±0.26	3.66±0.25 a*	0.06±0.18	6.40±1.02 b*
Outlet	7.6±0.23	0.33±0.01 b*	0.1±0.33	2.56±0.54 b*	0.03±0.09	6.75±0.97 b*

*Note: Values are mean ± SD (n=7), * p< 0.1, Source: Data from analysis in Dec 2020*

Phosphate (PO_4^{3-}) varied drastically in the rainy season, decreasing from 5.29 mg L^{-1} in the inlet to 1.42 mg L^{-1}in the outlet. In both seasons PO_4^{3-} decreases from inlet to outlet point. The drop of PO_4^{3-} concentration in both middle and outlet points may be attributed to agricultural activities occurring on the lake's surface, which absorb the available PO_4^{3-} in the water.

Similar to PO_4^{3-}, nitrate (NO_3^-) concentrations were observed to be decreasing in the dry season suggesting urban run-off. In the outlet point in the rainy season, NO_3^- increase again may be caused by the construction activities nearby. These activities in proximity to the lake have induced water turbulence, leading to the release of sediment from the lake's bottom causing the elevation of NO_3^- level in the outlet point.

Dissolved oxygen (DO) in the lake ranged from 3.55 to 6.06 mg L^{-1} in the rainy season and 3.25 to 6.75 mg L^{-1} in the dry season. The elevated levels of DO observed at the inlet point during the rainy season can be attributed to temperature fluctuations. The wastewater discharged into Cheung Ek Lake flows from the city through an open channel. In the rainy season, this water becomes diluted with rainwater, leading to a reduction in water temperature. This drop in temperature is responsible for the rise in DO levels. Additionally, the runoff during the rainy season can raise the PO_4^{3-} levels, potentially promoting increased algae growth along the open channel in the city. Algae, in turn, contributes to dissolved oxygen (DO) production in the daytime.

The low and high precipitation during dry and rainy seasons in tropical countries can greatly change the water quality of the lake (Ling et al., 2017). The high precipitation during the wet season can either decrease the pollutant concentration by dilution or deteriorate the lake water quality due to increased surface runoff from anthropogenic activities. Seasonal variations in the water quality of the Cheung Ek Lake have a relatively minor impact on the pH parameter, whereas EC increases because of dilution with rainwater. However, in terms of nutrients such as NO_3^-, PO_4^{3-}, and DO, the water quality exhibits improvement during the dry season.

The concentration indicated in Table 3, Figs. 2 and 3 show the load of four parameters in Cheung Ek Lake between the inlet and outlet site. The result for PO_4^{3-}, NO_3^- showed a decreasing trend. Fe increased in the rainy season and decreased in the dry season, which contrasts with DO 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 both seasons.

Table 3 Nutrient loads of the inlet and outlet in the rainy and dry season

Parameter	Inlet	Outlet
NO_3^- (g/s)	28.08	18.65
PO_4^{3-} (g/s)	222.81	64.42
Fe^{2+} (g/s)	1.26	2.03
DO (g/s)	216.50	120.38

Source: Data from analysis in Sept 2019

Parameter	Inlet	Outlet
NO_3^- (g/s)	0.24	0.04
PO_4^{3-} (g/s)	2.74	1.07
Fe^{2+} (g/s)	0.05	0.01
DO (g/s)	1.92	2.84

Source: Data from analysis in Dec 2020

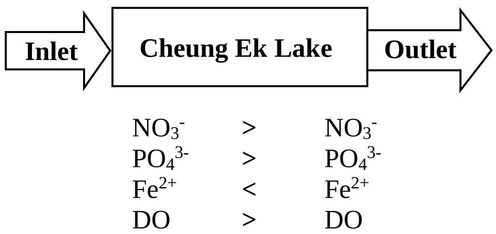

Fig. 2 Function of Cheung Ek Lake in the rainy season

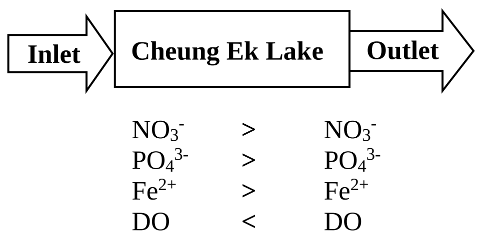

Fig. 3 Function of Cheung Ek Lake in the dry season

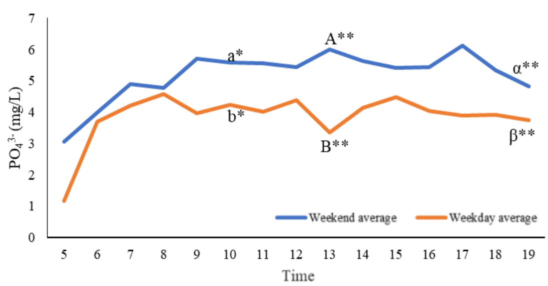

Fig. 4 Average PO_4^{3-} in weekend and weekday

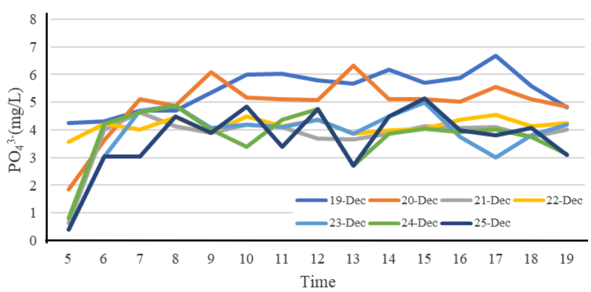

Fig. 5 Hourly Changes in PO_4^{3-}

Figures 4 and 5 indicated the hourly changes in phosphate concentration between weekdays and weekends. Changes in the concentration of PO_4^{3-} can be seen and fluctuate starting from 6 a.m. until 6 p.m. At 5 a.m., the concentration ranges from 1.2 to 3 mg/L, while the data at 7 p.m. show a concentration range between 3.5 to 5 mg/L. These observations suggest that during the nighttime, particularly on weekdays, concentration experienced a significant decrease. A significant difference was found at 10 am, 1 pm, and 7 pm with confidence levels at 95% and 99%, respectively. The lake's hours represent the busy hours of household activities, which can indicate that the main contribution of PO_4^{3-} level in the lake's water came from the household.

CONCLUSION

According to the findings of this study, the current situation pH and EC of the lake's water did not change much in both seasons, whereas an increase in nutrient levels was seen by comparing the water quality of the dry season to the rainy season, especially in the inlet point. This result indicates the urban run-off of nutrients and suggests the importance of implementing effective management for the inlet point to prevent any further deterioration in the lake's water quality. Furthermore, the result from nutrient loads indicates that the lake's water quality has improved from the input to the output, demonstrating the possibility for potential pollution removal in the lake for both seasons.

Additionally, from the results of hourly analysis of PO_4^{3-}, water quality monitoring should focus more on inlet sites, which are one of the primary sources of pollution. Further research is required to gain a better understanding of PO_4^{3-} and how to address it effectively. Also, when it comes to regulating water discharge from cities, particularly from households, stricter measures should be implemented to control nutrient content.

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Research article

Consumer Behavior Towards Ethical Bananas in Japan

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Received 1 September 2023 Accepted 24 November 2023 (*Corresponding Author)

Abstract Japan imported over 1 million tons of bananas in 2021, 76% of which were from the Philippines. Meanwhile, in banana production fields including in the Philippines, there are problems such as unfair contracts between banana producers and companies and bad working conditions. Although consumers' interest in ethical consumption is growing in Japan, the market of ethical bananas, including bananas certified under the Fair Trade (FT), Rainforest Alliance (RA), and organic[3] standards that are the focus of the current study, is still small. Therefore, this study aimed to identify consumer behavior toward ethical bananas and the possibility of expanding the market for ethical bananas in Japan. An online questionnaire survey using Google Forms was conducted throughout August 2021, and 279 valid answers were obtained. Factor Analysis and Cluster Analysis revealed that the respondents were segmented into three clusters, which are "quality-conscious," "ethical-possible," and "unconcerned". In addition, Conjoint Analysis clarified that when the respondents purchased bananas, consumers attached the highest importance to the “price” attribute, followed by the "appearance," "ethical", and "cultivation method" attributes. Furthermore, the perceived utility for consumers of RA and organic bananas was as high as that of non-ethical bananas, while that of FT bananas was low. As such, the results suggested that there is significant potential for an increase in the demand for organic and RA bananas, while the potential for an increase in demand for FT bananas is low. Meanwhile, the "ethical-possible" cluster, which accounted for over 50% of the respondents, displayed the highest utility scores towards FT bananas among the three clusters. To expand the market for ethical bananas in Japan, the authors recommend increasing consumer recognition and comprehension of FT and issues in the banana production field and promoting the sale of RA and organic bananas in supermarkets.

Keywords consumer segmentation, ethical consumption, fair trade, rainforest alliance, organic

INTRODUCTION

Bananas are the most consumed fruits in Japan (Statistics Bureau of Japan, 2022). Japan imported over 1 million tons of bananas in 2021 76% of which were from the Philippines (Ministry of Agriculture, Forestry and Fisheries Japan, 2021). In the production field, there are problems caused by multinational companies. One of the problems is the unfair contract between banana producers and the company. Long-term agreements and low purchase prices are regulated in the contract. Besides, several expenses are deducted automatically from the producers' sales amount. Thus, the producers usually resort to borrowing some money from the company to continue producing bananas. This situation strengthens the company's domination. The other problem is bad working conditions. The company forces the workers to work long hours and does not make suitable payments to them.

[3]Fair Trade products are produced and exported in a way that seeks greater equity in international trade. Products with Rainforest Alliance certification is produced in an environmentally-friendly way that mainly aims to conserve forest. Lastly, organic agriculture is a production system that sustains the health of soils, ecosystems, and people (IFOAM, 2008).

In addition, pesticide spraying causes health damage to the workers and residents around the production area. It also causes environmental damage (Ishii et al., 2020).

Meanwhile, consumers' interest in ethical consumption is growing according to the survey by Watanabe in 2020. This survey also clarified that while "organic" is a well-known term, the degrees of recognition of labels of fair trade (FT) and rainforest alliance (RA) are increasing in Japan.

On the other hand, the market for ethical bananas is still small in Japan. For this study, ethical bananas refer to FT, RA, and organic bananas in this study. The market share of multinational companies' bananas exceeds 90% in the current situation (Ishii et al., 2020). There is one company that imports FT bananas with an FT label, but these bananas are from Ecuador and Colombia. Thus, there seems to be no bananas with an FT label from the Philippines in Japan. A Japan-based trading company has been importing *barangon* bananas. Grown naturally in the Philippines, these bananas are cultivated without agrochemicals and are imported as non-labeled FT bananas to Japan. However, the amount of its import accounts for only 0.1% of total imported bananas (Alter Trade Japan, Inc., 2021). For the improvement of the harsh situation in the production field, there is a need to expand the ethical banana market in Japan.

For market expansion, grasping consumer perception for the purchasing of ethical bananas seemed to be vital. However, past studies discussing consumer behavior towards ethical bananas are limited in Japan. Kishimoto, et al. (2021) have studied consumer preferences for FT bananas. Their study focuses on discussing the relationship between providing information and willingness to pay. Consumers' utility and importance of each factor when they purchase FT bananas are not clarified. Besides, this study has discussed organic and FT bananas. As of now, RA banana is sold more than FT bananas in the Japanese banana market. Considering the market situation, consumer behavior towards RA bananas is also better to be clarified. Therefore, this study includes RA in addition to FT and organic.

OBJECTIVE

To identify the possibility of expanding the market for ethical bananas in Japan, this study aims to identify consumer behavior towards ethical bananas. Specifically, this study aims to identify the characteristics of the respondents using Factor Analysis and Cluster Analysis and to analyze consumer behavior towards ethical bananas using Conjoint Analysis.

METHODOLOGY

This study is based on primary data obtained by an online questionnaire survey using Google Forms, throughout August 2021, targeting people who live in Japan. A total of 279 valid answers out of 314 respondents were obtained. Factor Analysis and Cluster Analysis were utilized to segment respondents into clusters based on their purchase behavior of agricultural products. The data utilized for the segmentation was obtained by asking them about the important points when purchasing agricultural products. The respondents chose their answer from five choices which are "important," "slightly important," "neutral," "slightly not important," and "not important". Besides, a Conjoint Analysis was conducted to clarify consumers' utility and importance of each attribute regarding the purchase of ethical bananas.

Table 1 Attributes and levels for conjoint analysis

Attribute	Level
Appearance	Yellow, Brown
Cultivation Method	Custom (no indication), Organic
Ethical	Custom (no indication), FT (label), FT (no label), RA
Price (yen)*	100, 200, 300, 400

Notes: Standard: 4-5 banana (700-800g). JPY100=USD0.87 (as of March 2022)

The data used was obtained from 234 respondents' answers to eight questions for the analysis, except for 45 respondents who did not purchase bananas by themselves. The respondents chose their answer from three choices which are "buy," "do not know," and "do not buy". Table 1 shows attributes and levels used in Conjoint Analysis. The data obtained were analyzed using R for Factor Analysis and Cluster Analysis and Microsoft Office Excel for Conjoint Analysis.

RESULTS AND DISCUSSION

Segmentation of the Consumer-respondents

Table 2 shows three factors obtained from Factor Analysis. Factor 1 is composed of "producer information", "cultivation method", "effect on the environment", and "effect on society". Since these items are related to ethical consumption, this factor is regarded as an "ethical" factor. Factor 2 is composed of "place of production" and "brand/company", which are related to the person who produces the product. Therefore, factor 2 is regarded as a "producer" factor. Factor 3, which is composed of "freshness" and "taste" is regarded as a "quality" factor.

Cluster Analysis was applied to the data of factor scores obtained via Factor Analysis. Table 3 shows the result of the segmentation. The respondents were segmented into three clusters. Regarding the first cluster "quality-conscious", the value of the "ethical" factor was very low, and the value of the "quality" factor was high. It indicates that the respondents belonging to this cluster do not care much about the ethical aspect, but quality is their top priority. Over 50% of the respondents belong to the second cluster "ethical-possible". All values were positive for this cluster, especially the "ethical" factor. It implies most consumers have the potential for ethical consumption of agricultural products. As for the last cluster "unconcerned", all values were relatively low, especially the "quality" factor.

Table 2 Results of factor analysis[1]

Items	Extracted factors[2]			Uniqueness
	Ethical	Producer	Quality	
Producer information	**0.501**	0.471	-0.130	0.275
Cultivation method	**0.591**	0.334	-0.038	0.289
Effect on the environment	**0.957**	-0.114	0.061	0.192
Effect on society (producers, workers, subcontracts, etc.)	**0.971**	-0.114	0.028	0.183
Place of production	-0.195	**0.883**	0.036	0.394
Brand / Company	0.041	**0.749**	-0.101	0.454
Freshness	0.009	-0.040	**0.788**	0.402
Taste	0.053	0.120	**0.605**	0.525
Price	-0.015	-0.108	0.165	0.976
Safety	0.036	0.462	0.292	0.551

Notes 1) Method: Maximum Likelihood Method. Rotation: Promax.
2) The numbers are factor loadings. Those in bold represent that the absolute value is over 0.5.

Table 3 Results of cluster analysis[1]

		Clusters[2]		
		Quality-conscious	Ethical-possible	Unconcerned
Factors	Ethical	**-1.248**	**0.521**	0.004
	Producer	-0.279	0.272	**-0.384**
	Quality	**0.414**	**0.305**	**-1.181**
Cluster size		64	153	62

Notes: 1) Cluster method: ward.D. Distance: Euclidean.
2) The values represent the average of each factor of the cluster.
Those in bold represent the absolute value is over 0.3.

Preferred Attributes of the Consumer-respondents

As a result of Conjoint Analysis, the importance of "price" was the highest followed by "appearance" and "ethical" (Fig. 1). The "cultivation method" was the lowest. These results fit with the past survey by the Japan Banana Importers Association (2021), which reported that consumers care about the price the most when purchasing bananas, and the Kishimoto, et al. (2021) study reported that "FT" has the highest willingness to pay (WTP) followed by "appearance" and "organic". The "quality-conscious" cluster was sensitive to "price" the most among the three clusters. According to the result of segmentation, this cluster concerns quality the most. However, the importance of "appearance", which is related to the quality of bananas, was relatively low. The "ethical-possible" cluster concerns ethical aspects more than quality. However, the importance of "appearance" was higher than "ethical". Figure 2 shows the result of the part-worth utility. The "non-labeled FT" was negative for all clusters. Although labeled FT was positive for "ethical-possible" and "unconcerned" clusters, the utility was close to zero. On the other hand, RA was positive for all clusters. This finding seems to convey that consumers are more familiar with environmental issues such as global warming than social issues in the production field and are more interested in the improvement of environmental issues. However, it must be mentioned that, even though there is an explanation of RA and FT in the questionnaire, it is unknown how much the respondents understand them. As for the cultivation method, the utility of organic was positive for only the "ethical-possible" cluster.

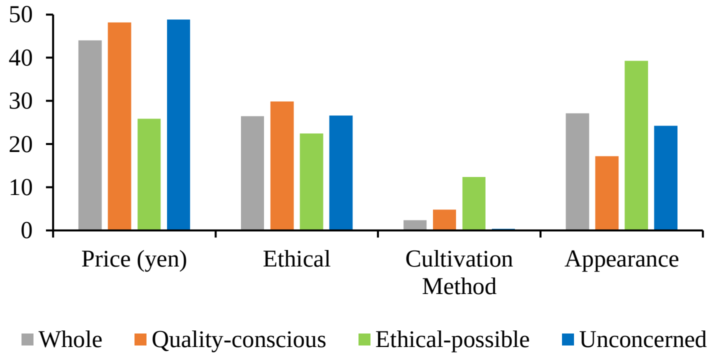
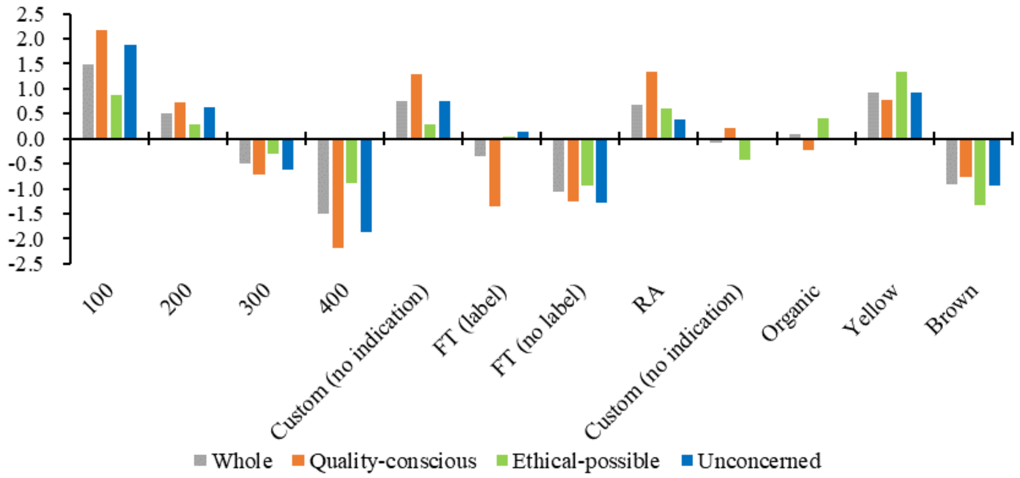


Fig. 1 Relative importance (%) of each attribute



JPY100=USD0.87 (as of March 2022)

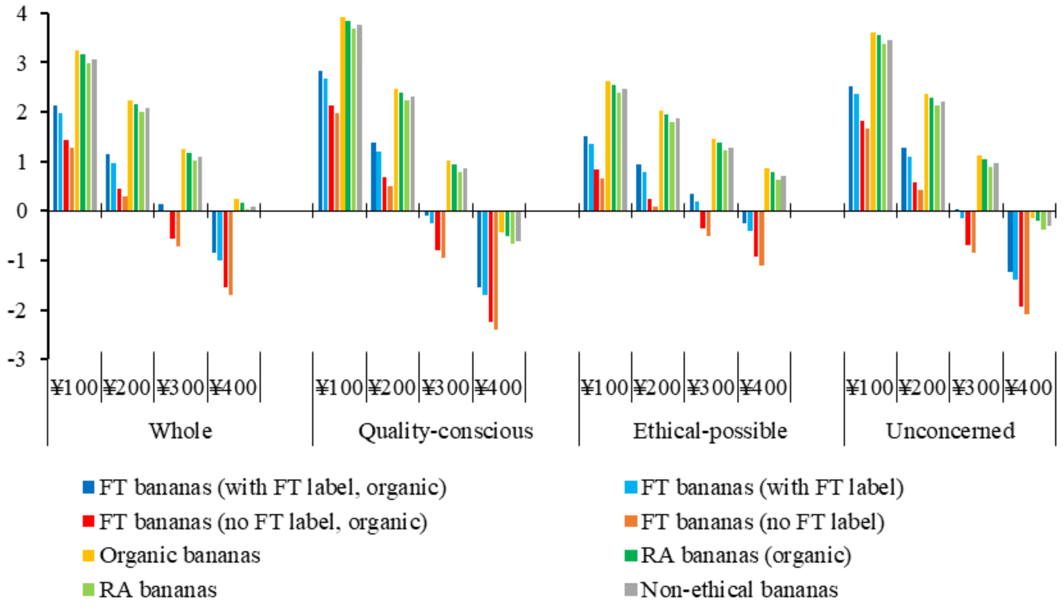
Fig. 2 Part-worth utility of each level

Utility of Ethical Bananas

In the current market in Japan, FT bananas including organic and conventional are usually sold online, and the price is over 400 yen per 500g. Organic and RA bananas are sold not only online but also in supermarkets. The prices of these bananas range from 200 yen to less than 400 yen. Organic bananas are sometimes sold at 200 yen and below.

Figure 3 shows the utility of each banana by each cluster. The utility of RA and organic bananas were almost the same as non-ethical bananas which are not organic and have no ethical label. On the other hand, they had a low utility towards FT bananas, especially non-labeled bananas. Compared to each cluster, the "quality-conscious" cluster had a negative utility to FT bananas including labeled and non-labeled with a price of over 300 yen. Similarly, the "unconcerned" cluster had a negative utility to those FT bananas with the price except FT-labeled organic bananas. The "ethical-possible" cluster had a positive utility to FT-labeled bananas at 300 yen but negative to non-labeled FT bananas at the same price. Concerning organic and RA bananas, "ethical-possible" had a positive utility for those bananas at 400 yen, while the other two clusters had positive utility at 300 yen and below. The bananas that consumers have the highest utility are organic bananas. Therefore, it is considered that organic and RA bananas have a possibility that the demand for those bananas increases but no possibility for FT bananas in the current situation.

A premium price is more effective than a reduced price for the sales promotion of ethical products (Onishi, 2021). In addition, the decrease in the current volume of FT products is a challenge to accomplish FT purposes. Therefore, to increase FT banana purchases, there is a need to increase consumers' recognition and comprehension of FT and issues in the banana production field while keeping the current retail price. Consumers mainly purchase fresh products in supermarkets because of their accessibility (National Supermarket Association of Japan, 2015). Therefore, for RA and organic bananas, it is considered that promoting the sales of these bananas in a supermarket leads to the expansion of the market.



**JPY100=USD0.87 (as of March 2022)*

Fig. 3 Utility of each banana by each cluster

CONCLUSION

From the results of Factor Analysis, Cluster Analysis, and Conjoint Analysis, the respondents have the utility towards RA and organic bananas as high as non-ethical bananas and have low utility towards FT bananas. Therefore, it is considered that organic and RA bananas have a possibility to increase demand while there seems to be no possibility of an increase for FT bananas in the current situation. Meanwhile, the "ethical-possible" cluster which accounts for over 50% of the respondents has the highest utility towards FT bananas among the three clusters. Hence, to expand the market for ethical bananas in Japan, there is a need to increase the recognition and comprehension of FT and issues in the banana production field and promote the sales of RA and organic bananas in a supermarket.

ACKNOWLEDGEMENTS

This study was conducted as a part of the undergraduate thesis accepted in January 2022. I would like to extend my appreciation to my advisers Prof. Dr. Katsumori Hatanaka, Prof. Dr. Kazunori Sato, and Asst. Prof. Dr. Ramadhona Saville for their constructive suggestions and unwavering support. I also would like to show gratitude to all the people who supported this research with their kind cooperation in answering my questionnaire.

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Research article

Ecosystem Carbon Stock Assessment in Upland Forest: A Case Study in Koh Kong, Mondulkiri, Preah Vihear, and Siem Reap Provinces

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Received 11 September 2023 Accepted 25 November 2023 (*Corresponding Author)

Abstract The climate change problem is caused by human-induced increases in the stock of greenhouse gases (GHGs) in the atmosphere. In Cambodia, forests provide many important ecosystem services to local people such as food production, natural medicine, water supply, and wind/storm protection. Additionally, Cambodian forests sequester a considerable amount of carbon, contributing to the mitigation of greenhouse gas-induced climate change on a global level. However, the amount of carbon stored in forests differs according to spatial and temporal factors such as forest type, size, age, stand structure, associated vegetation, and ecological zonation, among other things. The current research aimed to i) conduct forest inventory of upland forest area in the Koh Kong, Mondulkiri, Preah Viher, and Siem Reap provinces of Cambodia, and ii) assess carbon stock at the target sites across different provinces. The study applied the carbon stock assessment methodology as outlined in the National Forest Inventory and the Field Manual for the National Forestry Inventory of Cambodia issued by the Food and Agriculture Organization (FAO) in 2018, applied across different types of forest at several pilot project sites. In addition, the study conducted an assessment of carbon stock in soil and ground litter carbon pools. The research studied five carbon pools: aboveground biomass pool (AGB), belowground biomass pool (BGB), litter biomass pool, dead wood biomass pool, and soil organic carbon pool (SOC). The results indicated total carbon stock in Koh Kong Province at 200.04 tonnes C/ha for evergreen forest, in Mondulkiri Province at 246.18 tonnes C/ha for deciduous forest, in Preah Vihear Province at 185.06 tonnes C/ha for deciduous forest, and in Siem Reap Province at 207.67 tones C/ha for deciduous forest and 414.13 tones C/ha for evergreen forest

Keywords aboveground biomass, belowground biomass, carbon stock, dead wood, litter, soil organic carbon

INTRODUCTION

Many plant species, especially the native species are essential to understand the plant communities in Cambodia. The country is predominantly rich in biodiversity and other natural resources for socio-economic development, food, livelihoods, and well-being. Most of them are threatened with extinction through human activity. Most of the flora species, especially the native species are key to the plant communities in the country. The forest area of Cambodia is managed by three government institutions: Forestry Administration (FA) of the Ministry of Agriculture, Forestry and Fisheries (MAFF), the General Directorate of Administration for Nature Conservation and Protection (GDANCP) of the Ministry of Environment (MoE). FA is the government agency under MAFF, and its mandate is to manage forest and forest resources of the Permanent Forest Estate (PFE), including naturally growing and planted state forest resources and is subdivided into the Permanent Forest Reserve (PFR) and Private Forest. The PFR consists of production forest, protection forest, and conversion forestland. According to the Forestry Law (2002), Private Forests shall be maintained by owners with interesting rights to manage, develop harvest, use, sell, and distribute the product by themselves. Reducing Emission from Deforestation and Forest Degradation (REDD); and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries (REDD+) is a mechanism to use financial incentives to reduce greenhouse gases emitted by deforestation and forest degradation.

OBJECTIVE

The research aims i) to conduct forest inventory of upland forest area in the four provinces, and ii) to assess carbon stock in different provinces of the target sites.

METHODOLOGY

The study was conducted in four provinces such as Koh Kong (KK), Mondulkiri (MDK), Preah Viher (PVH), and Siem Reap (SR) province. There were 8 clusters or 24 permanent plots conducted forest inventory survey, and the case study was implemented from September 2021 until June 2022.

The overall procedure of this survey followed the National Forest Inventory (NFI) sampling design and Field Manual for the National Forestry Inventory of Cambodia issued by the Food and Agriculture Organization (FAO, 2018). The tool is used for producing information on the state of forests and forest resources for land use policy at the national and regional levels.

Carbon Stock Estimation

Aboveground biomass was estimated using different allometric equations for different types of forest. The allometric equation developed by Chave et al. (2014) was applied to evergreen forests and the equation developed by Kim et al. (2019) was used for semi-evergreen and deciduous forests.

Table 1 Allometric equations used to determine tree mass and each carbon pool of the forest types encountered in the study areas

Forest types / Pools	Equation	References
Evergreen forest	AGB = 0.0673* (DBH^2* H* WD) ^0.976	Chave et al. 2014
Semi-evergreen forest	AGB = 0.0607* DBH^2.2692* H^0.5122 WD^0.3183	Kim, et al. 2019
Deciduous forest	AGB = 0.0607* DBH^2.2692* H^0.5122 WD^0.3183	Kim, et al. 2019
Standing Dead trees	Mass = V * WD decomposition class V = A * L * 100	Chao et al. 2008
Stump	Mass = V * WD decomposition class V = A * L * 100 A = (d1/2) * (d2/2) * π	Chao et al. 2008
Fallen Dead Wood	Mass = V * WD decomposition class $V = L\left[\frac{\pi\left(\frac{D_1}{2}\right)^2 + \pi\left(\frac{D_2}{2}\right)^2}{2}\right]$	Chao et al. 2008

Note: AGB = Aboveground biomass (kg); BGB = Belowground biomass (kg); DBH = Diameter at breast height (cm); WD= wood density (g/cm^3)

Trees aboveground biomass was summed to plot level and converted to ton per hectare. A 95 % confidence interval was calculated with the forest types in average aboveground biomass. The carbon stocks were finally calculated as the sum of aboveground and belowground biomass multiplied by conversion factors see Eq. 1.

Equation Conversion from AGB to Carbon Stock:

$$C\ stock = AGB * (1+RS) * CF * 44/12 \qquad (1)$$

Where RS is the Root-to-shoot ratio. Different root-to-shoot ratios were applied to the different forest types: 0.37 for evergreen forest (IPCC 2006) and 0.2 for all other types (IPCC 2006). CF is carbon fraction, using the carbon fraction value 0.47 (IPCC 2006), and 44/12 is atomic mass conversion from carbon to CO_2.

Table 2 Main species in each forest type and province

Species Name	KK1	MDK1	MDK2	MDK3	MDK4	PVH1	SR1	SR2	Total	FRE	%
	Semi-evergreen	Deciduous						Evergreen			
Shorea obtusa	0	0	1	23	4	1	18	0	47	5	62.5
Terminalia alata	0	8	4	9	4	0	2	0	27	5	62.5
Xylia xylocarpa	0	9	1	4	0	0	2	0	16	4	50.0
Terminalia mucronate	0	0	4	1	7	0	1	0	13	4	50.0
Careya arborea	0	2	2	2	0	0	2	0	8	4	50.0
Shorea siamensis	0	4	85	0	0	0	11	0	100	3	37.5
Syzygium cumini	0	0	0	0	0	4	1	2	7	3	37.5
Irvingia malayana	0	0	0	0	0	2	1	2	5	3	37.5
Knema corticosa	0	0	1	1	0	3	0	0	5	3	37.5
Catunaregam tomentosa	0	0	4	0	0	0	9	0	13	2	25.0
Dipterocarpus tuberculatus	0	0	0	12	1	0	0	0	13	2	25.0
Melodorum fruticosum	0	0	0	0	0	1	0	11	12	2	25.0
Aporosa ficifolia	0	1	0	0	0	0	9	0	10	2	25.0
Cratoxylum cochinchinense	0	0	0	0	4	0	0	2	6	2	25.0
Shorea roxburgshii	0	0	2	0	4	0	0	0	6	2	25.0
Haldina cordifolia	0	0	1	3	0	0	0	0	4	2	25.0
Mitragyna sp.	0	0	0	1	0	0	3	0	4	2	25.0
Spondias pinnata	0	1	0	3	0	0	0	0	4	2	25.0
Syzygium lineatum	0	3	0	0	1	0	0	0	4	2	25.0
Antidesma ghaesembilla	0	0	2	1	0	0	0	0	3	2	25.0
Cinnamomum litseifolium	1	0	0	0	0	2	0	0	3	2	25.0
Grewia eriocarpa	1	0	0	0	0	0	0	2	3	2	25.0
Vatica odorata	0	0	0	0	0	2	0	1	3	2	25.0
Microcos paniculata	1	0	0	0	0	1	0	0	2	2	25.0

Wood density was added to the tree-level data based on species and genus averages from the Global Wood Density (GDW) database (Jerome Chave et al., 2009; Zanne et al., 2009). The data from Southeast Asia and Southeast Asia Tropical were selected, and averages were calculated for each species and genus. Wood density for each tree was based on species if available in the GWD, genus if species were not available, or a default value of 0.57 g/cm^3 if both species and genus were unknown, not recorded, or not in the data. The default value was based on a wood density average for Tropical Asia by Reyes et al. (1992). To estimate dead wood mass, it was initially calculated the volume of each dead wood piece. Then, converted the volume to dry mass using wood densities based on decomposition class, the wood density of class 1 was 0.55, class 2 was 0.41, and class 3 was 0.23. Some literature values are useful to adopt estimation of dead wood mass. For example, wood densities in three decomposition classes are estimated in Amazonian forests, in Peru (Chao et al., 2008).

Calculation of Soil and Litter Carbon Pools

Soil Sample was taken from a field survey at the General Directorate of Agriculture (GDA) laboratory. Soil samples were dried in the oven and recorded timely. The laboratory processing for soil samples was to explore the following parameters: Organic matter, Nitrogen, pH, total carbon, and Hydrogen. The liter sample was taken and put in a plastic bag and then dried in the dry oven or solar dryer. Follow-up and weigh the samples every day until constant drying.

RESULTS AND DISCUSSION

Main Tree Species for Each Forest Type

According to the field inventory survey in the study site, the tree species were found 98 species, including unknown Species 4 species in 8 clusters, 24 plots. It also described on number of species in each forest type and cluster ID in each province. The main tree species in the study site such as *Shorea obtusa*, *Terminalia alata, Xylia xylocarpa*, *Terminalia mucronate,* and *Careya arborea*.

Comparison of Height and Diameter of Height Breast by Each Cluster ID (Provinces)

Depending on the study on comparison of height, the maximum tree height in the research site is about 36 meters, where the highest Cluster ID is in SR2, located in Kulen mountain, Siem Reap province. DBH maximum cluster is MDK1 which is rich in *Terminalia alata* and *Xylia xylocarpa*.

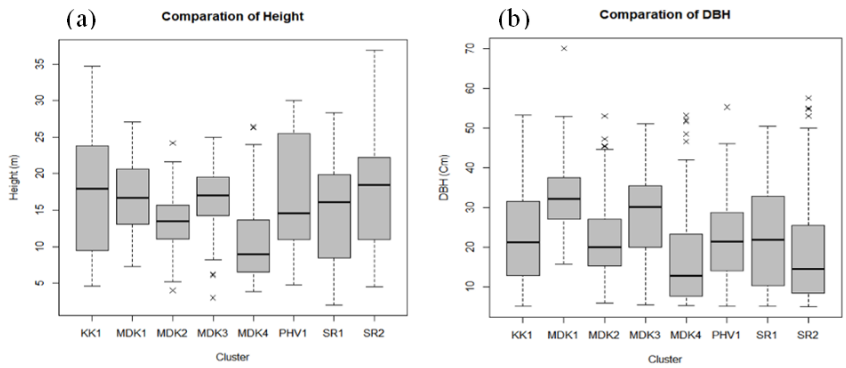

Fig. 1 Comparisons of height by cluster ID (a) and of DBH by cluster ID (b)

Carbon Pool (AGB, BGB, and Deadwood)

As a result, the aboveground tree (AGB) biomass in each plot was different depending on the number of trees present in the plot and forest types, too. The total aboveground biomass in this study excluded bamboo. Therefore, the estimated value of total aboveground biomass was higher than the Cambodia FRL, which excluded bamboo in aboveground biomass. The total aboveground biomass in the deciduous forest was 98.24 t/ha or 46.17 Ct/ha, semi-evergreen forest was 183.20 t/ha or 86.11 Ct/ha, while evergreen forest was 336.07 t/ha or 157.95 Ct/ha, and other was 75.92 t/ha or 35.68 Ct/ha.

Deadwood was defined as one of the carbon pools in terms of the calculation of carbon stock. In this study, the average biomass from deadwood in deciduous forests, semi-evergreen forests, and evergreen forests was a bit different (11.58 t/ha, 10.74 t/ha, and 6.79 t/ha, respectively). The result was similar to (USAID, 2014) which estimated the biomass from deadwood in Cambodia. By including the biomass from deadwood in the estimation, the total carbon stock in the research location will be increased.

Table 3 Aboveground biomass, belowground biomass, and dead wood biomass

Cluster ID	Plots	Forest Type	AGB	BGB	SD	CI95%	Dead Wood	SD	CI95%
KK1	2	Semi-evergreen	96.76	19.35	11.11	15.40	3.33	2.59	3.58
MDK1-4	12	Deciduous	119.07	23.81	58.79	33.26	3.30	2.14	1.21
PVH1	3	Deciduous	61.98	12.40	48.33	54.69	0.55	0.96	1.08
SR1	3	Deciduous	114.90	22.98	35.52	40.20	2.54	2.22	2.51
SR2	2	Evergreen	222.57	82.35	161.45	223.75	4.30	2.04	2.83

Soil Organic Carbon and Litter Carbon Pools

According to the manual of the National Forest inventory, the size of take soil sample was 40 x 40 cm, with three levels of soil layer (SL) (sampling position deep was 5 cm, 15 cm, 25 cm). The study showed that soil carbon pool as well as the C stocks in each of the three layers. Soil depths were 40 cm respectively. The mean of carbon in the soil was 80.06 C t/ha for the semi-evergreen forest in Koh Kong, the deciduous forest in Mondulkiri was 99.35 C t/ha, deciduous forest in Preah Vihear was 109.37 C t/ha, and deciduous forest in Siem Reap was 65.95 C t/ha and evergreen forest in Siem Reap was 104.09 C t/ha.

Litter was defined as one of the carbon pools in terms of the calculation of ecosystem carbon stock. Based on forest type, the semi-evergreen forest in Koh Kong was 0.54 C t/ha, the deciduous forest in Mondulkiri was 0.65 C t/ha, the deciduous forest in Preah Vihear was 0.76 C t/ha, the deciduous forest in Siem Reap was 1.3 C t/ha and evergreen forest in Siem Reap was 0.82 C t/ha. The result was similar to (RUA, 2020) which estimated the biomass from turnover leaves in Cambodia.

Table 4 Carbon pool in soil organic matter and litter by different forest types and provinces

Cluster ID	Forest type	Soil C (t/ha)			Total C (t/ha)	CO_2	Litter C (t/ha)	CO_2
		SL1	SL2	SL3				
KK1	Semi-evergreen	33.42	24.22	22.43	80.06	293.57	0.54	1.96
MDK1-4	Deciduous	48.12	25.95	25.28	99.35	364.29	0.65	2.39
PV1	Deciduous	36.79	36.45	36.13	109.37	401.01	0.76	2.77
SR1	Deciduous	18.03	24.11	23.80	65.95	241.82	1.30	4.76
SR2	Evergreen	38.04	37.98	28.07	104.09	381.66	0.82	3.02

Table 5 Total carbon stock in each province by forest types

Provinces	Koh Kong	Mondulkiri	Preah Vihear	Siem Reap	Siem Reap
Forest Types	Semi-evergreen (C t/ha)	Deciduous (C t/ha)	Deciduous (C t/ha)	Deciduous (C t/ha)	Evergreen (C t/ha)
ABG	96.76	119.07	61.98	114.90	222.57
BGB	19.35	23.81	12.40	22.98	82.35
Deadwood	6.31	5.97	1.18	5.41	8.87
Litter	0.54	0.65	0.76	1.30	0.82
Soil	80.06	99.35	109.37	65.95	104.09
Total C stock	200.04	246.18	185.06	207.67	414.13

Total Carbon Stock in Four Provinces Based on Different Forest Types

Forest ecosystem carbon stock is the amount of carbon that has been sequestered from the atmosphere and is stored within the forest ecosystem, mainly within living biomass and soil, and dead wood and litter. Results of forest carbon stock in the study areas shown in Table 5, semi-evergreen in Koh Kong was 200.04 Ct/ha, deciduous forest in Mondulkiri was 246.18 Ct/ha, deciduous forest in Preah Vihear was 185.06 Ct/ha, deciduous forest in Siem Reap was 207.67 Ct/ha, and evergreen forest in Siem Reap was 414.13 Ct/ha.

CONCLUSION

This case study provides a current estimation of forest biomass and carbon stock in the different forest types by four provinces of Cambodia, which are important biophysical outcomes of the forest landscape. A total of 8 clusters or 24 permanent sample plots within different forest types in natural forests were assessed from September 2021 until June 2022. Vegetation parameters, along with the total carbon stock were calculated separately for different forest carbon pools. It can be concluded that the forest, on the third forest type, can sequester more carbon in the future as the trees have enough DBH values, which means a greater tendency to build biomass, and therefore carbon content. There are 98 species in the tree layer were recorded, and *Shorea obtusa, Terminalia alata, Xylia xylocarpa, Terminalia mucronate, Careya arborea* were the dominant tree species in the third forest type based on density. The carbon stock of semi-evergreen forest in Koh Kong (200.04 C tone/ha) was lower than that of deciduous forest in Mondulkiri (246.18 C tone/ha), deciduous forest in Preah Vihear (185.06 C tone/ha) was lower than Siem Reap (207.67 C tone/ha) and evergreen forest in Siem Reap (414.13 C tone/ha) was highest carbon stock, if compare with each province in this research. Finally, the result indicates that different carbon stocks in different provinces and forest types contribute to improving environmental quality, reducing greenhouse gas emissions, and supporting the government strategy in terms of sustainable management of the forestry sector in Cambodia.

ACKNOWLEDGEMENTS

The study was made possible thanks to the project “Digitizing Herbarium Collection and Conservation of Native Species in Cambodia” implemented by the faculty of forestry science of the Royal University of Agriculture, funded by the HEIP Project of the Ministry of Education, Youth and Sports.

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Research article

Application of Probabilistic Risk Assessment to the Chalky Rice Grain Issue in Japan

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Received 19 November 2023 Accepted 26 November 2023 (*Corresponding Author)

Abstract In recent years, extreme weather events have become more frequent, and there are concerns about the increase of chalky rice grains. Therefore, it is important to understand the frequency and severity of high-temperature injuries to rice grains occurring nationwide in Japan. Thus, the objective of this research was to analyze the hazard of high temperature through a probabilistic method using big weather data and to assess the risk of chalky rice grain. In this research, we analyzed air temperature data from approximately 800 stations of the AMeDAS (Automated Meteorological Data Acquisition System) in Japan and checked the chronological changes. To assess the risk of chalky rice grain, the Probabilistic Risk Assessment (PRA) method was applied and the risk for each of the 20 years from 1980 to 1999 and from 2000 to 2019 was compared. Chalky rice grains, which reduce rice quality, increase when the average temperature exceeds 26℃ during the first 20 days after the heading date of rice. A comparison of the areas with air temperatures exceeding 26℃ at least once per three years (33.3%) between the past and the recent 20 years shows that the risk of high temperatures has increased in the inland areas of the southern Tohoku region and the southern part of Ibaraki Prefecture. Subsequently, a multiple regression model was applied to identify the factors affecting high temperature risk. The 20-day averaged daily mean temperature, which has a probability of 33.3%, was set as the dependent variable, and longitude, altitude, and urban area ratio were set as explanatory variables. As a result, regions located further north experience greater temperature increases due to climate change, and regions with higher urban rates also experience greater temperature increases due to anthropogenic effects.

Keywords climate change, climate hazard, agricultural damage, paddy rice quality

INTRODUCTION

In recent years, there have been many reports of high-temperature injury in rice (Terashima et al., 2001). The main symptoms are a decrease in grain filling rate and a decrease in grain weight per grain (MAFF, 2006), which can reduce the inspection grade and yield, respectively, thereby decreasing farmer income (Morita, 2008). The inspection grade is determined by the minimum grain filling rate and the maximum proportion of rice classified as a chalky rice grain or other non-grain filling categories (National Food Safety and Quality Association, 2002).

The reason CRGs appear "chalky" is due to empty spaces between starch granules in the endosperm, which cause light to scatter randomly (Tashiro and Ebata, 1975). In fact, in "chalky" areas caused by high temperatures, there have been observations of empty spaces between amyloplasts, normally polyhedral amyloplasts that are round, and small amyloplasts that only contain two or a few single-grain starches (Tashiro and Wardlaw, 1991; Zakaria et al., 2002).

Masutomi (2019) revealed that CRG begins to occur when the average temperature exceeds 26°C during the 20 days after rice heading. The study also presented the predicted spatial distribution of this damage under future climate conditions. However, in analyzing the risk of agricultural damage, it is important to consider not only the severity of the damage but also the probability (frequency) of its occurrence.

OBJECTIVE

This study aims to use a probabilistic method and weather big data to analyze the risk of high temperatures and assess the risk of CRGs in Japan.

METHODOLOGY

Probabilistic Risk Assessment

Probabilistic Risk Assessment (PRA) is a method of quantitatively evaluating risk using probability theory and is commonly used in the safety assessment of structures. For example, the International Atomic Energy Agency (IAEA) uses probabilistic risk assessment to evaluate the safety of nuclear facilities. PRA involves integrating probability fields that represent the predicted seismic forces at the construction site of the facility, represented as a hazard curve, with the load represented as a fragility curve when specific seismic forces are applied, and evaluating the risk in terms of annual damage probability (IAEA, 2010). In addition to structures, some studies quantitatively evaluate the risk that herbicides for rice fields pose to the surrounding ecosystem (Nagai et al., 2008). To assess the risk of CRGs, we applied the PRA method and compared the risk for two 20-year periods: 1980-1999 and 2000-2019. CRGs, which can negatively impact the quality of rice, are more likely to occur when the average temperature exceeds 26°C during the first 20 days after the heading date of rice.

We utilized daily mean temperature data from Japan's Automated Meteorological Data Acquisition System (AMeDAS), which consists of over 1600 observatories. However, due to the inclusion of recently established stations and the presence of missing values, we did not compute data for any station that had less than 90% data availability during the analysis period. After applying this criterion, the number of stations eligible for our calculations was approximately 830. The data of 20 days mean air temperature were extracted in descending order and the top five values per year were selected for further analysis. Using Eq. (1), the annual exceedance probability was calculated based on these values.

$$P_{(x)} = 1 - e^{\left(-\frac{n}{T}\right)} \tag{1}$$

where, x: 20 days mean air temperature (°C), T: observation period, n: The number of occurrences of mean temperatures above x°C.

Multiple Regression Analysis

To identify the factors that have the most significant impact on the increase in temperature resulting from global warming and anthropogenic effects, multiple regression analysis was conducted. The dependent variable was the 20-day averaged daily mean temperature with an annual exceedance probability of 33.3% (i.e., once in the 3-year probability of occurrence), while latitude and elevation were chosen as explanatory variables due to their well-established negative correlation with temperature. The reason for adopting a threshold of 33.3% can be exemplified by Sompo Japan Thailand. This company has set the frequency of early drought coverage in its weather index insurance for rice drought damage in Thailand to about once every three years. Additionally, we included urban land use coverage as an explanatory variable due to its known role in raising temperatures. For latitude and elevation, we used the coordinates and elevation data of AMeDAS stations published by the Japan Meteorological Agency. For urban land use coverage, we utilized land use data in 2010 from JAXA, calculating urban land use coverage within a buffer of 10 km in diameter centered on the AMeDAS station being examined following Fujibe (2011).

RESULTS AND DISCUSSION

To analyze the risk of CRGs, we calculated the annual probability of 20-day averaged daily mean temperature exceeding 26°C for the recent 20 years (2000-2019) in Fig 1. The probability of exceeding 26°C is low in Hokkaido or the northern part of Japan, where temperatures are relatively low throughout the year, and in high-elevation areas (mountainous regions), indicating a low risk of high-temperature injury. In the areas south and western parts of Japan, the annual probability of exceeding 26°C frequently occurs, except in high-elevation areas.

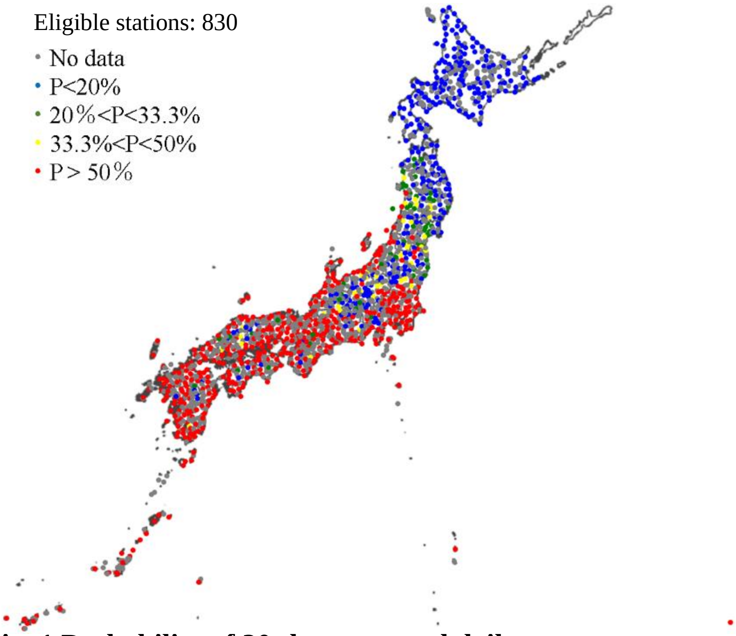

Fig. 1 Probability of 20-day averaged daily mean temperature exceedance by 26°C for the last 20 years (2000-2019)

To examine the changes in the probability of annual exceedance of 26°C for the 20-day averaged daily mean temperature over the past 20 years and the recent 20 years, we calculated the difference of temperature with a probability of 33.3% between the two periods. Yoshida et al. (2019) indicated that the most frequent climate hazard in Northeast Thailand occurs once every four years. The concern of this research lies in high-frequency climate hazards that are not covered by insurance, hence setting a threshold of 33.3%, which means a frequency of once every three years. To identify locations with significant differences, we used color-coded observation points based on the significance of the difference. As shown in Fig. 2, locations with insufficient data are represented in gray, those with negative change are depicted in blue, locations with no change are represented in green, locations with a change greater than 0°C and less than 0.3 are depicted in yellow, and locations with a change greater than 0.3°C are depicted in red. Notably, Fig. 2 has more 'No Data' points than Fig. 1. This is because each station needed to have over 90% data availability in both time periods. This stricter rule reduced the number of sites with sufficient data, resulting in an increased number of locations categorized as 'No Data'. With a few exceptions, most of the sites depicted in red are located slightly inland from the coast. This is likely due to the high heat capacity of the oceans in coastal areas, which makes it difficult for temperature changes to occur. There are many locations in the southern part of the Ibaraki prefecture where the risk of high-temperature injury has increased, consistent with the findings of Masutomi et al. (2019), who observed a decreasing trend in the ratio of first-class rice in future climates.

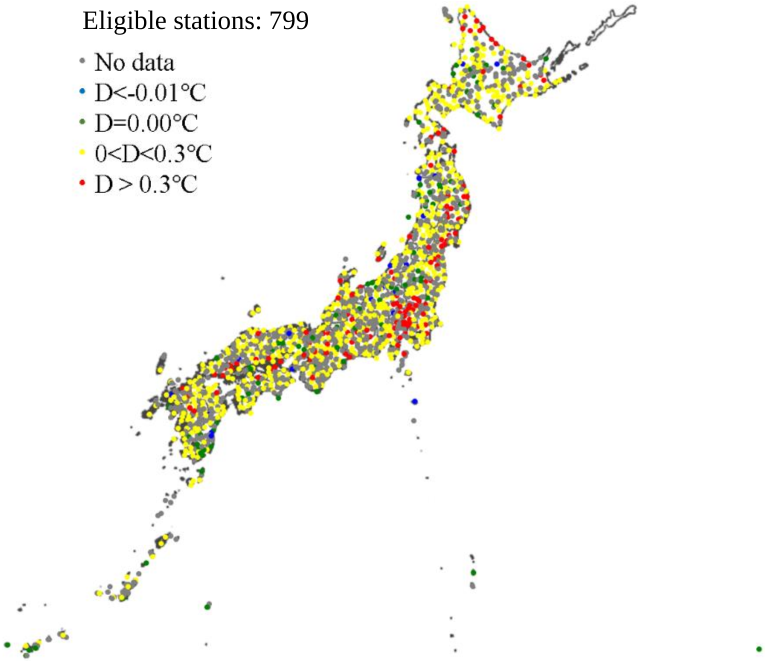

Fig. 2 Difference in temperature for two periods with a yearly exceedance probability of 33.3%

The data were organized for multiple regression analysis with the dependent variable being the difference of past and recent 20-day averaged daily mean temperature which occurs in 33.3% probability of the year and the explanatory variables being latitude, elevation, and urban land use ratio within a 10 km diameter buffer centered on the AMeDAS observatory. In the analysis, points with more than 90% of the observation period for substantial explanatory variables were extracted and examined. Applying this rule reduced the sample size to 799. The explanatory variables were standardized using the following Eq. (2), and multiple regression analysis was conducted using the standardized variables.

$$x' = \frac{x-\overline{x}}{s} \quad (2)$$

where, $\overline{x}$: mean value in sample, *s:* standard deviation in sample.

The difference in temperature between two periods with a yearly exceedance probability of 33.3% was used as the dependent variable, and latitude and urbanization rate were used as explanatory variables in a multiple regression analysis. Table 1 shows the coefficients and p-values for the results. The coverage of urban land use within a 10 km buffer is represented by the percentage of JAXA land use maps classified as "urban," so it is referred to as the "urban rate" in the table. From this multiple regression analysis, it was found that there were statistically significant results for latitude and urban land use coverage at the 1% level. The partial regression coefficients for the explanatory variables were 0.124 for latitude and 0.279 for urban land use coverage. This indicates that regions located further north experience greater temperature increases due to climate change and that regions with higher levels of urbanization also experience greater temperature increases due to anthropogenic effects. Among these, it was also shown that urbanization has a greater contribution to temperature increases. Also, the analysis suggested that the impact of urbanization on temperature rise is more pronounced in northern regions compared to southern regions. In Fig. 2, most points near cities in northeastern regions are shown in red, while there are fewer red points near cities in southern regions. This means that cities in different places are affected differently by urbanization when it comes to temperature changes.

Table 1 Results of the multiple regression analysis

	coefficients	P-value
Intercept	0.000	1.000
Elevation	-0.029	0.401
Latitude	0.124	0.000
Urban rate	0.279	0.000

CONCLUSION

In this study, hazard curves were probabilistically created from nationwide AMeDAS data mainly using temperature as a meteorological factor, and based on the results, the risk of chalky rice grain was examined using a probabilistic risk assessment method. The 26°C yearly exceedance probability of the 20-day averaged daily mean temperature was calculated for the past 20 years (1980-1999) and the recent 20 years (2000-2019) at all AMeDAS observatories in Japan, and the change in the two periods was calculated to analyze the change of high-temperature risk. When the acceptable frequency of damage for farmers was set to 33.3%, it was shown that the risk of high-temperature damage in inland areas of the southern Tohoku region and the southern area of Ibaraki Prefecture has increased in the recent 20 years. The characteristics of points where the risk of high-temperature damage has greatly increased were inland areas slightly away from the coast. On the other hand, the risk of high-temperature damage decreased in the northern part of the Tohoku region, especially surrounding areas near the ocean. To quantitatively measure regional differences in temperature increases due to climate change, multiple regression analysis was conducted with the change in temperature with a yearly exceedance probability of 33.3% as the dependent variable and latitude, elevation, and urbanization rate as dependent variables. It was found that there were statistically significant results for latitude and urban land use coverage at the 1% level. The partial regression coefficients for the explanatory variables were 0.124 for latitude and 0.279 for urban land use coverage. This shows that climate change affects the northern part more and might become significant in the agricultural land located near the urban city area. In this study, we just used 26°C Celsius as a threshold of CRG and 33.3% probability as a farmer's acceptable frequency level, however further research is needed about the rice varieties or farmer's perception.

To tackle the issue of Chalky Rice Grains (CRGs), various strategies have been suggested. Morita et al. (2015) recommended applying enough nitrogen during or after the panicle initiation stage. Similarly, Chiba et al. (2013) suggested using deep-flood irrigation to control the temperature at the surface of rice paddies. In addition to these immediate solutions, Masutomi (2019) proposed the development and use of rice varieties that can better withstand high temperatures, as a long-term approach. Although these methods have been effective in reducing CRGs, they often involve significant costs. Therefore, it is important for future research to include detailed cost-benefit analyses to identify the most cost-effective adaptation strategies.

ACKNOWLEDGEMENTS

This research was supported by the MEXT/JSPS Grant-in-Aid for Scientific Research (KAKENHI) no.19H03069 and no.20KK0346.

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Research article

Agricultural Support for New Farmers in H City, Tokyo, Japan

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Received 6 September 2023 Accepted 26 November 2023 (*Corresponding Author)

Abstract In Japan, engaging in agriculture as a new farmer comes with various challenges and uncertainties. To sustain and secure the agriculture sector's future, national and local governments, farmers, private entities, and other stakeholders provide a wide range of support. Seeking best practices is a sound basis for increasing the number of new farmers and improving their resilience. Through a case study approach, this study aimed to clarify the current condition and issues of agricultural support for new farmers in H City, Tokyo, and determine the initiatives and agricultural support that assisted a young female farmer in establishing an urban farm. This study conducted interviews with a young female farmer and city officers. The in-depth key informant interviews revealed that training, subsidies, securing land services, and referral to farmer's organizations are some of the available forms of support. The interviewed farmer considered the recent revision of the Law on Productive Green Areas a significant opportunity for her to rent farmland, which is a challenge for most new farmers. Despite the fact that a 5-year rental period is commonly practiced, she could avail of a 30-year lease, conveying the importance for new farmers to also develop trust, confidence, and a good relationship with the farmland owner. Although the interviewed farmer has successfully established a farm, there is a need for further investigation to clarify consumer preferences, buying behavior, and their degree of familiarity with her farm and products to improve her farm business and resilience.

Keywords new farmers, law on productive green areas, farm resilience, female farmer

INTRODUCTION

According to the Ministry of Agriculture, Forestry and Fisheries Japan (MAFF Japan, 2020), the country's self-sufficiency level was 73% in 1965 and decreased severely to 38% based on calorie-based calculation in 2021. Therefore, the primary source of food for human consumption and feed for livestock mainly depends on imports from abroad. Although the country must increase its self-sufficiency level, decreasing trends in farmland area and population are apparent challenges in the agricultural sector of Japan. According to MAFF Japan (2021a), the total cultivated area was 6.0 million ha at a peak in 1961 and gradually decreased to 4.3 million ha in 2021. For the past four decades, the number of individuals employed in the agricultural sector declined by more than 60% from 5.77 million in 1980 to 2.13 million in 2020 (Statistics Bureau Japan, 2022).

Under such circumstances, urban agriculture supplies agricultural products and provide muti-functioned environment in the cities. According to MAFF Japan (2022), 13.0% of the total agricultural management entities are in urbanization-designated area (*shigaika-kuiki* in Japanese), commonly defined by the urban municipalities. These 140,000 agricultural management entities contribute about 7.0% of gross domestic agricultural production, only cover 62,000 ha of farmland limitedly 1.4% of the total domestic farmland. Looking at those farmers who work mainly in agriculture, 70% of them are over 65 years old and only 11% of them are younger than 49 years old (MAFF Japan, 2022). In this apparent situation of aging farmers, identifying ways to increase the number of new farmers is crucially important. What kind of support new farmers need remains a question here. In this study, we organize policies of the government and attempt how new farmers are supported by introducing a case of a new tomato farmer in H city.

METHODOLOGY

We described policies and trends of agriculture in the H city based on key informant interview of H City Agricultural Affairs Division on 20 June 2022 at the H city hall. Through a case study approach, we collected reference materials related to the sequence of events when starting farming and establishing agricultural cooperation, and conducted an interview and observation survey regarding the current business of Ms. K.

RESULTS AND DISCUSSION

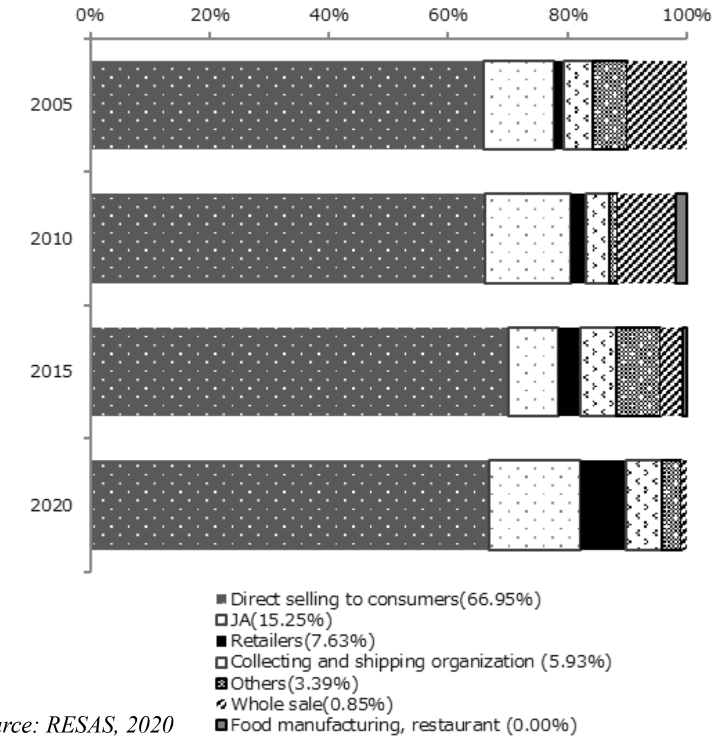
Policy for New Farmers in Japan

According to Bureau of Urban Development (2022), the promotion of productive green areas was proceeded as the *Productive Green Area Act* among large cities for city planning development, to avoid farmland conversion to housing land area and maintain the agricultural environment in cities. If landowners keep the land as the green area which are not only farmland but also related business including farm restaurant and direct selling shop for agricultural products; benefits include payment of fixed asset tax of the green area under farmland category, and eligibility for inheritance tax payment grace system. It is expected that agriculture promotion leads to land retention.

The *Productive Green Area Act* and at same time *Urban Farmland Leasing Facilitation Act* assist new farmers in accessing farmland for the long-term. The latter act secures the landowner's right over the farmland for a long-term lease contract. It protects them not to lose the land rights after leasing out the land to non-family members. Historically, Japan had a landlord system between landowners and tenants before land reforms were implemented twice in the 1940s. With this act, tenants were entitled to hold landownership of the land as actual cultivators. This may be a reason why the landowner avoids long-term leases to others, especially non-families. When new farmers' parents are not from a farming family without succession, they experience difficulties in starting farming. Hashimoto and Mitsuhashi (2017) studied the case of Utsunomiya City's new farmers. When they start farming, they need access to land, financial support, and training opportunities. Osawa (2014) also pointed out that especially access to farmland become a barrier for new farmers from non-farming families. His research illustrates a way to create places for new farmers to sell vegetables at direct selling markets and let them gain more profit even though they produce small volumes at a time. In addition to the land access, a new farmer needs support. Tokyo Metropolitan Government (Bureau of Industrial and Labor Affairs, n.d.) designs supporting systems for new farmers: A farming preparation fund (supports financially new farmers during the training period before they start farming on their own within 2 years) and Business start-up capital (supports new farmers immediately after they start farming when management is unstable within 3 years). In the new farmer settlement support project as a farming preparation fund, the Tokyo Chamber of Agriculture supports newly certified farmers. Municipalities subsidize 3/4 of the operating costs for cultivation-related facilities and agricultural machinery (Tokyo Chamber of Agriculture, 2021). The new farmers gained experience and reached an annual income of 3 million yen.

Background of H City, Tokyo

With regards to agriculture, blueberry, pear, apple, persimmon strawberry, radish, and tomato are well-known agricultural products of H City. There are many picking farms of blueberries and/or apples as popular agritourism destinations. The high season of picking farms is in summer, between July and August. Radish is Tokoji (Toko temple) in a line of Nerima radish as one of the Edo vegetables.



Source: RESAS, 2020

Fig. 1 Management entities by marketing channels for agricultural products (%)

According to the H City based on an interview, agriculture in the H City was once used to be active in rice farming, but from the mid-1950s onwards there was a shift to upland farming. The conversion was to produce crops with a higher selling price than rice. Tomatoes were one of them. Cultivation in greenhouses was introduced in the 1960s, and it became important. Since 2009, tomatoes have been produced using a barrel cultivation system. Tomatoes have become a specialty product. Currently, there are 8 tomato farmers in the H City. Based on the key informant interview of H City agricultural affairs division staff, the total number of farm households decreased from 371 in 2005 to 273 in 2020. Moreover, there are only 57 farmers who are younger than 50 years old, 238 farmers are older than 50 years old including 76 farmers above 75 years old. In H City, more than 100 cases convert farmland of paddy fields and fields into housing areas every year. There is a total of 57 ha of farmland under cultivation of H City, comprising of paddy field 4 ha, a vegetable field 37 ha, and a fruit orchard 16 ha. The ratio of farmland compared to the whole land of H city decreases from 4.1% in 2005 and 2.1%. Out of 129 farm households in 2020, 123 households averagely cultivate less than 1 ha, 5 households cultivate in the range from 1.0 to 1.5 ha and only one household cultivate larger than 1.5 ha in 2020. Notedly, as shown in Fig. 1, 67% of the agricultural products harvested in H city are sold directly to the citizens in H city through farmer's market or roadside stand locally, indicating that producers and consumers seems to have close distance in H City. It may be predictable that people in H City are used to purchasing local products and being familiar with the local brands or producers of fruits and vegetables.

A Case of the New Farmer as a Tomato Producer

There are three main attempts by the municipal administration based on the Tokyo metropolitan government's policy: (1) implementing the New Farmer Settlement Support Project with the additional subsidy by H City, (2) increasing the motivation of citizens to support farm work for local farmers, and (3) producing and consuming locally through the direct farm shop and school lunch catering. As of 20 June 2022, funds of new farmers come from the Tokyo metropolitan government subsidy (equivalent to 75% of the total expense) and the remaining 25% is equally sourced from H city subsidy and new farmer's own capital.

There are three types of new farmer support in the H City: (1) new farmer as the successor of an existing farmer, (2) newly employed farmer at agricultural cooperation, and (3) new entrants from non-farm households. Among these new farmer types, there is the "authorized new farmer (*nintei shinki shunousha*)" who submits own management plan to the municipal office. New entrants of farming in this system are limited to youth in the age range from 18 to 44 years old. H City prepares not only subsidies but also support to rent in farmland and introduces agricultural organization under the municipal administration.

In the H City for the past 22 years from the year 2000 to 2021, there have been 29 new farmers as heirs of the existing farmers who start working at home. On the other hand, there are only 2 new farmers as authorized new farmers, and Ms. K is the first case of new farmer under the new farmer settlement support project in 2020 to develop one tomato cultivation facility. According to Ministry of Land, Infrastructure, Transport and Tourism (n.d.), the *Law on Productive Green Area* was enacted first in 1974. In 1992, it was revised to add tax reductions on inheritance tax and property tax with the condition of area larger than 500 sq. m. In 2017, it was again partially revised to allow the following: (1) municipalities can reduce the area from 500 sq. m. to 300 sq. m. or more by ordinance, (2) to set up restaurants, processing facilities, and farmer's markets in the area, and (3) If 30 years have passed after the municipality register the land as a productive green area, the purchase offer period can be extended to 10 years. Landowners can receive tax break for property tax as farmland tax not as housing and deferring inheritance tax payment. In September 2018, after the Urban Farmland Leasing Facilitation Act was enacted, tenants could rent the land directly from the owner of the land, and those owners still could maintain the grace period for paying inheritance tax after they rent out in the urban area (*shigaika--kuiki*) (MAFF, 2021b). This act is limited to the land that is designated as a Productive Green Area. Advantages of the act area; for tenant it is easier to rent-in directory, and for owner after the contract period usually long term, the farmland will be returned, therefore the landowner can rent it with confidence.

After graduating from university, Ms. K started working for a large-scale tomato greenhouse company. In 2017, she became a farm trainee in Tokyo and established the Farm in H City in 2018. When she was looking for farmland to start farming, there was a revision of the law on productive green areas in 2018. It triggered for Ms. K to rent farmland from a local landowner. The law allows landowners to receive tax breaks even if they rent own farmland out to others. Ms. K became very first new farmer who could have access to the land lease in Japan after the law on productive green area was revised. She gained support from Tokyo Chamber of Agriculture member (Tokyo Chamber of Agriculture, 2021) and the municipal officer as third parties. When someone is new to be farmers, it is quite hard to gain trust from landowners. With the support of the Tokyo Chamber of Agriculture and the H City, she was assisted in having a 30-year rental contract for the land and installed facilities to produce tomatoes and other crops. For the land rental, she seemed to have benefitted from *Urban Farmland Leasing Facilitation Act* and the revision of Productive Green Act. Moreover, she purchased three greenhouses with the subsidies under new farmer settlement support project. Since seven-eighth was paid by subsidies, her expense became only one-eighth of the total expense. As Ms. K explains, the landlord understands her desire to make a large investment and build a greenhouse, and in anticipation of the payback period of the investment, she was able to rent the land for an extended period.

She produces vegetables in the cultivating facilities of the plastic greenhouse as shown in Fig. 2a. Her products are certified as Tokyo GAP (Good Agriculture Practice) and eco-farm products of Tokyo (Fig. 2b). In addition to medium-sized, large-sized, and mini-sized tomatoes, the farm also produces turnips, blueberries, and other vegetables. Most vegetables are sold fresh, except for some tomatoes that are processed tomato puree with yellow, green, and red colored tomatoes and bottled separately. These colorful puree products are sold online. She sells fresh tomatoes and others through her online shop in a box. The marketing channels of the fresh tomatoes include the unmanned store (*mujin hanbai*) in front of the farm (Fig.4), the farmer's market of Japan Agricultural Cooperative (JA), a shop supported by the municipality, local fruits and vegetable shops, and chain supermarkets in Tokyo. Moreover, she proactively participates in a local young farmer's club since 2020 to revitalize the agriculture of H City. She also sells her own products at those coordinated events. She also opens events at her farm for local kids with parents to and feel the importance of food through various farming activities such as harvesting fruits and vegetables.

To promote sustainable agriculture in Tokyo, issuance of Tokyo GAP started in April 2018. As of 2 March 2022, 130 farmers were certified (Bureau of Industrial and Labor Affairs, n.d. on Promotion of GAP in Tokyo). Farmers who apply for Tokyo GAP are required to fill out the checklist and comply with water quality, recordings of management, soil cultivation, IPM (Integrated Pest Management) to reduce chemical input, and other recommended farming practices. On the other hand, the certification of eco-farm products started in 2021. It intends to reduce the usage of synthetic pesticides and chemical fertilizers. There are three categories of certification: 25% or more reduction, 50% or more reduction, and no usage at all. When farmers do not apply any of the inputs, their products are considered "Tokyo Eco-100" (Tokyo Metropolitan Government, 2017). In the case of tomatoes, these are commonly certified as "Tokyo eco-25" with a 25% reduction of synthetic pesticides and chemical fertilizers through agriculture. These two certifications ensure her concerns on human health and the environment load reduction by applying sustainable farming practices.

(a) Production facility (b) Certification sign boards (c) Unmanned store (*mujin hanbai*)

Source: Farm Visit, 2022

Fig. 2 Pictures taken at Ms. K's farm

CONCLUSION

This paper presents the national and municipal policies to support new farmers. After the overview of agriculture in the H City was introduced, the case of new farmers were described. In the H City, the number of farmers has been on the decline, and maintaining and increasing the number of farmers is an important mission. For this reason, the city actively implements support for new farmers. When they start farming, they need access to land, financial support, and training opportunities. They support not only those who become farmers as successors but also non-farmers who are new to farming as one of the important policies of the city. This article took up the case of Mr. K, a tomato producer who also produces blueberries and vegetables. To start production in the H city in 2019, access to land was a challenge. But after the revision of the *Productive Green Area Act*, as the first new farmer (non-farmer who is from a non-farming household), she has been producing tomatoes. Now, she is one of the popular local farmers featured in various media so people often recognize her face and name. A specific element of the successful case in the H City is still not commonly seen in Japan. Municipal officer and Tokyo Chamber of Agriculture supported her to have access to a 30 year-land lease which is a very rare case. However, this implies that without third parties support including land access, new farmers from non-farming family cannot start farming even though they intend to be as farmer as the general implication.

ACKNOWLEDGEMENTS

The authors wish to extend appreciation to the H City Officers and Ms. K for sharing time and valuable information.

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Research article

Technical Efficiency of Potato Producers in Benguet Province, Philippines

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Received 25 September 2023 Accepted 28 November 2023 (*Corresponding Author)

Abstract The Benguet Province of the Philippines is endowed with distinct agroecological zones favorable for the production of high-value vegetables. Potato is one of the top ten vegetable crops in Benguet Province in terms of production area, volume, and value. However, potato production in the Philippines in general is characterized by low yield, with a yield per hectare of 15.5 tons compared to the world average yield of 20.9 tons in 2018. This study examined the technical efficiency (TE) and inefficiency determinants of potato producers in Benguet Province, Philippines. Data from 101 farmers from the major potato-producing municipalities in Benguet Province was collected in 2019. We employed the Cobb-Douglas stochastic production frontier after the null hypothesis for the translog function was rejected. The production function result revealed that land, hired labor, organic fertilizer (chicken dung) and fungicide had significant effects on potato yield. We also found that the mean technical efficiency of potato farmers is about 0.89, implying that farmers can increase their production by about 11%, with an average yield increase from 15.8 to 17.6 t/ha, using existing resources. The yield gap result further revealed that farmers are producing below the production possibility frontier. However, the observed average yield is about 50% lower than the potential yield (31 t/ha) found by Benguet State University. The inefficiency model result depicted that a larger household size, higher level of education, using the Granola potato variety, receiving training related to vegetable production, and partial irrigation significantly improve technical efficiency, while hand tractor ownership and rainfed cultivation were the major sources of technical inefficiency in potato production. In conclusion, while comprehensive plot-level studies including various parameters remain important to understanding why potato producers' yields are significantly lower than the potential yields, we recommend promoting the Granola variety along with the use of organic fertilizers and the provision of training to enhance the efficiency of producers.

Keywords potato production, technical efficiency, stochastic production function, Philippines

INTRODUCTION

Vegetable production in the Philippines shows an increasing trend in terms of total value of production compared to rice production which was the leading crop until 2020 (Department of Agriculture, 2021). The vegetable production is divided into two main classifications based on location and climatic conditions i.e., highland and lowland. Benguet province in the Cordillera Administrative Region (CAR) is the leading highland vegetable producer area endowed with distinct agroecological zones favorable to producing high-value vegetables. Potato is one of the top ten vegetables in terms of production area, volume, and high value in Benguet. Among the six regions that grow potatoes in the Philippines, CAR contributes 73% and 83% of production area and volume respectively (PSA, 2020). However, potato production is characterized by low yield in the Philippines in general is among the lowest yield per hectare (15.5 tons) compared to the world average yield (20.9 tons) in 2018. According to the JICA 2019 report, there is a reduction in the production of cabbage, cauliflower, carrots, and potatoes in Benguet province. The decrease in the area planted, extreme weather events, pest and disease problems, and low adoption of high-yielding varieties were among the main causes. In this context, only a few studies exist including the status of potato varieties (Kiswa et al., 2020); identification of potato varieties, agronomic characteristics, and potential yields (Gonzales et al., 2016). As far as our knowledge, no studies have been conducted in Benguet to investigate whether the declining production trend is attributed to the technical efficiency of producers. Therefore, this study aims to understand the extent to which potato producers can attain the utmost output from the available combination of inputs.

OBJECTIVES

The objectives of this research are as follows;
1) to estimate the technical efficiency of potato producers, and
2) to identify major sources of technical inefficiency in potato production.

METHODOLOGY

The data used in this study was collected by Benguet State University (BSU) with funding from the Department of Agriculture, Bureau of Agricultural Research (DA-BAR) in 2019, in reference to 2018 production season. Farm-level information including farm profile, facilities, input-output information, perception of recommended practices, and other variables were collected from 700 farmers (7 crops) in eight selected municipalities of Benguet Province, Cordillera Administrative Region, Luzon Island. This study used the potato data collected from 101 farmers in the Atok, Bakun, Buguias, Kibungan, and Mankayan municipalities. Multistage sampling was employed first by selecting the top five municipalities of Benguet with the largest area planted to potatoes. All the villages in the sample municipalities with areas that planted potatoes were then shortlisted from where three villages were randomly drawn.

Empirical Model

Following the neo-classical definition of technical efficiency, a production process is considered technically efficient when it attains the highest achievable output from a given combination of inputs. This study utilized the Stochastic Frontier (SF) approach, which is a parametric method for evaluating farm-level efficiency. The SF model dissects the error term into a two-sided random error that accounts for uncontrollable random effects beyond the firm's control (the decision-making unit), and a one-sided efficiency component. In this research, we adopted the model outlined by Battese and Coelli (1995), and the model specification is provided as follows (Eq.1):

$$Y_i = f(x_i;\beta)\exp(v_i - u_i) \tag{1}$$

where Y is the quantity of output (potato yield) on the ith firm, x is a vector of inputs (production inputs shown in Table 1) used, β is a vector of parameters, $f(x_i;\beta)$ is a suitable production function, v is a random error term assumed to be independently and identically distributed as $N(0,\sigma_u^2)$, independent of u, which represents technical inefficiency and is identically and independently distributed as truncated normal, with truncation at zero of the normal distribution (Battese and Coelli, 1995). The maximum likelihood estimation of Eq. 1 yields an estimator for β and γ, where $\gamma = \sigma_u^2/\sigma^2$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$. The total variation of output from the frontier, which is attributed to technical inefficiency, is given by γ and has a value between zero and one. Battese and Coelli (1995) proposed a model in which the technical inefficiency effects in a stochastic production frontier are a function of other explanatory variables. In their model, the technical inefficiency effects, u are obtained by truncation (at zero) of the normal distribution with mean, $z_i\delta$ and variance σ_u^2 , such that:

$$u_i = z_i\delta \tag{2}$$

where z_i is a vector of farm-specific explanatory variables (Table 1) and δ is a vector of unknown coefficients of the farm-specific inefficiency variables.

The technical inefficiencies in Eq. 2 can only be estimated if the technical inefficiency effects, u_i are stochastic and have distributional properties (Coelli and Battese, 1995). These conditions lead to conducting different hypothesis tests using the generalized likelihood-ratio statistic, λ, given by Eq. 3.

$$\lambda = -2[\ln\{L(H_0)\} - \ln\{L(H_1)\}] \tag{3}$$

where L (H_0) and L (H_1) denote the values of the likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. In the end, predictions of technical efficiency scores were done as follows in Eq. 4.

$$TE_{ij} = \exp(-u_{ij}) \tag{4}$$

Summary statistics of output, input, and farm-specific explanatory variables are given in Table 1.

RESULTS AND DISCUSSION

Technical Efficiency of Potato Production

To select the accurate functional form for potato producers' technical efficiency estimation, a loglikelihood ratio test was done. The test result revealed that the Cobb-Douglas production functional form is appropriate to estimate potato technical efficiency. Moreover, gamma was computed following the Cobb-Douglas production function to confirm the presence of technical inefficiency in the stochastic frontier model. The result shows that about 25.5% of the total variation in potato production is explained by technical inefficiency. Following the lower value of the gamma, both the unrestricted (stochastic frontier model) and restricted (ordinary least square) estimations were undertaken to confirm whether the presence of technical inefficiency is significant or not. For this purpose, the loglikelihood ratio (LR) test result was generated by applying LR = -2[L(H_0)-L(H_1)][4]. The LR test result (42.68) was statistically significant at $p < 0.01$, affirming the significance of technical inefficiency in potato production. This substantiates the appropriateness of employing the stochastic frontier model to estimate potato producers' technical efficiency. Additionally, the log-likelihood of the stochastic frontier model was also statistically significant at $p < 0.01$, indicating the overall fitness of the model is robust. This suggests that the model's parameters for the variables differ significantly from zero.

The model result revealed potato productivity and the area allocated for potato production had a negative and statistically significant relationship. This implies that an increase in area allocated to potato production results in a decrease in potato productivity. This implies that a large farm size is less productive than a small farm size. On the other hand, hired person day per hectare and potato productivity had a positive and statistically significant relationship. For instance, a 1% increase in hired person day per hectare will increase potato productivity by 0.041%. Similarly, chicken dung

[4] L(H_0) and L(H_1) are the loglikelihoods of the unrestricted and restricted models, respectively.

per hectare had positively and significantly affected potato productivity. This means that potato productivity will be increased by 0.334% for a 1% increase in chicken dung per hectare. Moreover, the number of fungicides had a positive and statistically significant effect on potato productivity at $p<0.05$. This implies that potato producers were effectively using fungicides to protect against harmful fungal diseases that severely affect potato growth and productivity.

Table 1 Descriptive statistics and variables included in the stochastic frontier analysis

Variables	Description	Mean	Standard deviation
Output			
Potato yield	Potato yield ton/ha	15.78	12.52
Production inputs			
Land	Potato planted area in hectare (ha)	0.48	0.37
Family labor	Total family and exchange labor in person day/ha	4108.00	8108.00
Hired labor	Total hired labor person day/ha	323.88	617.49
Chemical fertilizer	Total chemical fertilizer in kg/ha	543.18	483.88
Organic fertilizer	Total chicken dung fertilizer in kg/ha	9522.81	7904.91
Insecticides	Total insecticides kg a.i.* /ha	2.33	3.44
Herbicides	Total herbicides kg a.i.* /ha	2.97	3.20
Fungicides	Total fungicides a.i.* /ha	41.84	38.13
Technical inefficiency variables			
Household size	Number of family members	4.68	2.19
Education	Number of years of schooling	9.52	3.36
Training	Dummy (1= if farmers have veg. production training, 0= No)	0.24	0.43
Potato seed variety	Dummy (1= Granola, 0= Igorota (PO_3))	0.60	0.49
Land topography	Dummy (1= hilly/undulating terraced, 0= river/flood plain)	0.82	0.38
Hand tractor ownership	Dummy (1= yes, 0= No)	0.28	0.45
Partially irrigated	Dummy (1= if farmers use partial irrigation, 0= otherwise)	0.38	0.49
Rainfed	Dummy (1= if farmers use fully rainfed, 0= otherwise)	0.63	0.48
Atok Municipality	Dummy (1= if Atok Municipality, 0= otherwise)	0.03	0.17
Bakun Municipality	Dummy (1= if Bakun Municipality, 0= otherwise)	0.10	0.30
Buguias Municipality	Dummy (1= if Bugaias Municipality, 0= otherwise)	0.39	0.49
Kibungan Municipality	Dummy (1= if Kibungan Municipality, 0= otherwise)	0.29	0.45
Mankayan Municipality	Dummy (1= if Mankayan Municipality, 0= otherwise)	0.20	0.40
Number of observations			101.00

Source: Benguate State University (BSU) in collaboration with the Department of Agriculture (DA), 2019
Note: Actual use in liters and kg/ha were converted to kg active ingredient (ai)using ai equivalent from FPA, 2021

On the other hand, herbicide and potato productivity had a negative and statistically significant relationship. This shows that more herbicide users are less likely to be efficient in potato production than their counterparts. The model result further reveals that potato productivity will be decreased by 0.076% for a 1% increase in herbicide. The technical efficiency scores result shows that the score ranges from 0.19 to 0.99 and the average score was 0.89. This shows that potato producers were producing about 11% below the average production capacity. Moreover, the distribution of technical efficiency was categorized into six groups considering statistical procedures. The result shows that about 78.2% of the technical efficiency level was 0.9 and above. Whereas, about 7.9% of the technical efficiency level was 0.8.

Factors Affecting Technical Inefficiency in Potato Production

The results in Table 2 demonstrated that various factors influenced the technical efficiency of potato production. Household size had a negative effect on the technical inefficiency of potato production, indicating that an increase in household size is associated with reduced technical inefficiency. Agricultural production, especially potato farming, is known for its labor-intensive nature. Therefore, a larger household size facilitates the demanding tasks of farm plot preparation, sowing, follow-up, and harvest. Furthermore, a larger household size plays a crucial role in lowering the costs of hiring labor and reducing the time required to find labor during peak production seasons.

Table 2 Parameter estimates of the stochastic frontier and inefficiency model

Variables	Coefficient	Std. Error	T-value	P-value
Log (Planted area)	-0.275***	0.091	-3.040	0.002
Log (Family labor)	-0.045	0.035	-1.270	0.205
Log (Hired labor)	0.042*	0.022	1.920	0.055
Log (Chemical fertilizer)	-0.018	0.030	-0.600	0.549
Log (Organic fertilizer)	0.334***	0.066	5.070	0.000
Log (Insecticide)	0.023	0.033	0.690	0.493
Log (Fungicide)	0.135**	0.062	2.180	0.029
Log (Herbicide)	-0.076***	0.034	-2.270	0.023
Constant	6.092	0.562	10.840	0.000
			Technical inefficiency	
Household size	-0.739**	0.333	-2.220	0.026
Educational level	-0.429**	0.175	-2.450	0.014
Training	-1.648**	0.828	-1.990	0.047
Potato seed variety	-1.078*	0.604	-1.780	0.074
Land topography	-1.230**	0.607	-2.030	0.043
Hand tractor ownership	3.117**	1.259	2.480	0.013
Partially irrigated	-1.274**	0.553	-2.300	0.021
Rainfed	2.845**	1.355	2.100	0.036
Bakun	0.755	4.156	0.180	0.856
Buguias	0.559	4.099	0.140	0.892
Kibungan	-2.198	4.308	-0.510	0.610
Mankayan	3.226	4.006	0.810	0.421
Constant	3.942	4.581	0.860	0.389
σ_u	0.268**	0.120	2.230	0.026
σ_v	0.458***	0.035	13.180	0.000
λ	0.584***	0.126	4.640	0.000
γ				0.255
$\sigma^2 = \sigma_\mu^2 + \sigma_v^2$				0.281
Mean technical efficiency				0.898
Loglikelihood				-64.59***
-2[L(H₀)-L(H₁)]				42.68***
Number of observations				101

*Source: Benguate State University (BSU) in collaboration with the Department of Agriculture (DA), 2019. *, **, *** indicate significant at 10%, 5% and 1% level respectively.*

Similarly, there is a negative and statistically significant relationship between educational level and technical inefficiency. As the educational level of the household head increases, the technical inefficiency of potato production decreases. This implies that less educated farmers exhibit greater inefficiency compared to those with higher educational attainment. This might be due to the proficiency of literate household heads in crop production and management, understanding the dynamics of production trends, and implementing yield-enhancing strategies that surpass that of less educated farmers. Likewise, a negative and statistically significant relationship occurred between training access and technical inefficiency.

Granola potato seed had a negative and statistically significant effect on the technical inefficiency of potato production. This shows that Igortoa seed users are more inefficient than Granola seed users. Moreover, the mean comparison result confirms that the mean productivity of Granola seed (16.8 tons/ha) is higher than Igorota seed (14.2 tons/ha). The cross-tabulation result depicted that about 53.16% and 46.84% of Granola and Igorota seed users' technical efficiency distribution is 0.9 and above, respectively. This shows that Granola seed users are more efficient than Igorota seed users. Therefore, the model result is congruent with the cross-tabulation and mean comparison results. Additionally, land topography had negative and statistically significant effects on the technical inefficiency of potato production. This implies that river/floodplain land topography increases potato production inefficiency more than hilly/undulating terraced land topography. This might be due to river/floodplain land topography being more susceptible to soil erosion that results in poor soil fertility. Then, poor soil fertility directly affects potato growth and productivity.

Conversely, hand tractor ownership had a positive and statistically significant effect on the technical inefficiency of potato production. This shows that hand tractor users are more inefficient than non-users. The mean potato productivity comparison result also reveals that the mean potato productivity of hand tractor owners and non-owners was 14.3 tons/ha and 16.4 tons/ha, respectively. This result is unexpected and might be hand tractor owners renting out their tractors for better returns instead of using them for potato cultivation, or the tractor type may not be suitable for potato production. However, this requires further validation.

Whereas potato production through partial irrigation had a negative and statistically significant relationship with technical inefficiency. In contrast, rainfed production and technical inefficiency had a positive and statistically significant association. This illustrates that rainfed producers are more inefficient than fully irrigated production users. This further shows that rainfed potato production might be prone to water shortage due to drought and erratic rainfall as potato production needs more water compared to other cereal crops.

CONCLUSION

This study found that the observed average potato yield (15.8 t/ha) in Benguet province is about 50% below the potential yield found by the BSU-Northern Philippine Root Crops Research and Training Center. About 60% of producers used the Granola variety obtaining 16.8 t/ha on average and the remaining used the Igorota variety (14.2 t/ha). Besides, the estimated mean technical efficiency of potato producers was 0.89. The model result depicted that yield and technical inefficiency of potato production are determined by land size, hired labor, amount of organic fertilizer (chicken dung), agro-chemicals, household size, education level, training access, Granola variety, topography, irrigation use, and hand tractor ownership respectively. Therefore, we conclude that concerned stakeholders such as the Department of Agriculture, universities, and research institutes, among others should conduct a measured plot level study including various parameters to understand why potato producers' yield is much lower than the potential yields of the two dominantly grown varieties (Igorota variety (25-35 t/ha) and Granola (21-30 t/ha)) despite farmers' relatively efficient potato production. Furthermore, the promotion of the Granola variety, coupled with the application of organic fertilizers and the provision of training related to potato production, is essential for enhancing the efficiency of potato producers and, consequently, boosting productivity in Benguet province.

ACKNOWLEDGEMENTS

We acknowledge Benguet State University and the Department of Agriculture, Bureau of Agricultural Research for allowing us to use part of the data on "Highland Vegetable Value Chain Analysis for Use in Policy Formulation and Impact Evaluation of Agricultural Training Posts".

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Research article

Effect of Dry Brewery Residue on the Growth of Local Chicken (*Gallus domesticus*)

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Received 20 October 2023 Accepted 2 December 2023 (*Corresponding Author)

Abstract Residue from the food industry such as dry brewery residue (DBR) has the potential to replace traditional ingredients used in chicken feed, the costs of which have been increasing greatly year by year. The current study is aimed at evaluating the effect of different levels of DBR in chicken feed on chicken growth. The basic diet was supplemented with 0% (used as a control), 20%, 25%, or 30% DBR content. The broiler chickens were raised in a Completely Randomized Design (CRD) with three replicates, and each replicate contained ten six-week-old broilers. Experimental results showed that there was no significant difference in the mean weight of chickens among the four treatments from week 1 to week 5. However, in weeks 6 and 7, the third treatment which applied 25% DBR, resulted in greater weight gain than the first treatment (0% DBR), the second treatment (20% DBR), and the fourth treatment (30% DBR), at $P<0.05$. Additionally, the intake of feed by chickens in the third treatment was significantly higher than for other treatments ($P<0.05$) during weeks 6 and 7. Taken together, these results suggest that basic feed supplemented with 25% DBR can promote chicken growth better than other levels of DBR, and this increased growth is likely promoted by more feed intake.

Keywords dry brewery residue (DBR), local broiler chicken, intake, growth

INTRODUCTION

Animal husbandry plays a pivotal role in contributing to the growth of the agricultural sector. According to the General Department of Animal Health and Animal Production, Cambodia achieved USD 5.1 billion in 2021 in the animal husbandry sector, an increase of six percent compared to 2020's USD 4.8 billion (Khmer Times, 2022).

In rural Cambodia, the people's livelihoods are dependent predominantly on agriculture. More than half of all rural Cambodian households keep poultry (IFAD, 2021). Still, Cambodian farmers who raise chickens face a range of problems, such as slow-growing chickens, disease, markets, and expensive feed. Feed is commonly imported from neighboring countries such as Vietnam and Thailand, costing approximately USD 200-300 million each year (The Phnom Penh Post, 26 July 2022).

Poultry production in Cambodia is still a small-scale industry compared with neighboring countries and the production can be classified into traditional/backyard, semi-intensive small or medium-scale, and intensive large-scale industrial (Birhanu et al., 2021). About 90% of poultry production is under the traditional/backyard system that has small flock sizes usually less than fifty birds per household (Birhanu et al., 2021). Demand for poultry products has significantly increased in the past decades and this upward trend is projected to continue (ICEM, 2014; Sun, 2018). Local bird breeds are the highest in demand in the local market, especially during festivals and celebrations (IFAD, 2021).

Animal feed is one of the most important factors for determining animal growth, quality, and price in animal chain production. However, the main problem needed to be addressed is to lower the cost of animal feed through the efficient utilization of local input. The current study applied different levels of Dry Brewery Residue (DBR) discarded by the brewery industry to the chickens' basic feed diet and we found that the application of 25% DBR promoted growth better than other DBR inputs.

OBJECTIVE

The main objective of the study is to find out the optimal level of DBR supplemented with the basic diet that best promotes local chicken growth.

METHODOLOGY

Experimental Location

The experiment was conducted at the Department of Livestock Research Section, Kampong Speu Institute of Technology (Figure 1) from June 1st to July 12th, 2022.

Fig. 1 Location of the experimental site in Angkom Village, Amlaing Commune, Thpong District, Kampong Speu Province

The red point indicates the chicken farm (11°48'05.8"N 104°17'29.4" E).

Table 1 Experimental design with 4 treatments and 3 replicates

Experimental Design		Number of Chickens	Level of DBR (%)
T0 (control)	T0R1	10	0%
T0 (control)	T0R2	10	0%
T0 (control)	T0R3	10	0%
T1	T1R1	10	20%
T1	T1R2	10	20%
T1	T1R3	10	20%
T2	T2R1	10	25%
T2	T2R2	10	25%
T2	T2R3	10	25%
T3	T3R1	10	30%
T3	T3R2	10	30%
T3	T3R3	10	30%

Note: T stands for Treatment, whereas R for Replicate

Experimental Design

The experiment was designed as a Complete Randomized Design (CRD) including 4 treatments with 3 replicates with each replicate containing 10 chickens (Table 1). Each treatment (referred to as T) was added with different levels of DBR as follows: T0 (0%), T1 (20%), T2 (25%), and T3 (30%). The same amount of basic diet including rice bran 10%, broken rice 8%, dietary supplement 42%, final feed product 18%, brewers Dried Grains 20%, and corn 9% was added to each treatment.

Feeding: First, brewery residue was received from the brewery factory (Khmer Beverages) and was put in the dryer at 280°C for 45 seconds in order for it to become Dried Brewery Residue (DBR) (Kuleile et al., 2019). Different levels of DBR (as mentioned in Table 1) were supplemented with a basic diet. This feeding method is primarily based on the description by Leang, 2004 with a slight modification. The feed was provided three times a day starting at 6:00 AM for the first time, 12:00 pm for the second time, and 17:00 pm for the third time (Leang, 2004).

Data collection and statistical analysis: The amount of feed intake (FI), initial weight of chicken, and weekly chicken growth weight were recorded. All relevant data was analyzed using the Excel program. One-way ANOVA was performed to compare the quantitative data among the treatments.

RESULTS AND DISCUSSION

Chicken Growth

The current study focused on the growth of local chickens (*Gallus domesticus*), through the application of different levels of DBR. The experimental results revealed that each treatment steadily increased chicken weight growth from week 1 to week 7 (Table 2).

There was no significant difference in weight growth of chickens during weeks 1, 2, 3, 4, and 5 among the 4 treatments (P>0.05). However, the average chicken weight of treatment 3 (T3) using 25% DBR increased significantly as compared to the other treatment levels tested in weeks 6 and 7 (P<0.05) (Table 2). Nevertheless, the application of 30% DBR (T4) to the basic diet showed significantly decreased chicken weight as compared with chicken feed with 25% DBR (Table 2). Hence, these results indicate that the optimal level of DBR for chicken growth is 25%, and an increased amount of DBR beyond that value led to the reduction of chicken growth weight. This result is consistent with the previous study in poultry that found that the application of 10-20% of DBR resulted in better growth of young birds and up to 30% in older poultry (Fasuyi et al., 2018).
Parpinelli et al. (2018) reported that a 10% inclusion rate of DBR in broiler chickens during the finishing phase maintained a high production performance. In broilers between 12 and 33 days old, the inclusion rate ranged between 10% and 20% of DBR, supporting acceptable growth and feed utilization and seeming to favor the development of a well-functioning gizzard (Denstadli et al., 2010). According to the National Research Council (NRC 1994), standard brewers' ingredients contain 25.3% protein, 6.3% fat, 92% dry matter, and approximately 2080 kcal/kg of metabolizable energy.

Table 2 Chicken weight growth during 7 weeks of feeding (g/chicken)

Weeks after feeding	T1 (DBR=0%)	T2 (DBR=20%)	T3 (DBR=25%)	T4 (DBR=30%)	P-value
1	702.58 ± 92.4	700.64 ± 47.4	672.25 ± 24.8	695.48 ± 97.8	0.833
2	855.80 ± 61.0	860.00 ± 77.5	841.29 ± 48.3	829.33 ± 43.5	0.918
3	991.61 ± 32.8	1024.51 ± 97.9	1027.74 ± 61.1	998.00 ± 78.8	0.883
4	1156.12 ± 97.5	1159.05 ± 43.2	1171.61 ± 73.9	1141.83 ± 28.6	0.970
5	1302.25 ± 34.9	1326.00 ± 96.2	1389.66 ± 89.3	1317.35 ± 93.3	0.597
6	1478.06 ± 21.1	1441.33 ± 25.2	*1560.66 ± 25.4	1496.89 ± 45.8	0.041
7	1532.74 ± 23.1	1554.00 ± 35.1	**1680.66 ± 22.9	1518.10 ± 45.1	0.001

Notes: Values shown are each average of 30 chickens (±SD) with 3 replicates.
** and ** indicate significance at the 5% and 1% level, respectively, compared with other treatments at the same period of feeding, as judged by One-way ANOVA analysis. T is referred to as Treatment.*

Feed Intake Index (FI)

The feed intake index (FI) is crucial for chicken weight growth and ensuring economic benefit in poultry production. To understand whether the chicken gains weight as related to FI, we observe the average amount of chicken of different DBR treatments for 7 weeks. Table 3 shows that in the first week, the FI showed no significant difference among the 4 treatments. In the second week, treatment 1 (T1), without the supplement of DBR, produced higher FI ($P<0.05$). However, there was no significant difference at week 3 ($P>0.05$) among the 4 treatments. At week 4, the highest FI was observed in treatment 4 ($P<0.05$). From weeks 5, 6, and 7 treatment 3 (T3) (DBR=25%) produced significantly higher weights than other treatments ($P<0.05$). These results suggest that younger chickens showed no clear feed intake among different levels of DBR. However, it is probable that when a basic diet is supplemented with 25% DBR, the chickens consume more feed, a trend that is consistent with the increased weight of chickens among the group (Table 2).

Table 3 Feed intake index of chicken of different DBR treatments (% of the total amount of diets)

Weeks after feeding	T0 (DBR=0%)	T1 (DBR=20%)	T2 (DBR=25%)	T3 (DBR=30%)	P-value
1	56.49 ± 7.80	53.61 ± 9.84	43.73 ± 16.0	52.28 ± 8.60	0.250
2	**76.73 ± 5.57	52.77 ± 8.22	59.60 ± 11.3	58.20 ± 7.72	0.001
3	53.68 ± 2.66	60.39 ±12.2	64.65 ± 9.96	65.27 ± 9.84	0.235
4	67.81 ± 2.31	81.78 ± 4.17	85.48 ± 4.87	**88.08 ± 1.37	0.001
5	78.04 ± 1.47	81.92 ± 5.29	*85.20 ± 3.71	82.20 ± 4.24	0.011
6	84.39 ± 3.57	84.04 ± 5.60	*88.87 ± 4.36	80.96 ± 8.12	0.044
7	85.12 ± 5.82	83.15 ± 6.20	**90.13 ± 6.54	78.85 ± 7.78	0.001

Notes: Values shown are each average of 30 chickens (±SD) with 3 replicates.
** and ** indicate significance at the 5% and 1% level, respectively, compared with other treatments at the same period of feeding, as judged by One-way ANOVA analysis. **T** is referred to as Treatment.*

Feed Conversion Ratio (FCR)

Feed conversion ratio (FCR) is the amount of feed eaten relative to the weight of one chicken. It plays an important part in determining feed efficiency and production cost. To see whether the chicken growth is relevant to FCR, we observe the feed conversion ratio of the 13-week-old chicken. As shown in Table 4, the ratio of FCR seems slightly decreased when the basic diet supplemented with T1 (DBR=20%, T2 (DBR=25%), and T3(DBR=30%) compared with control T0 (without DBR supplement) but there is no significantly different among 4 treatments tested. These results suggest that the optional DBR promoted chicken growth by 25% DBR is not relevant to the ability of feed conversion but it is caused by the increased intake (Table 3)**.**

The main factors affecting the conversion ratio in poultry include genetics, age, and feed quality. In the current experiment, we used the same chicken variety and age. Another study reported that feed conversion was not significantly different when Ross 308 chickens fed cassava flour mixed with universal concentration (UC +Cas) gained weight higher than chickens fed a commercial diet (Jeremiah et al., 2015).

Table 4 The Feed conversion ratio (FCR) of 13 weeks-old chickens

Treatment	T0 (control)	T1 (DBR=20%)	T2 (DBR=25%)	T3 (DBR=30%)	P-value
FCR ratio	4.36 ± 0.64	3.71 ± 0.60	3.35 ± 0.59	3.37 ± 0.60	0.186

Notes: Values shown are each average of 30 chickens (±SD) with 3 replicates

CONCLUSION

This study finds that the optional inclusion of DBR in the basic diet for the better growth of local chicken (*Gallus domesticus*) is 25%. This performance of the chicken growth is likely due to feed intake (FI). The result is similar to findings from Fasuyi et al., in which the application of 10-20% of DBR resulted in better growth of young birds and up to 30% in older poultry (2018). Similarly, another study demonstrated that the inclusion of 25% DBR only (without basic diets such as soybean, sunflower, fish milk, and maize) caused a similar effect on broiler growth compared with control (basic diets) (Kuleile et al., 2019). This finding suggests that DBR can be used to substitute conventional protein sources and reduce production costs. Yet, in this present study, further investigation is required to find different types of basic diets supplemented with DBR and the meat quality of chicken after taking DBR.

ACKNOWLEDGEMENT

We thank Khmer Beverages for providing the brewery residue for the experiment. We also thank Ms. Rachel Brown, a U.S. State Department Fulbright Student researcher affiliated with Prek Leap National Institute of Agriculture for kindly review and English corrections.

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Research article

Development of Indexes to Evaluate the Effectiveness of Low Water Level Control in Irrigation Ponds – A Case Study of Irrigation Ponds in Tottori, Japan

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Received 27 September 2023 Accepted 3 December 2023 (*Corresponding Author)

Abstract The spillways of most irrigation ponds in Japan need additional repairs to safely pass the 200-year flood event, which is the design criteria set by the government. At the same time, low water level control (LWLC) in irrigation ponds is currently recognized as one of the countermeasures for mitigating floods and avoiding damage to aging spillways. However, the pond managers do not know to what extent the water level of the pond should be lowered. In this study, the flood mitigation function of LWLC in each pond was quantitatively evaluated, and indexes were proposed to determine whether it is worth practicing LWLC in each pond or whether the spillway needs to be repaired. Seventy-two irrigation ponds in Tottori prefecture were selected for analysis and the water balance of each pond was calculated with 10-, 50-, and 200-year rainfall events. The results showed that half of the ponds cannot safely cope with a 10-year rainfall event even if they are empty prior to the event. The ratio of the catchment area to water surface area at full capacity in such ponds often exceeds 50 to 1. On the other hand, ponds with a catchment to water surface area ratio of less than 50 show a high flood mitigation function due to LWLC. In addition to this, priority for repair work can be evaluated in terms of whether the spillway can pass peak runoff or not, because the size and the type of spillway are different among ponds. The effectiveness of LWLC can be evaluated in terms of the ability of the spillway to pass peak runoff from the catchment when the pond is full. The three indicators, namely, the ratio of catchment area to water surface area at full capacity, difference of peak flood reduction rate, and peak discharge ratio, are simple and useful indexes for LWLC to prevent irrigation pond failure.

Keywords flood mitigation, spillway, water management, water balance

INTRODUCTION

In recent years, unexpected, short, and heavy rain has been increasing in Japan. Especially in 2021 one of the strongest rainfall events occurred at many meteorological observing stations in Japan. Some irrigation ponds have been damaged and broken down due to heavy rainfall. For instance, Hutago Pond in Tottori was broken down because of a heavy rainfall event in July 2021. An irrigation pond is generally constructed to irrigate agricultural water which is mainly used for the paddy rice fields if there is no river near the irrigated district. The number of irrigation ponds in Japan is about 150 thousand and most of them are constructed over 100 years ago (MAFF). The spillways of most irrigation ponds in Japan require repairs to safely pass the 200-year flood event which means the probability of flood occurrence, is once per 200 years, which is the design criteria set by the Japanese government (MAFF, 2015). However, due to the large number of ponds and the high repair costs, extensive time will be required to repair the spillways of every irrigation pond. Therefore, the low water level control (LWLC) was suggested as one of the low-cost and non-structural solutions to prevent overflow. However, the water control entirely depends on the manager's experience and the municipality doesn't have clear guidelines or indicators on the amount of water that should be released in advance. Moreover, no assessment of the flooding mitigation function of irrigation ponds when LWLC is practiced has been done.

OBJECTIVES

In this study, the flood mitigation function of LWLC in irrigation ponds was quantitatively evaluated, and indexes were proposed to determine whether it is worth practicing LWLC in each pond or whether the spillway needs to be repaired. This study was conducted on the irrigation ponds certified as priority irrigation ponds for disaster prevention in Tottori Prefecture, Japan.

METHODOLOGY

Study Area

In this study, the water levels of the irrigation ponds in Tottori were estimated using a water balance model under the different heavy rainfall events at each rainfall station. The number of irrigation ponds in Tottori is around 950 (Tottori Prefecture, 2022). Of these 72 irrigation ponds were selected for analysis. Figure 1 shows selected 72 irrigation ponds that are indicated as black spots. Most of them were constructed in mountainous areas and store water only from the runoff from the catchment areas. Therefore, when LWLC is practiced, the farmers will take on the risk increase that the storage water would be dried up. They are located near residences which could be damaged if the ponds are flooded. Besides, all of them cannot safely pass the peak runoff with a 200-year rainfall event, which is a design criterion set by the government. Table 1 shows the features of irrigation ponds in the study area. The irrigation ponds are classified by storage capacity.

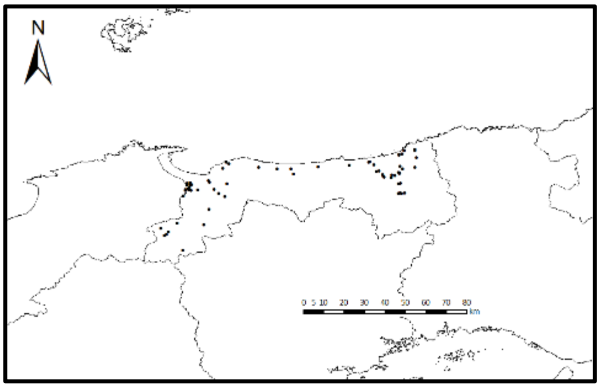

Fig. 1 Selected irrigation ponds in Tottori

Location source: Tottori web map

The distribution of the storage capacities is biased to a small, less than 10,000 m^3. Of the 72 selected irrigation ponds, the number of the small-sized ones is 55. Those with a storage capacity of less than 3,000 m^3 account for 36. The number of beneficiary farmers in these irrigation ponds is quite small, and some of them are often not well maintained. The capacity of medium-sized irrigation ponds ranges from 10,000 m^3 to 100,000 m^3. The number of medium irrigation ponds is 15. The capacity of large-sized irrigation ponds is more than 100,000 m^3 and there are two such irrigation ponds in the study area, with capacities of 101,000 m^3 and 120,000 m^3. The number of beneficiary farmers is large, and downstream damage due to these irrigation ponds' failure would be enormous.

Table 1 Features of irrigation ponds in the study area

Irrigation Ponds	Capacity (m^3)	Numbers of ponds
Small	<10,000 m^3	55
Medium	10,000~100,000 m^3	15
Large	> 100,000 m^3	2

Water Balance Analysis

Outline of Irrigation Pond Water Balance Model

The irrigation pond water balance model was developed by referring to the Guidance of flood control function intensify of irrigation ponds (MAFF, 2018). The difference points are estimation formulas of coefficient K for the storage function method, effective rainfall intensity, outflow water estimation from the spillway, and height-volume curve of the irrigation pond (H-V curve).

To determine and compare the effectiveness of LWLC from the aspect of the return period, 10-year, 50-year, and 200-year return period hourly and daily rainfall was estimated by Iwai formula and Talbot formula. The hourly and daily return period was estimated at 9 stations such as Iwai, Tottori, Shikano, Kurayoshi, Shiotsu, Daisen, Eo, Yonago, and Chaya. The rainfall duration was assumed to be 3 hours, and the rainfall distribution was assumed to have a rainfall intensity peak in the latter half of the rainfall. The inflow of water to the ponds is estimated by the storage function method. It needs to estimate coefficient K, p, and effective rainfall intensity. K is referred from Nagai et al. (1987). p is set to 0.6 as Sugiyama et al. (1988) suggested. Effective rainfall is estimated to multiply rainfall intensity by the theoretical peak outflow rate referred from the internal documents of Tottori Prefecture. Only the outflow from the pond is considered for the outflow from the spillway of the pond. In this study, the outflow from intake taps is not considered because it is negligibly small compared to that from the discharge from the spillway. In addition to this, due to the assumption of short and heavy rainfall, evaporation and infiltration from the irrigation pond are also ignored (Shimizu et al, 2016). To estimate the amount of released water, the relationship between the water level and the storage capacity of a pond is required, but these data are not available. Therefore, in this study, a simplified method is employed to make an H-V curve with the assumption that the shape of the irrigation pond is approximated as frustum (Tanakamaru et al., 2015).

Validation

To validate the results of the water balance model, the actual water level fluctuation was observed at 3 irrigation ponds in Tottori using the heavy rainfall data at 2 rainfall stations from 7th July to 9th July 2021.

Indexes Proposal and Classification

In the analysis, the extra height of each irrigation pond was defined as the height of the spillway in case of seepage collapse of the irrigation pond. There are three main reasons for irrigation ponds failure by heavy rainfall, namely overflow erosion, sliding, and seepage failure. In the case of seepage failure, internal erosion occurs from the upstream slope near the full water level (Hori et al., 2002). Moreover, the interval of intake taps is supposed to be 0.5 m and release water level 0.5 m each, and estimate released water previously that peak water level is less than the height of the spillway at each irrigation pond. To calculate how many meters of water level should be lowered, storage water was released corresponding to 0.5m each from full water level until the peak water level in case the irrigation pond conducts LWLC would not over the height of the spillway. The water level reduction rate (R) can be expressed as a ratio of released water level and water storage depth (the height difference between the bottom and full water level) shown in Eq. 1.

$$R = \frac{D}{H} \tag{1}$$

Where R is the water level reduction rate, D is the depth after the water is released from the full water level, and H is the water storage depth.

As follows, we proposed 3 indicators that are useful to classify the irrigation ponds based on the calculation from the data of irrigation ponds and rainfall data. Catchment to storage ratio (CSR) is one of the indexes that can be calculated to divide the catchment area with the storage area (full surface water area) of each irrigation pond shown in Eq. 2.

$$A_r = \frac{A}{S_1} \tag{2}$$

Where A_r is the catchment to storage ratio, A is the catchment area, and S_1 is the full water surface area.

Design discharge to peak discharge ratio (DPR) is the index that can be calculated to divide the design discharge of the spillway (Q_{out}) and peak discharge (Q_p) when the water level is full of each irrigation pond shown as Eq. 3.

$$D = \frac{Q_{out}}{Q_p} \tag{3}$$

Where D is the design discharge to peak discharge ratio, Q_{out} is the design discharge of the spillway, and Q_p is peak discharge when the water level is full.

In addition to this, to understand how much water discharge could be reduced by conducting LWLC, the flood peak mitigation rate was calculated when the initial water level was 0.5m lower than the full water level. The difference in flood peak reduction ratio (PRR_d) is expressed as the ratio of the difference in peak discharges with and without LWLC implementation to the peak runoff from the catchment area shown in Eq. 4.

$$Q_d = \frac{Q_p - Q_p'}{Q_n} \tag{4}$$

Where Q_d (%) is a difference in flood peak reduction ratio. Q_p is the peak water flow rate when the irrigation pond is full, Q_p' is the peak water flow rate when the irrigation pond conducts LWLC, and Q_n is the peak inflow water flow rate from the catchment area.

RESULTS AND DISCUSSIONS

Validation

The difference between the estimated peak water levels and observed ones of the irrigation ponds are around 10 cm, 1 cm, and 13 cm. Figure 2 shows observed and simulated water level data at the Kanaguri irrigation pond. The irrigation pond is located in the middle of Tottori prefecture. The peak water level difference is 13cm at Kanaguri irrigation pond.

The observed water level until the peak water level seems to be lower than the calculated peak water level. It is considered that because of the degree of soil saturation. If the soil is dried, the outflow rate is affected to be lower inevitably.

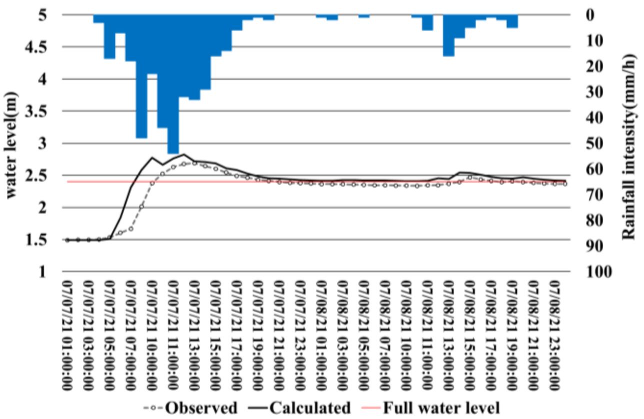

Fig. 2 Comparison with observed water level and calculated water level

Relationship between DPR, CSR, and WLRR

Figure 3 shows the relationship between design discharge to peak discharge ratio (DPR), catchment to storage ratio (CSR), and water level reduction rate (WLRR) in the case of 10-year rainfall. From Fig. 3, half of the irrigation ponds need to release water level until empty because to spillway size is comparatively small to consider their catchment area. Especially under the conditions that the design discharge is smaller than 1 and CSR is relatively higher (>50), WLRR gets almost 100 % which means if the water level is released to empty, the theoretical peak water level would exceed the height of the spillway of each irrigation pond. It can be considered that the effectiveness of LWLC has a strong relationship with the inflow of water from the catchment area while it has almost no relationship with the size of the spillway, but the priority of LWLC for preventing failure can be judged by DPR.

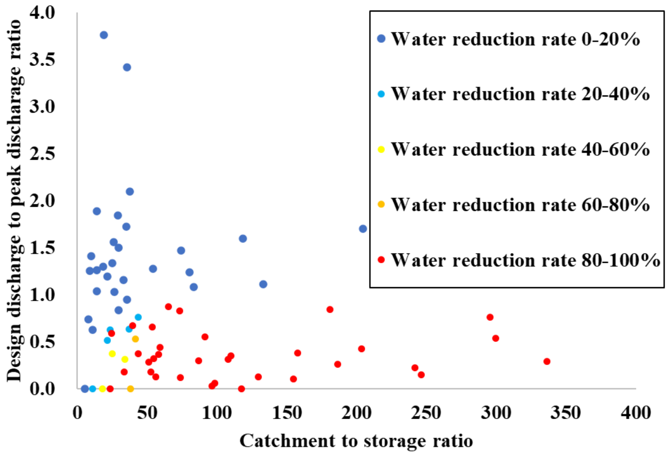

Fig. 3 Relationship between DPR, CSR, and WLRR in case of a 10-year return period

Relationship between CSR and PRR_d

Figure 4 shows the relationship between CSR and the difference in flood peak reduction ratio (PRR_d). The figure shows the difference when the irrigation pond is full and, the irrigation pond has released storage water corresponding to 0.5m from the full water level. If the CSR is under 50, PRR_d tends to be higher. However, in the case of heavy rainfall, PRR_d becomes lower. Therefore, it needs to consider the PRR_d and rainfall intensity carefully when the CSR is under 50. Tanakamaru. et al (2019) selected 1,902 irrigation ponds with a large effect on flood mitigation by water release in advance at Awaji district in Hyogo prefecture, Japan. The effectiveness of LWLC was calculated by the storage function method. After that, the outflow during the flood period was estimated at each irrigation pond. As a result, the study showed that if normalized storage becomes higher, the effectiveness of LWLC will be higher. However, it needs to be careful when calculating the flood control function using normalized storage since the reliability of capacity is low.

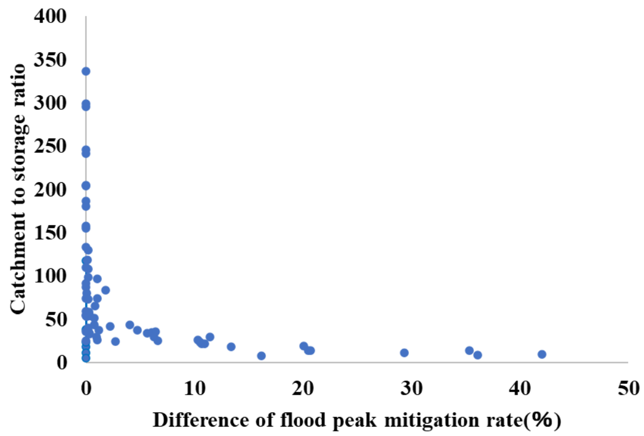

Fig. 4 Relationship between CSR and PRR_d in case of a 10-year return period

Classification of Irrigation Ponds

Based on the above results and discussion, studied irrigation ponds are classified. We proposed 3 classifications as groups A, B, and C. Group A is characterized by lower CSR (<50) and lower DPR (<1). Irrigation ponds categorized in group A are recommended to implement LWLC or rehabilitate the spillway immediately due to the high risk of overflow. Group B is characterized by lower CSR (<50) and sufficient DPR (>1). It is recommended to implement LWLC to prevent the overflow of the ponds and the overflow of the downstream canal even if the pond is safe. Group C is characterized by higher CSR (>50). It is recommended to rehabilitate the spillway immediately due to the high risk of overflow. Thus, it is of no use in implementing LWLC due to its quite small effect ($PRR_d \fallingdotseq 0$). The number of irrigation ponds classified as groups A, B, and C is shown in Table 2.

Table 2 Classification of irrigation ponds

Group	10-year return period rainfall	50-year return period rainfall	200-year return period rainfall
A	20	28	31
B	17	9	6
C	35	35	35

CONCLUSION

There are a lot of irrigation ponds in Japan, and some of these do not have large enough spillways to safely pass the 200-year return period. In this study, we proposed a method to classify irrigation ponds concisely using relatively easy-access data. As a result of calculation, even if low water level control is implemented, some of these have very little effectiveness against flood mitigation. In the case of the ponds with high irrigation use frequency, i.e., high dependence, immediate rehabilitation of spillways should be considered, while in the case of the ponds with very low irrigation use frequency, the abolition of irrigation ponds should be considered to prevent flood dame in case of heavy rainfall events.

ACKNOWLEDGEMENTS

The authors would like to express their deepest gratitude to the Tottori Prefecture of Japan for the data provision on irrigation ponds in Tottori Prefecture and the financial support for this study.

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Research article

Impact Evaluation of Climate Change on Disaster Risk of Forested Watershed Rivers in Snowy Regions using SWAT+

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Received 1 October 2023 Accepted 13 December 2023 (*Corresponding Author)

Abstract In this study, we analyzed the reduction in snowfall and snowmelt under climate change scenarios in a cold snowy region. Also, we clarified the causal relationship between deforestation and disaster risk in watershed management in Mishima Town, Fukushima Prefecture. We used SWAT+ to conduct simulations; the SWAT+ model of Mishima town was built in a previous study, and its reproducibility was verified by NSE and RMSE by correcting parameters and using auto-calibration. The latest set of models from the CMIP6, also used in the 6th Impact Assessment Report of the IPCC and statistically downscaled scenarios in Japan developed by the Center for Climate Change Adaptation, National Institute for Environmental Studies, was adapted to simulate climate change scenarios. The Emission Scenarios are based on RCP8.5, which has been used in future climate change discussions (i.e., the assumption that greenhouse gases will continue to increase without any global warming countermeasures). We simulated the end of the 21st century situation. As the result of the simulation, the RCP8.5 scenario showed a significant decrease in snowfall and snowmelt, with only one day of snowfall of RCP8.5 from January to March. The potential for early spring snowmelt water availability of RCP8.5 at the end of the 21st century could have been much higher. Additionally, we conducted a simulation of deforestation. We assumed that 5% of the forested area became agricultural land due to deforestation. Simulation results indicated that the surface flow under deforestation conditions was 145.1 mm, a 7% increase over the surface flow of the original forest prior to deforestation (135.1 mm). Heavy and long-lasting rainfall showed no difference in water storage function between the two cases, but 5% deforestation was shown to increase river discharge at the beginning of a rainfall event.

Keywords SWAT+, climate change, snowmelt, runoff, prediction

INTRODUCTION

Climate change significantly impacts the increase in average annual temperatures and fluctuations in rainfall and snowfall, resulting in more frequent natural disasters worldwide. The IPCC Sixth Assessment Report (2021) states that a 2°C rise in temperature would lead to a 14% intensification of rainfall intensity. On the other hand, land use change due to deforestation is known to increase runoff and affect flood risk, with 5.2 million hectares deforested each year (2000-2010), mostly in developing countries in Africa, Latin America, and Southeast Asia, where agricultural activities account for about 80% of the loss (Synthesis Report for REDD+ Policymakers, 2012). The impacts of climate change are also significant in Japan, where mountain disasters and floods are becoming more frequent and severe, and the importance of the water source recharge and flood mitigation functions of forests is increasing (Gunma Prefecture Basic Plan for Forest and Forestry 2021- 2030). Since an increase in average temperature due to climate change is expected to significantly impact the amount of snowfall and snowmelt and affect the availability of water for agriculture in early spring in snowy and cold regions, future predictions based on climate change scenarios are essential. Still, the assessment of the impact of climate change on water resources at the small watershed level has not been sufficiently verified.

In addition, although previous studies have examined the relationship between land use change due to urban development and other factors and disaster risk (Qingmu et al., 2017) and the flood control effects of agricultural land (Yoshikawa et al., 2009), there are few studies on the relationship between deforestation and additional agricultural land.

OBJECTIVE

In this study, we analyzed the effects of climate change on snowfall and snowmelt and the impact of deforestation on making agricultural land in the Hashigo River in Mishima town, Fukushima prefecture, a forested area with a cold and snowy climate.

We used SWAT+ to conduct simulations, the SWAT+ model of Mishima town was built in a previous study (Kikuchi et al., 2022), and its reproducibility was verified by NSE and RMSE by correcting parameters and using auto-calibration.

METHODOLOGY

Study Site

The study site is the Hashigo River watershed in Mishima Town in Fukushima Prefecture (Fig.1). The Hashigo River is a tributary of the Tadami River. The watershed is located at latitude 37.50 °-37.47 °, longitude 139.62 ° -139.63 °, and range of altitude 350-370 m. The watershed area is 2.85 km^2, covered mainly by mountain forests (Table 1). 0.4 % of paddy fields are located along the main river. The annual mean daily temperature, the minimum, and maximum daily temperatures are 10.6°C and 6.9°C, snowfall is from December to February, and snowmelt is from March to April. Rainfall is relatively heavy during the rainy season from June to July, and typhoons are more frequent from September to October. Annual precipitation was 1,340 mm in 2020.

Table 1 Land-use of the target watershed

Watershed area	Land-use (%)			River length
(km^2)	Forest	Grassland	Paddy field	(km)
2.85	98.4	1.2	0.4	2.5

Fig. 1 Location of target watershed (Hashigo River)

SWAT+

Utilizing a hydrological model for analyzing the hydrological cycle throughout a river basin is an effective method to assess the impacts of climate change on water resource management, flood control, and agriculture. SWAT (Soil and Water Assessment Tool) developed by USDA-ARS is a hydrological cycle model used worldwide for over 20 years (Williams et al., 2008). To face present and future challenges in SWAT code has undergone significant modifications over the past few years, resulting in SWAT+, a completely revised version of the model (Katrin et al., 2016). SWAT+ is a model that analyzes water movement by subdividing the target watershed into subwatersheds called HRUs (hydrologic runoff units) and can predict river discharge and water quality for an unspecified watershed with few input parameters. The data collection is shown in Table 2, and data sets of SWAT+ are shown in Table 3. The time interval for the calculations in this study was set to days. The warm-up period was set from 1st February 2019 to 31st December 2019, and the simulation period was set from 1st January 2020 to 31st December 2020. Some parameters were adjusted and entered from actual measurements.

Table 2 Data collection

Data	Source	Note
Elevation data	Geospatial Information Authority of Japan (GSI)	Raster data (10 m mesh)（Fig. 1 A）
Land use	The Japan Aerospace Exploration Agency (JAXA) and Earth Observation Research Center (EORC)	10m mesh <Land use: 12 categories>. Land use was confirmed by foot survey, and some obviously different land uses were corrected（Fig. 1 B）
Soil map	The National Institute of Agrobiological Sciences (NIAS)'s basic land classification survey data (Shapefile, 1:200,000)	Shapefile (polygon)
Soil component	Field survey data (17/Dec/2021)	Soil moisture content, EC, pH, specific gravity, permeability coefficient, particle size distribution
Weather data	National Institute for Environmental Studies of Japan (NIES)	10 min Data: River discharge (m^3/s) Daily data: rainfall, temperature (max., min., avg.), relative humidity, solar radiation, wind speed

Table 3 Data set of SWAT+ model

Item	Contents
Version	- SWAT+ Editor 2.0.4
Period	- Warm-up：2019/2/1-2019/12/31 Simulation：2020/1/1-2020/12/31
Time interval	- Daily data
Input parameters	- The following parameters are adjusted and input from actual measured values Permeability (soil k), maximum water capacity (awc), clay, silt, sand, rock, EC, clay, silt, sand, rock. - Snowfall temperature: 2.51°C, Melting snow temperature: 2.71°C
Calculation method	- Evapotranspiration calculation: Penman-Monteith method - Calculation of surface flow: Curve Number method

Climate Change Scenario

In this study, we generated a hypothetical dataset for the year 2090 by adjusting the data of 2020 using the variability parameters (e.g., temperature increases) from published climate change scenarios. As the publish methods, We adopted the latest set of models from the CMIP6 (Coupled Model Intercomparison Project 6th), which is also used in the 6th Impact Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and adapted statistically downscaled scenarios NIES2020 in Japan developed by the center for climate change adaptation, National Institute for Environmental Studies (NIES)（Ishizaki, 2021）. The Emission scenarios use the Representative Concentration Pathway (RCP) scenarios, introduced as part of the IPCC's Special Report on Emissions Scenarios (SRES). There are several RCP scenarios, but in this study, RCP8.5, which assumes no action on global warming and continued greenhouse gas emissions, was selected. The hypothetical dataset as input for the SWAT+ model to simulate how climate change will impact various factors: snowfall, snowmelt, and flow, comparing conditions between 2020 and 2090.

Table 4 Basic information on climate change scenario

Name of climate scenario	NIES2020
Climate model	MIROC6
Climate parameters	Max. and mini. temperature, precipitation, total solar radiation, relative humidity
Emission scenarios	RCP8.5
Forecast period	2090

Table 5 Data prediction of RCP 8.5 for 2090 and 2020 in Fukushima

SSP585-MIROC6-NIES2020 for Fukushima	2090			2020		
	Jan.	Feb.	Mar.	Jan.	Feb.	Mar.
Max temperature	6.2	7.5	11.4	3.0	3.5	8.1
Min temperature	-2.2	-2.1	1.2	-4.9	-5.1	-1.7
Relative humidity	70.3	67.1	70.1	73.6	72.2	71.8
Solar radiation	6.8	9.5	13.1	7.1	9.7	12.7
Precipitation	103.3	77.1	129.0	90.3	73.2	107.7

Deforestation Situation

In Mishima Town, a renewable energy project using woody biomass resources is being considered with the establishment of the Regional Recycling and Symbiosis Promotion Council. On the other hand, flood risk from deforestation needs to be adequately assessed. According to studies by the National Institute for Environmental (Ooba et al., 2017), the upper limit of forest use is estimated to be 1/50 (2%) due to the limitation of age class composition. In this study, the upper limit of forest use, 2%, was exceeded, and a case was assumed in which 5% of the forest area became agricultural land due to logging. From the standpoint of convenience in transporting timber, the area of deforestation was assumed to be two downstream watersheds (Fig. 1 Watershed 3 and 4).

RESULTS AND DISCUSSION

Climate Change Scenario

The simulation results based on the observed data for 2020 (Original) and the 2090 climate change scenario (RCP8.5) are shown in Fig. 2. The river discharge of January is more significant for RCP8.5 because precipitation is more considerable for RCP8.5. On the other hand, after mid-February, the original data tends to have more significant river discharge.

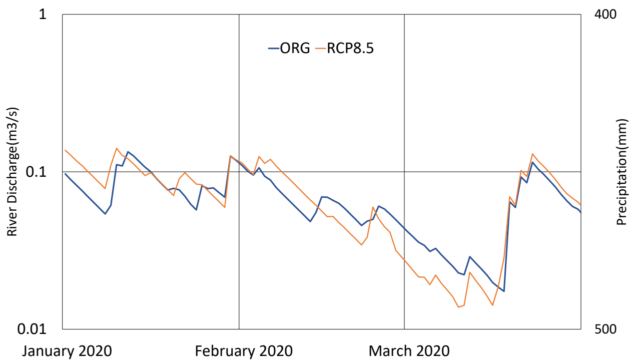

Fig. 2 River discharge of original (2020) and RCP8.5 (2090)

The results of average river discharge, snowmelt, snowfall, evapotranspiration, days of snowfall, and days of snowmelt from January to March are shown in Table. 6. River discharges of RCP 8.5 are higher than the originals, except in March. After mid-February, the river discharge of RCP8.5 temporarily decreased a little, but there is no significant difference between RCP8.5 and the original in terms of monthly river discharge. On the other hand, the original from January to March had 78.8 mm of snowfall and 93.4 mm of snowmelt, while RCP 8.5 had 5.7 mm of both snowfall and snowmelt. In addition, RCP 8.5 has only 6-7% of the original snowfall and snowmelt, and RCP 8.5 has only one snowfall and snowmelt day. The above results indicate a significant decrease in snowfall and snowmelt in RCP 8.5 in 2090. The evapotranspiration of RCP 8.5 during January-March is 19.48 mm, which is about 1.37 times higher than the original (14.19 mm). The impact of climate change on the flow rate indicates that there is no significant difference between RCP8.5 and the original (2020) due to increased rainfall. The results indicate that while changes in river discharge may not be immediately apparent due to increased rainfall in the RCP 8.5 scenario, the alarming decrease in snowfall and snowmelt could have far-reaching consequences for water resources management and the ecosystem.

Table 6 Simulation results of the original (2020) and RCP8.5 (2090)

	Original				RCP 8.5			
	Jan.	Feb.	Mar.	Total	Jan.	Feb.	Mar.	Total
Average River discharge (m^3/s)	0.086	0.067	0.050	0.068	0.098	0.069	0.049	0.075
Snowmelt (mm)	52.80	32.80	7.80	93.40	0.00	5.70	0.00	5.70
Snowfall (mm)	38.30	32.70	7.80	78.80	0.00	5.70	0.00	5.70
Evapotranspiration (ET) (mm)	0.65	1.80	11.74	14.19	1.13	3.17	15.18	19.48
Snowfall days	7	6	5	18	0	1	0	1
Snowmelt days	10	10	4	24	0	1	0	1

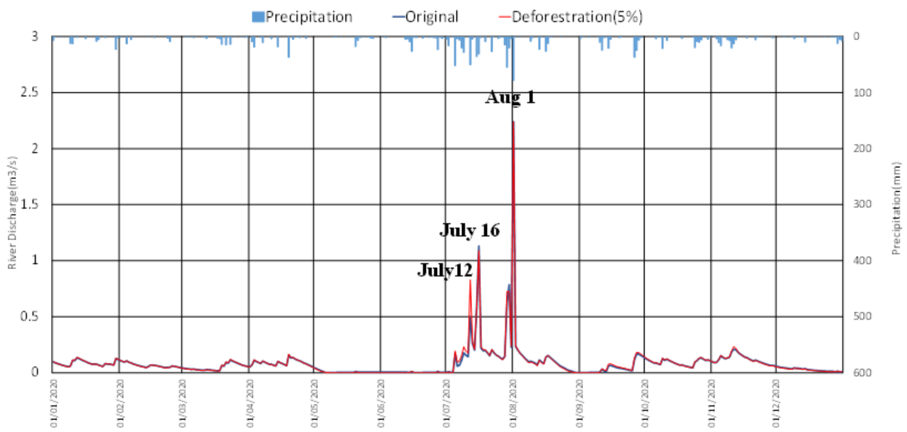

Fig. 3 River discharge of the simulation of deforestation

Deforestation Situation

In the one-year river discharge data for 2020 (Fig. 3), days with particularly high daily river discharge (July 12th, July 16th, and August 1st) were extracted and compared between the original and deforestation. there were no significant differences for July 16th and August 1st, but July 12th increased the daily river discharge by a factor of 1.66. Heavy and long-lasting rainfall showed no difference in water storage function between the two cases, but 5% deforestation was shown to increase river discharge at the beginning of a rainfall event. The result of the deforestation situation is shown in Table 7. Surface flow of deforestration was 145.1 mm, 7% increase over surface flow of the t original (135.1 mm). The ET of deforestration was 395.9 mm, 0.3% increase over ET of the original (394.7 mm). The result of surface flow also indicates that the water storage function of the watershed is declining due to the decrease in forest area. This effect was particularly pronounced at the beginning of precipitation events, indicating that the presence of forests role which moderate early-stage discharge.

Table 7 Simulation results of the original (2020) and deforestation 5%

	Surface flow	Evapotranspiration (ET)	River discharge			
			Annual average	July 12th	July 16th	Aug. 1st
Original	135.1 mm/y	394.7 mm/y	0.083 m^3/s/y	0.50	1.13	2.24
Deforestation 5%	145.1 mm/y	395.9 mm/y	0.084 m^3/s/y	0.83	1.09	2.24

CONCLUSION

Herein, we analyzed the effects of snowfall and snowmelt (from January to March) in a small watershed in Mishima, Fukushima Prefecture. The results of the climate change simulations indicate a significant reduction in snowfall and snowmelt in RCP8.5 (2090) within CMIP6 when compared to the original simulation results for 2020. If climate change were the RCP8.5 scenario, agricultural use of spring snowmelt would be problematic by the end of the 21st century. However, there would be no significant difference in river discharge because of increased precipitation. However, climate change mitigation measures need to take into account that the water storage function of forests through snowfall and snowmelt will disappear. In addition, it may not show significant changes in the short term, but the loss of snowfall and snowmelt and the associated changes in forest water storage functions by snow raise concerns about the long-term sustainability of water resources and ecosystems.

The results of the deforestation simulation showed a 7% increase in annual surface runoff and a reduction in water storage function during the first rainy season. It is crucial to consider the need for the water storage function of forests in combination with the effects of climate change and deforestation. Both climate change scenarios and land use change simulations are few in small watershed studies. However, local governments need to update their water resource management based on climate change scenarios, and in small watersheds, water balance simulations based on climate change scenarios should be more necessary. Although only runoff analysis was conducted in this study, inundation analysis based on calculated river flow data would provide a more accurate assessment of disaster risk.

ACKNOWLEDGEMENTS

This research was supported by the Fukushima Regional Collaborative Research Center (FRECC) in the National Institute of Environmental Studies (NIES) and by the Tokyo University of Agriculture as the Doctoral Research Grant Program of the Tokyo NODAI Research Institute, and JSPS KAKENHI (JP20K06351).

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Research article

Challenges and Prospects for Increasing Vegetable Production in Cambodia

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Received 5 October 2023 Accepted 21 December 2023 (*Corresponding Author)

Abstract Vegetable production in Cambodia is minimal; thus, 70% of the country's internal consumption is dependent on imported vegetables, primarily from Thailand and Vietnam. Although the government is encouraging vegetable production, clarifying the status, issues, and challenges is crucial to establishing detailed strategies for vegetable production in the country. This study aimed to identify the challenges and prospects of vegetable production in Cambodia by examining the status of vegetable cultivation, including production volumes and varieties, vegetable business conditions, and producers' socio-economic characteristics. A commune in Takeo province, which has year-round access to agricultural water, was selected as the study area. Semi-structured interviews based on a questionnaire were conducted with both vegetable producers and non-producers for comparative analysis. Producers were asked about their vegetable production and other income-generating activities and expenditures. Non-producers were asked about their income-generating and expenditure activities. Valid responses were obtained from 113 vegetable-producing households (HHs) and 89 non-producing HHs. The survey results indicated that 97% of vegetable producers had a surplus; however, the average net profit (35 USD) was minimal compared with other income sources, such as factory work. The net profit was strongly influenced by the production volume derived from the size of owned farmland and the limited planted area due to unsuitable production methods. Nevertheless, nearly 60% of non-producers had arable upland, but they stopped production owing to a lack of sales channels. Thus, the low production volume per producer and limited sales channels were identified as the key challenges Cambodia faces in terms of increasing vegetable production volumes.

Keywords vegetable production, current status, issues, challenges, Cambodia

INTRODUCTION

Cambodia is located on the Indochina Peninsula and is surrounded by Thailand, Laos, and Vietnam (Fig. 1). Owing to rapid economic growth in recent years, Gross National Income (GNI) per capita exceeded 1,000 USD in 2013. It reached 1,500 USD in 2018 (World Bank, 2023. However, as many people live below the poverty line in rural areas, it is one of the poorest countries. Agriculture accounts for 25% of the country's GDP. In addition, about 40% of the people in Cambodia are engaged in agriculture, which is one of the country's core industries. The main crops include rice, maize, and cassava. Although self-sufficiency in rice has been achieved, vegetable production could have been more active, with approximately 70% of domestic consumption dependent on imports from neighboring countries. In response to this situation, Cambodia's Rectangular Strategy (Royal Government of Cambodia, 2013) indicated the necessity of research activities to develop a policy framework for expanding vegetable production. During the expansion of vegetable production, anyone can purchase domestic vegetables, and increasing production and distribution volume is necessary to realize the situation (Fig. 2). Existing research on vegetable production in the country covers marketing channels, such as market status (Itagaki, 2010), marketing (Olney et al., 2009), and logistics (Kawahara and Yoshida, 2006). However, research should focus more on the reality and challenges of production volume, including the yield, acreage, and number of producers, which is essential for exploring the potential for expanding production.

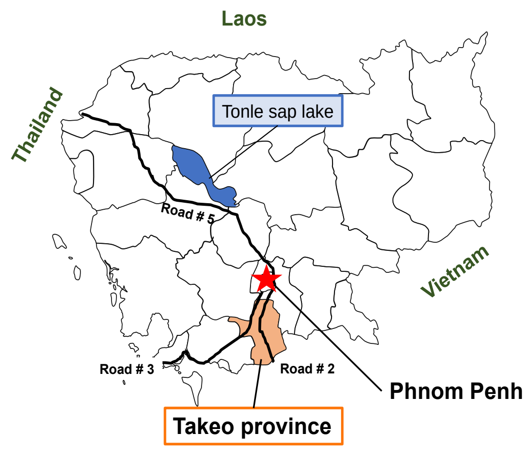

Fig. 1 Map of Cambodia showing the study area

OBJECTIVE

This study aims to identify the challenges of vegetable production for increasing production volume in Cambodia by clarifying the status of vegetable cultivation, including production amount and varieties, vegetable production business conditions, and producers' socio-economic characteristics.

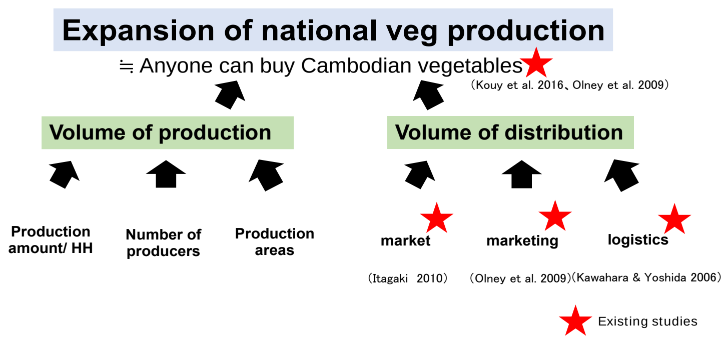

Fig. 2 Concept map of the study

METHODOLOGY

The survey area is in Takeo Province, about 80 km south of the capital Phnom Penh. It is Cambodia's main agricultural production area (Fig. 3). A commune comprising 12 villages near a huge reservoir constructed during the Pol Pot regime was selected as the study area. This commune has year-round access to agricultural water, such as reservoirs and irrigation, and has been confirmed as a vegetable production area. It is 20 minutes by car from one of the largest markets in the province along National Road No. 3. This road connects to Sihanoukville Port, the only port in Cambodia, and Phnom Penh, the capital city (Fig. 3).

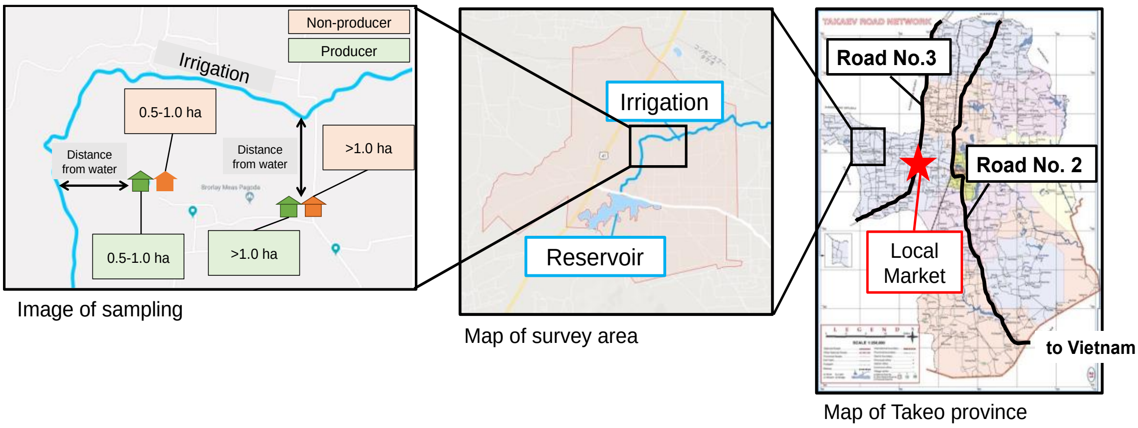

Fig. 3 Study area and sampling

For comparative analysis, a semi-structured interview based on a questionnaire was conducted with both vegetable producers and non-producers. All households in the area producing vegetables for sale during the 2017 production season were selected as “vegetable producers.” All the other households in this area were automatically identified as “non-producers.” To select non-producers facing natural environments and economic conditions similar to those faced by producers were selected through stratified sampling. Stratification was based on water access and agricultural land ownership (Table 1). First, the neighbors of each "producer" who could access the same water source were selected as candidate respondents. Then, we selected households in the same land size category as neighboring “producers” among the candidates. Only households that met the criteria were selected. Consequently, 122 vegetable-producing and 92 non-producer HHs were selected as subjects for the survey. Producers were asked about their vegetable production activities from October 2016 to September 2017 and their other income-generating activities and expenditures. Non-producers were asked about their income-generating activities and expenditures. The number of valid responses included 113 (92.6%) producer HHs and 89 (96.7%) non-producer HHs.

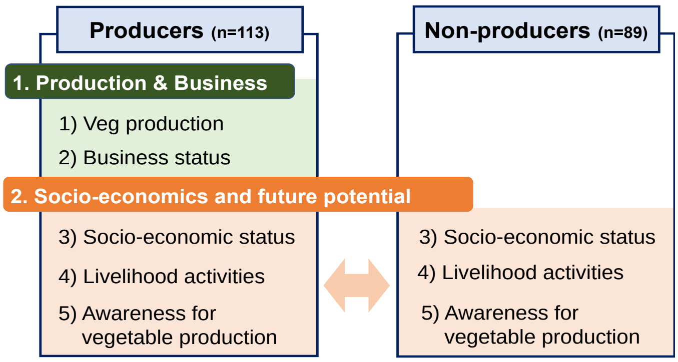

Fig. 4 Data collection framework

Table 1 Results of stratified sampling

Area (ha)	Producers[1]	(%)	Non-producers[1]	(%)
below 1.0	30	(26.5)	27	(30.3)
1.0-	50	(44.2)	35	(39.3)
2.0-	25	(22.1)	23	(25.8)
3.0-	8	(7.1)	4	(4.5)
Total	113	(100.0)	89	(100.0)

**Number of households and ratio*

This study first focuses on the respondents’ profile, followed by vegetable production status and business conditions, including costs and profits. Then, we explore the possibility of increasing production and producers by conducting a comparative analysis of the socio-economic status, including household composition, income, and awareness of both producers and non-producers (Fig. 4).

RESULTS AND DISCUSSION

Socio-economic Status of Respondents

Table 2 shows the profile and socioeconomic status of all respondents. Producer HHs had fewer family members than non-producer HHs. Producer HHs had fewer female members, children under 15, and employed members. By contrast, the average age of each household and the primary agriculture worker were significantly higher in producer HHs. The sizes of owned agricultural land did not differ due to stratified sampling according to land size; both producer and non-producer HHs tended to have an upland field suitable for vegetable production. No socio-economic or cultural anthropological studies were found to provide background on the significant differences in household composition. Household income data are analyzed in the later section.

Status of Vegetable Production

A total of 27 vegetables were produced by the respondents, including peanuts (30 HHs), pumpkins (23 HHs), melons (22 HHs), water spinach (21 HHs), and yams (21 HHs), with an average of 2.7 items per household (Fig. 5). Many of these were seen as native vegetables in the tropics, and direct sowing was the mainstream. Therefore, it is assumed that the vegetable production in this area is not for specific demands, such as exporting or sending to foreign residents in the country but for local needs. Vegetable cultivation averaged 4.8 months per year and was concentrated in the dry season. Substantially little cultivation occurs during the rainy season (Fig. 6). It is common to grow vegetables using paddy fields after harvesting rice in Cambodia, according to existing studies (Hamano et al., 2013). In that case, cultivation in the rainy season is physically impossible. However, the producers in this region should be able to cultivate vegetables even in the rainy season, as more than 70% (80 HHs) of them own upland fields (Table 2).

Table 2 Socio-economic profile of respondents

Respondents' attributes	Producers (N=113)	Non-producers (N=89)	Total (N=202)	P-value[1]
Total number of HH[2] members	4.1	4.6	4.3	0.049 *
Female	2.0	2.5	2.2	0.003 **
Male	2.1	2.1	2.1	0.957
Workforce (age 16-64)	2.9	3.1	3.0	0.546
Age 15 or more	1.0	1.3	1.1	0.028 *
Age 65 or more	0.3	0.2	0.3	0.212
Employed worker	0.4	0.7	0.5	0.009 **
Average age among all members	36.2	28.7	33.0	0.000 **
Main agriculture worker				
Age	52.4	46.0	49.6	0.000 **
Years of schooling	5.1	5.0	5.1	0.995
Owned agricultural land area[3]	1.49 (113)[4]	1.43 (89)	1.5	0.567
paddy field	1.16 (113)	1.31 (89)	1.2	0.266
upland field	0.45 (80)	0.49 (21)	0.5	0.315

1 Mann-Whitney U test P-value: *(P<0.05) **(P<0.01)
2 HH: Household
3 average area in hectar
4 Respondents who own each type of land

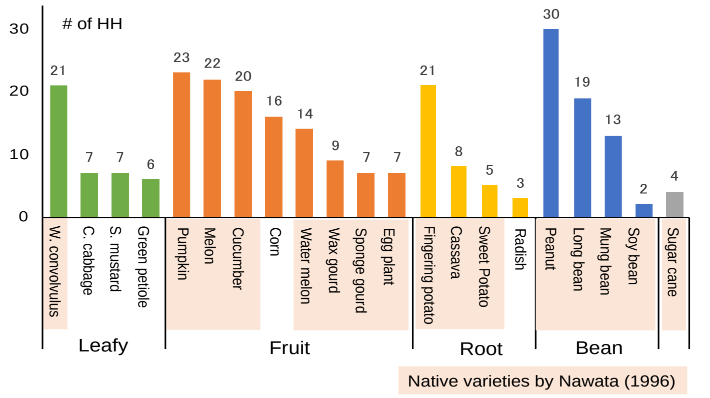

Fig. 5 Vegetable items produced

As a result of asking about vegetable production, the most common answer was damage by pests and disease (63.0%), followed by lack of water (39.8%), growth failure (32.4%), and lack of labor force (17.6%) (Table 3). Additionally, many producers needed help using pesticides, including how to use them appropriately (Table 4). Unsuitable cultivation techniques were sometimes observed, such as crawling cultivation that cultivates vine vegetables, including cucumber, horizontally without using any poles. Those vegetables will be placed directly on the soil, and insects will quickly eat them. Moreover, the fruits will be soaked in rainwater and quickly rot.

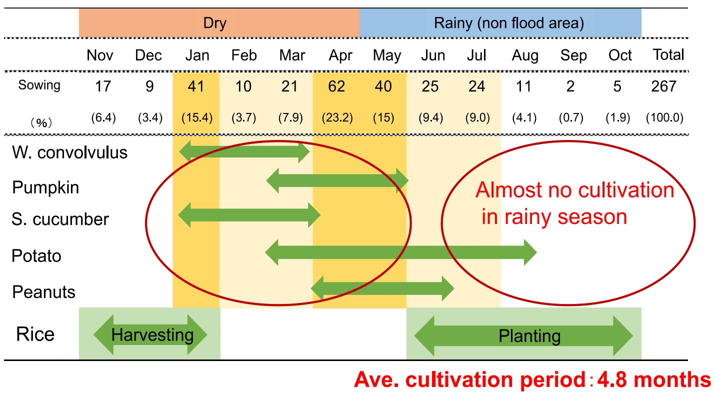

Fig. 6 Cultivation calendar and timing of seeding

Table 3 Issues of vegetable production

Problems of veg. production	# of HH	(%)
Lack of water	43	(39.8)
Excess water by flooding	13	(12.0)
Growth failure	35	(32.4)
Damage by diseases & insects	68	(63.0)
Lack of labor force	19	(17.6)
Hight costs	13	(12.0)
No special problem	4	(3.7)
Total	195	(180.6)

Multiple answers allowed (N=100)

Table 4 Problems of using pesticides

Problems of using pesticide	# of HH	(%)
Selection	71	(65.7)
How to use	67	(62.0)
Amount to use	55	(50.9)
Pests & diseases control	55	(50.9)
Others	13	(12.0)
Total	261	(241.7)

Multiple answers allowed (N=100)

Although this area has a vast reservoir built during the Pol Pot regime in the 1970s, only the primary channel works. Water is not well distributed far from the reservoir owing to the poor irrigation system. These results imply that a probable reason for rare cultivation in the rainy season is the difficulty of pests and disease management due to a lack of knowledge and appropriate cultivation techniques. Another possible explanation is that producers may need more workforce to grow vegetables and rice simultaneously, even if there is land.

Business Conditions of Vegetable Producers

Analysis of the vegetable producers' business revealed that 100 out of 113 producer HHs (88%) sold vegetables. Still, three HHs (3%) were at a loss, or in the red, as shown in Fig. 7. The average monthly net profit was 35 USD or 166 USD for the cultivation period. This is considerably small compared to the study area's factory labor wage of 160–200 USD/month. Thirteen households did not sell vegetables for unknown reasons, even though they produced them with the intention of selling.

A comparative analysis was done by dividing producers into two groups based on the median profit to find the critical factors for lower or higher profits (Table 5). Producers above the median tended to own more upland and planted areas, resulting in significant production and sales volumes and larger profits. Their cost per hectare, unit yield, and unit selling price were lower than those of producers below the median. Although this study did not include own labor costs, productivity was nearly the same between the two groups. In this survey, no producers planted in the same farmland twice; thus, the planted area's size equals the owned farmland area. Therefore, the larger the farmland area owned, the larger the net profit obtained.

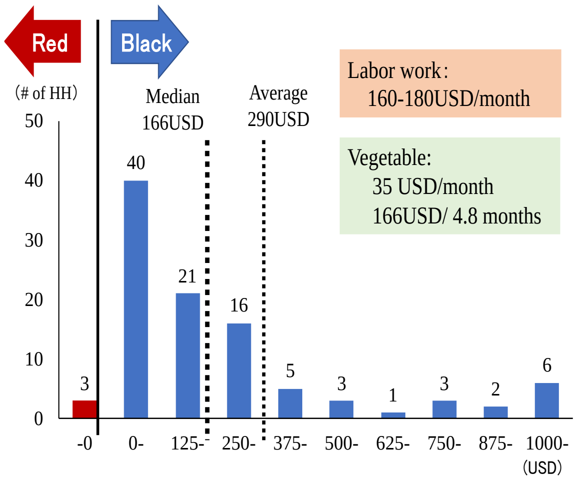

Fig. 7 Profits from vegetable production (N=100)

Pearson's correlation coefficients show positive correlations between net profit and total sale amount, cost, planted area, production, sales volume, number of items, and upland field ownership. Meanwhile, unit yield, which is also an essential component of production volume, was not correlated with net profit and costs per hectare (Table 5). Thus, profits from vegetables seem to be influenced more by production scale than by productivity.

Table 5 further shows the material inputs households used. Among 100 producer HHs, 69 purchased seeds, 79 purchased fertilizers, 39 purchased pesticides, 4 hired workers, 21 rented machinery, and 51 purchased fuels. However, these costs did not influence the net profits.

Table 6 shows the results of the analysis of the relationship between the unit yield of four kinds of vegetables and six material input costs. The costs of seeds, fertilizer, and fuel had highly significant positive correlations with leafy vegetables and beans yields. Labor and rental fees had a weak relationship with root vegetable yields, whereas fruit vegetable profits were not correlated with any input goods. Seeds and fertilizer costs had a highly significant correlation with profits. Some input material costs, such as pesticides, had slightly negative relationships with the unit yield of some vegetables. Pesticides are generally effective at preventing crop loss to pests, diseases, and weeds; however, producers may lack knowledge on how to use them appropriately. Thus, introducing inputs could be more effective in increasing unit yields and profits in vegetable production.

The critical factor of net profits for vegetable producers in this area is production scale — not strategic production, such as low cost, high selling price, high productivity, and high yield. The World Bank (2015) has indicated that the farm size of small-scale farmers is decreasing while that of large-scale farmers is expanding. Rural households with smaller agricultural land have fewer opportunities to get more significant net profits from current vegetable production. Small landholders need to increase productivity, selling price, or production frequency for more profits. Increasing productivity needs technical improvement, including appropriate ways of using input materials, such as fertilizers and pesticides.

Table 5 Status of vegetable production and the results of the analysis

Variables	Unit	All producers N=100		r[1]		above 166USD N=50		below 166USD N=50		P-value[2]	
Total sale amount	USD	328		0.995	**	571		84		0.000	**
Total cost	USD	38		0.466	**	52		23		0.011	*
Net profit	USD	290		1.000		520		61		0.000	**
Total sales amount/ha	USD/ha	1,989		0.064		2,047		1,931		0.007	**
Total cost per hectare[3]	USD/ha	464	(100)	-0.119		261	(50)	666	(50)	0.461	
seeds	USD/ha	282	(69)	-0.082		171	(33)	383	(36)	0.862	
fertilizers	USD/ha	306	(76)	-0.010		263	(40)	354	(36)	0.397	
pesticides	USD/ha	63	(39)	0.020		49	(21)	78	(18)	0.460	
labor fee	USD/ha	396	(4)	-0.022		147	(3)	1,146	(1)	0.500	
rental machines	USD/ha	111	(21)	0.009		146	(10)	80	(11)	0.756	
fuel	USD/ha	533	(51)	-0.108		103	(30)	1,149	(21)	0.034	*
Net profit/ha	USD/ha	1,526		0.169		1,786		1,265		0.000	**
Total planted area	ha	0.31		0.510	**	0.43		0.19		0.000	**
Total production	kg	1,115		0.641	**	1,917		313		0.000	**
Total sale volume	kg	735		0.850	**	1,253		217		0.000	**
Unit yield	kg/ha	11,440		-0.009		9,979		12,902		0.058	
Unit price	USD/kg	0.60		0.005		0.61		0.59		0.150	
Number of items	number	2.73		0.322	**	3.24		2.22		0.013	*
Self-consumption	kg	380		0.204	*	664		97		0.004	**
Main agriculture worker	age	52.02		0.019		53.68		50.36		0.155	
Education	yrs	4.92		0.032		4.82		5.02		0.601	
Years of schooling	yrs	20.08		0.018		22.32		17.84		0.084	
Owned agricultural land area	ha	1.49		0.222	*	1.7		1.28		0.075	
paddy field	ha	1.15		0.036		1.25		1.05		0.420	
upland field	ha	0.34		0.375	**	0.45		0.23		0.049	*

1 Peason's correlation coefficient between net profit and other variables
* significant at 5% level, ** significant at 1% level (two-sided)
2 Mann-Whitney U test * significant at 5% level, ** significant at 1% level (two-sided)
3 The number in parentheses ( ) indicates the number of households that have invested costs.

Table 6 Relationship between costs and unit yield and profits

Costs (USD/ha)	Unit yield (kg/ha)				Unit yield (kg/ha)	Profits (USD/ha)
	Leafy (N=27)	Fruit (N=61)	Root (N=33)	Beans (N=59)		
Seeds	0.509 **	0.101	-0.127	0.456 **	0.847 **	0.857 **
Fertilizers	0.525 **	0.230	0.263	0.833 **	0.396 **	0.424 **
Pesticides	-0.022	0.230	-0.065	0.909 **	0.073	0.018
Labor fee	-	-	0.392 *	-0.045	-0.016	0.000
Rental fee (machine)	0.320	0.005	0.407 *	-0.018	0.053	0.086
Fuel	0.538 **	0.159	0.334	0.829 **	0.304 **	0.088

* significant at 5% level, **significant at 1% level (two-sided) by peason's correlation analysis

Characteristics of Producer Households

Table 7 shows the structure of household income for both vegetable producers and non-producers. The average total household income was 2,309 USD, and there was no significant difference between producers and non-producers. Non-agricultural income accounted for an extremely high proportion of total household income. This trend was common for both producers and non-producers. However, the average agricultural income of vegetable producers was two times greater than that of non-producers. Additionally, the composition of agricultural income, such as rice, natural resources, and processing, was significantly different between the two groups. The primary source of income for each household shows that more than 50% (55.8%) of vegetable producers and 73.1% of non-producers depend on non-agricultural income. Only 21 HHs (18.6%) of all producers answered that vegetable production was their primary source of income. Although vegetable production was an essential contributor to the agricultural income of producers, its contribution to total household income is still low.

Perceptions of Producer and Non-producer Households

This study asked producers and non-producers about their perception of vegetable production. Among 100 producers, 74% of them answered positive intentions for future production, including increasing production amount (6%), the number of product items (24%), and production area (7%), as well as maintaining the current production (37%) (Table 8). Since current vegetable production does not bring much economic benefit, and many producers mentioned production issues (Tables 3 and 4), producers may see some benefit or significance, such as self-consumption other than financial benefit. Figure 8 shows the results of asking for future intentions for non-producers. Among 89 non-producers, 63% (56 HHs) had experience in vegetable production for sale. According to the socio-economic profile of all respondents of this study (Table 2), 23.6% (21 HHs) of 89 HHs had an upland field. Additionally, 78% (69HHs) answered that they want to produce vegetables for sale. The results show that the number of vegetable producers in this region may be increased. However, clarifying why they stopped vegetable production and eliminating their concerns is necessary.

Table 7 Structure of household income and primary sources of income

	Income souces[a]							Main source of income[b]			
Income sources	All respondents[3]		Producers[3]		Non-producers[3]		P-value	Producers[4] (%)		Non-producers[4] (%)	
Total household income	2,309	(202)	2,113	(113)	2,558	(89)	0.530				
Agricultural income	412	(202)	570	(113)	211	(89)	0.000 **				
vegetable	257	(113)	257	(113)	0	(0)	-	21	(18.6)	0	(0.0)
rice	-97	(202)	90	(113)	-335	(92)	0.000 **	13	(11.5)	12	(13.5)
animals	177	(122)	205	(78)	127	(44)	0.094	7	(6.2)	3	(3.4)
N. resources[1]	116	(106)	115	(68)	117	(38)	0.007 **	4	(3.5)	3	(3.4)
N. resources[2]	467	(13)	462	(12)	525	(1)	0.615	3	(2.7)	0	(0.0)
processing	787	(17)	116	(8)	1,383	(9)	0.002 **	0	(0.0)	6	(6.7)
rice milling	-385	(14)	-513	(11)	85	(3)	0.456	2	(1.8)	0	(0.0)
Non-agricultural income	1,996	(192)	1,661	(105)	2,400	(87)	0.032 *	16	(14.2)	11	(12.4)
off-farm business	2,594	(46)	2,493	(24)	2,704	(22)	0.800	34	(30.1)	43	(48.3)
employed work	1,986	(107)	1,551	(52)	2,397	(55)	0.002 *	13	(11.5)	11	(12.4)
Remittence	355	(144)	378	(89)	319	(55)	0.510	113	(100.0)	89	(100.0)

(a) Income in USD from each souce

(b) the number of household according to the result of calculation of each household income

1 rsources: fruits, fishes, medicinal plants, mushrooms, etc. (backyard)

2 rsources: fruits, fishes, medicinal plants, mushrooms, etc. (forest etc.)

3 ( ) indicates the number of household

4 according to the result of calculation of each household income

*significant at 5% level, **significant at 1% level (two-sided) by Mann-Whitney U test

Table 8 Future intentions of producers

Future vegetable production	# of HHs	(%)
Increase production amount	6	(6.0)
Increase # of products	24	(24.0)
Increase production area	7	(7.0)
Keep current production	37	(37.0)
Decrease production	6	(6.0)
Stop production	17	(17.0)
Others	3	(3.0)
Total	100	(100.0)

Single answer (N=100)

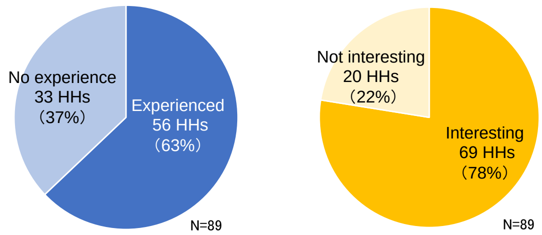

Fig. 8 Future intentions of non-producers

CONCLUSION

This study attempted to identify the challenges to increasing the vegetable production volume in Cambodia by clarifying the status of vegetable cultivation, including production amounts and varieties, vegetable production business conditions, and producers' socio-economic characteristics. The results implicated two major challenges for increasing vegetable production volume in Cambodia and several means to achieve them.

The first challenge is to increase production volume per producer. This study showed that vegetable production in rural Cambodia is profitable, but the profits need to be more significant to sustain the family as their primary income source. The critical factor for low net profits from vegetable production was the production scale derived from the size of owned farmland — not strategic production, such as low cost, increased selling price, increased productivity, or high yield. Growing farmland area or productivity is essential to increase production volume per producer. However, land size, including farmland, is reducing owing to a system of equal inheritance among siblings in Cambodia (Acharya et al., 2003; World Bank, 2013; Diepart, 2015), and a growing number of households (more than 25% in the low land) live with less than 0.5 ha of land, which is not enough to sustain a family throughout the year (Taylor, 2011). Therefore, increasing the total planting area will be more practical than expanding the farmland size. In the study area, most producers did not cultivate any vegetables during the rainy season, despite owning arable upland areas, owing to the risk of disease due to unsuitable cultivation methods. The limited cultivation is thought to be owing to the avoidance of damage from pests and root rot that tend to occur during the rainy season. The annual planted area is expected to increase through the appropriate use of pesticides and the introduction of cultivation techniques, such as ridges and stanchions, to allow cultivation in the rainy season and double-cropping. The development and introduction of a combination of suitable cultivation techniques, agricultural materials, and chemicals in Cambodia may positively influence the production volume.

Increasing the number of producers will be another challenge to obtain more production volume with the limited farmland size per household. This study identified that more than 60% of non-producers would produce vegetables, with 23.6% having an upland field. The main reason for stopping vegetable production was the limitation in sales channels and the difficulties of making the channel by themselves. However, nearly 80% of non-producers were interested in starting vegetable production. To involve experienced households and new producers, vegetable production needs to be more attractive as a profitable income-generating activity. Currently, rural households with smaller agricultural land have few opportunities to attain reasonable net profits from vegetable production. As mentioned above, the net profit should be improved by increasing production volume. Moreover, post-harvesting issues, such as quality management, the sales channel for rural small-scale producers, and value addition are as significant as those for other agricultural products in Cambodia. Developing a one-stop service for agriculture-related issues, including technical and informative dimensions, is urgent.

This study focused only on the status of vegetable production. Further studies to verify the above-mentioned means to increase output per producer, such as developing a combination of suitable cultivation techniques, agricultural materials, and chemicals, are needed. In addition, the target of this study was limited to the active vegetable-producing area with enough agricultural water throughout the year. Further studies need to cover potential production areas to discuss the possibility of expanding the total production area in the country.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI, Grant Number JP21KK0013—Fund for the Promotion of Joint International Research (Fostering Joint International Research [B]).

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Research article

Antimicrobial Resistance Profiles Found in a Case Study of *Escherichia coli* from Cohabitant Pets and Environmental Surfaces at Animal Clinics, Phnom Penh City

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Received 20 November 2023 Accepted 22 December 2023 (*Corresponding Author)

Abstract *Escherichia coli* (*E. coli*) can be transmitted from dogs to surfaces through direct exposure to dog faeces, pus, and urine; alternatively, it can live in the environment for a short period. We aimed to determine the prevalence and antibiotic resistance profile of *E. coli* from dogs and environmental surfaces of animal clinics in Phnom Penh, Cambodia. We swabbed twenty-four samples from dogs (18 faeces and 6 pus) and twenty-three from environmental surfaces (8 cage-floor, 7 cage-wall, 1 feeding-plate, and 7 treatment-table) at animal clinics. The bacterial culture method was used to isolate *E. coli* from both dog and environmental surface samples. An antibiogram of the isolates was tested using the disk diffusion method, following the standard of the Clinical and Laboratory Standard Institute and using six antibiotics (amoxicillin, ampicillin, ceftriaxone, gentamycin, levofloxacin, and tetracycline). The results showed that *E. coli* was present in approximately 54% of dog samples and 22% of environmental surface samples. The *E. coli* isolates from dog samples showed high resistance to amoxicillin, ampicillin, and tetracycline (54%) and lower resistance to ceftriaxone, gentamycin (27%), and levofloxacin (8%). *E. coli* isolates from environmental surfaces demonstrated high resistance to amoxicillin, ampicillin, ceftriaxone, and tetracycline (80%-100%), and lower resistance to gentamicin and levofloxacin (60%). In conclusion, *E. coli* was found to be present in both dogs and veterinary clinic surfaces and demonstrated resistance to numerous antibiotics. This study suggests that further research is necessary to identify the specific genes responsible for the antibiotic resistance of *E. coli* found on dogs, clinic surfaces, as well as on humans –including clinic technicians and dog owners – in order to better understand how this resistance is affected by the transmission of *E. coli* between different carriers.

Keywords dog, environmental surfaces, *E. coli*, antibiotic resistance, antibiogram.

INTRODUCTION

The use of antimicrobial drugs does not only increase the antimicrobial resistance (AMR) of pathogenic bacteria but also the endogenous commensal flora. (Berge et al., 2006; Dancer, 2004; Goosens, 2009). It is reported that the potential problem of AMR among pet animals may cause human health, due to the increasing utilization of the same antimicrobial substances in human medicine and to the close contact between pets and their human cohabitants (Guardabassi et al., 2004; Moyaert et al., 2006; Schwarz et al., 2001).

The spread of antimicrobial-resistant bacteria can occur directly, by skin-to-skin contact and contact with bacteria-containing material (e.g., saliva, feces, urine), or indirectly via the household environment (Guardabassi et al., 2004; Schwarz et al., 2001). Leite et al. (2013) reported that direct, close contact between all the cohabitants including pets and humans, and the touch of contaminated household surfaces and objects could lead to shared antimicrobial-resistant bacteria. In the new host, resistant bacteria can both colonize and infect and remain in that particular environment for a short time. During this period, the resistant bacteria are capable of either spreading their resistance genes to other bacteria residing in the new host (endogenous or pathogen bacteria), but also accepting resistance genes from other bacteria (Livermore, 2003; Schwarz et al., 2001). *Escherichia coli* (*E. coli*) has possible biology in spreading resistance not only to the acceptor and donor of the transmissible drug-resistant gene but also commonly found in the intestinal tract of both humans and animals (Costa et al., 2008). *E. coli* can also be implicated in various intestinal and extra-intestinal diseases including urinary tract infection (Johnson et al., 2008; Johnson et al., 2001) and Pyometra (Bassessar et al., 2013). Likewise, Markey et al. (2013) showed that *E. coli* can cause diseases such as Colisepticaemia, Pyometra, and Urinary tract infections in dogs. No study has been conducted in Cambodia regarding the *E. coli* resistance in pets and its associated environment.

OBJECTIVE

The present study aimed to determine the prevalence and resistance profiles among *E. coli* from cohabitant pets and environmental surfaces at animal clinics in Phnom Penh City, Cambodia.

METHODOLOGY

Study Site and Sampling

The study was conducted in three animal clinics in Phnom Penh city, Cambodia from March to May 2019. In total, forty-six samples were swabbed from dogs and environmental surfaces. The pet samples were selected based on the diagnosis of bloody diarrhea (3 to 8 months old), canine parvovirus, and Pyometra disease. The environmental samples were selected regarding the case-reported animals above which animals were exposed to. Twenty-four samples (18 faeces and 6 pus) were collected from dogs. Twenty-three samples (8 cage-floor, 7 cage-wall, 1 feeding plate, and 7 treatment-table) were collected from the environmental surface. All samples were collected and transported on the same day to the Veterinary Microbiology Laboratory of the Faculty of Veterinary Medicine, Royal University of Agriculture, Cambodia.

E. coli Isolation

Samples were collected and the bacterial culture was followed by Markey et al. (2013). Briefly, the swap was subcultured into 5 mL of Buffered Peptone Water (BPW) and incubated at 37^0C for 24 hours. Then the presumptive was streaked on MacConkey agar and incubated at 37^0C for 24 hours. The suspected colonies with large/medium dark pink colonies were confirmed with biochemical tests such as gram staining, Catala's test, Triple Sugar Iron (TSI), and Motility-Indole-Lysine (MIL) test.

Antimicrobial Susceptibility Testing

Antimicrobial susceptibility was performed using the disk diffusion method following Clinical and Laboratory Standards Institute (CLSI, 2017) guidelines. Briefly, fresh *E. coli* isolates were plated on Trypton-Soja-Agar (TSA) plates and incubated at 37^0C for 24 hours. Then 2-3 colonies on TSA were inoculated on NaCl suspension to a turbidity equivalent to 0.5 McFarland standards. One hundred microliter suspension was plated on 15cm depth Mueller-Hinton agar (MHA) and standard discs were applied using a dispenser and incubated for 16-18 hours at 37^0C. A total of six antimicrobial agents including Tetracycline (30 µg), Ampicillin (10 µg), Amoxicillin (10 µg), Gentamycin (10 µg), Ceftriaxone (30 µg), and Levofloxacin (5 µg) were tested. All antibiotics used for the study are based on the treatment protocol of each animal clinic.

RESULTS AND DISCUSSION

The present study found that a high prevalence of *E. coli* (54.16%) presented in dogs; whereas, a low prevalence (21.74%) in environmental surfaces isolated from the animal clinics in Phnom Penh city. *E. coli* is presented in about 67% and 17% of dog faeces and pus respectively. The result is similar to the previous finding according to Das et al. (2012) in the faeces of dogs. *E. coli* is the major pathogen in the genital tract (Bassessar et al., 2013). Some studies showed that 50-85 % of *E. coli* in bitches suffer from pyometra disease (Bjurström et al., 1993; Sandholm et al., 1975; and Trevena et al., 1996). Sharif et al. (2017) found that the prevalence of *E. coli* in the pus of bitch with Pyometra was higher than the present study as the sample is much larger. Dog age is a factor contributing to the prevalence of *E. coli* in faeces. Greene et al. (1998) have reported two strains of *E. coli* were associated with gastrointestinal disease in young dogs. 77% of *E. coli* is present in young dogs at age 1-3 months (Younis et al., 2015). However, Torkan et al. (2016) showed a significantly low prevalence of *E. coli* (47%) in the adult dog's faeces. The present study was on dogs with age from 3-8 months old which shows the prevalence is in between these studies.

Table 1 The prevalence of *E. coli* distributed the animal clinics

Animal Clinics	Dogs (faeces and pus)		Environmental surface	
	Number (n/N)	Percent (%)	Number (n/N)	Percent (%)
A	1/5	20.00	0/2	0.00
B	5/10	50.00	5/16	31.25
C	7/9	77.78	0/4	0.00
Total	13/24	54.16	5/23	21.74

Table 2 The prevalence of *E. coli* distributed in animal and environmental surface samples

Sample		Prevalence		Total	
		Number (n/N)	Percent (%)	Number (n/N)	Percent (%)
Dogs	Faeces	12/18	66.67	13/24	54.16
	Pus	1/6	16.67		
Environmental surfaces	Cage-floor	3/8	37.50	5/23	21.74
	Cage-wall	1/7	14.28		
	Feeding plate	0/1	0.00		
	Treatment table	1/7	14.28		

Table 3 The antimicrobial resistance profiles of *E. coli* in dogs and environmental surfaces

Antibiotics	Dogs		Environmental surfaces	
	Number (n/N)	Percent (%)	Number (n/N)	Percent (%)
Tetracycline	7/13	53.85	5/5	100.00
Ampicillin	7/13	53.85	4/5	80.00
Amoxicillin	7/13	53.85	5/5	100.00
Gentamycin	3/13	23.08	3/5	60.00
Ceftriaxone	4/13	30.77	4/5	80.00
Levofloxacin	1/13	7.69	3/5	60.00

The prevalence of *E. coli* on the environmental surface varies according to the animals that have been exposed to Sidjabat et al. (2006). The highest (37.50%) prevalence of *E. coli* on the environmental surfaces of the animal clinics in this study was isolated from the cage floor which is the most contaminated between faeces or pus of the dogs on the cage floor during hospitalization. Instead, it might also be attributed to poor hygiene of the animal clinics and the cross-contamination between dogs and the surfaces. However, Madubuike et al. (2016) reported a lower prevalence of *E. coli* bacteria on environmental surfaces (3.60%), especially the cage floor (0%) of the animal clinics in Nigeria might be the biosecurity measures taken in the animal clinics were able to reduce the contamination of *E. coli*.

E. coli showed high resistance to amoxicillin, ampicillin, and tetracycline (54%); while less resistant to ceftriaxone (31%), gentamycin (23%), and levofloxacin (8%) in dogs. Similarly, this isolate also has high resistance to amoxicillin, ampicillin, ceftriaxone, and tetracycline (80-100%); while less resistance to gentamicin and levofloxacin (60%) on environmental surfaces. The high resistance to antibiotics on environmental surfaces was higher than the dog samples in the present study. This might be fewer samples in the environment and the possibility of *E. coli* surviving on the surface. However, Leite et al. (2013) and Carvalho et al. (2016) reported that pet dogs were shown to be a potential household source of multi-resistant *E. coli* strains to humans through the environment. Resistance to antibiotics in dogs in the present study is consistent with the study of Nam et al. (2010).

CONCLUSION

In conclusion, both dogs and environmental surfaces showed identical prevalence of *E. coli* and its resistance to several important antimicrobials. This is correlated with the spreading of antimicrobial resistance into the environmental surfaces of the animal clinics from hospitalized dogs and could be spreading to the owners and veterinarians. That was the most significant implication of animal clinical usage and public health.

ACKNOWLEDGEMENTS

The study is supported by the Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CE SAIN) of the Royal University of Agriculture (RUA) receives financial support from the U.S. Agency for International Development (USAID) through Feed the Future Innovation Lab for Sustainable Intensification (SIIL).

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Research article

Assessing the Acceptability and the Feasibility of an Agricultural Package of Technologies for Risk Management in Southern Haiti

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Received 22 November 2023 Accepted 23 December 2023 (*Corresponding Author)

Abstract Haitian farming faces serious climate risks linked to natural disasters. Losses due to hurricanes, droughts, floods, and diseases seriously threaten productivity. This paper aimed to study the feasibility and acceptability of agricultural technology packages that could help manage risk while improving the productivity of farming in Haiti. Significant risks faced by farmers include uninsurable disasters due to their systemic and catastrophic nature. Therefore, a package of technologies including a paid-in-kind "stabilization account" component may be an appropriate financial tool for risk management. Are Haitian farmers open to such innovation? To answer this question, we collected data from 28 agricultural experts and 1,400 farmers, including 234 maize farmers in southern Haiti, and adopted the new product development (NPD) process to test the feasibility of the concept. We used the Spearman correlation, multinomial logistic regression, and linear regression to determine factors affecting the openness of Haitian farmers to innovation. We also conducted the Cochran-Mantel-Haenszel test to analyze the association between "financial inclusion" and "openness to innovation." Based on the results, 70% of farmers expressed their willingness to pay 6% to more than 12% of their harvested crop as a stabilization account. Farmers with "financial inclusion" are expected to be twice as likely to adopt innovative technologies, while farm size, gender, household size, and revenue had a significant positive impact on openness to innovation. However, contrary to the trends found in other literature, we found that risk aversion may positively affect the acceptance and adoption of some technologies. The results also suggest that, in Haitian farming, risks linked to natural disasters are more strongly related to financial incapacity than uncertainty. Therefore, access to proper just-in-time inputs complemented by a financial tool to overcome uncertainty will significantly boost the adaptability and resilience of Haitian farmers toward climate risks.

Keywords climate, product development, stabilization account, technology adoption

INTRODUCTION

Natural hazards present themselves as a severe issue disrupting farming activities in Haiti. Between 1990 and 2008, Haiti was the Caribbean country most affected by natural disasters (3 droughts, one epidemic, 22 floods, 23 storms, and hurricanes) (Weissenberger, 2018). Regions with exceptionally high production in agriculture generally present higher vulnerability to natural risks and disasters (earthquakes, landslides, floods, hurricanes, and droughts) (UNDP, 2015). In the aftermath of Hurricane Matthew in 2016, the agricultural sector was most affected; with losses and damages estimated at 603.8 million dollars (around 4.3% of the country's GDP at the time), 80% of the agricultural plantations were destroyed in its path (Icart, 2017). The southern peninsula of Haiti is particularly exposed to tropical storms, hurricanes, floods, and landslides (IFAD, 2022). Haitian agricultural producers, who already operate with inadequate working capital, additionally find themselves confronted with various risks accelerating the process of decapitalization. Thus, an appropriate model of Haitian agriculture should put risk mitigation first (Bureau et al., 1994) because exposure to uninsured risks is a proven major cause of low yields, slow growth, and persistent poverty (Carter et al., 2015). Over 20% of the country's GDP is from agriculture (Vansteenkiste, 2022); therefore, the agricultural sector demands serious consideration despite its high-risk exposure.

Technology refers to tools and techniques or knowledge, ideas, and methods people use to achieve an activity (Dholey, 2019). In agriculture, climate-smart technology has been used for risk mitigation, such as drought-resistant seed, rescheduling planting, and micro-irrigation (Tanti et al., 2022). Therefore, adopting technology (tools and techniques) for managing climate risk may be an essential alternative for Haitian farmers. In addition, agribusiness firms supplying inputs to farmers may need to provide new products and services. Thereby, this research provides insights relevant to the acceptability and feasibility of integrating stabilization accounts in an agricultural package of technologies in Southern Haiti as tools and techniques for managing risks linked to climate hazards. The southern peninsula of Haiti is particularly exposed to tropical storms, hurricanes, floods, and landslides (IFAD, 2022). Some previous works mention the risk aversion of Haitian farmers (Bureau et al., 1994) and its possible negative impact on technology adoption in general (Murray and Bannister, 2004; Macours et al., 2018). These works focused on lessons learned from agroforestry projects and a pilot phase of subsidizing technology transfer. For this reason, our study provides a specific view of how adopting technology to manage hazards may be approached differently.

Armstrong et al. (2014) suggest eight (8) stages to develop a new product: idea generation, idea screening, concept development and testing, marketing strategy development, business analysis, product development, test marketing, and commercialization. As a feasibility study, this research covers the three initial phases of a new product development process (NPD), the purpose of which is to find out whether Haitian farmers are willing to accept such innovation. Continuous and discontinuous innovations are inevitable for all business activities regarding productivity improvement and risk management. The NPD process is suitable for continuous and discontinuous innovation (Corso and Pellegrini, 2007); therefore, we focused on this process to guide our methodology.

In the remaining part of this work, after clarifying the content of the package of technologies, we present a brief review of the "stabilization account," the study's objectives, the methodology used, the results, the discussions, and the conclusions with some recommendations.

The package of technologies: It was demonstrated by Valcin and Uchiyama (2021) that an adequate package of technologies has a significant positive impact on productivity in southern Haiti. This package included plowing service, certified seed, fertilizers, irrigation, and pesticides. These inputs would be provided to farmers in the contract framework as a loan. Besides, farmers mentioned that climate risk may prevent them from reimbursing their credit. This feedback is the basis for testing the feasibility of including a financial tool, the “stabilization account,” as a risk management component in the package.

A brief review of "stabilization accounts": Several approaches to agricultural insurance have been implemented worldwide (Nair, 2010); each country finds a more suitable scheme based on its situation (Kalfin et al., 2022). However, for countries or regions where catastrophic risks are frequent, risk management tools such as stabilization accounts for farmers are increasingly being considered (ČOP and Njavro, 2020).

According to Diaz-Caneja et al. (2009), "the stabilization accounts is a form of self-insurance. They consist of individual accounts where farmers put in a certain amount of money every year.

Which they can withdraw in a year of big losses. Stabilization accounts can be based on yield, revenue, or other indices." The stabilization accounts will be managed as a mutual fund. It is based on the accumulation of reserves from participants' contribution (in kind, in our scenario) from which members will receive support in the event of a loss according to the arrangement between farmers and the managing company (Meuwissen et al., 2013; Kislingerova and Spika, 2022). Risks such as drought and hurricanes are examples of systemic and complex for insurers to diversify (Kislingerova and Spicka, 2022); they are hard to insure. Having a disaster-based stabilization account paid in kind as part of a mutual fund can be an excellent financial tool for managing risk for Haitian farmers. The stabilization account is the most innovative aspect of this research. Its acceptability by farmers is the ultimate purpose of this feasibility study. This alternative has been chosen instead of the traditional form of agricultural insurance because we assume that Haitian farmers' most significant risks are insurable.

Conceptual framework: The concept consists of an arrangement between firms and farms, through which farmers will receive a package of technologies on credit from the firm after a subscription fee is paid in kind. Farmers will repay the firm at harvest time by returning the crop-equivalent value of the granted package. According to a prior agreement, the firm will also buy the farmer's harvested crop. The subscription fee paid in kind will be held as a contribution to the stabilization account of each farmer and will vary according to the plot size. We are testing the following concept: an agreement between the firm and the farm. This arrangement will help farmers access high-quality inputs on time and credit. We aim to reduce the inability to meet the crop calendar while offering specific coverage in case of significant loss. On the other hand, it is advantageous for firms to provide risk management tools to their clients (farmers), as it helps to protect, increase, and sustain their investment (Maggio and Sitko, 2019).

OBJECTIVES

This study assesses the Acceptability and Feasibility of Integrating Stabilization Accounts in an Agricultural Package of Technologies among farmers in Southern Haiti. Specifically, the study aims include: i) discovering the perception of Haitian agricultural experts on introducing a climate-smart package of technologies to Haitian farmers, ii) identifying the relationship between farms and farmers' characteristics and the propensity to adopt new technologies, and iii) evaluating the Haitian farmer's willingness to pay (in-kind) for the agricultural new technologies (Disaster-based Stabilization Account (DSA)) through a contractual agreement.

METHODOLOGY

Two categories of data were used in this research:

Primary data: Besides the variables from the primary data that we used to analyze the determinants of farmers' openness to innovation, some additional variables necessary for the idea screening and the concept testing, such as the willingness to accept and to pay, were collected in the summer of 2022 in the framework of this study. Two samples were surveyed for this purpose: a sample of 28 Haitian agricultural experts and a sample of 234 farmers. A Google Form was used for data collection among experts; however, a direct paper survey was distributed to farmers. Experts were asked to give the concept a score (from 0-100%) based on the following criteria: "How much will the product meet a need? Will it offer superior in-use value? Can it be distinctively advertised? Will the product deliver the expected sales volume, sales growth, and profit?" For each question, 70% was considered as the target to conclude validity. We adopted this methodology from Toubia and Florès (2007). This information was explicitly used to conduct a qualitative analysis. In addition, key informants were interviewed for a comprehensive understanding of the sector. Some key informants include the Director of the Organization for the Rehabilitation of the Environment (ORE), the Dean of the Faculty of Agricultural Sciences and Environment at Quisqueya University (FSAE/UniQ), the Director of the Agro-socio-economy of FSAE/UniQ, a former employee of the Financing and

Agricultural Insurance System in Haiti (SYFAAH), an employee of the Industrial Development Fund (FDI), and an employee of Haitian Foundation for Sustainable Agricultural Development (FONHDAD). They were asked to give their expert opinion, on the importance, the advantages, inconveniences, and challenges of the proposed package concept. Primary data were collected in the Sud district of Haiti; however, secondary data also cover an additional district called Artibonite (Fig. 1).

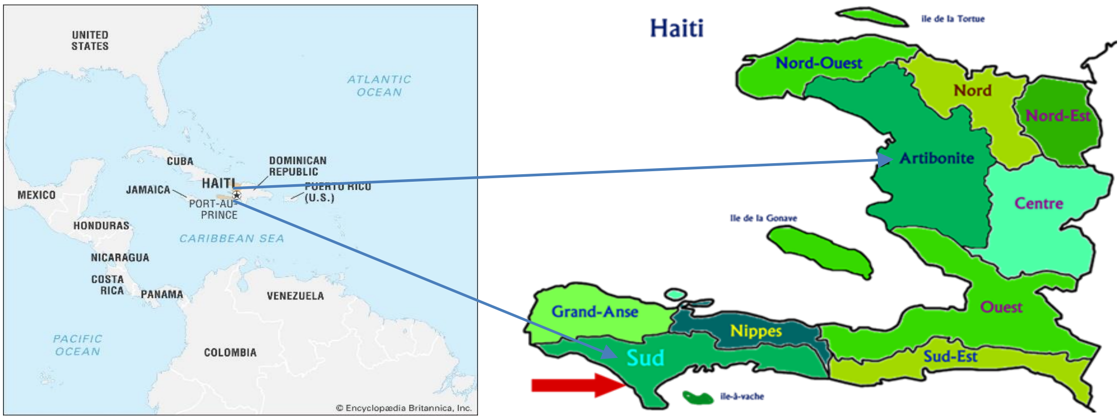

Fig. 1 Location of the study area

Secondary data: In the fall of 2022 and winter of 2021, a survey targeting more than 1,200 farmers was conducted by the University Quisqueya and the Ministry of Agriculture in Haiti, funded by the Interamerican Development Bank. Until our study, this database remained unused for similar research purposes. Variables related to our objectives found in this database were used in this paper. This information enabled us to make a quantitative analysis, including modeling and previsions.

For data analysis, multinomial logistic regression and the Cochran-Mantel-Haenszel test were used through the Statistical Package for Social Science (SPSS). The techniques were used respectively to analyze factors affecting openness to novelty and the association between financial inclusion and openness to innovation. The New product development process is used as the guideline for this research project. Three steps are taken in this paper: ideation, idea screening, and concept testing.

RESULTS AND DISCUSSIONS

The General Situation of Haitian Farmers

The interview with key informants revealed that farmers usually begin in risky agricultural timeframes because of their inability to start their cultural operations on time. The crop calendar is so tight in Haiti that even slight delays may lead the farmer into the beginning of spring's heavy rain or the cyclonic season (June to November). Our study defines *uncertainty* as a lack of knowledge or data on future events based on Machiels' findings (Machiels, 2023). In Haitian farming, risks linked to natural disasters seem more correlated with financial incapability to observe an ideal crop calendar than general uncertainty.

Expert Perception of the Firm-Farm Concept

For the idea screening, each expert surveyed was an agronomist. Among the 28 experts, 16 participants had 10 to 38 years of experience, and 9 participants had experience working in financial institutions. They were asked to score the firm-farm concept (from 0 to 100%) based on the questions from Table 1.

Table 1 Screening result of the concept according to expert point of view

Label / Indicator	Score Level	Validity
Will the product meet a need?	100%	High
Does the product offer superior in-use value?	92%	High
Can the product be distinctively advertised?	59%	Fair
Does the company have the necessary know-how and capital?	60%	Fair
Will the product deliver the expected sales volume, sales growth, and profit?	86%	High

Note: Number of respondents=28, Source: Survey by authors, 2022

When questioned about the possibility of success, in terms of acceptability, adoption, and profit, their answers were as illustrated in Fig. 2.

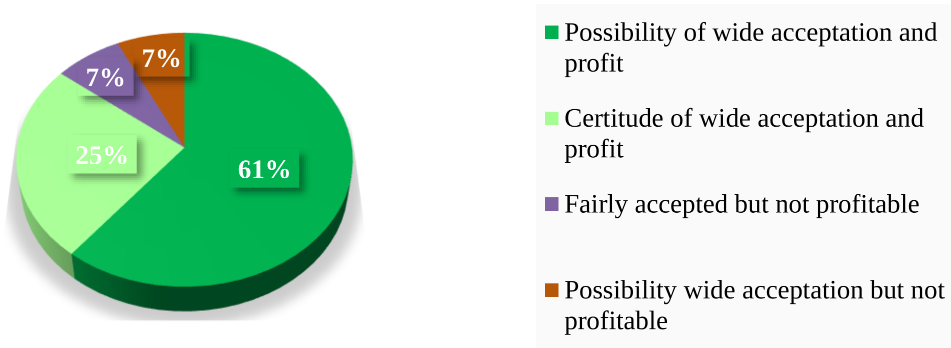

Fig. 2 Experts' points of view on the prospective success of the concept

Results shown in Table 1 and Fig. 2 suggest that experts highly score the concept's potential ability to meet a need, its superior in-use value, and its expected financial success. However, it will require more effort to build awareness and may require additional know-how and capital. These efforts do not limit the concept quality as innovation is always costly, risky, and requires knowledge capital (Laperche, 2013; Zambon and Monciardini, 2015).

Farms and Farmers' Characteristics and the Propensity to Adopt New Technologies

In this section, we highlight a key finding suggesting that aversion to risk linked to natural hazards may boost the propensity to adopt new technologies to mitigate those risks. This could be considered a sort of risk preference influenced by loss aversion (Filiz et al., 2020). Many factors have already been identified for their impact on technology adoption. Some of them have been confirmed in the Haitian farmer's framework; some factors have been expressed differently. Farmers from this area are not significantly different in education level since most have only completed primary education. Table 2 shows how the relevant factors affect their openness to innovation.

Table 2 Factors affecting the openness of farmers to technology for risk management

	B	S.E.	Wald	df	Sig.	Exp(B)
Gender	-.463	.172	7.200	1	.007	.630
Age	-.004	.005	.714	1	.398	.996
Revenue	.000	.000	16.824	1	.000	1.000
Farm Size	.985	.203	23.491	1	.000	2.677
Household Size	.113	.041	7.441	1	.006	1.119
Org. Membership	-.365	.135	7.300	1	.007	.694
Constant	.322	.330	.954	1	.329	1.380

Note: Dependent variable: Openness to innovation; Number of respondents: 1078. The model was well fitted as shown by the Omnibus Tests of Coefficients (Chi-square: 83.8; Sig.: .000) and the Hosmer and Lemeshow Test (Chi-square: 10.3; Sig.: 0.244). However, the Nagelkerke R Square was relatively low (0.10), therefore including more variables in the model might increase the explanatory power.
Source: Computed from FSAE-UniQ data by the authors

Female Haitian farmers were more likely to accept new technologies, which is opposite to the findings of Doss (2001) who found that female African farmers are less likely than their male counterparts to adopt improved crop varieties and management systems. However, this result is in line with what was observed in Zimbabwe's situation (Masuka et al., 2016), as well as a New Zealand case (Brown and Roper, 2017).

Farmers with a higher revenue are more capable of affording new technologies; by acquiring good quality or lasting tools, they enact changes less frequently than farmers with lower revenue. In addition, low-revenue farmers have much to lose; adoption decisions appear rational. Therefore, if there is no direct benefit, farmers will not adopt (Suri, 2011).

Household size could affect the decision to adopt new technology either positively or negatively. Suppose the new technology will require additional routine maintenance and operation. In that case, it may be more adapted to a bigger family (Uhunamure et al., 2019). However, if it is seen as an opportunity to diminish labor, it will be more attractive to smaller households.

Like the Haitian case, most studies agreed on a farm size's positive effect on technology adoption because, in many cases, technologies help farmers reduce the cost and difficulties of farm operations (Gargiulo et al., 2018). However, Mwangi and Kariuki (2015) suggest a mixed effect.

Ultimately, having affiliation with some local organization or being part of a farmers' association is known to influence the adoption of new technology (Ruzzante et al., 2021). However, in some cases, the effect may differ based on the type of technology (Buyinza and Wambede, 2008; Chuchird et al., 2017); these groups will also influence individual decisions.

Association Between Openness to Innovation and Financial Inclusion

"Having a bank account" is critical evidence of "financial inclusion" (Karlan and Morduch, 2009; Brune et al., 2016; Grohmann et al., 2018). The Cochran-Mantel-Haenszel was used to analyze the association between financial inclusion and openness to innovation using a sample of 1,078 Haitian farmers. They were asked whether they had owned a savings account within the past five years. Table 3 shows a significant association between "financial inclusion" and the "Openness to Innovation." According to the estimated Odds ratio, a farmer with "financial inclusion" tends to be 1.5 times more disposed to accept and use new technologies. A farmer who is open to new technology and has financial inclusion will be a potential target for the developing concept.

Table 3 Crosstabulation and tests of conditional independence

		Financial inclusion		Total		Chi-squared	df	Asymp. sig (2-sided)
		No	Yes					
Oppen-ness	No	367	159	526	Cochran-Mantel-Haenszel test	10.554	1	.001
	Yes	333	219	552		10.134	1	.001
Total		702	378	1,078	Est. odds ratio	1.518		.001

Source: Computed from FSAE-UniQ data by the authors

With the integration of the financial component (disaster-based stabilization account) for risk management, farmers must have a bank account to join the contract. Therefore, it is a good antecedent for farmers to have financial inclusion history because it enhances access to financial services such as credit and insurance (Peprah et al., 2020).

Farmer's Willingness to Pay (In-kind) for Agricultural New Technologies (WSA)

At the beginning of all interviews, the concept features were explained in detail to farmers, as described in the conceptual framework section. Then, we asked questions concerning their understanding of the concept, willingness to accept the agreement, and willingness to pay in-kind as an account deposit. Two hundred twelve farmers answered these questions; they were primarily male (91%). The respondents were between 22 and 82 years old, averaging 47.5 years old. They had anywhere from 0 to 17 years of schooling, with 32% having at least seven years (up to the secondary level). As a result, seventy percent of farmers express a propensity to accept the arrangement by paying from approximately 6% to more than 12 % of the harvested crop as a stabilization account, as shown in Fig. 3. This percentage refers to the subscription fee which will be held in the stabilization account. This contribution will return to the farmer in the event of a qualifying natural hazard as stipulated in the agreement. At the beginning of all interviews, the concept features were explained in detail to farmers, as described in the conceptual framework section. Then, we asked questions concerning their understanding of the concept, willingness to accept the agreement, and willingness to pay in-kind as an account deposit. Two hundred twelve farmers answered these questions; they were primarily male (91%). The respondents were between 22 and 82 years old, averaging 47.5 years old. They had anywhere from 0 to 17 years of schooling, with 32% having at least seven years (up to the secondary level). As a result, seventy percent of farmers express a propensity to accept the arrangement by paying from approximately 6% to more than 12 % of the harvested crop as a stabilization account, as shown in Fig. 3. This percentage refers to the subscription fee which will be held in the stabilization account. This contribution will return to the farmer in the event of a qualifying natural hazard as stipulated in the agreement.

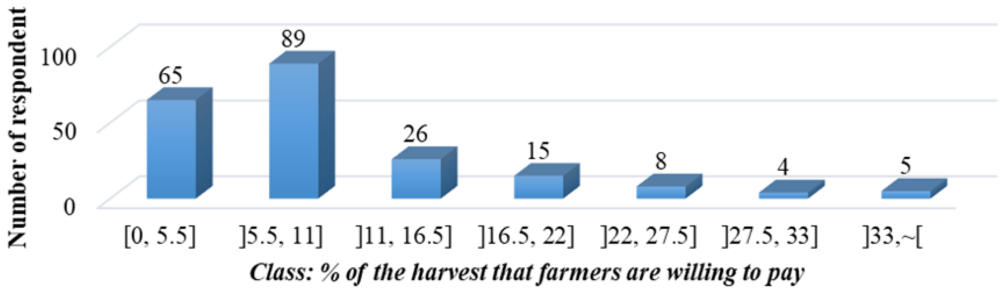

Fig. 3 The percentage that farmers are ready to pay from their harvest

CONCLUSIONS AND RECOMMENDATIONS

This study proposes a systemic approach by including risk management tools and techniques in a package of technologies. The latter includes appropriate inputs, including credit and a stabilization account as financial tools for risk management. The stabilization accounts were chosen instead of the traditional form of agricultural insurance because major risks affecting Haitian farming are complex to insure due to their systemic and catastrophic character. Interviews and surveys were conducted to assess the arrangement's acceptability and feasibility. The main results were as follows:
Haitian agricultural experts and farmers favor the concept and predict its financial success.

i. Farmers expressed a high propensity to pay up to 12% of their harvested crop as a stabilization account. Therefore, the concept successfully passes the screening and testing phases of its development. The results convey some evidence of its acceptability and feasibility in Haitian farming.
ii. "Financial inclusion" plays an essential role in financial technology adoption; farmers with financial inclusion will be two times more open to innovative technologies. Thus, prioritizing farmers with bank accounts may guarantee higher success rates during concept implementation.
iii. In Haitian farming, risks linked to natural disasters are more related to financial incapacity than uncertainty. Therefore, if farmers could adhere to the crop calendar, that would be a significant step towards risk mitigation in Haitian farming.

As per the above results, the following recommendations were given:

1. The implementation of this concept should be started with a limited group of farmers, preferably young, literate, and financially included. This small group will be used as a model for potential scaling.

2. A clear explanation or a demonstration of any concept to the potential buyers (farmers in the framework of this study) will enhance its probability of acceptance and adoption. That will be very important in promoting new technologies to Haitian farmers.
3. A paid-in-kind stabilization account worth 7% to 10% of the farmer's harvested crop or about 180 kg of maize equivalent will be affordable for most farmers.

Limitations of the Study

The study needs to provide more information regarding the viability aspect of the concept feasibility. A subsequent study should focus on developing a cross-sector business model demonstrating the concept's viability.

ACKNOWLEDGMENTS

This research was funded by:
- The Ministry of Education, Culture, Sports, Science, and Technology (MEXT) of Japan.
- Tokyo Nodai Research Institute (TNRI).
- Haitian Republic Bank (BRH) through UniQ/FSAE

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Research article

Changes in Soil Physical Properties Owing to Soil Reduction Treated with Electrokinetic Treatment

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Received 17 September 2023 Accepted 26 December 2023 (*****Corresponding Author)

Abstract Increasing soil water content due to soil reduction is generally confirmed in rice paddy soils after flood irrigation or in littoral sediments with high organic matter content. This could be caused by soil aggregates during the reduction process through biological and electrostatic phenomena. In the literature, changes in liquid and plastic limits owing to soil reduction treated with electrokinetic treatment (ET) have been reported; however, there was no report relating to changes in other soil physical properties, such as grain size distribution (GSD) and water-holding capacity (WHC). Thus, this study aimed to examine changes in soil physical properties caused by soil reduction treated with ET. Changes in GSD, hydraulic conductivity, and WHC were examined in laboratory experiments to understand soil aggregates due to soil reduction. During ET application, a decrease in electrical conductivity was observed, indicating the cohesion of ions (soil aggregate). This resulted in increases in the percentage of particles ranging from 0.075-0.212 mm, hydraulic conductivity, and WHC. However, particle dispersion occurred when the electrical current was high (10 mA), resulting in a significant decrease in hydraulic conductivity and WHC. Therefore, it can be said that soil aggregates can develop electrostatically. Thus, ET can be used for developing soil aggregate.

Keywords soil reduction, electrokinetic treatment, soil aggregate, grain size distribution, hydraulic conductivity, water-holding capacity

INTRODUCTION

In rice paddy fields, oxygen diffusion from air into the soil is suppressed after flood irrigation on the soil surface, causing soil reduction. Touch et al. (2021) experimentally examined soil redox potential (ORP) after making a water layer on paddy soils. They observed that soil reduction occurred in 45 days. Generally, the water content of paddy soil increases temporally during soil reduction. Ozaki et al. (2013) observed an increase in water content from 30% to 50% after flooding irrigation in winter. Moreover, an increase in water content due to soil reduction occurs in littoral sediments. Fukui et al. (2012) reported that the water content of sediments with high organic matter content is higher than that of sediments with low organic matter content. Hattori et al. (2018) reported an increase in water content with an increase in total organic carbon. Therefore, it can be said that organic matter influences the water content of sediments. However, the mechanisms behind the increasing water content owing to soil reduction or organic matter remain unclear.

It is believed that an increase in water content owing to soil reduction occurs through soil aggregate by biochemical and electrostatic mechanisms. Generally, the released substances during the decomposition of organic matter can act as binders in soil aggregate. With the proceeding of organic matter decomposition, and fungal hyphae development, water-stable aggregates increased and then decreased (Limura and Egawa, 1956). Many researchers have since focused on the correlation between soil organic matter and soil aggregate (Okolo et al., 2020; Mustafa et al., 2020).

Soil aggregate may also occur through electrostatic bonding. Liaki et al. (2010) investigated physicochemical effects on clay after ET application. They observed changes in water content owing to ET application and pointed out that ET application varied the zeta potential of clay particles, causing changes in share strength, liquid limit, and plastic limit of clayey soils. However, the effects of ET on other soil physical properties remain unknown.

OBJECTIVE

This study aims to examine changes in soil physical properties owing to soil reduction treated with ET. This can be done by inducing reduction reactions in upland soils with a constant flow of electrical current using a potentiostat (current fixation). Specifically, changes in grain size distribution (GSD), hydraulic conductivity, and water-holding capacity (WHC) are examined. In addition, changes in ion concentration present in soil pore water after the generation of electrical current are determined.

METHODOLOGY

Experimental Procedures and Operations

Figure 1 shows the experimental device, comprising a cylindrical bottle with an inner diameter and a height of 120 mm and 150 mm, respectively. First, the upland soil collected from the farmland was placed in the bottle until it reached a height of 20 mm from the bottom, and an electrode (anode) was placed on the soil layer. 30 mm of the soil layer was then placed on the electrode (Fig. 1a). Finally, tap water was poured over the soil layer. The bottle was then placed in a container (360 mm in width, 510 mm in length, and 300 mm in height) filled with tap water (Fig. 1b). In the container, an electrode (cathode) was submerged close to the water surface.

The electrode material was carbon cloth (News Company, PL200-E), which was heated at 500°C for 1 h before using it, as Nagatsu et al. (2014) suggested. The heated carbon cloth with a width of 10 cm and height of 10 cm was separated into fibers to form a brush-type electrode (Fig. 1c) used in the experiments.

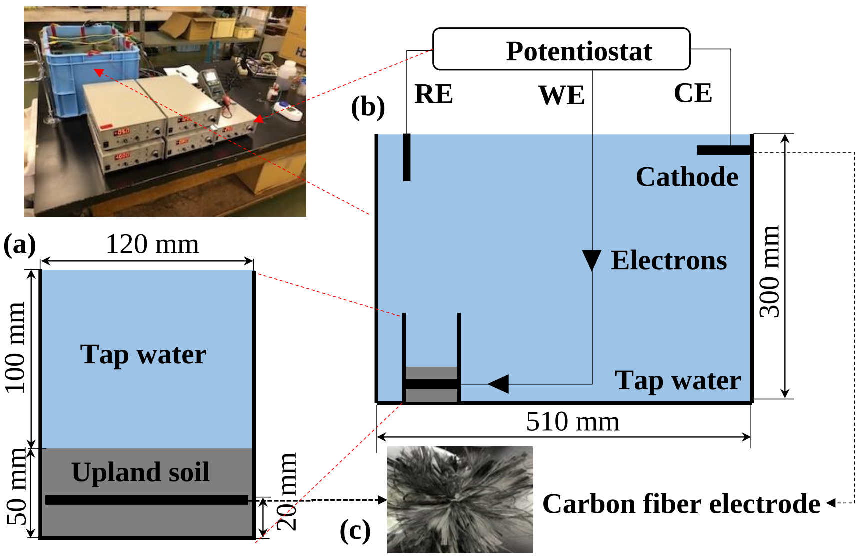


Fig. 1 Experimental devices and operations

To generate an electrical current, the anode, cathode, and reference electrode (Toyo Corp., W-RE-7A) were connected to a potentiostat (Hokuto, HA-151B) using the circuit shown in Fig. 1b. A potentiostat was used to maintain a constant electrical current of 4, 6, 8, and 10 mA. The current generation lasted for 7 days. As the treatment duration was less than 7 days, the effects of organic matter decomposition on soil aggregate are thought to be less significant.

Analyses

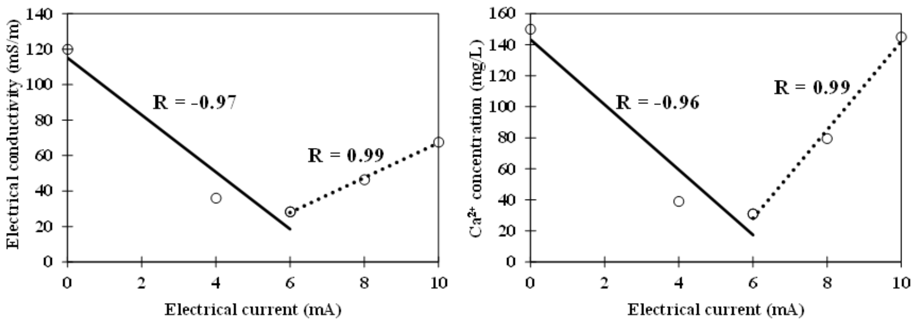
Soil sampling was conducted at the end of the experiments. Surface soil of 1 cm was removed, and the residue was centrifuged at 6000 rpm for 5 min (As One, CN-2060) to extract pore water. The electrical conductivity (EC) and calcium ion (Ca^{2+}) of extracted pore water were measured using an EC meter (Horiba, D-74) and a Ca^{2+} meter (Horiba, Ca-11), respectively.

Grain size distribution (GSD), hydraulic conductivity, and water holding capacity (WHC) were measured to examine changes in soil physical properties owing to soil reduction. GSD, hydraulic conductivity, and WHC were measured using the wet sieving method, the falling head permeability test, and the centrifugation method, respectively. In the falling head permeability test, the soil sample was placed in a 100 cm^3-sampler can with a soil surface area of approximately 20 cm^2 and a soil height of 0.4-1.2 cm. In the centrifugation method, the soil sample was centrifuged at 500 rpm (pF = 2) and 3900 rpm (pF = 3.8).

RESULTS AND DISCUSSION

Changes in Ion Conditions in Soil Pore Water Owing to Soil Reduction

Figure 2 shows changes in EC and Ca^{2+} concentration in soil pore water at different electrical currents. EC is an index that indicates the total ion concentration. Generally, changes in ion concentration by cohesion or dispersion cause a variation in EC. For example, from Fig. 2a, EC decreased from 120 mS/m to 28 mS/m with an increase in electrical current from 0 mA to 6 mA and increased from 28 mS/m to 68 mS/m with an increase in electrical current from 6 mA to 10 mA.



(a) Electrical conductivity (EC) *(b) Ca^{2+} concentration*

Fig. 2 Electrical conductivity and Ca^{2+} concentration at different electrical currents

In other words, decreases in ion concentration occurred when the electrical current increased until 6 mA, and the release of ions occurred when the current was higher than 6 mA. This can be confirmed in Fig. 2b, wherein Ca^{2+} concentration decreased from 150 mg/L to 31 mg/L when the electrical current increased from 0 mA to 6 mA. However, when the electrical current was higher than 6 mA, Ca^{2+} concentration increased from 31 mg/L to 145 mg/L. These results suggest that ion cohesion occurs in soils with an increase in electrical current from 0 mA to 6 mA. Interestingly, ion dispersion occurs in soils with an increase in electrical current from 6 mA to 10 mA. Furthermore, it was observed that ion cohesion or dispersion strongly correlates with electrical current, and the correlation coefficient was higher than 0.95 (Fig. 2). It is thought that this cohesion or dispersion induces soil aggregates, resulting in changes in soil physical properties.

Changes in Grain Size Distribution Owing to Soil Reduction

Based on the results of the sieve analysis, the residual rates on the sieve range of 0.075-0.212 mm, 0.212-0.850 mm, and 0.850-2 mm were determined, and Fig. 3 shows their relationship with the electrical current. In Fig. 3, the correlation coefficients were 0.22 and 0.41 for the particle size range of 0.85-2 mm and 0.212-0.850 mm, respectively. This suggests that soil reduction has less effect on particles larger than 0.212 mm.

Interestingly, the residual rate of the particle size range of 0.075-0.212 mm increased with an increase in electrical current, with a correlation coefficient of 0.61. Thus, it can be said that soil reduction causes the cohesion of soil particles less than 0.075 mm, contributing to the increase in residual rate. Liaki et al. (2010) and Wang et al. (2022) reported that generating electrical current in the soil causes changes in the zeta potential of soil particles, leading to cohesion or dispersion of the particles responding to an increase or decrease in zeta potential.

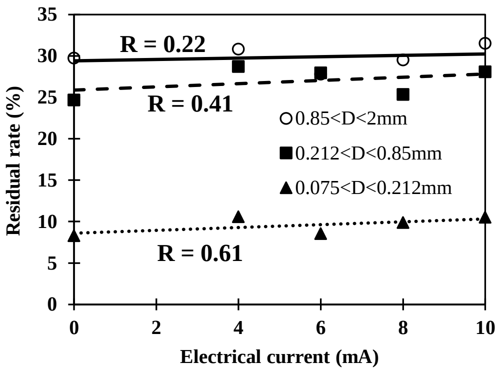
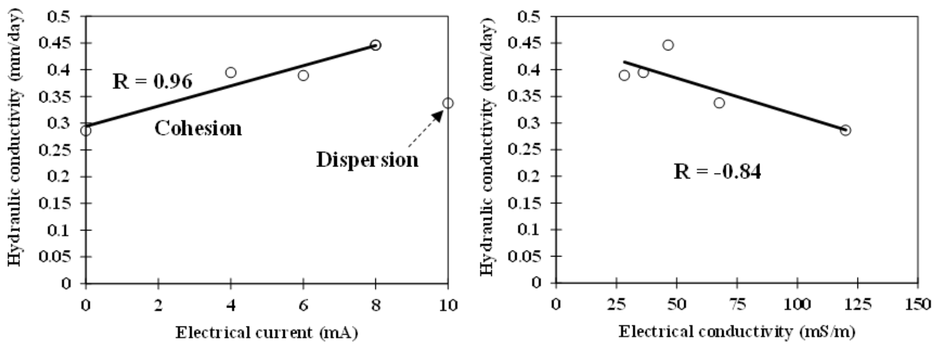


Fig. 3 Particle cohesion due to soil reduction

Changes in Hydraulic Conductivity Owing to Soil Reduction

Figure 4 shows the hydraulic conductivity at different electrical currents and its relationship with EC. The hydraulic conductivity increased from 0.29 to 0.45 mm/day when the current increased from 0 mA to 8 mA (Fig. 4a). Based on Fig. 2, the cohesion of particles occurred in the electrical current range of 0-6 mA. This cohesion induced soil aggregates, leading to an increase in hydraulic conductivity.



(a) Hydraulic conductivity (b) Correlation of hydraulic conductivity with EC

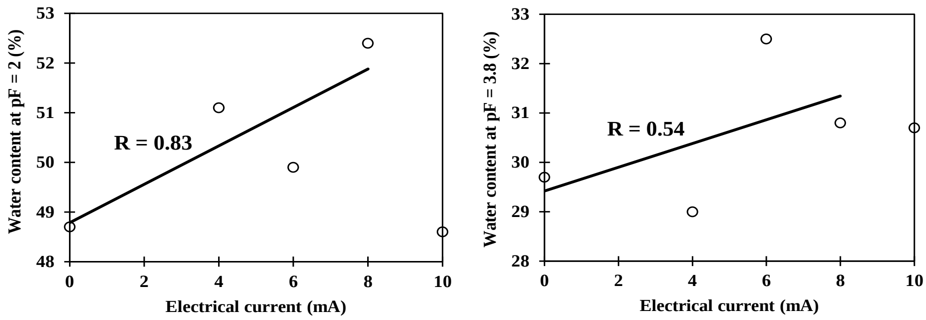
Fig. 4 Hydraulic conductivity at different electrical currents and its relationship with EC

Furthermore, the dispersion of particles occurred in the electrical current range of 6-10 mA. However, there was no decrease in hydraulic conductivity when the current was 8 mA, while there was a decrease when the current was 10 mA (Fig. 4a). This indicates that cohesion and dispersion of particles influence the hydraulic conductivity of soils, and a high rate of dispersion causes large decreases in hydraulic conductivity. It was also observed that hydraulic conductivity had a strong correlation (R = −0.84) with EC, and a larger hydraulic conductivity with a lower EC (cohesion state).

Changes in Water-Holding Capacity Owing to Soil Reduction

Generally, soil aggregates influence not only hydraulic conductivity but also the WHC of soils. Figure 5 shows the water content at pF 2 and 3.8. A similar trend was observed with the variation in hydraulic conductivity. The water content at pF 2 increased with an increase in electrical current from 0 mA to 8 mA, and a strong correlation (R = 0.83) was observed (Fig. 5a). An increase in the water content at pF 3.8 was also observed (Fig. 5b); however, the correlation was less significant (R = 0.54). In addition, a large decrease in water content was observed when the current was 10 mA (Fig. 5a). From Fig. 5a, it can also be said that the cohesion of soil particles induces soil aggregates, which increases WHC; however, high rates of particle dispersion decrease WHC.

Commonly, there are three types of water in soil: adhesion (the water on the surface of soil particles), cohesion (the water attached to adhesion water), and gravitational (the water that flows with gravitational force). The water content at pF larger than 1.8 refers to the amounts of adhesion and cohesion water. From these results, because a strong correlation between the electrical current and the water content at pF 2 was observed, it is thought that only cohesion water is influenced by electrical current generation (soil reduction).



(a) Water content at pF 2 (b) Water content at pF 3.8

Fig. 5 Hydraulic conductivity at different electrical currents and its relationship with EC

CONCLUSIONS

Laboratory experiments were conducted to examine the electrostatic effects of soil reduction on the physical properties of soil. Specifically, we examined changes in GSD, hydraulic conductivity, and WHC after introducing an electrical current into the soil (i.e., soil reduction caused by ET). When the electrical current was increased from 0 mA to 10 mA, EC and Ca^{2+} concentrations decreased when the current was less than 6 mA and increased when the current was higher than 6 mA. This suggests that the cohesion of particles occurs in soils due to soil reduction; however, a high current (10 mA) can lead to the dispersion of soil particles. From GSD, the residual rate of the particle size range of 0.075-0.212 mm increased when the current increased, indicating that soil reduction causes soil aggregates. Furthermore, the hydraulic conductivity had a strong correlation (R = −0.84) with EC, indicating that cohesion or dispersion influences the hydraulic conductivity of soils. This study also confirmed that hydraulic conductivity and WHC increased when the cohesion of soil particles occurred. Therefore, it can be concluded that soil aggregates can form electrostatically during soil reduction. In other words, ET can be used to develop soil aggregates and change the physical properties of soils.

ACKNOWLEDGMENTS

The authors gratefully acknowledge partial funding from the Tokyo University of Agriculture: FY2021 Grant-in-Aid for Sustainable Agriculture Research Projects. The authors would like to thank the students of the Rural Environmental Engineering Laboratory, Tokyo University of Agriculture, for their efforts in collecting data.

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Research article

On the Number of Seedlings for the System of Rice Intensification: Experiment Results from Lombok Island, Indonesia

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Received 4 October 2023 Accepted 28 December 2023 (*Corresponding Author)

Abstract The System of Rice Intensification (SRI) is an environmentally friendly and sustainable rice farming practice developed in the 1980s in Madagascar. It has spread to many countries in the early years of the 21st century, with Indonesia becoming one of the early adopters of SRI practices. The authors conducted experiments on SRI plots on Lombok Island, Indonesia, measuring water consumption, rice growth, GHG emissions and other variables. The focus of the current study was on accessing the appropriate number of seedlings under different irrigation regimes. This experiment prepared 30 small plots and set 2 types of irrigation: intermittent and continuous; 3 types of seedlings by nursery age: 0, 7, and 21 days; and 3 types of seedling groups: 1, 2, and 4 seedlings. At the harvest stage, the number of tillers, number of panicles, grain weight, filled grain weight, and root weight of 5 samples were measured from each plot. In terms of the irrigation method, intermittent irrigation achieved a higher yield than continuous irrigation. 2 seedlings achieved the best yield under intermittent irrigation, regardless of nursery age, while 4 seedlings achieved the best yield under continuous irrigation for both 7 day- and 21 day-old seedling types. In Indonesia, SRI promoters including local government and NPO staff recommend farmers to transplant one 7-day seedling. However, the experiment conducted in this study demonstrated that two day-old seedlings achieved better results. The two-seedlings method costs twice as much as the one-seedling method, but is only about half the cost of the traditional method. Moreover, the two-seedlings method gives farmers peace of mind at the transplant stage. The two-seedling method can thus be considered more reasonable than the one-seedling method.

Keywords system of rice intensification, number of seedlings, intermittent irrigation, yield

INTRODUCTION

The System of Rice Intensification (SRI) is an environmentally friendly and sustainable rice farming practice developed in the 1980s in Madagascar. This practice can reduce resources, such as irrigation water, chemical fertilizer, number of seedlings by keeping and sometimes increasing the yield of rice. It has spread to many countries in the early years of the 21st century. Indonesia is one of the early diffused countries and many farmers adopted this practice (Sato, 2006; Sato, 2007).

In Indonesia, SRI promoters of local government and NPO recommend farmers to transplant One 7-day seedlings. However, farmers are very afraid of less growth, and they often transplant two seedlings although they were taught to transplant one.

Previous research has shown that the adoption of intermittent irrigation reduced water use but not yield (Shimizu et al., 2007). However, a deeper consideration of the appropriate number of seedlings was needed. So, the authors made an SRI Experimental station at Puyung village, Lombok Island of Indonesia, and executed an experiment to identify an appropriate number of seedlings, measuring water consumption, rice growth, GHG emissions and other variables.

OBJECTIVE

The authors set the objective to identify which number of seedlings would be appropriate in conventional rice growing and in the System of Rice Intensification.

METHODOLOGY

The experiment involved setting up 30 small plots of size 5.0 m x 2.5 m (Fig. 1) and applying a number of different experimental treatments, including 2 types of irrigation: intermittent and continuous; 3 types of seedlings by nursery age: 0, 7, and 21 days, and 3 types of seedling groups: 1, 2, and 4 seedlings. The most popular rice variety in the area around the experiment station, Ciherang rice, was planted. The spacing of each seedling was 25 cm by 25 cm and irrigated each plot as an irrigation schedule (Table 1). At the growing stage, the number of tillers and height of 5 samples from each plot are precisely measured every week. At the harvest time, the number of panicles, grain weight, filled grain weight, and root weight of 5 samples from each plot. Also, grain weight with moisture content is measured in each plot. Grain weight was converted to yield (t/ha) at 14% moisture.

Fig. 1 View of experimental plots

Table 1 Setup of the experiment

Treatment		D1	D2	D4	S1	S2	S4	T1	T2	T4	N1	N2	N4	C1	C2	C4
Nursery	Direct seeding	○	○	○												
	7 days				○	○	○				○	○	○			
	21 days							○	○	○				○	○	○
Irrigation	Continuous										○	○	○	○	○	○
	Intermittent	○	○	○	○	○	○	○	○	○						
Number of Seedlings	1	○			○			○			○			○		
	2		○			○			○			○			○	
	4			○			○			○			○			○
Repetition	2	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Table 2 Variety characteristics of Chiherang

Growing period	116 ~ 125 days
Average 1000-grain weight	28 g
Average number of tillers	14 ~ 17 tillers
Average plant height	107 ~ 115 cm
Average yield	6.0 t / ha
Yield potential	8.5 t / ha

Note: Data from Suprihartno et al., 2006

Seedlings for all plots were transplanted on May 17th, 2007. Rice variety is a local high-yield variety called Chiherang, which is widely cultivated on Lombok Island. Characteristics of Chiherang are summarized in Table 2.

RESULTS AND DISCUSSION

Weather and Irrigation

In this experiment, the sowing and harvesting dates were aligned. Sowing took place on 5 December 2007. Direct sowing was fielded on that day, 7-day seedlings were transplanted to the main field after 7 days in the nursery, as were 21-day seedlings. The harvest date was 8 April 2008 in every plot.

It was the rainy season and there was occasional precipitation. The total precipitation for the 118 days until harvest was 1,286 mm. During the experiment, the average temperature was 30.1 degrees, and the relative humidity was 60.2%.

Intermittent irrigation is applied until the end of the vegetative growth stage, about 60 days after transplanted, and after this water depth is also kept shallow (1-2 cm water depth) until stopping water to harvest, while conventional irrigation uses continuous flooding with deep water (4-5 cm water depth) (Fig. 2).

Treatments are two irrigation patterns, three seedlings, and three transplanting methods, a total of 15 treatments l duplicated two times, are prepared. A control plot was also prepared.

For all plots, seedling age, spacing, weeding method, fertilizer amount, and variety of rice are selected to match for local rice cultivation method. Fertilizers are chemical fertilizers standing on the position SRI technology does not include the application of compost. Weeding for 15 treatment plots was done 3 or 4 times depending on weed condition.

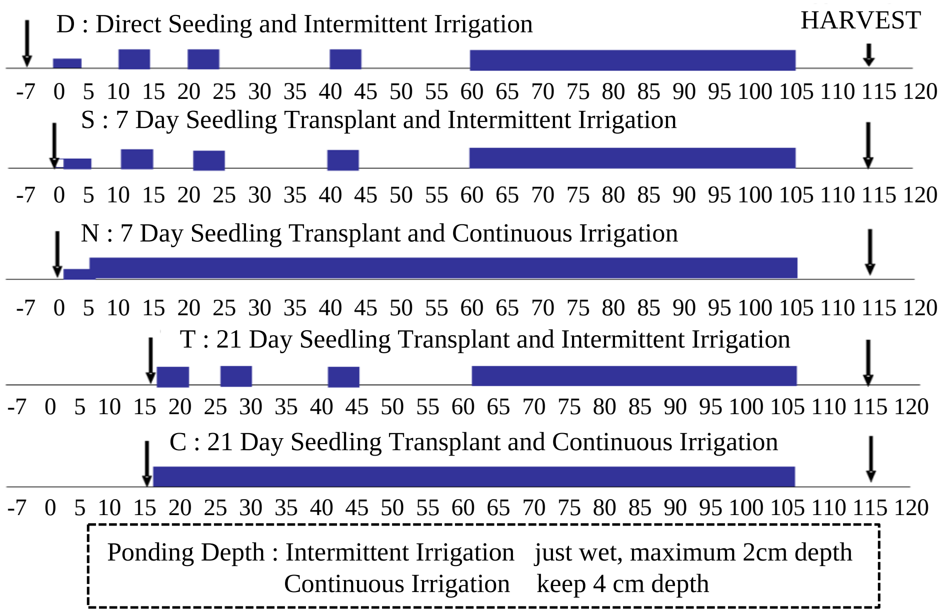

Fig. 2 Irrigation schedule (2007/2008 rainy season)

Growth

Rice seedlings were planted in each plot at 200 rice plant hills. Measurements of height and stem number were taken weekly on five plant hills in the middle of the plot. After the earing stage, the number of tillers is also counted. Changes in the number of tillers are shown in Fig. 3. One seedling set (D1, S1, N1, T1, C1) starts with one seedling, two seedlings set (D2, S2, N2, T2, C2) with two seedlings and four seedlings set (D4, S4, N4, T4, C4) with four seedlings. The seedlings then grow and divide by earing. The number of tillers declines after the maximum tillering period. The number of tillers at harvest time was almost all between 15 and 20.

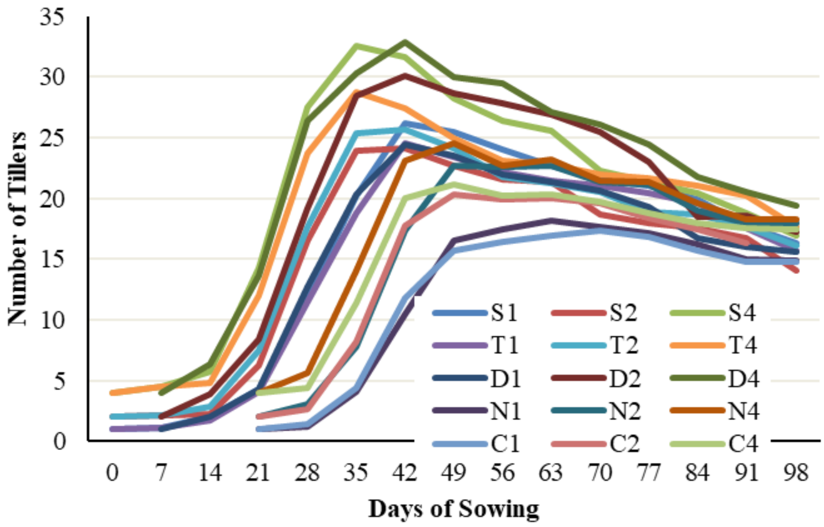

Fig. 3 Number of tillers

The plant height is shown in Fig. 4. Although plant height was low in the nursery due to dense cover, growth was vigorous after transplanting, with almost all reaching 130-140 cm at harvest time.

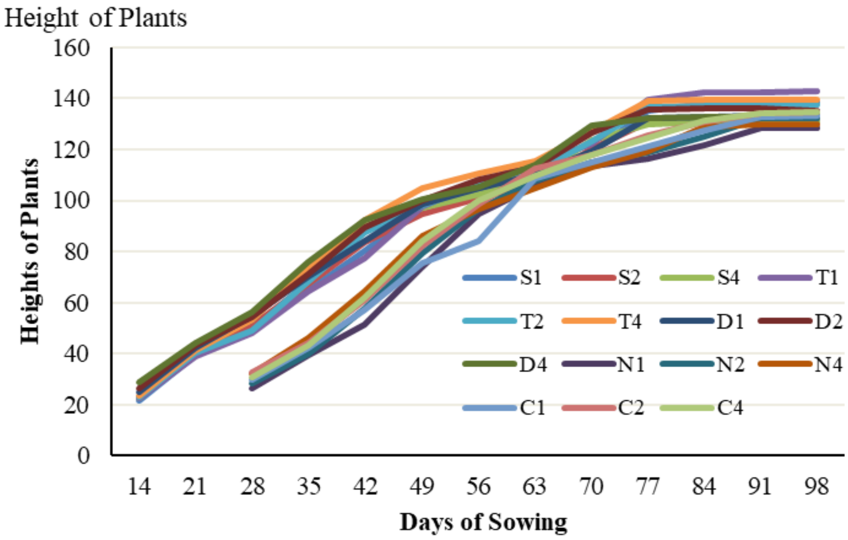

Fig. 4 Height of rice plant

Yield and Components

At the harvest, the number of tillers, number of panicles, grain weight, filled grain weight, and root weight of 5 plant hills from each plot are measured. One plant hill produces 43-73 grams of grains, meaning 1500-2600 grains. To identify 1000 grains' weight, sampled grains are well mixed, and 20-30% of grains are used for counting. By this method, 1000 grains weight from each plot was calculated.

From this measurement, the following was revealed. The intermitted irrigation group (D, S, T) had a few fewer panicles but greater grain weight, which was attributed to the fact that each grain was larger and heavier. It was revealed that the roots of the intermitted irrigation group were very heavy. Especially, the root weight of treatment D4 were several times heavier than in continuous irrigation. This suggests that many roots grow deeper under intermittent irrigation, which is presumed to be the reason for the higher growth. The comparison between seedling numbers did not show a clear difference.

Table 3 Details of rice plant at the harvest time

Treatment	Number of tillers	Number of panicles	Grain weight (gr)	Filled grain weight (gr)	Root weight (gr)	Sample grains			
						Weight (gr)	Number	Moisture (%)	Weight of 1000 grains (gr)
D1	16.3	15.2	63.1	61.8	24.4	16.4	561.3	23.4	29.2
D2	17.9	17.4	64.5	62.5	20.3	15.8	517.7	22.9	30.5
D4	20.6	19.4	73.5	72.3	43.0	15.9	523.9	22.8	30.3
S1	15.7	14.8	50.9	48.9	16.4	20.0	784.3	23.4	25.4
S2	12.9	12.7	53.8	52.8	19.1	19.3	583.5	23.3	33.1
S4	15.0	14.7	50.8	48.2	23.2	20.5	731.5	23.3	28.1
T1	16.8	15.8	53.8	50.8	19.9	20.9	824.4	23.6	25.3
T2	19.6	15.9	52.9	51.1	23.7	18.2	658.6	23.5	27.6
T4	18.5	17.4	59.2	57.4	21.0	21.4	751.0	23.1	28.6
N1	14.7	14.6	45.8	43.9	8.7	12.4	512.7	22.7	24.2
N2	18.0	17.3	50.6	48.3	10.5	10.8	445.0	23.5	24.2
N4	18.9	17.6	60.4	58.8	10.7	14.3	595.7	21.5	24.0
C1	14.8	14.3	43.5	42.1	7.9	13.6	558.7	23.2	24.4
C2	16.4	16.2	49.4	47.0	10.1	16.9	705.4	22.5	23.9
C4	18.0	17.4	43.7	42.0	7.4	11.4	485.4	21.7	23.4
D, S, T	17.0	15.9	58.1	56.2	23.4	18.7	659.6	23.2	28.7
N, C	16.8	16.2	48.9	47.0	9.3	13.2	550.5	22.5	24.0
1	15.7	14.9	51.4	49.5	15.5	16.6	648.3	23.3	25.7
2	17.0	15.9	54.2	52.3	16.8	16.2	582.0	23.1	27.9
4	18.2	17.3	57.5	55.7	21.0	16.7	617.5	22.5	26.9

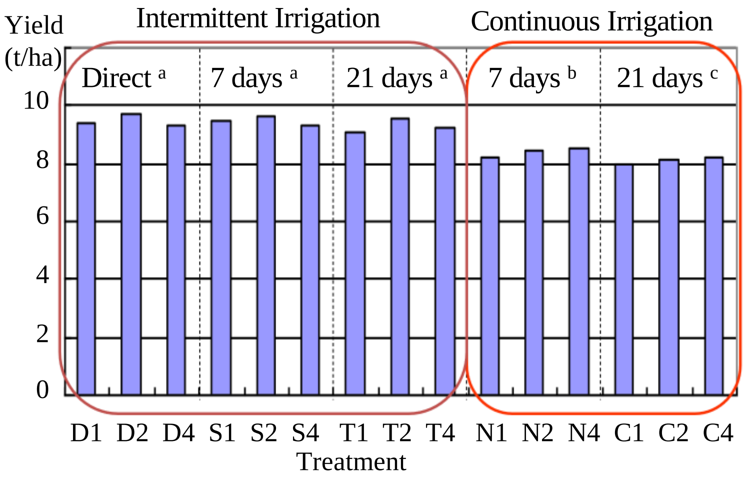

Fig.5 Yield of each treatment

After measuring five plant hills in detail, the rest 195 plant hills were harvested from the entire plot. There are 2 plots for each treatment and the average yield is shown in Fig. 5.

From these results, intermittent irrigation produces greater yields than continuous irrigation. On the number of seedlings, 2 seedlings achieved the best yield in intermittent irrigation and 4 seedlings achieved the best yield in continuous irrigation. Comparison between the five groups shows that 3 groups of intermittent irrigation achieved best, 7 days seedling in continuous irrigation was second-, and 21-days seedling in continuous irrigation was third. All comparisons are statistically significant at the risk of 5%.

CONCLUSION

The results of this experiment showed that in continuous irrigation, two seedlings were better than one, and four seedlings were better than two in terms of yield. In traditional farming, the number of transplanted plants is 3-5. As a result, the correctness of the farmers' choice of number of seedlings in traditional farming methods was proved as rational.

In intermittent irrigation, the highest yield was obtained with two seedlings. The two-seedling method needs two times the cost of seedlings than one seedling method. However, this method costs about half the cost compared with the traditional method. Moreover, two seedlings method gives farmers peace of mind or a sense of security during the transplant stage. So, this method is to be said as more reasonable than one seedling method. We need to execute this experiment in every place where the SRI method is introduced.

ACKNOWLEDGEMENTS

The authors are deeply grateful for the support of the DISIMP team, Mr. Bagus Santika, and team members.

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Research article

Experiment on Smart Mushroom Cultivation Using an Environmental Control System

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Received 12 September 2023 Accepted 29 December 2023 (*Corresponding Author)

Abstract The purpose of this research was to implement smart mushroom cultivation by applying a sensor network and control algorithm to test the performance of the cultivation system and yield obtained compared to the conventional method. This research introduced innovative automated methods to the cultivation of rice-straw mushrooms by utilizing sensor technology and a controller with a control algorithm. The control algorithm automatically controlled the environment in the mushroom house based on feedback from the sensors to maintain the environment in an optimum condition for mushroom growth. The experimental setup included two cycles for growing the rice-straw mushrooms in different control environments, with three stages per cycle. The first stage was used during the vegetative phase, the second stage was used to control mushroom growth during the spawn-run phase, while the last stage was applied during the pinhead and cropping phases. The first cycle of the experiment was implemented to verify the circumstances surrounding mushroom growth under automated control based on three parameters: ambient temperature, relative humidity, and carbon dioxide (CO_2). The experiment utilized one controller with four pieces of equipment to automate control based on those parameters, which included the ventilation fan, exhaust fan, sprinkler, and motor pump for the cooling pad. During the first cycle, some problems with the CO_2 sensor and the exhaust fan were encountered, so it was necessary to implement a combination of manual control and automated control in the controlling algorithm for the second cycle. After completing these experiments, we determined that utilizing a combination of automatic and manual control, mushroom farmers will be able to save time, money, and labor while also increasing mushroom yield to satisfy market demand.

Keywords smart mushroom cultivation, rice-straw mushroom, automation control system, automation technology, environmental control system.

INTRODUCTION

Agriculture is the most critical sector of the Cambodian economy in terms of its contribution to the Gross Domestic Product (GDP) because most of the population are farmers (Encyclopedia Britannica, 2021). Nowadays, most farmers in Cambodia are trying to evolve farming into modern agricultural techniques (Fosbenner, 2018). With the help of various technologies, agriculture has gotten more convenient while also producing higher yields to meet the demand for supplies. Among other agriculture sectors, the mushroom industry is still done in a very traditional way, which restricts production capacity and prevents it from producing enough yield to support both the farmer and the country's economy. As a result of these factors, it is essential to modernize the facilities to maximize production through the most efficient use of resources.

The main purpose of this research is to apply automation technology to the production of rice-straw mushrooms by utilizing sensor technology such as a Temperature sensor, Humidity sensor, CO_2 sensor, and a controller with a control algorithm that can control the devices in the mushroom house and automatically based on feedback from the sensors to maintain the environment in an optimum condition for mushroom growth. This experiment's goal is to test the performance of the system and the yields obtained compared to the conventional method.

MATERIALS AND METHODS

Experimental Setup

The smart mushroom house is constructed with dimensions of 5 meters by 6 meters (5 m × 6 m) which is equal to 30 square meters (32 m^2). The bamboo trees used to build the mushroom trays are 1.6 meters by 4 meters (1.6 m × 4 m) or 6.4 square meters (6.4 m^2), and there are ten trays altogether as shown in Fig. 1. One motor pump, one cooling pad, one exhaust fan, a shrinker system, a control panel, and monitoring sensors such as a temperature and humidity sensor and a CO_2 sensor were all included in the smart mushroom house's control equipment. The surrounding area is constructed of plastic. The ventilation fan is placed against the mushroom house wall above the door and faces the exhaust fan on the other side. The motor is mounted over the cooling pad that leans up against the wall, and the shrinker system is equipped around the mushroom house's corner.

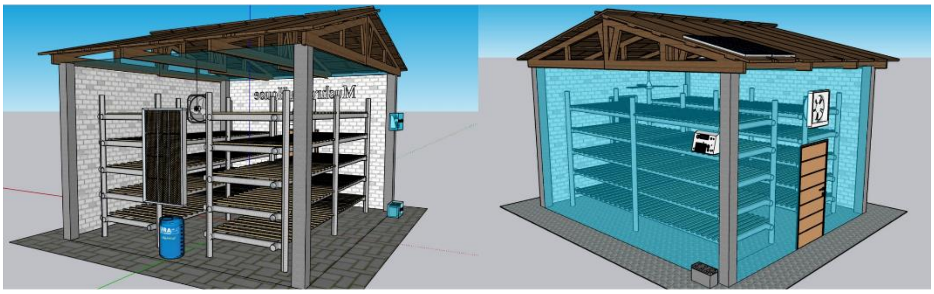

Fig. 1 Smart mushroom house simulation in 3D view

Environmental Requirement

Normally, the Rice Straw Mushroom grows in warm weather, typically in the tropics and sub-tropics. The optimal temperature for rice straw mushrooms to grow in mycelial is from 28°C to 30°C for its fruiting body production. where the ideal temperature for growing mushrooms is between 25°C and 40°C (Fasidi, 1996). The ideal humidity range for rice straw mushroom growth is between 70% and 90% (Bawis, 2014). While other research claimed that the mushroom's humidity might reach 99%. Additionally, the level of carbon dioxide ranges from 1000 to 2000 ppm.

Mushroom Substrate

In our case study, several materials, including rice straw, mung bean shells, rice bran, sugarcane (black sugar), limestone, and gypsum, have been employed to create the compost or substrate. The process of making this compost will take around six to seven days. First, the rice straw and mung bean shell will need to be soaked for at least a night to make them soft, then drain before mixing with limestone water. After combining these three ingredients, it must be fermented once more for a total of six days, with two days of re-mixing. The remaining components must be combined after six days and fermented for one night before use.

Table 1 Ingredients for substrate

Ingredients	Amount (kg)
Rice Straw	400.0
Mung Bean Shell	150.0
Rice Bran/ Wheat	50.0
Sugarcane (Black Sugar)	2.0
Limestone	5.5
Gypsum	3.0
Total	610.5

Table 2 Parameter requirements during each stage

Parameters	Stage I	Stage II	Stage III
Temperature (°C)	29-36	32-36	26-33
Relative Humidity (%)	100	92-96	86-92
CO_2 (ppm)	>1500	<1500	<1500

System Overview

The Smart Mushroom House has been equipped with all components and sensors, including a solar panel, a battery (Power Can), a circuit breaker, a transformer, a motor pump, a cooling pad, an exhaust fan, a ventilation fan, a sprinkler, a Honeywell ambient temperature and humidity sensor, a Honeywell carbon dioxide sensor, and a Honeywell controller (CIPer Model 50). To do the configuration, we must first ensure that the controller is powered with the appropriate current and voltage. Since the controller and the sensors require 24 VDC or VAC to work, but the standard range of electrical power is 220 VAC, a transformer is required to convert 220 VAC to 24 VAC for the controller.

The rice-straw mushroom grows in four stages, including the vegetative phase, spawn run, pin head initiation, and cropping mode. We have decided to divide the controlling stage into three stages. The first stage is to manage the vegetative phase which the temperature will stay between 32°C and 36°C. The second stage is to manage the system during the spawn run which the temperature will persist between 32°C and 36°C, the relative humidity stays between 92% and 96%, and the carbon dioxide stays at about 1500 ppm. The last is to handle the system during the pin head initiation and cropping mode, in which the temperature will stay between 26 and 33°C, the relative humidity will remain between 85% and 92% RH, and carbon dioxide will remain at about 1000 ppm. Also, we have decided to test in 2 cycles. The first cycle is in March, and the second cycle is in May because both months have similar weather and it is easier for us to study since both cycles use different configurations to test the differences between each condition.

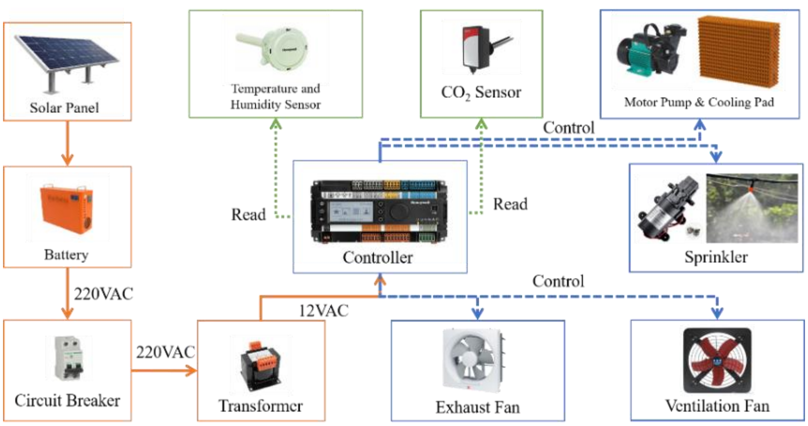

Fig. 2 System architecture of smart mushroom house

Experiment for 1st Cycle

After setting up all the controllers and assigned points, it needs to configure each step of mushroom cultivation to obtain and control the environment inside the mushroom home to its excellent condition during its growth stage.

The mushroom must be in stage I (vegetative phase), where the temperature must range from 29°C to 36°C, the humidity must range from 92% to 96%, and the CO_2 level must be less than 10000 ppm. In this case, the configuration follows the flowchart as shown in Fig. 3. below. It indicates that the Exhaust Fan and Sprinkler will activate whenever the temperature rises above 36°C and remain on until the ambient temperature falls below 36°C. The time required for this stage is approximately 3-4 days before we can see the spawn running through the compost and appearing as a thin white thread.

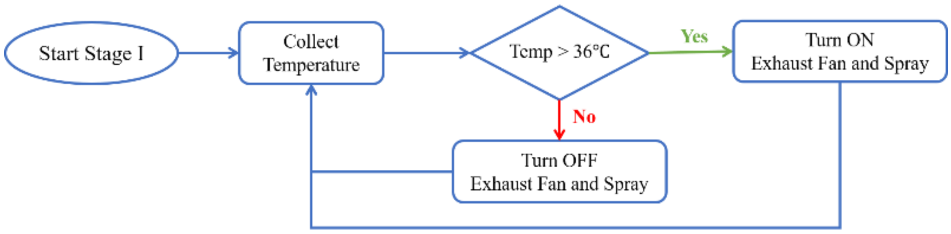

Fig. 3 Flowchart of stage I configuration

Under stage II (spawn run), the mushroom must grow in conditions with a CO_2 level of less than 1500 ppm, a temperature range of 29°C to 36°C, and a relative humidity range of 92% to 96%. In this case, the system configuration follows the flowchart as shown in Fig. 4. In this stage, the controller will read data from all three sensors, and based on that data, it will control the system. For example, if the temperature rises above 36 °C, the sprinkler and exhaust fan will turn on until the temperature falls below 36 °C. Additionally, if the relative humidity rises above 96% RH, the system will automatically switch on the ventilation and exhaust fans until the humidity returns to its typical range of 92-96%. In this situation, if the relative humidity falls below 92%, the system will automatically turn on the spray and motor for the mushroom house to hydrate the compost and moist the air, as too much dryness will prevent the compost from producing much output. The controller will also read information from the CO_2 sensor when the CO_2 level rises above 1500 ppm, the system will activate the exhaust fan to draw in the fresh air and the ventilation fan to circulate the air inside the mushroom house so that it is all the same. The time required for this stage is approximately 3-4 days before we can see the little thread that will eventually grow into a mushroom leg rising from the spawn that spread during the earlier stage.

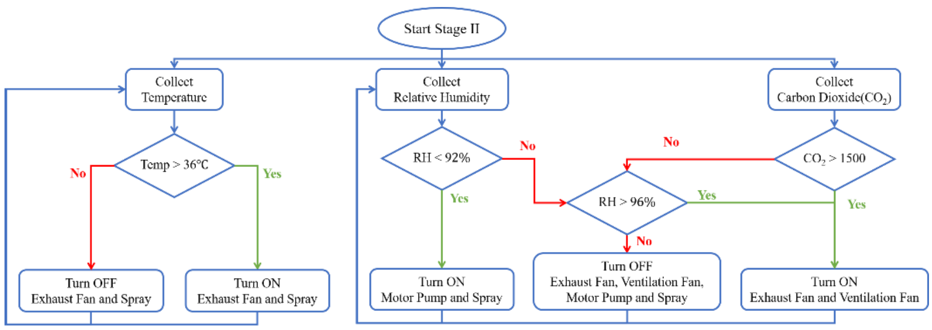

Fig. 4 Flowchart of stage II configuration

Stage III includes the pin head initiation and cropping mode. The ambient temperature must be between 29°C and 33°C, the relative humidity must range from 92% to 96%, and the CO_2 level must be less than 1000 ppm for the mushroom to thrive. The flowchart illustrates the system configuration in this condition as shown in Fig. 5. The configuration for this stage is the same as the previous stage, but there are differences between the fixed static variables that we input in the temperature, humidity, and CO_2 sensors. The controller will read the parameters from all three sensors and control the system based on those data. For example, if the temperature rises above 33°C, the sprinkler and exhaust fan will turn on until the temperature drops below 33°C. When relative humidity rises above 92%, the system automatically turns on the ventilation and exhaust fans until the humidity falls below the typical range of 85% to 92%. In this condition, the system will automatically turn on the spray and motor for the mushroom house if the relative humidity falls below 85% in exchange for hydrating the compost and moistening the air, as too much dryness will prevent the compost from producing much yield. The controller will also read data from the carbon dioxide sensor, and when the CO_2 level rises above 1000 ppm, the system activates the exhaust fan to filter out the fresh air and the ventilation fan to circulate the air inside the mushroom house so that it is equally heated and cooled. The time required for this stage is approximately six to seven days since the little mushroom must first grow to the point where its head is an egg shape.

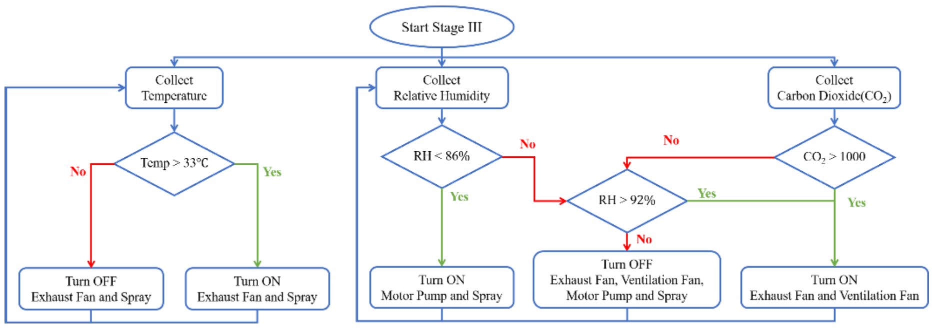

Fig. 5 Flowchart of stage III configuration

Experiment for 2nd Cycle

Based on the results from the first cycle of the experiment, we encountered some problems with the carbon dioxide sensor and the exhaust fan, which caused the compost to become excessively dry and provide less yield than expected. To find a solution, we come up with another configuration in which we will use scheduling time to regulate the exhaust fan to turn on for five minutes and three times a day during stage II (spawn run) because in stage II the mushroom does not require too much oxygen from outside and the air does not require to ventilation much. Additionally, because mushrooms need frequent ventilation during stage III and require more fresh air to grow, the scheduling time for these stages was adjusted to five minutes every hour or 24 times per day. In addition to fixing the problem, we also have installed another two sensors, including an ambient temperature and relative humidity sensor and a carbon dioxide sensor outside the mushroom house to compare the environment outside and inside the mushroom house.

RESULTS AND DISCUSSION

Results of 1st Cycle

The stage I configuration has turned on and the system has been running based on the design algorithm. During this process, the temperature has never risen above 36°C which is the set point to turn on the exhaust fan and spray. It means that the environment inside the mushroom house has stayed under our control. When it reached the pin head stage, the stage II configuration system turned on, and we can see that the temperature during this stage increased by 36°C, allowing our control system to turn on the exhaust fan and spray. After both components were turned on, we observed that the temperature decreased below 36°C. The ventilation fan and exhaust fan have been turning on when the CO_2 level has risen above 1500 ppm and turning off when it has fallen below 1500 ppm.

However, this procedure has made both components run inexorably because the CO_2 level rarely stays below 1500 ppm. The problem with our sensor's response time is that it responded too late, which causes problems for our system. During stage III of the control process, the set points for temperature, CO_2, and relative humidity are 33°C, 1000 ppm, and 92%, respectively. However, the received data have all exceeded the set points of all parameters, which makes all of the mushroom house's components turn on unstoppable. With this issue, we have decided to turn off the automatic system and use the manual system instead.

With the results from the first cycle, we harvested a total yield of 80 kg with a total substrate weight of 610 kg, which represents a percent of 0.13%, or 0.13 kg of rice straw mushrooms per kilogram of the substrate. According to the standard, 10 kg of dried straw yields 2 kg. Our yield is less than 0.7 kg compared to the standard because some errors also happened during the growing process (Gummert, 2022). The CO_2 sensor that we utilized has caused errors in the data flow, causing the receiving data to be delayed and the ventilation and exhaust fans to operate automatically based on configuration, drying up the compost and producing less yield.

Results of 2nd Cycle

The only difference between the received data and the first cycle of control from stage I to stage III is that the relative humidity has reached 99%, causing our exhaust fan and ventilation fan to run nonstop following the stage configuration and causing the compost to become too dry. Regarding this issue, we have set the set point to 99% in stage II and stage III configurations in favor of activating the exhaust fan and ventilation fan. As previously mentioned, the second cycle's stage II temperature set point is the same as the first cycle, but the humidity only remains at 99%, which is higher than the set point of the first cycle, so we changed the set point of the second cycle to 99% instead to prevent the control the environment inside the mushroom better. The ventilation and exhaust fans were not directly controlled by the CO_2 level during this stage because we already had a schedule for when to turn them on and off. During stage III, the process is the same as the first cycle but we have only added the scheduled time to turn on and off the exhaust fan and ventilation fan every five minutes.

With the second cycle implementation, we harvested the rice straw mushroom with a total yield of 85 kg and a total substrate of 610 kg, which equals a percent of 0.14%, which means that one kilo of the substrate produces 0.14 kg of rice straw mushroom. There were still a few errors that happened between these stages where the humidity sensor reading was above 99% RH, causing the ventilation fan and exhaust fan to run continuously in accordance with the stage setting, drying out the compost.

CONCLUSION

Based on the results of both cycles, we can compare the configuration and yield and find that the second cycle is a little better than the first cycle, which generated more than 5 kg of rice straw mushrooms. With both results, we have discovered and faced some obstacles regarding the exhaust fan, ventilation fan, CO_2 sensor, and humidity sensor. Even though there were a few issues with the experiment, this is not the end of the research. We have recommended a different configuration to assist in resolving the issue. Since some sensors were not capable of the system, we will replace those and do another config algorithm to help upgrade the systems. This study is focused on figuring out the best control algorithm for the mushroom house. It is also possible to estimate and analyze the accuracy of real-time data using the data collected from all the sensors. The data achieved in this study have to be regarded as a significant input for subsequent research on the issue that cropped up during the testing phase to make the system more stable and dependable. Applying both automated control and manual control has helped local farmers save their labor, money, and time and create products of the mushroom to meet the demand of the market.

ACKNOWLEDGEMENTS

This work was funded by the Cambodia Higher Education Improvement Project (Credit No. 6221-KH).

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