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Research article

Rice Yield Variation Associated with Time-dependent Shifts in Area Cultivated by Farmers in Northeast Thailand

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Abstract The rice area cultivated by individual farmers in Northeast Thailand has gradually decreased since the 2010s. As Northeast Thailand is a major rice-growing region in Thailand, this trend might suggest a potential decline in total rice production at the national level. In order to examine this concern, we investigated fluctuations in the scale of rice production among individual farmers in Northeast Thailand from 2010 to 2019, focusing on the relationship between cultivated area and rice yield. This study used household panel data collected by Thailand Vietnam Socio-Economic Panel project. We compared 445 farmers who reduced their rice cultivation area with 208 who expanded it, comparing rice yield, production disposal, and input usage. The results indicate a decrease in the number of farmers cultivating a rice area of more than 3.2 ha and an increase in those cultivating less than 1.6 ha during the period. The farmers who enlarged their rice cultivation area had a higher yield in 2010 than those who reduced it, but their unit yield fell below that of the reducing group by 2016. This finding suggests difficulties for farmers who increase the area under rice production in sustaining the intensity of production over time.

Keywords rice farmer, farm size strata, rice yield, agricultural inputs, Northeast Thailand

INTRODUCTION

Thailand ranks among the world's leading producers and exporters of rice, holding the sixth position in production and the second position in exports in 2020 (FAO, 2022). However, the rice productivity of Thailand lags behind that of competing countries in the international market. Thailand's rice productivity was 2.7 tons/ha, with that of India (4.1 tons/ha), Pakistan (3.8 tons/ha), and Vietnam (6.0 tons/ha) higher than Thailand in 2020-2021 (USDA, 2022). Even though other countries kept increasing their rice yield, Thailand's yield stagnated in the 2010s. To keep the competitiveness of Thailand as a rice exporter, improving rice productivity is an urgent issue.

In this regard, rice farmers in Northeast Thailand should be a major target. In Thailand, there are two major rice ecosystems: rainfed lowland rice and irrigated lowland rice. Rainfed lowland rice is mainly produced in the region, just in the wet season (Jun-Nov). Irrigated lowland rice is mainly produced in Central Thailand, in both wet- and dry-season (Feb-May). Coverage of rainfed lowland rice reaches around 80% of total rice paddies in Thailand. The yield of rainfed lowland rice is persistently lower than irrigated lowland rice due to frequent strikes of drought and flood. While the yield of dry-season rice has stagnated over the past 30 years, the yield of wet-season rice has continued to increase (Suwanmontri et al., 2020). Notably, Northeast Thailand accounts for more

than half of the country's wet-season rice production (OAE, 2022). The region has experienced significant progress in the commercialization of rice farming in recent decades. Marketing channels for rice have been established, connecting rice farmers in Northeast Thailand directly to the international market. This offers farmers more opportunities for rice sales (Suebpongsang et al., 2020). Farmers are increasingly obtaining high-yield seeds and chemical fertilizers through market channels and using them widely (Promkhambut et al., 2023). Additionally, rapid mechanization of farmwork is occurring to address labor shortages (Baird et al., 2022). These facts suggest that the rainfed lowland rice has greater potential for yield growth compared to the irrigated lowland rice.

However, the data disclosed by the Office of Agricultural Economics (OAE) indicated that the rice area cultivated by individual farmers in Northeast Thailand kept decreasing over the last decade (Toyama et al., 2022). Previous studies mentioned the trend of the stratum structure of rice production scale by individual farmers (Shigetomi, 2015; Inoue, 2015). The studies found that the upper stratum of rice farmers diminished, and the rice farm size became standardized to the middle scale. However, the discussion was based on the census data up to the 2000s. The trend observed in the OAE data during the 2010s, which generally shifted towards lower strata, clearly deviated from the earlier trend of mid-size farms. It is expected that if farmers withdraw from rice production and the cultivated area of rice decreases, maintaining total rice production will be challenging. However, detailed evidence is necessary to validate the feasibility of this concern.

OBJECTIVE

The objectives of the current study are twofold: 1) understanding the changes in cultivated area and unit yield of rice production by individual farmers in Northeast Thailand in the 2010s based on household panel data, and 2) investigating the relationship between changes in cultivated area and rice yield.

METHODOLOGY

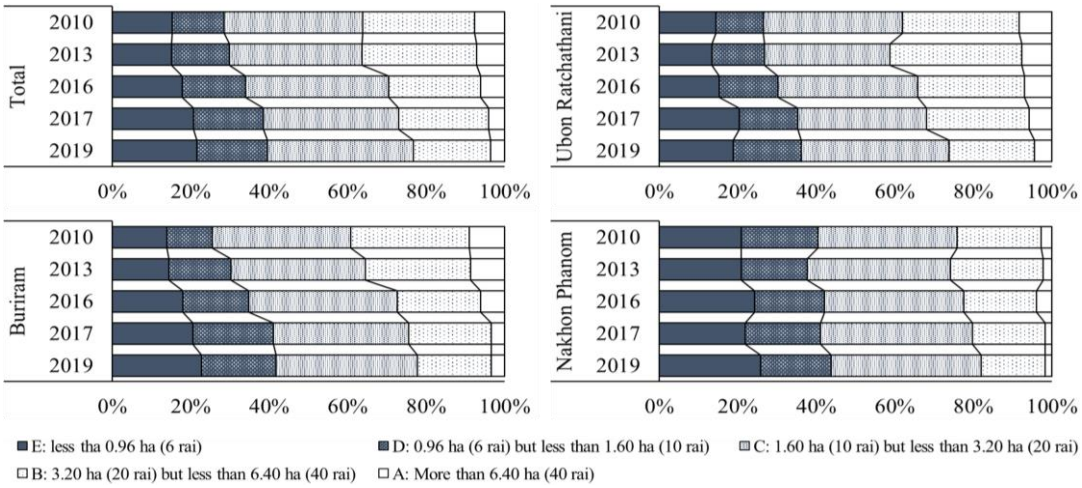
This study used household panel data collected by the Thailand Vietnam Socio-Economic Panel project (TVSEP, 2015a). Upon registration, we received the requested data free of charge. The household survey was implemented with a sample of 2,186 households (HHs) in 220 villages in 3 provinces (Ubon Ratchathani: 970 HHs, Buriram: 819 HHs, and Nakhon Phanom: 397 HHs) in Northeast Thailand. The sampling procedure consisted of a 3-stage cluster sampling design (TVSEP, 2015b). We used the data from 5 surveys in 2010, 2013, 2016, 2017, and 2019. While the survey included non-farm households, this study focuses specifically on rice farmers. Therefore, from the 2,186 surveyed households, 1,051 households that engaged in rice production between 2010 and 2019 were selected as the "rice farmer" sample (Ubon Ratchathani: 468, Buriram: 405, Nakhon Phanom: 178). We excluded 1,135 households because they were not targeted in one or other surveys (TVSEP, 2015b) or had no rice production in the period.

Firstly, we observed the general trend of rice areas cultivated by individual rice farmers and tracked how the rice farmers changed the area from 2010 to 2019. Then, we selected the farmers enlarging and reducing their rice-cultivated area. To categorize farmers in the enlarging group, we selected those whose rice-cultivated area in 2010 was less than the average of five surveys and in 2019 exceeded the average. For the reducing group, we identified farmers whose area in 2010 surpassed the five-survey average and in 2019 fell below the average. As a result, 208 and 445 farmers were selected as the enlarging and reducing farmers, respectively.

RESULTS AND DISCUSSION

Change of Rice-Cultivated Area by Surveyed Farmers in Three Provinces

Figure 1 shows the changes in rice area cultivated by individual farmers from 2010 to 2019. We classified the rice-cultivated area into five strata (strata A-E, from the largest to smallest). The boundaries for farm strata were defined at 0.96 ha (or 6 rai, "rai" being the local unit of area in Thailand with 1 rai = 0.16 ha), 1.60 ha (10 rai), 3.20 ha (20 rai) and 6.40 ha (40 rai), in line with the statistical data of the Office of Agricultural Economics (OAE) in Thailand. The trend in rice-cultivated areas in the TVSEP data was almost the same as in the OAE data. The ratio of stratum B (more than or equal to 3.20 ha but less than 6.40 ha) decreased in all provinces, and the ratio of strata D (more than or equal to 0.96 ha but less than 1.60-ha) and E (less than 0.96-ha) increased clearly in Buriram and Ubon Ratchathani.



*Source) Household panel data in Thailand was collected by the TVSEP project. Remark) *1 rai = 0.16 ha.*

Fig. 1 Changes in the rice area cultivated by farmers from 2010 to 2019

Table 1 Movement of farmers between rice-cultivated area strata from 2010 to 2019

All

	Strata*	A	B	C	D	E	Total
2010	A	17	35	17	8	4	81
	B	16	121	**102**	27	33	299
	C	2	**35**	197	**78**	**60**	372
	D	0	4	**41**	51	43	139
	E	3	12	**33**	26	86	160
	Total	38	207	390	190	226	1051
Delta (2010-19)		-43	-92	18	51	66	-

All (%**)

	Strata	A	B	C	D	E	Total
2010	A	2	3	2	1	0	8
	B	2	12	**10**	3	3	28
	C	0	**3**	19	**7**	**6**	35
	D	0	0	**4**	5	4	13
	E	0	1	**3**	2	8	15
	Total	4	20	37	18	22	100
Delta (2010-19)		-4	-9	2	5	6	-

Reduce

	Strata	A	B	C	D	E	Total
2010	A	6	34	16	8	4	68
	B		35	79	27	33	174
	C			42	54	53	149
	D				8	26	34
	E					20	20
	Total	6	69	137	97	136	445
Delta (2010-19)		-62	-105	-12	63	116	-

Reduce (%**)

	Strata	A	B	C	D	E	Total
2010	A	1	8	4	2	1	15
	B		8	18	6	7	39
	C			9	12	12	33
	D				2	6	8
	E					4	4
	Total	1	16	31	22	30	100
Delta (2010-19)		-14	-24	-3	14	26	-

Enlarge

	Strata	A	B	C	D	E	Total
2010	A	2					2
	B	10	18				28
	C	2	29	33			64
	D	0	4	34	4		42
	E	3	11	29	15	14	72
	Total	17	62	96	19	14	208
Delta (2010-19)		15	34	32	-23	-58	-

Enlarge (%**)

	Strata	A	B	C	D	E	Total
2010	A	1					1
	B	5	9				13
	C	1	14	16			31
	D	0	2	16	2		20
	E	1	5	14	7	7	35
	Total	8	30	46	9	7	100
Delta (2010-19)		7	16	15	-11	-28	-

*Source) Same as Table 1. Remarks) *The ranges of each stratum are the same as in Figure 1,*
***Dividing the number of farmers in each column by the total number of farmers in each category*

Table 1 illustrates the major flows of farmers between the strata from 2010 to 2019. The most significant flow of farmers was from B in 2010 to C (more than or equal to 1.60 ha but less than 3.20 ha) in 2019, namely, 102 farmers, or almost 10% of all surveyed farmers. Regarding flows to lower strata, flows from C to D and C to E were larger than others. On the other hand, farmers moving to the upper strata were observed in the following paths: from C to B, D to C, and E to C. As a result, the number of farmers in strata A and B (more than or equal to 3.20 ha) decreased and the number of farmers in strata C, D, and E increased. We made the same kinds of tables for the reducing and enlarging groups of farmers. The major flows in both groups were similar to the table of all surveyed farmers. In the reducing group, the numbers of farmers in strata A, B, and C decreased and the number of farmers in strata D and E increased. In contrast, in the enlarging group, the numbers of farmers in strata A, B, and C increased and the number of farmers in strata D and E decreased.

The shift from the upper strata (A and B) to the lower strata (D and E) can be attributed to two primary factors: declining family farm labor and the fragmentation of farmland through inheritance. The decline of family farm labor is a general trend among farmers in Northeast Thailand, driven by population aging and outflow to urban areas (add source). As farmers struggle to secure sufficient labor, reducing rice-cultivated areas might be one of the coping strategies. Additionally, the region's custom of dividing farmland among children upon inheritance has led to the gradual fragmentation of holdings over generations. This phenomenon likely influences individual farmers' decisions regarding their rice-cultivated area.

Table 2 Status of rice production by reducing and enlarging groups from 2010 to 2019

Classified group*	N	Rice-cultivated area (ha/farm)		Total cultivated area (ha/farm)		Area cultivated others (ha/farm)		The ratio of rice-cultivated area (%)		Ratio of home consumption (%)	
		2010	2019	2010	2019	2010	2019	2010	2019	2010	2019
Reducing	445	4.25	1.79	4.72	2.44	0.46	0.65	93	84	40	47
A	68	10.93	3.55	11.51	4.64	0.58	1.09	95	85	29	34
B	174	4.35	2.04	4.68	2.70	0.33	0.66	95	83	36	43
C	149	2.27	1.15	2.84	1.69	0.57	0.54	90	83	43	50
D and E	54	0.96	0.53	1.39	0.85	0.43	0.32	87	85	58	68
Enlarging	208	1.66	3.08	2.15	3.63	0.48	0.56	85	91	52	47
A and B	30	4.32	6.13	4.82	6.36	0.50	0.24	93	96	37	29
C	64	2.06	3.30	2.26	3.83	0.20	0.53	96	94	45	44
D	42	1.17	2.16	1.63	2.46	0.46	0.30	88	93	52	53
E	72	0.49	2.14	1.24	3.01	0.75	0.87	69	84	69	54

*Source) Same as Table 1. Remarks) *Strata from A-E are the same as Figure 1.*
***Most farmers produced KDML105 and RD6 as non-glutinous variety and glutinous variety, respectively.*

Yield and Input Use by Farmers Reducing and Enlarging Rice-Cultivated Area

Table 2 shows the status of rice production by individual farmers in the reducing and enlarging groups. Regarding the reducing group, both the rice-cultivated area and the total cultivated area decreased from 4.25 ha to 1.79 ha and from 4.72 ha to 2.44 ha, respectively, but the cultivated area for other crops increased from 0.46 ha to 0.65 ha. Farmers in the enlarging group increased cultivated area for both rice and other crops from 1.66 ha to 3.08 ha and from 0.48 ha to 0.56 ha, respectively. As a result, the ratio of rice-cultivated area dropped from 93% to 84% in the reducing group and rose from 85% to 91% in the enlarging group. We also examined the ratio of home consumption of rice to total production in each group. Small-scale farmers tended to produce rice for home consumption in both groups. While the ratio in the reducing group rose from 40% to 47%, the ratio in the enlarging group dropped from 52% to 47%. This trend may reflect changes in the purpose of rice production among farmers in each group.

As a general trend among surveyed farmers, rice yield per unit area fluctuated and it was difficult to identify either a decreasing or an increasing trend (Table 3). The average yield for farmers in the enlarging group was lower than the average for all farmers and the average for the reducing group from 2010 to 2019. In 2010, the yield of the enlarging group was significantly higher than the reducing group, but in 2017 and 2019, the yield of the enlarging group was significantly lower than the reducing group. We also compared Z-scores of the expenditure of fertilizer used and working

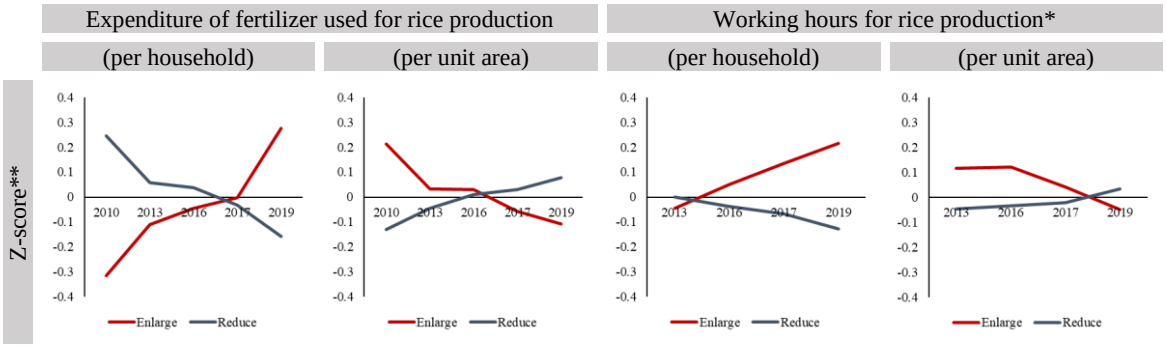
hours for rice cultivation between the reducing and enlarging groups (Fig. 2). Regarding fertilizer expenditure and working hours, the total input of the reducing group was greater than that of the enlarging group in 2010, but this trend reversed by 2019, with the enlarging group demonstrating higher total input. Conversely, while the input per unit area of the enlarging group exceeded that of the reducing group in 2010, the input per unit area of the reducing group was higher in 2019.

Table 3 Change of unit rice yield by enlarging and reducing group

Category	Strata*	N	2010	2013	2016	2017	2019
Reducing group (N=445)	Total avg.	445	1.78**	1.89	2.39	2.39**	1.91**
	A	68	1.58	1.83	2.13	2.36	1.70
	B	174	1.68	1.74	2.38	2.35	1.87
	C	149	1.89	1.89	2.50	2.41	1.98
	D + E	54	2.04	2.33	2.40	2.43	2.20
Enlarging group (N=208)	Total avg.	208	2.23**	1.96	2.31	2.16**	1.54**
	A + B	30	2.06	1.60	2.21	2.34	1.78
	C	64	2.06	2.02	2.19	1.93	1.43
	D	42	2.03	2.05	2.36	2.13	1.58
	E	72	2.63	1.97	2.42	2.31	1.52

(unit: ton/ha)

*Source) Same as Table 1. Remark) *Strata from A-E are the same as Figure 1. **p<0.01 between the enlarging and reducing group examined by the student's t-test.*



*Source) Same as Fig. 1. Remarks) *Because there was no data on working hours in 2010, we only used the data from 2013 to 2019. **Z-scores of each group's means in all surveyed farmers. The reason for using the Z-score to capture the transition is that the forms of fertilizer and labor input data in the TVSEP survey changed across the years, potentially weakening the data's continuity.*

Fig. 2 Change of fertilizer and family labor use by enlarging and reducing group

These results suggest that farmers in the enlarging group did not maintain the intensity of their rice production during the surveyed period. The following possibilities may explain this observation. First, the farmers in the enlarging group may not be accumulating farmland as a result of the strategic expansion of farm size. In Northeast Thailand, most farmers trade farmland among relatives and neighbors (Shigetomi, 2015). When farmers in the region find it difficult to continue rice farming due to poor health or labor/capital shortages, they tend to look for someone to look after their paddy fields temporarily. If the farmers who look after the others' paddy fields do not aim to increase rice productivity, extensive rice farming may be the most rational practice for them. The high risk of natural disasters also leads farmers to reduce the inputs they use to cultivate rice. As most of Northeast Thailand is a flood and drought-prone area, farmers in the region have to cope with the risk of losing rice yield every year (Kaida et al., 1985). In this situation, investment in rice farming may be limited, especially among farmers with large paddy field areas. The above possible behaviors may be enabled by increasing the off-farm income of rural residents in the region. As the importance of rice farming as an income source gradually declines (Takeuchi, 2010), farmers are potentially induced to adopt such strategies.

CONCLUSION

Based on the household panel data from 2010 to 2019 in 3 provinces of Northeast Thailand, the number of farmers having more than 3.20 ha of rice-cultivated area decreased between 2010 and 2019, and the number of farmers with less than 1.60 ha of rice-cultivated area increased during the same period. To understand the relationship between the trend of cultivated area, yield, and inputs on rice production, we classified farmers into two groups: those who either reduced or enlarged their rice-cultivated area from 2010 to 2019. In 2010, farmers who reduced their rice-cultivated area had lower yields than those who enlarged their area. However, by 2019, the yield of the reducing farmers had surpassed that of the enlarging farmers. Regarding two key agricultural inputs for rice cultivation – fertilizer and labor – farmers who enlarged their rice-cultivated area used higher amounts per unit area in 2010 than those who reduced the area. Interestingly, by 2019, this trend had reversed, with the reducing farmers using more fertilizer and labor per unit area than the enlarging farmers.

The results suggested that while some farmers in Northeast Thailand reduced their rice cultivation area, other farmers increased their rice cultivation area. However, this expansion was associated with a decrease in both yield and input levels per unit area. This raises concerns that farmers who aim to continue expanding rice production may be unable to maintain the intensity of their operations. Several possible explanations exist for this disinvestment among enlarging farmers: customary land transactions among relatives and neighbors, the high risk of natural disasters, and the increasing availability of off-farm income opportunities. To maintain and improve rice productivity in Northeast Thailand, targeted support is needed for these farmers to incentivize them to invest capital and labor into rice production.

A limitation of the current study is that we could not demonstrate the mechanisms behind the reduction of the rice-cultivated area by individual farmers and the decline in rice production intensity among enlarging farmers, based on actual field data. To confirm the hypothesized reasons we discussed above, further studies are needed using data on livelihoods, incomes, land transactions, and social relationships of rice farmers in the region.

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Research article

The Effect of GlobalGAP Certification on Horticulture Production in Kenya

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Abstract Promoting sustainable production systems is one of the pillars of sustainable development. Rural development strategies, therefore, should enhance production systems that are sustainable for the future. In Kenya, horticulture exports are a state-induced development strategy meant to raise incomes, improve productivity, and eradicate poverty in rural areas. However, with the ongoing proliferation of regulatory standards and stiff competition, horticulture is becoming increasingly challenging for producers in developing countries. Phytosanitary standards have become a de facto requirement for participating in the lucrative market, intended to bridge the information asymmetry between buyers and producers and serve as an assurance of food safety and environmentally conscious production systems, thereby ensuring that more areas of production are certified. Consequently, buyers prefer producers certified by at least one of the internationally recognized schemes. Producers strive for certification, often certifying only a portion of their producing area to meet the standards, which can hinder the promotion of sustainable agricultural practices. This study aimed to assess the recent priorities for Kenyan horticulture in terms of more certified producers or more certified areas of production, what the trends are, and how these trends affect production. Using panel data obtained from GlobalGAP and FAOStat (2008 to 2020), the study found that the number of certified producers and the certified production area (ha) have both increased. The Pseudo–Poisson Maximum Likelihood (PPML) estimator shows that increasing the number of certified producers has a significant effect on exported volumes and total value, while the area under certified production for both covered and uncovered crops has no significant effect. This could imply that farmers are keen on maintaining the market requirements as opposed to increasing the certified area.

Keywords GlobalGAP, certification, horticulture, regulatory standards, Kenya

INTRODUCTION

Facilitating global market access for developing countries has been a significant achievement during the past two decades (Balié, 2020). This is because of the income opportunities it draws from a rural development perspective (McCalla and Nash, 2019). However, researchers have yet to reach a consensus on the benefits of certifications for the long-term growth of agricultural systems, specifically for resource-poor farmers (Pingali, 2017). Some researchers have argued that the expensive nature of these standards may exclude farmers with limited resources if they do not comply (Krauss and Krishnan, 2022; Ouma, 2010; Shepherd, 2015) others have referred to the certification standards as a "protectionism" strategy employed by developed countries to limit competition from developing countries, in response to the removal of tariffs and subsidies in World Trade Organization

(WTO) Doha 2002 agreement (Boza Martinez, 2015; Fiankor et al., 2020; Weinberger and Lumpkin, 2007).

Utilizing certification standards can serve as a strategic advantage to meet the rising demand for fresh produce and enhance competitiveness in global markets (Asfaw et al., 2010; Boza Martinez, 2015; Jaffee and Masakure, 2005). Moreover, certification standards build trust between producers and consumers by addressing disparities in information, thereby facilitating trade. However, even though certification standards are not mandatory, they have effectively become the prevailing practice as producers strive to maintain relationships with buyers who have a preference for certified producers. Even so, it is still debatable whether producers from developing countries gain any advantages from certifications such as market access, which would potentially increase sales revenue or increase production and improve production practices. Highlighting the issue of arguments surrounding the expansion of certification requirements (Balié, 2020; Bennett, 2017; Fiankor et al., 2017; Dolan and Humphrey, 2000; Kariuki, 2014; Krauss and Krishnan, 2022). Other works of literature have highlighted the impending high sunk cost of adopting certification for smallholder farmers (Fiankor et al., 2020; Mithöfer et al., 2009; Tallontire et al., 2014) except for Henson et al. (2011) who found that despite increasing costs burden, certified middle and large-scale farmers earn higher incomes. Other strands of literature explore the determinants of the decision to certify (Henson et al., 2011; Kariuki, 2014). Some of the literature speculates on the potential benefits of certifications, possibly because of data limitations. Regardless, a gap still exists between theoretical knowledge and empirical evidence on the effect of certification on production. To our knowledge, very little research has provided empirical evidence on this important aspect, with exceptions (Fiankor et al., 2020; Henson et al., 2011), who utilized cross-sectional data to assess the effect of certification on export value.

Hence, using panel data, this paper goes beyond asking the most important question from a development perspective: more certified producers or more certified land areas; what is more important? In that case, how does it affect production?

METHODOLOGY

The data used in the study were obtained from the GlobalGAP database (2008-2020), encompassing information on the number of certified producers, the area of certified land (in hectares), and the type of crops, such as fruits, vegetables, or cut flowers. Additionally, it detailed whether the crops were grown in a shaded greenhouse or similar structure, or an open field. We also utilize data from FAOstat and the Horticultural Crops Directorate in Kenya to obtain data on product volume and market volume. This study adopts the econometric models used by Fiankor et al. (2020). The Poison Pseudo-Maximum Likelihood (PPML) estimator is used as certification data is likely issues of heteroscedasticity as data is disaggregated trade data and to account for zeros in the trade data. Each product was run differently to account for possible heterogeneity within products (Shepherd and Wilson, 2013). The model is specified as Eq. (1)

$$X_{it} = exp_{it} + \lambda_i + t + \beta_0 + \beta_1 ln\, GAPit_{it} + \beta_2 ln\, Y_{it} + \beta_3 ln\, vol_{it} + \beta_4 \text{no. prdcts}_{it} + \beta_5 no.mrkts_{it} + \beta_6 covered\ crop_{it} + \beta_7 openfield\ crops_{it} + e_{it} \quad (1)$$

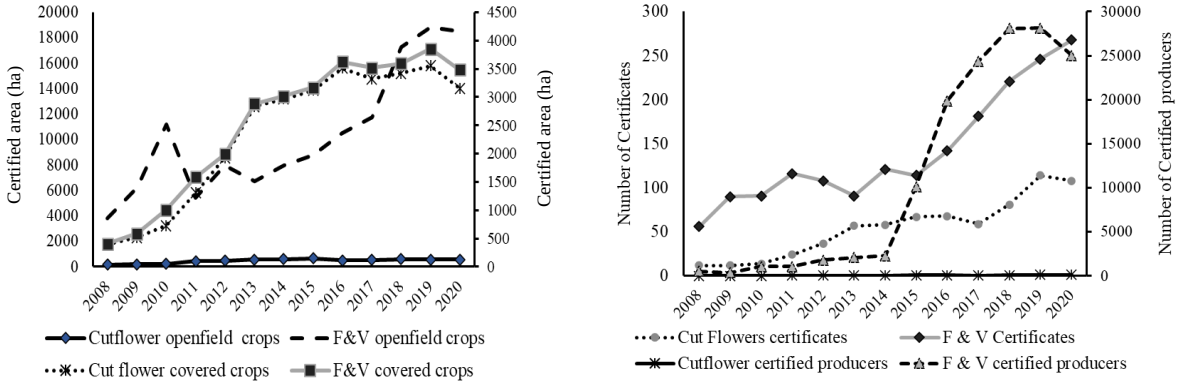
The dependent variable X_{it} represents the level of certification of product i at time t, indicated by the count of certified producers and certified area in hectares. The independent variables include product demand, indicated by export volumes, which, in major markets, drive higher certification allocation. Product characteristics (e.g., number of products exported), market access (e.g., number of markets), and production specifics, distinguishing between open-field crops and covered ones, like greenhouse or shaded cultivation. This is because certification is likely to affect the demand for produce grown in open fields and covered crops and the farmers' decisions on how to allocate land. Nonetheless, field management is different in terms of pest and disease control; open field crops are likely to use more chemicals to control pests and diseases, which attracts more keenness on measures of health and safety and making sure producers do not exceed maximum pesticide limits. On the other hand, buyers and retailers are sometimes willing to pay a premium on certified crops produced

under a controlled environment, and farmers might be moved to allocate more certified areas into covered growing structures. t is time and e_{it} is the error term.

RESULTS AND DISCUSSION

Trends of GlobalGAP Certification in Kenyan Horticulture

The number of certified producers and certified areas has increased from 2008 to 2020, as shown in Fig. 1(a). There was a spike in the certified area in 2009-2010 because of the banning of Kenyan horticulture in EU markets due to exceeding maximum residue limits. Many certified fruits and vegetables are produced in open fields which take up space of land compared to cut flowers and covered crops, which take significantly less area. Vegetables and fruits consist of majority producers consisting of small-scale farmers compared to cut flowers owned by multinational companies operating on covered crops mostly greenhouses.



a) Certified land area b) Certified producers

Source: own calculations using GlobalGAP data F& V is fruits and vegetables

Fig. 1 The trend of GlobalGAP certified producers and land area by product

Figure 1 (b) shows the trend of certified producers and the number of certificates in 2008-2020, which has been increasing. The number of certified producers for fruits and vegetables is higher than the number of certificates issued; this is because some farmers get certified as individuals and others as groups, as also found by Tallontire et al. (2014).

The Effects of GlobalGAP Certification on Horticulture

The key variables examined in this study include the volumes of exported horticulture, market count, and production characteristics, such as the area of covered and open field crops, the number of products, and the impact of certified producers on these variables over time. The certification metrics will be discussed individually while making a comparison between the products. The impact is more significant for certified producers than for certified land areas. Specifically, a percentage rise in the number of certified producers has a greater beneficial influence on horticulture production compared to a one percent increase in certified land areas. The computed elasticity coefficients exhibit a positive and statistically significant relationship with the variables of exported volumes, number of markets, number of products, and method of production, i.e., covered and open field crops. More precisely, a rise in the number of certified producers leads to a 0.93% increase in open-field crops, a 2.9% increase in market access, and a 5.4% increase in the number of products exported. Nevertheless, the coefficient estimates for the total certified land area are negative, indicating that a 1% increase in certified producers results in a 1.4% decrease in the certified area. This indicates that the number of certified producers has been growing at a faster pace than the expansion of certified areas. This could be because the farmers' decision to obtain certification and expand their certified

area is influenced by the utility they expect to gain from the certification. However, if the decision to certify is driven by market regulations and the need to maintain buyer relationships rather than the actual benefits, the utility remains unchanged (Gichuki et al., 2020).

Open-field crop fields show a more significant influence in comparison to covered crop areas. This is because around 80% of vegetable producers in Kenya are small-scale farmers who predominantly cultivate their crops in open fields. With the tightening of Phytosanitary regulations, small-scale farmers are expected to face increased scrutiny due to the imposition of limits on pesticide residue. This is particularly relevant for open-field crops, which are more susceptible to pests, diseases, and other environmental challenges compared to crops grown in controlled environments. Another explanation is that contracting companies are eager to comply with market standards to sustain their presence in the market (Tallontire et al., 2014).

Table 1 Results of the effect of the certification PPML model (benchmark model)

	Pooled data		Fruits and vegetable		Cut flowers	
	Certified land area	Certified producers	Certified land area	Certified producers	Certified land area	Certified producers
LnGAP ^{hectares}		-1.409** (0.543)		-1.549** (0.595)		-6.309 ** (2.001
LnGAP ^{producer}	-0.028* (0.017)		-0.002 (0.029)			
LnOpenfield crops	0.928*** (0.119)	0.928** (0.422)	0.423** (0.173)	1.187* (0.677)	0.137*** (0.027)	6.294** (1.879)
LnCovered crops	0.132** (0.053)	1.470*** (0.501)	0.810*** (0.202)	1.132 (0.895)	0.832*** 0.016	0.863** (0.328)
LnVol (MT)	0.002 (0.056)	2.909*** (0.690)	0.220*** (0.035)	3.638*** (1.192)	-0.005 (0.003)	-0.129*** (0.042)
LnNo. Markets	0.231 (0.377)	5.410*** (1.533)	0.401 (0.460)	6.740** (3.099)	0.041 (0.031)	-1.152*** (0.188)
LnNo. Products	-0.513** (0.205)	3.873** (1.555)	-1.39** (0.546)	3.003 (4.174)	-0.058 (0.041)	-2.453*** (0.612)
Cons	1.484 (1.911)	-73.15*** (17.065)	-1.164 (2.206)	-80.82*** (22.078)	0.669*** (0.138)	12.787*** (1.935)
R^2	.952	.9196	.930	.882	.947	.932
Observations	26	26	13	13	13	13

*Notes: Robust product clustered standard errors in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. LnOpenfield is whether the crop is produced in an open field while LnCovered is if produced in a production structure. LnVol is the volume exported product, and year-fixed effects are included in all regressions.*

The impact on the certified land area is significantly less in all variables when compared to the impact of certified producers. The lack of significance in the exported volumes of crops and some markets may be attributed to GlobalGAP's emphasis on environmental and social responsibility, which may not directly influence yields and hence does not have a substantial impact on the volumes exported. The number of markets accessed is not significantly influenced by the certified area, as farmers may not be aware of the advantages of certification. Additionally, expanding the area of certification may not have a significant impact on market access if farmers continue to sell to the same buyers. Like certified producers, the impact of certified open fields is greater, with significantly lower volumes, namely 0.78% accordingly.

On an individual basis, the volumes of exported fruits and vegetables grew by 0.22% due to a rise in certified producers. Similarly, the number of markets accessed for fruits & vegetables increased to 6.7% for a % increase in unit land area. In this case, the number of certified producers increased by 2.9%. The resulting coefficient of elasticity for certified producers led to a 5.4% rise in the number of markets accessed and a 3.8% increase in the number of products produced.

Controlling for Fixed Effects of Global Gap Certification

The study followed Fiankor et al. (2020) and introduced fixed effects as described in Table 2 to confirm the robustness of our model to possible endogeneity. This confirms that there is no big change; however, the effect of power changes in certified land where both volumes and markets are significant. The coefficient estimate for uncovered crops reduces to 0.78% but is still higher than that of covered crops, The model results confirm that our estimate is valid. Further time and product fixed effects allow the difference in yield between varieties, and yield may vary across years and seasons; specifically, the volumes of fruits and vegetables increase by 2.9% with a % percent increase in a unit area of certified land.

Table 2 Results of fixed effects on certification for the PPML model

	Pooled data		Fruits and vegetables		Cut flowers	
	Certified land area	Certified producers	Certified land area	Certified producers	Certified land area	Certified producers
LnGAP ^{Hectares}		-1.41***		-1.549***		-6.309*
		(.021)		(.021)		(3.783)
LnGAP ^{producer}	-.003		-.002		-.018**	
	(.003)		(.005)		(.009)	
LnOpenfield crops	.786***	1.462***	.423***	1.132***	.156***	.863
	(.014)	(.022)	(.017)	(.024)	(.052)	(.65)
LnCovered	.211***	.932***	.22***	1.187***	.838***	6.294**
	(.006)	(.013)	(.008)	(.015)	(.03)	3.147
LnVol (MT)	.027***	2.921***	.81***	3.638***	-.005	-.129*
	(.008)	(.027)	(.023)	(.031)	(.009)	(.07)
LnNo. Markets	.449***	5.435***	.401***	6.74***	-.014	-1.152***
	(.035)	(.07)	(.051)	(.081)	(.057)	(.342)
LnNo. Products	-1.626***	3.797***	-1.39**	3.003***	-.095	-2.453*
	(.055)	(.112)	(.069)	(.113)	(.179)	(1.387)
Mean dependent var	5933.79	5597.38	8700.1	11143.92	2852.08	54.69
Observations	26	26	13	13	13	13
SD dependent var	4549.41	5597.30	4516.90	11902.82	1380.9	34.121

*Notes: Robust product clustered standard errors in parentheses. ***, **, * denote significance at 1%, 5% and respectively., LnOpenfield crops are whether the crop is produced in the open field while LnCovered is produced in a production structure. LnVol is the volume exported product, and year-fixed effects are included in all regressions.*

CONCLUSION

Food safety regulation is likely to increase as demand for fresh produce increases and the world further opens in international trade. Increasing more certified producers has been more economically significant compared to the certified land area. Farmers' certification from 2008 to 2020 has been a priority perhaps for market access. Further, the volumes of exported have increased confirming that certification can be an important catalyst of trade growth. Production characteristics and types of crops are important in determining the benefits of certification. Nonetheless, both measures of certification, i.e., certified land and certified producers, are important as one caters to the economic needs in terms of enhancing continued business while certified land area can potentially lead to increased production, ensuring environmentally conscious production systems. While the data used in this study offers valuable insights into trends and certification practices in Kenyan horticulture, it also presents a limitation due to the aggregated nature of the data, which might obscure regional or local variations in certification and horticulture production.

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Research article

Identifying the Japanese Foreign Technical Intern and Training Program (TITP) in the Agriculture Sector and Its Outstanding Training Models: A Case Study of Indonesia

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Abstract The Japanese government established the Foreign Technical Intern and Training Program (TITP) for developing countries, enabling trainees from these countries to improve technology, skills, and practical knowledge in an actual work environment and apply their skills when they return home. However, due to issues including improper wage payments and overwork, this approach has received harsh criticism from human rights organizations inside and outside Japan. Previous research has primarily focused on the negative aspects of this program, with little emphasis placed on its positive impacts. TITP is considered critical for Indonesia because it provides high-paying jobs for "unskilled" youth, accounting for more than half of the unemployed population. This research aimed to summarize the current general condition of the TITP, classify the different programs under TITP, and compare the socio-economic conditions of the alumni after finishing TITP and returning to Indonesia. Based on the findings, we can assert that the TITP in the agriculture sector has attracted TITP alumni to pursue a career in agriculture, thereby contributing to an increase in young farmers, desperately needed to ensure the future of Indonesia's agriculture. The majority of alumni became farmer entrepreneurs. The average income of TITP alumni working in the agriculture sector was found to be more than three times that of the average Indonesian farmer's monthly income. The main programs realized under the TITP and reviewed in the current study included the Industrial Training Program (ITP) and the Technical Intern Program (TIP). These programs were compared with the NT Farm (NTF) in Fukui, which is recognized for its exceptional training methodology, including entrepreneurship development training. All NTF alumni now own land, and their average income is slightly higher compared to that of the ITP and TIP alumni.

Keywords TITP, agriculture entrepreneurship, young farmers

INTRODUCTION

The Indonesian Institute of Science (LIPI) survey on the national farmers in 2017 concluded that Indonesia is on the verge of an agriculture crisis in the long term. This is due to the decrease in agriculture households and the aging of farmers, which is not accompanied by the regeneration of the farmers. Regeneration is a key to sustainability. However, many youths (aged 18-35) assume that

agricultural enterprises are less profitable, old-fashioned, dirty, muddy, and provide low income. Hence these assumptions, only 21.95% of the youth engage in agriculture, fisheries, and forestry sectors. Access to meaningful employment is also challenging, particularly for the 1.7 million youth entering the workforce annually. Youth account for over 50% of Indonesia's unemployed population.

Indonesia lacks qualified young farmers. Training is a principal means of developing human resources to achieve this goal. Japan provides technical training for developing countries under the Foreign Technical Intern and Training Program (TITP) in many sectors, including agriculture. In 2021, Indonesia sent hundreds of its youth to this program since 1984 and is still actively engaged to this day (Gusnelly and Riskianingrum, 2019). The main goal of TITP is to enhance the technology, skills, and knowledge pragmatically and practically in an actual work environment so trainees from developing countries can apply their skills when they return to their home countries. However, this approach encounters severe criticism from human rights organizations inside and outside Japan due to several issues it has caused.

Past studies (Chiavacci 2012, Ratnayake et. al. 2020, Tong 2019) mainly focus on the negative side of this program, while good qualities are hardly recognized. TITP is considered highly important for Indonesia as it provides high-paying jobs for the "unskilled" youth, accounting for over 50% of the unemployed population. In recent years, the Indonesian government strongly supported the TITP, claiming it attracts youth to engage in agriculture, and many of its alumni return to Indonesia and become agriculture entrepreneurs. However, scientific literature proving these statements could not be found. This study is needed to clarify the condition of the TITP alumni, especially in the agriculture sector.

OBJECTIVE

This study uses examples of Indonesian trainees and trainee alumni who have conducted training and internships over the past 26 years to illustrate the common condition of Indonesian trainees in the agriculture industry under TITP. It also examines cases of outstanding training models, including the alumni's current livelihood after conducting TITP in the agriculture sector in Japan.

METHODOLOGY

Primary data was gathered through direct observation of training, in-depth interviews, and online questionnaires conducted from November 2021- August 2022. This study interviewed two farmers employing Indonesian trainees under two separate programs: under the *kenshuseido* or Industrial Training Program (ITP) and under *ginou jisshuseido* or Technical Intern Program (TIP). NTF is a farm that oversees Indonesian trainees under TIP. Both ITP and TIP are part of TITP.

Eleven trainees conducting internships under TIP and all trainees (four people) from NTF were also interviewed to grasp the general condition of training in the agriculture sector. Alumni of the programs were also interviewed to understand their perspective toward TITP and their current source of income and livelihood. Of the interviewed alumni, 36 are graduates of ITP, 12 are alumni of the NTF, and 15 are TIP alumni other than NTF alumni. In total, 80 respondents are analyzed for this research.

Secondary sources, such as scientific journals or publications, articles, and reports, were also used in this study. The data was analyzed through comparative analysis since it is descriptive and qualitative in nature. Comparative analysis is essential, especially in clarifying different training methods, to help understand how the different methods affect the trainees' livelihood. In the future, this study aims to aid in developing an adequate training method that will result in a better livelihood for its alumni.

RESULTS AND DISCUSSION

General Condition of TITP for Indonesian Trainees in the Agriculture Sector

In 1984 the Indonesian and Japanese governments approved an agriculture internship program for Indonesian youth called the Industrial Training Program (ITP). In the agriculture sector, the Ministry of Agriculture selects young farmers or children of farmers to work and receive training at a Japanese farm for around one year. Problems arose, primarily due to the restriction of giving a wage to trainees under the *kenshuu* visa. Only allowance, far below the standard wage, is permitted in addition to all accommodation, including lodging and food, that the farmer provides. In response to the issues, the Japanese government 1993 introduced a new program called the Technical Intern Training Program (TITP), where unskilled labor from developing countries will train and work for 3 to 5 years in 14 sectors, including agriculture while receiving an hourly wage. Currently, TIP is more commonly known as TITP.

The program aims to transfer technical knowledge and skills from Japan to developing countries. Nevertheless, previous studies state that the program has not successfully improved intern trainees' skills in technical expertise and matters. The trainees learned more about Japanese work ethics (*5S; Seiri, Seton, Seiso, Seiketsu, Shitsuke*) and habits, creating networking opportunities, and earning money, which helped them open their own business back home (Ratnayake et al., 2016). Recently, in 2019, the Special Skilled Worker Program (SSW – *Tokutei Ginou)* was launched to help solve the problems faced under TITP.

In terms of the number of TITP trainees in Japan, the total number has consistently increased. Indonesian trainees are in fourth place for the total number of trainees. Every year the number of Indonesian trainees in Japan has increased and is predicted to multiply. Figure 1 shows the number of Indonesian trainees from 2012 to 2019.

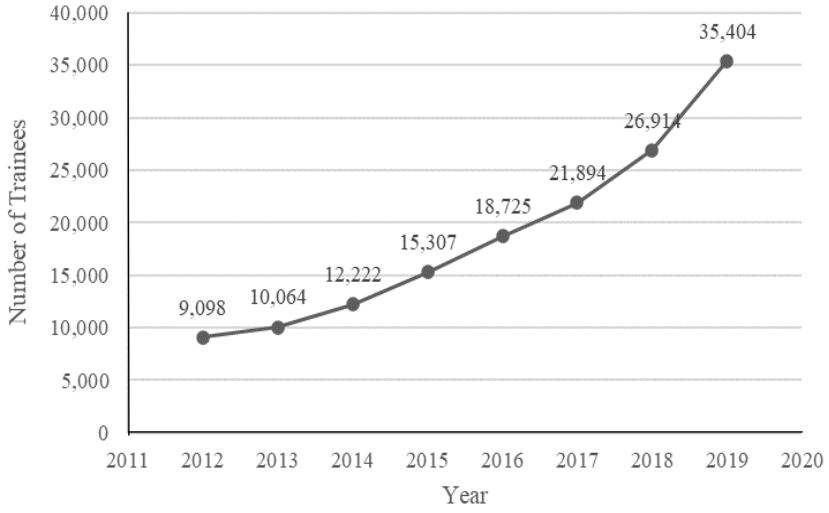

Fig. 1 Number of Indonesian trainees in Japan
Source: Japan Ministry of Justice Statistics on Foreign Residents

While these figures indicate the demand, the TITP has gained attention and multiple criticisms. Domestic and foreign organizations called for the program's abolition due to the alleged exacerbated cases of human rights and labor violations. Nearly every year since 2010, the US Department of State Trafficking in Persons Report 5 calls out to Japan to improve its foreign labor schemes as it operates under the auspices of TITP. Meanwhile, the United Nations Human Rights Committee expressed concern about many reports of sexual abuse, labor-related deaths, and conditions that could amount to forced labor in the TITP (OHCHR, 2014). Sending countries acknowledge the mistreatment. However, each country has its stance (JICA, 2019). Unlike most countries, the Indonesian government considers this program as a means of developing human resources, particularly in the agricultural sector (JICA, 2021). In 2021, more than 3,427 Indonesian trainees worked in the agriculture sector, putting them in second place after the construction sector.

The Indonesian government supports this program and claims it is a good source of social remittance and prospers new agriculture leaders and entrepreneurs, even though entrepreneurship is

not part of the training they receive. From an interview with the Head of the Agricultural Education Center, Agricultural Human Resources Extension, and Development Agency (BPPSDMP) of the Indonesian Ministry of Agriculture, it is understood that since the end of 2021, the government has been planning to start a new program to send selected Indonesian youth to the TITP or SSW program in the agriculture sector by providing agriculture entrepreneurship training prior departure and after graduating from the program to help them get a head start in building their agriculture enterprise in Indonesia. To aid in the development of such programs, this research would like to highlight two cases of adequate training methods of TITP in the agriculture sector and the livelihood of their alumni. One is the ITP training conducted in cooperation with the Indonesian Ministry of Agriculture, and the second case will be training conducted at the NTF.

Differences between ITP, TIP, and NTF Training Methods

Table 1 shows the main differences between each program compiled from interviews and secondary data. It reveals that the most significant differences are divided into three aspects; 1) the trainees selected for the program, 2) the pre-departure training and education received during the program, and 3) the trainee's wage and accommodation while in Japan. In ITP and NTF, youth with an agriculture background become one of the main requirements. Including this precondition ensures the trainees have preexisting knowledge and interest in agriculture and have a significant chance of performing better than those with no agriculture background. Work in agriculture is demanding and requires a great deal of energy. Respondents mentioned that many trainees could not keep up with work on a farm and tended to quit before the contract ended. This requirement will help prevent that sort of case from happening. As for NTF, all trainees finished their contract; some even extended it for another year or two.

Table 1 Main differences between the ITP, TIP, and the NTF

Program element	Kenshu (ITP)	Ginou Jisshu (TIP)	NTF farm in Fukui (NTF)
Pre-departure training	P4S or Organization under the Indonesian Ministry of Agriculture (MA)	Registered Training Organization (LPK), pays a minimal 10 million IDR	No requirements apart from attending a Japanese language school in Indonesia
Trainee candidates	Young farmers or families of farmers	Anyone who is under is training under the LPK	Alumni of Tanjung Sari Agriculture Vocational High School (SMK)
Selection of the trainee	Selected by the farmer group under MA	Selected by the farmer via LPK through online interview	Selected by the principle of Tanjung Sari SMK
Length of training	Up to 1 year	2 - 5 years	3 years
Training/education in Program	Before and in the middle of the program	None	Yes, weekly
Financial literacy education	Yes (starting with 2021)	None	Yes
Income	Allowance (around ¥40,000/month)	Wage (hourly, more than ¥100,000/month)	Wage (hourly, more than ¥100,000/month)
Accommodations (lodging and food)	Provided, by the farmer	Not provided (paid by the trainee)	Not provided (paid by the trainee)
Overtime work	Not allowed, not paid	Paid	Paid

The second aspect is from the training and education received by the trainees. The pre-departure training for trainee candidates of ITP is conducted in an Agriculture and Rural Training Center (or

P4S in Indonesian). P4S is a community institution owned and managed by farmers directly to increase the development of agricultural human resources through training, extension, and education with the support of the Ministry of Agriculture. There are 1,562 P4S centers in Indonesia, one in almost every district. Since the trainees are spread throughout Indonesia, they will intern in the nearest P4S for at least three months. The trainees of NTF are all alumni of Tanjung Sari Agriculture Vocational High School (SMK), located in West Java. This vocational school is one of Indonesia's best agriculture vocational schools. Two hard-working exceptional alumni are selected by the school's principal every year. Regarding the cost to become a trainee in Japan, standard TITP programs applied through a registered training sending organization (or LPK in Indonesian) charge the trainees at least 10,000,000 IDR or around 670 USD. Some even charge more than 2,000 USD. Under the ITP and NTF, this kind of fee is unnecessary. As for ITP trainees, pre-departure training in P4S is less than 150 USD, while under NTF the trainees only need to pay for private Japanese lessons before their departure to Japan.

Unlike the common ITP, both ITP and NTF provide agriculture training during the program. In ITP, trainees receive intensive Japanese language and culture, plus an introduction to agriculture in Japan, for around two weeks before being spread all around Japan to work on a farm. The appointment of the farm where they will intern is also decided based on their agriculture experience and interests. In the summer, they will participate in hands-on agriculture training given by farmers in various fields. This is conducted for around three weeks.

In NTF, trainees and the farm owner will have weekly classes to discuss agriculture and entrepreneurship. At the beginning of the program, each trainee is asked to make a business plan on what they would like to do with the money they saved from working in NTF. Each week they will give an update on their business plan. The CEO of NTF also provides financial literacy education and advises on investments made for their business plan. Trainees interviewed say they have already started to invest their money in their business, like buying land, cattle, and machinery, just after one year of working. For alumni, NTF also provides loans to help expand their business. The main goal of NTF in employing Indonesian trainees is to help them become wise agripreneurs.

The final main difference is the wage (allowance) and accommodation provided. During the internship, ITP trainees are given an allowance of 40,000 JPY or around 312 USD per month. However, all accommodation expenses are paid by the farmer. As for trainees in NTF, they receive a monthly wage of more than 100,000 JPY (around 780 USD) after taxes and insurance charges. NTF trainees are also paid an hourly wage for any overtime work done. However, lodging and food expenses are borne by the trainees. This wage is almost more than ten times the average income of Indonesian farmers of around 1,400,000 IDR or around 92 USD per month.

Current Condition and Livelihood of Industrial Training Program Alumni and NTF Alumni

This study hypothesized that alumni of NTF will become more prosperous farmers (in terms of higher income and assets owned) compared to alumni of the other programs due to the agriculture and entrepreneurship education they received. This study accepts it with the following discussions as support. NTF currently has 13 alumni. When respondents were categorized into three groups; ITP (n=36), TIP (n=15), and NTF (n=12), only 52% of alumni of NTF had farmer parents, and only 25% of the alumni worked in the agriculture sector before coming to Japan. While 92% of ITP alumni had farmer parents, 86% of the respondents were farmers or worked in the agriculture sector before TITP.

After finishing the program, currently, 97% of the ITP alumni are farmers, own agriculture entrepreneurship, or work in the agriculture sector, or an 11% increase from before conducting TITP. As many as 92% of NTF alumni currently earn an income from the agriculture sector, a significant increase from 25%. Land is considered an essential asset, especially in agriculture-related sectors. As for land owned or cultivated, 92% of ITP trainees owned the land before coming to Japan. Unlike ITP alumni, only 42% of NTF trainees owned land before training in Japan. Nevertheless, interviews reveal that all NTF alumni (100%) currently own land and do farming as their primary or secondary source of income. Figure 2 shows the details.

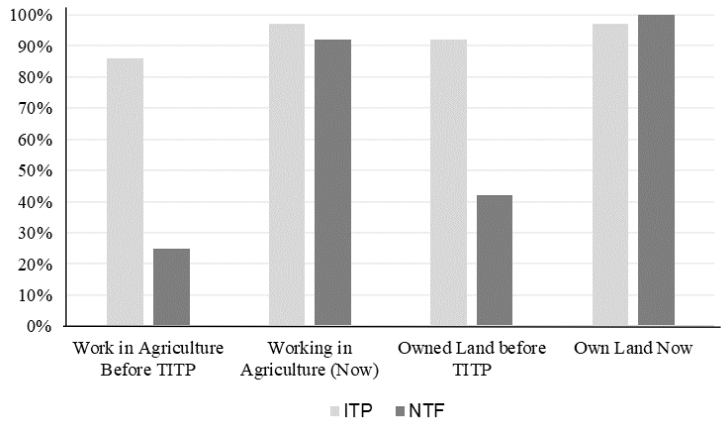

Fig. 2 Condition of ITP and NTF alumni (%)

Another contributing factor that needs to be considered is that 92% of the NTF alumni returned to Sumedang or Bandung, West Java. Land prices have become higher in this area due to the construction of highways nearby, and many agricultural lands have been converted to other uses. Hence, the fact that NTF alumni have land and are still cultivated in this area is a notable factor to be considered, as they have contributed to sustaining the number of farmers in the area. Regarding the average income of alumni, NTF alumni earn an average of 4,791,667 IDR (around 320 USD) compared to ITP alumni with 4,693,548 IDR (approximately 310 USD) and TIP alumni with 4,750,000 IDR (around 316 USD). Even though the nominal is almost equal, with regards to the land owned, NTF alumni have a higher value in assets due to the higher price of land in the area.

CONCLUSION

Based on this study's findings, it is concluded that TITP in the agriculture sector has successfully attracted its alumni to proceed with a career in the agriculture sector, contributing to more young farmers, which is critical for the future of Indonesia's agriculture. The hypothesis set that alumni of NTF will become more prosperous farmers compared to alumni of the other programs due to the agriculture and entrepreneurship education they received can be accepted because all NTF alumni became farmers as their primary or secondary source of livelihood. All NTF respondents own their land, 92% in Bandung and Sumedang, West Java, where land prices are high. Regarding income, the majority of ITP, TIP, and NTF alumni earn three times the average income of farmers in Indonesia. Future studies should elaborate on the factors impacting the TITP alumni's livelihood and develop a recommendation for training for agriculture trainees to generate more high-quality young farmers.

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Research article

Characterizing Salinity and Salinity Matrixes in the Burdekin and Fitzroy Catchments, Queensland, Australia

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Abstract In Australia, salinity is a significant issue plaguing freshwater systems, especially in catchments modified by mining activities. River salinity varies in composition from changes in aquifer lithology, natural salt deposits and salt accumulation due to land altering activities (e.g., mining and agriculture). Complex salinity matrixes arise when different salinity sources and compositions are diluted into freshwater systems. Monitoring waterway salinity and characterizing salinity matrixes is vital to mitigating adverse impacts on agriculture, drinking water supplies and ecosystem health. However, to date, few studies have focused on characterizing salinity in freshwater systems based on source. In this paper, case studies drawn from the Burdekin and Fitzroy catchments, Queensland, are characterized for different salinities associated with mining and natural geogenic mineralization. Salinity coefficients (k_e), a ratio of total dissolved solids (TDS in mg/L) to electrical conductivity (EC in μS/cm), are utilized to identify variations in salinity composition. Long-term water quality data (1964-2023) is retrieved from the Queensland Government's water monitoring program. Findings indicate that mining activities in both catchments have a significant influence on freshwater salinity matrixes, driving lower k_e values (0.561-0.587). A novel method for analyzing long-term k_e data is introduced, utilizing the slope (m) of k_e in cumulative distribution plots. Significant variations in slope in the Fitzroy (m: 9.6, 5.3, 2.3) and in the Burdekin River (m: 8.9, 1.6, 1.0, 0.7) reveal influences on local mineralization and industry, not readily evident when only considering average k_e. This study demonstrates that utilizing known geochemical, EC and TDS relationships and k_e is an effective preliminary method for identifying salinity complexity, composition and source. Salinity in the Fitzroy catchment surpasses aquatic toxicity thresholds (EC50: 2410 µS/cm), revealing significant risks to freshwater aquatic species.

Keywords salinity, salinity characterization, water quality, mining, ecosystem health

INTRODUCTION

Freshwater salinization is an emerging global issue impacting water quality and ecosystem health. Salinity refers to dissolved salts, minerals, or ions in water, with major ions consisting of: sodium (Na^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), potassium (K^+), sulfate (SO_4^{2-}), bicarbonate (HCO_3^-), and chloride (Cl^-). Electrical conductivity (EC) or specific conductance, is the ability of an aqueous substance to conduct an electric current. Total dissolved solid (TDS) or ionic concentration, is the total concentration of salts present within a solution (Hem, 1989). Charged ionic species in solution drives conductance. For example, pure deionized water has very low EC (< 5 µS/cm), containing no salts. Both EC and TDS are quantitative measures of salinity.

The correlation between ionic concentration and specific conductance is well established; as ion concentration increases, conductance increases, thus EC can infer ionic concentration (Hem, 1989). The mathematical relationship between ionic concentration and specific conductance can be described in Eq. (1) as:

$$k_e = TDS/EC \quad (1)$$

Where, k_e is the salinity coefficient, EC is electrical conductivity in µS/cm and TDS is total dissolved solids in mg/L. As EC of a solution increases, TDS increases, resulting in a linear relationship between EC and TDS. This direct relationship applies to both anion and cation components of compounds in a solution. It is common to utilize EC readings and predefined k_e (e.g., U.S. standard of 0.64-0.66) to determine TDS (Hem, 1989). Natural waters however, are not simple solutions, containing both ionic and undissociated species that range widely in amount and proportion (Hem, 1989). Ionic mobility, is the capacity of ions to move through a solution, which transfers charges and enables a conduction of current. Ionic mobility decreases with increasing concentration, owing to interference and interactions among ions (Hem, 1989). Factors such as temperature, solvent, specific ions and high salinity (or ionic concentration) can cause interferences and non-linear behaviour in the EC and TDS relationship, resulting in variable k_e coefficients (Hem, 1989). Therefore, large variations in k_e can convey salinity matrix complexity.

In literature it is well established that k_e is variable in some freshwater systems. However, there is limited data identifying specific k_e associated with local geology and mining (Table 1). The given table identifies a range of k_e values and associations to geogenic and mining influences in literature.

Table 1 k_e value ranges in literature

k_e Ranges	Description	Reference
0.64 - 0.66	US Geological Survey Standard Coefficient at 25°C	Hem (1989)
0.59 - 0.72	Australian surface waters (EC range 50 - 1000 µS/cm)	McNeil & Cox (2000)
0.54 - 0.96	Natural waters	Parker (2001)
0.90 - ≥ 1.00	Natural waters influenced by dolerite or schist	Parker (2001)
0.24 - 1.34	South Africa Mine Waters (EC range of 70 -16000 µS/cm)	Hubert & Wolkersdorfer (2015)

Complex salinity matrixes of multiple contaminants arise when different salinity sources (i.e., mine water and industrial effluent) are diluted into freshwater systems (Kaushal et al., 2021). These irregular salinity compositions are of varying ionic strength, pH, redox, and temperature (e.g., mine pit water discharge can increase water temperatures by 3.9℃); collectively influencing adsorption, contaminant mobilization and ecotoxicity risk (Wright et al., 2017). High salinity (>1000 µS/cm) can impact freshwater aquatic specie reproduction and cause death (Mann et al., 2014).

OBJECTIVE

This study's objective is to demonstrate the application of k_e as a preliminary method to identify and characterize complex salinity matrixes in highly altered freshwater environments. This paper aims to investigate salinity matrixes in the Burdekin and Fitzroy catchment by (1) identifying k_e values associated with mining (Fig. 1, Table 2), and (2) k_e cumulative distribution plots (Fig. 2) to distinguish long-term influences of local geogenic mineralization and industry. This study further examines the impact of salinity composition on ecosystem health, by comparing salinity data to aquatic toxicity thresholds for 6 freshwater species (Fig. 3) (Mann et al., 2014).

METHODOLOGY

The Burdekin (~130,000 km^2) and Fitzroy (~142,000 km^2) catchments have extensive gold (Charters Towers, Ravenswood, and Mt. Morgan) and coal mining (Collinsville, and Callide), sugarcane farming, grazing, and hydrological alterations (Burdekin Falls Dam: 1,860,000 ML and Fitzroy River Dam: 480,000 ML) (Fig. 1). These subtropical river systems are two of the largest coastal river inputs to the Great Barrier Reef (GBR), a world heritage listed site. The Burdekin and Fitzroy catchments were chosen as case studies due to their established mining developments and the potential impact upon protected ecosystems.

In this study, water quality data is retrieved from the Queensland Government's Water Monitoring Information Portal (WMIP). The WMIP database provides long-term water quality measurements (1964 – 2023) for both TDS and EC (Queensland Government, 2023). A total of 21 gauging stations were chosen; 10 sites in the Fitzroy and 11 in the Burdekin River (Fig. 1). Site selection focused on gauging stations downstream from mining developments. Sites located in tributaries, without anthropogenic activity were utilized as a comparison to natural geogenic inputs.

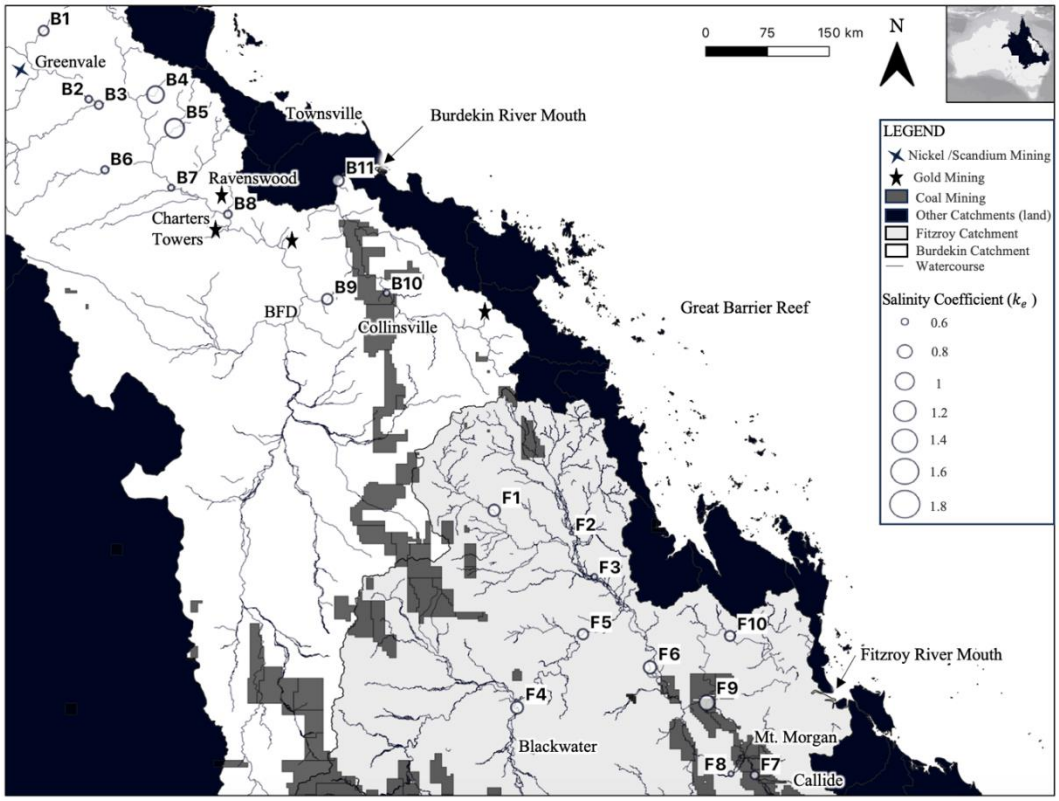

Fig. 1 Fitzroy and Burdekin catchments with electrical conductivity at gauging station sites

RESULTS AND DISCUSSION

Table 2 provides mean TDS, EC, and k_e in the Burdekin and Fitzroy Rivers. In both catchments, river waters in proximity to mining areas (nickel [Ni], scandium [Sc], gold [Au] and coal) are correlated to lower k_e values (0.561 - 0.587) (Table 2). Sites B2 and B3 positioned near Greenvale (Ni and Sc), have a k_e range of 0.576 to 0.587. Charters Towers and Ravenswood (Au), B7 and B8, have a k_e range of 0.571 to 0.583. Sites in proximity or downstream of coal mining operations (F2, F3, F7, F8 and B10) have a k_e between 0.561 and 0.584. B10 is downstream of the decommissioned Collinsville coal power station (operated from 1967-2018) and the mean k_e of 0.570 likely captures previous inputs. Henderson et al. (2022), linked lead isotopes ($^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$) to coal fly ash signatures in Burdekin waterways, further validating the influence of the coal power station. F9, is located at a junction of tributaries downstream of coal and gold mining and likely captures a complex salinity composition from multiple sources, driving a higher k_e of 0.685.

Sites outside of mining operations in the Burdekin (B1, B9 and B11) and the Fitzroy (F1, F4, F5, F6 and F10) have notably different k_e (Burdekin: 0.607-0.628 and Fitzroy: 0.608-0.643), reflecting reduced ionic complexity and a stronger association to k_e standard (0.64-0.66). B4, B5, and B6 are located in areas of minimal anthropogenic activity but have high and low k_e ranges (B4: 0.725, B5: 0.777, B6: 0.580). Exposed pegmatites and granites are prominent at B4 and B5, likely contributing to high silica content in the water column. Eroded basalts at B6 increase Mg-Ca-$NaHCO_3$, impacting local water chemistries. High k_e ratios are driven by the prominence of weakly

ionized cations and anions; from pesticides, organic compounds, dissolved gases, and neutral salts (calcium carbonate, silicates, and boron) (Day and Nightingale, 1984; Hubert and Wolkersdorfer, 2015). Alternatively, low k_e are reflective of waters high in free acid, alkalinity, $NaHCO_3$ and NaCl. (Hills et al., 2022; Hubert and Wolkersdorfer, 2015). These geochemical trends align with our findings of low k_e associated with mining and basalt mineralization and high k_e driven by dissolved silica from local geology.

Table 2 Mean total dissolved solids (TDS), electrical conductivity (EC), and salinity factor (k_e) in the Burdekin and Fitzroy catchments

Station [a]	Site	N[b]	Description	TDS (mg/L)[c]	EC (µS/cm)[c]	k_e [c]
120123A	B1	24	Burdekin: Valley of Lagoons	295 ± 81.8	487 ± 134	0.607 ± 0.016
120107B	B2	31	Burdekin: Blue Range (Ni, Sc)	258 ± 72.2	448 ± 121	0.576 ± 0.022
120110A	B3	151	Burdekin: Blue Range (Ni, Sc)	229 ± 83.5	394 ± 150	0.587 ± 0.033
120120A	B4	36	Burdekin: Mt. Bradley	42 ± 9.6	60 ± 15	0.725 ± 0.236
120112A	B5	35	Burdekin: Star R.	82 ± 58	117 ± 102	0.777 ± 0.354
120106B	B6	71	Burdekin: Basalt R.	400 ± 156	690 ± 263	0.580 ± 0.029
120122A	B7	30	Burdekin: Charters Towers (Au)	222 ± 80.1	394 ± 152	0.571 ± 0.030
120002C	B8	187	Burdekin: Ravenswood (Au)	174 ± 58.3	301 ± 108	0.583 ± 0.038
120015A	B9	92	Burdekin Falls Dam	108 ± 33.6	179 ± 64.5	0.615 ± 0.044
120205A	B10	56	Burdekin: Bowen R. (Coal)	144 ± 64.2	253 ± 110	0.570 ± 0.076
120006B	B11	201	Burdekin: Home Hill	130 ± 53.0	222 ± 94.4	0.628 ± 0.547
130410A	F1	47	Fitzroy: Upper Isaac	182 ± 141	313 ± 259	0.629 ± 0.181
130404A	F2	130	Fitzroy: Connors (Coal)	195 ± 73.0	352 ± 140	0.561 ± 0.056
130401A	F3	138	Fitzroy: Lower Isaac (Coal)	187 ± 67.0	335 ± 129	0.568 ± 0.057
130504B	F4	47	Fitzroy: Blackwater	140 ± 76.0	228 ± 145	0.637 ± 0.054
130106A	F5	86	Fitzroy: Mackenzie	128 ± 46.0	213 ± 89.0	0.613 ± 0.079
130105B	F6	14	Fitzroy: Mackenzie	107 ± 32.0	171 ± 62.0	0.643 ± 0.052
130327A	F7	82	Fitzroy: Callide (Coal)	228 ± 143	399 ± 262	0.584 ± 0.037
130306B	F8	123	Fitzroy: Callide (Coal)	955 ± 1299	1684 ± 2243	0.565 ± 0.035
130003B	F9	106	Fitzroy: (Coal, Au)	242 ± 190	370 ± 337	0.685 ± 0.146
130005A	F10	223	Fitzroy: Rockhampton	164 ± 111	284 ± 204	0.608 ± 0.072

Source: a WMPI Database retrieved 2023, b. number of samples between 1964-2023, and c mean± standard deviation

Figure 2 shows the cumulative distribution of k_e in the Burdekin and Fitzroy Rivers between 1964 and 2023. In freshwater environments, the proportions and quantity of dissolved salts naturally fluctuate over time (Walton, 1989). In Fig. 2, differences in k_e slope offers an additional approach to identify geogenic mineralization and industry influences on river chemistries. Fig. 2A demonstrates three types of salinity matrixes which correspond to shifts in k_e , slope (m) (m: 9.6, 5.3, 2.3). Fitzroy is heavily impacted by mining activity, with sites F2, F3, F7, and F8 aligning with slope m: 9.6.

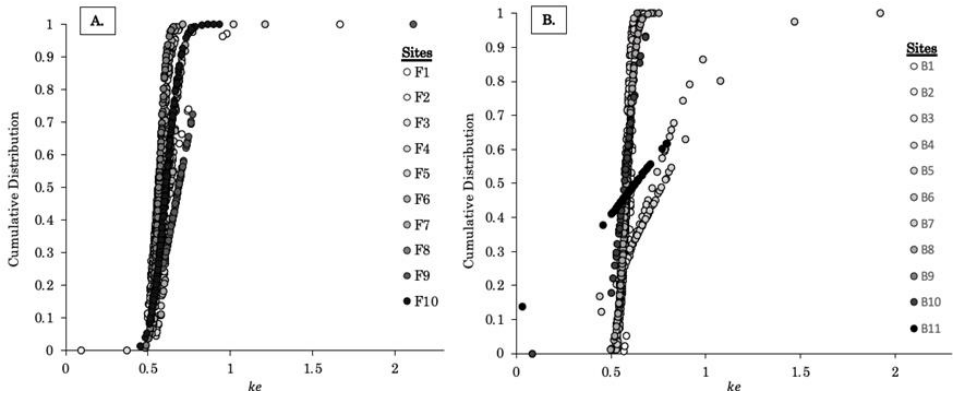

Fig. 2 Cumulative distribution of k_e values for the Fitzroy (A) and Burdekin Rivers (B)

Sites not impacted by mining (F1, F4, F5, F6, F10) fall under slope m: 5.3. As previously identified, F9 is located at a junction of multiple tributaries downstream from coal and gold mining sites. F9 has the largest k_e variation (m: 2.3) within the Fitzroy catchment, reflecting the ionic complexity from multiple salinity sources. Fig 2B indicates four distinct k_e slopes (m: 8.9, 1.6, 1.0, 0.7) in the Burdekin River. B1, B2, B3, B6, B7, B8, and B10 align with m: 8.9 (k_e : 0.70-0.607). B4 (m: 1.6) and B5 (m: 1.0), have a significantly larger variation of k_e, indicating geogenic influences previously established by mean k_e (B4: 0.725, B5: 0.777).

B11 is also distinctive (m: 0.7) and although not previously apparent by its mean k_e (0.628), the cumulative distribution curve demonstrates B11 has a complex ionic composition. Located in the estuary B11 variations are likely driven by pesticide run-off from nearby sugarcane farming and the sugar mill industry established at Home Hill (Henderson et al., 2022).

Figure 3 compares both acute and chronic EC50 (effective concentration; where 50% of the toxicity response is observed) toxicity thresholds to salinity levels in the Burdekin and Fitzroy Rivers. Mann et al. (2014) dosed test species in solutions representative of coal mine water to generate freshwater toxicity limits identified in Fig. 3. The majority (95%) of Burdekin and Fitzroy sites have salinity levels well below aquatic toxicity limits (Fig. 3). F8 (k_e : 0.565) however, has high salinity levels (EC maximum: 11,500 µS/cm); four out of five test species surpassed the ecotoxicity limit, indicating the high toxicity response of aquatic species at this location. These results align with Chapman and Simpson (2005) findings, a study which outlined issues of acid mine drainage and heavy metal toxicity (aluminum and copper) from mine water at Mt. Morgan (EC 12,900 µS/cm; pH 2.7).

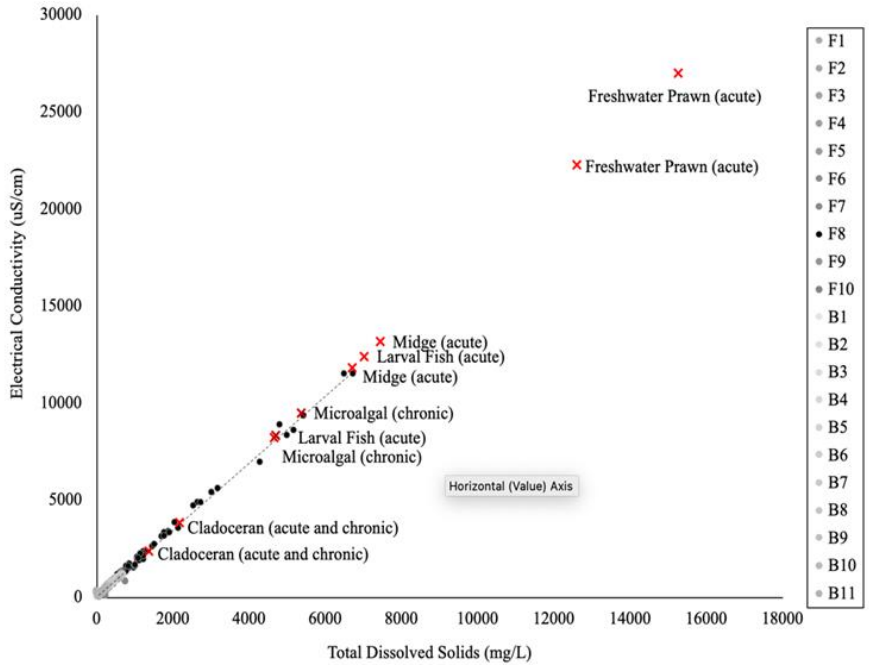

Fig. 3 Aquatic ecotoxicity data retrieved from Mann et al. (2014). Electrical conductivity versus total dissolved solids for the Burdekin and Fitzroy Rivers

CONCLUSION

In highly altered freshwater environments, river salinity reflects a blend of ionic compositions from diverse anthropogenic and natural sources. The Fitzroy and Burdekin River waters are heavily influenced by mining activities, which are characterized by lower k_e (0.561-0.587). An innovative approach utilizing the slope (m) in k_e cumulative distribution plots reveal distinct differences in k_e slope (m: 9.6, 5.3, 2.) in Fitzroy and in the Burdekin River (m :8.9, 1.6, 1.0, 0.7). This slope-based analysis offers an additional approach to examine salinity distribution structure in freshwater systems

and provides additional insights, not readily evident when only considering mean k_e (B11 m: 0.7, k_e: 0.628). High salinity values at F8 exceed Mann et al.'s (2014) EC50 aquatic species limit (minimum 2410 µS/cm), demonstrating high risks to ecosystem health from coal and gold mining at this location.

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Research article

A Comparison of Organic Matter Dynamics Among Degraded, Dam-Restored, and Preserved Peat Swamp Forests

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Abstract The exploitation of tropical peatlands has triggered serious environmental problems such as deforestation and peat fires, loss of biodiversity, and emission of greenhouse gases. This process includes peat drainage and drying, followed by peat degradation. Dam construction is expected to decrease the vulnerability of peatlands to fires and improve the regeneration of degraded peatland. This study investigated the effects of dam restoration for peat swamp forests degraded by drainage on the dynamics of organic matter that regulate peat conditions. We compared the organic matter dynamics of three types of forest in Palagnkaraya, Central Kalimantan, Indonesia: less-drained (almost natural), drained (degraded), and dam-restored forest. Both drained and dam-restored forests experienced drainage in 1995; however, dams were constructed at the dam-restored site in 2005. Within each site, we measured litterfall, fine root production, and decomposition as indices of the peat accumulation rate, water table, and soil moisture. The mean groundwater level at the dam construction site was significantly higher than that of the drained forest. Litterfall was highest in the drained forest and lowest in the dam-restored site. The decomposition rates were not significantly different among the sites. We estimated the changes in peat mass using a model. The amounts of peat accumulation after 5 years were found to be 3.46, -1.60, and -2.86 kg/m^2 in the less-drained, drained, and dam-restored sites, respectively. These results showed that peat deposition decreased at the dam construction site but decreased less in the drained forest. A possible explanation for the observed results is increased primary production in drained forests caused by reduced flooding stress and increased nutrient supply from oxidized peat for primary producers.

Keywords tropical peat swamp forest, dam restoration, decomposition, production

INTRODUCTION

The extensive peatland areas in Southeast Asia have been degraded by exploitation (Shimamura, 2016). The conversion of peatland to farmland involves processes such as drainage of peatland, clear-

cutting, and field burning. These activities have led to various environmental issues, including increased greenhouse gas emissions, loss of biodiversity, and peat fires. Excavated channels were used for logging and to dry out the peat, but excessive drainage has severely degraded the peatland. As peat dries, it becomes more susceptible to fires and undergoes faster aerobic decomposition. Peat consists mainly of dead plant matter and, when dried, behaves like kindling and firewood, burning easily. Consequently, drainage increases peat vulnerability to fire. Similarly, drainage exposes peat to an aerobic environment. Aerobic conditions accelerate decomposition, whereas flooded and anaerobic conditions inhibit peat decomposition. The frequent fires and accelerated aerobic decomposition result in the release of carbon accumulated in peat into the atmosphere as greenhouse gases. To address this issue and conserve peat, dams have been constructed. The goal of dam construction is to reduce the risk of fire and prevent aerobic peat decomposition by restoring water levels and re-saturating degraded peat.

Previous studies that examined carbon flux found that dam construction does not significantly improve carbon deposition (Jauhiainen et al., 2008; Darusman et al., 2022). However, there is limited knowledge about the impact of dam construction on organic matter dynamics, such as primary production and decomposition processes, which directly regulate changes in peat deposition.

OBJECTIVES

The objective of this study was to clarify the effects of dam restoration of peatlands on organic matter dynamics. To this end, we investigated and compared 1) water table and soil moisture, 2) above- and below-ground production, and 3) decomposition processes in undrained, drained, and restored peat swamp forests.

METHODOLOGY

Study Area

This study was conducted in tropical peat swamp forests in two areas: Setia Alam (2°18’ S, 113°55’ E) and Kalampangan (2°20’ S, 114°2’ E), Central Kalimantan, Indonesia. The mean (SD) annual temperature and rainfall averages between 2009 and 2020 were 29.1 (0.63) °C and 2725 (1161) mm, respectively (https://weatherspark.com/). Seasonality in rainfall is not fixed; however, in most years, a distinct dry season is evident from May to August.

Fig. 1 Dam constructed in the canal near the restored forest

Setia Alam is situated in the Natural Laboratory of Tropical Peat Swamp Forest, which is located in the upper watershed of the Sabangau River. This area consists of large, continuous areas of relatively undisturbed and undrained forests. Although the forests had been logged selectively until the late 1990s, they remained relatively intact because it was designated a National Park in 2006.

The Kalampangan site is located between the Sabangau River and a large canal that runs from north to south. The large canal (25 m wide × 3.5-4.5 m deep) that was excavated in 1996 and 1997 functioned to facilitate drainage of the forest (Page et al., 2009). In June-August 2005, the canal was blocked at several points by small dams to facilitate hydrological restoration (Jauhiainen et al., 2008).

We established three sets of rectangular plots (50 m × 20 m) in the undrained forest (UF) in Sabangau, and the drained forest (DF) and restored forest (RF) in the Kalampangan site. Most of the field research was conducted between September 2005 and October 2006.

Water Table and Soil Moisture

The groundwater level (GWL) was measured monthly at a dip well between October 2005 and October 2006. The dip well was located at the centre of each plot. A PVC pipe perforated with small holes was vertically inserted into the peat, allowing the water level inside the pipe to be measured.

We established five points within each plot to measure soil moisture monthly. The distance between the points was more than 10 m. The volumetric water content of surface peat soil was measured monthly using a time domain reflectometry probe (UIZ3635-50mV) between September 2005 and September 2006, but not between October and November 2005 as we failed to collect data.

Organic Matter Dynamics

Litter was collected monthly in each plot from October 2005 to October 2006, using ten litter traps per plot. Each litter trap was a rectangular basket (0.75 m × 0.75 m) made from a 2 mm nylon mesh suspended from strings, and the device was held 1 m above the ground. After collection, the litter samples were sorted into leaves, flowers, branches, fruits, bark, and others, dried to a constant mass, and weighed. Traps were placed at points selected through random computation from grids of 5m intervals within each plot.

The litter deposits above the peat surface were collected in September and November 2005 and February and May 2006. All recognizable above-ground litter was harvested from five quadrats (50 cm × 50 cm) in each plot. When traces of disturbance from the previous sampling were observed, samples were collected at the nearest intact site. After collection, the litter samples were immediately dried in a self-made drying room to a constant mass and weighed.

The decomposition processes of leaf litter were studied using the litter bag method. To unify the litter samples, the leaves of *Combretocarpus rotundatus* (Miq.), one of the dominant species, were used. The litter (20 g in dry weight) was enclosed in a litter bag (20 cm × 15 cm) made of polypropylene cloth with a mesh size of 2 mm. Litter bags were set in September 2005. Five locations within each plot were selected, and five litter bags were placed on the ground floor at each selected point. The distance between each point was more than 20 m. Samples were collected five times in one year: October 2005, January 2006, April 2006, July 2006, and September 2006. A sample was collected from each sampling point. After transport to the laboratory, the dry weight loss was determined by drying the samples to a constant mass at 80 °C. Decomposition rates were estimated using Olson's k (Olson, 1963), given by Eq. (1):

$$W_t = W_0 \times e^{-kt} \quad (1)$$

Where W_t is the litter weight after a given period, W_0 is the original litter weight, k is the decomposition rate, and t is time.

Ingrowth cores (20 cm length, 10 cm diameter), which were made of 2 mm nylon mesh, were filled with root-free soil and installed in the ground (0-20 cm in depth). The soil used for this purpose was taken from a nearby location, and care was taken to fill the cores so that the bulk densities were similar to the *original* levels. Ten locations per plot (distanced 10 m or more from each other) were selected, and an ingrowth core was buried in September 2005 and harvested 1 year later. At harvest, 12 cores from the UF were lost or broken. Consequently, the sample numbers were 13 from the UF and 25 from the others (DF and RF). After transporting them to the laboratory, root samples from each core were dried at 80 °C until they reached a constant mass and were then weighed.

Estimation of Change in Peat Depth

To understand the differences in the regimes of organic matter dynamics among the three types of forests, we used a model that simulates changes in peat depth (Shimamura and Momose, 2005). In the simulation, peat was characterized by two horizons: surface aerobic acrotelm and deeper anaerobic catotelm. Differences in acrotelm thickness strongly contributed to differences in peat thickness and peat deposition. On the other hand, the depth of the catotelm layer was defined by the height of the water table and the bottom of the peat. The peat deposition model expressed by Eq. (2) was used to simulate peat deposition in the acrotelm layer, which is influenced by organic matter dynamics.

$$m_A = A \exp(p_A/b\text{-}k_A)t + sk_L(p_L/k_L\text{-}m_{L0}) \exp(\text{-}k_L t) / (k_L + (p_A/b\text{-}k_A)) - (sp_L\text{-}m_C k_C) / (p_A/b\text{-}k_A) \quad (2)$$

where m_A is the acrotelm layer mass, A is an integral constant, p_A is the root input per unit depth, b is the bulk density of the acrotelm layer, k_A is the rate of mass loss from the acrotelm materials through respiration, t is the time, s is the portion of fragmented litter not lost from soils by respiration or leaching, k_L is the decomposition constant of litter, pL is litterfall mass, m_C is the catotelm layer mass, m_C is the mass of the catotelm layer, and k_C is the decomposition constant of the catotelm layer. Eq. (3) yields the integral constant A.

$$A = m_{A0} - sk_L(p_L / k_L - m_{L0}) / (k_L + (p_A / b - k_A)) + (sp_L - m_C k_C) / (p_A / b - k_A) \quad (3)$$

where m_{A0} is the initial acrotelm layer mass and m_{L0} is the initial mass of the litter layer. In this study, we focused on the changes in peat mass and thickness over a relatively short period (5-10 years). The change in elevation (Δh) is given by Eq. (4).

$$\Delta h = (m_A - m_{A0}) / b \quad (4)$$

Most variables in the model were estimated based on the present study; however, for the variables k_A, s, and k_C, we applied data from PI9 and PI12 in Brady (1997) to the DF, RF, and UF sites, as the bulk densities of these combinations were similar. For variable b, we used data collected from the study sites (Shimamura et al., unpublished data).

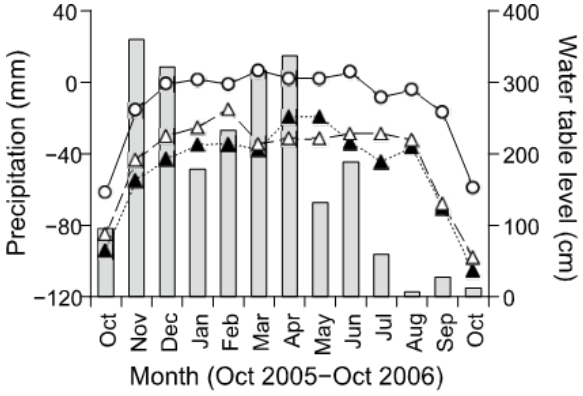

Fig. 2 Monthly precipitation at Cilik Riwut Airport and water table for UF (open circle), DF (shaded triangle), and RF (open triangle)

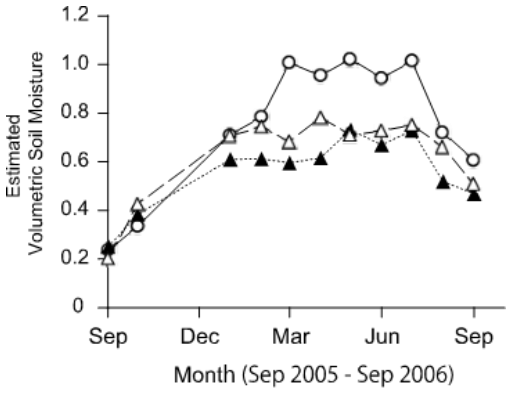

Fig. 3 Estimated surface peat moisture for UF (open circle), DF (shaded triangle) and RF (open triangle)

RESULTS

Water Table and Soil Moisture

During the study period, the rainy season began in November 2005 and ended in June 2006 (Fig. 2). The GWLs of the study sites showed similar trends; they increased during the rainy season and

decreased during the dry season. The GWL at the UF sites was the highest throughout the study period. The GWL of the RF sites was higher than that of the DF sites, except between April and May 2006. The mean annual (SD) GWLs were -7.5 (18.6), -43.5 (23.2), and -37.8 (20.2) cm in the UF, DF, and RF, respectively. The results of the General Linear Model (GLM) analysis showed that there were significant effects based on the month ($F_{12,78} = 66.5$, $p < 0.001$) and site ($F_{2,78} = 190$, $p < 0.001$), but the interaction between month and site was not significant ($F_{24,78} = 1.6$, $p = 0.056$). Post-hoc multiple comparisons (Holm's method) showed that all pairs of sites showed significant differences ($p < 0.01$).

The rank of the estimated annual mean soil moisture among the three sites was in the order UF > RF > DF, and the values (SD) were 0.812 (0.286), 0.670 (0.196), and 0.593 (0.214), respectively. It should be noted that the estimated values at the UF sites often exceeded 1.0; such values are not realistically possible but can be used as a guide. The results of GLM analysis showed that there were significant effects based on month ($F_{10,551} = 58.1$, $p < 0.001$), site ($F_{2,551} = 63.7$, $p < 0.001$), and interaction between the two ($F_{20,551} = 3.8$, $p < 0.001$). Post-hoc multi-comparison (Holm) showed that all pairs of sites showed significant differences ($p < 0.01$) (Fig. 3).

Table 1 Summary of organic matter dynamics and the values applied in the peat surface profiling model

	UF	DF	RF
Litterfall (kg/m^2/y)	1.03[a]	1.10[a]	0.923[b]
Initial mass of litter layer (kg/m^2)	0.738	0.787	0.744
Litter decomposition constant	0.708	0.749	0.737
Fine root production (kg/m^3)	3.44[a]	2.25[b]	1.86[b]
Initial acrotelm thickness (water table) (m)	0.075[a]	0.435[b]	0.378[c]
Leaf litter respiration rate*	0.0681	0.0681	0.0681
Peat loss rate in acrotelm*	0.00103	0.0094	0.0094
Proportion of fragmentation loss of litter**	0.904	0.909	0.907
Bulk density (kg/m^3)***	71	129	129
Output to catotelm ($m_c k_c$) (kg/m^2/year)****	1.06	1.70	1.95
Catotelm			
Peat thickness***	4	5.07	5.12

*Note: Means for different variables within a row followed by the same letter are not significantly different at p = 0.05. *Data from Brady (1997), **calculated from: leaf litter respiration rate/litter decomposition constant, *** Shimamura et al. (unpublished data). The values of k_c and m_c were obtained from Brady (1997) and Shimamura et al. (unpublished data), respectively.*

Above and Belowground Production

The rank of annual litterfall among the three sites was in the order DF > UF > RF, and the values (SD) were 11.0 (3.07), 10.3 (2.12), and 9.23 (2.27) ton/ha/year, respectively. The monthly amount of litterfall was higher during the dry season, when the GWL was low. The results of GLM analysis showed that there were significant effects based on month ($F_{12,1105} = 12.4$, $p < 0.001$), site ($F_{2,1105} = 1.90$, $p < 0.001$), plot ($F_{6,1105} = 4.04$, $p < 0.001$), and the interaction between month and site ($F_{24,1105} = 1.61$, $p < 0.001$). Multiple comparison (Holm) showed that the annual litterfall of the RF site was significantly lower than that of both UF and DF, and that there was no significant difference between UF and DF (Table 1, Fig. 4). The rank in above-ground litter mass among the sites was in the order DF > RF > UF, and the values (SD) were 7.87 (2.24), 7.44 (2.00), and 7.38 (4.82) ton/ha, respectively. The results of GLM analysis showed that neither month, site, nor the interaction had significant effects on above-ground litter deposition. The rank of root production among the sites was in the order UF > DF > RF, and values (SD) were 3.44 (2.00), 2.25 (0.97), and 1.86 (1.28) kg/m^3/year, respectively (Fig. 5). The results of GLM analysis showed that there was a significant effect of site ($F_{2,59} = 5.86$, $p < 0.01$). Post-hoc multiple comparison (Holm) showed that the annual root production of UF was significantly higher than that of the other sites, whereas there was no significant difference between RF and DF. The ranking of litter decomposition constants among the sites was in the order DF > RF > UF, and the values (SEB) were 0.749 (0.016), 0.737 (0.021), and 0.708 (0.027),

respectively (Table 1, Fig. 6). The results of GLM analysis showed a significant effect of time ($F_{1,216}$ = 51.1, $p < 0.001$) but no significant effect of site or interaction.

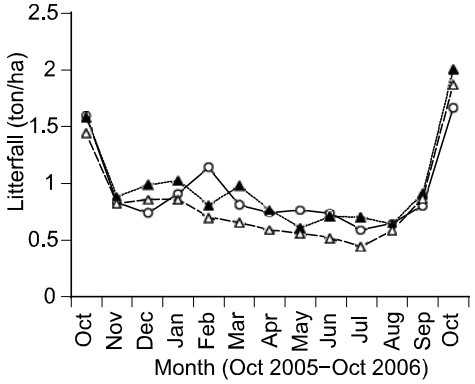

Fig. 4 Monthly litterfall for UF (open circle), DF (shaded triangle), and RF (open triangle)

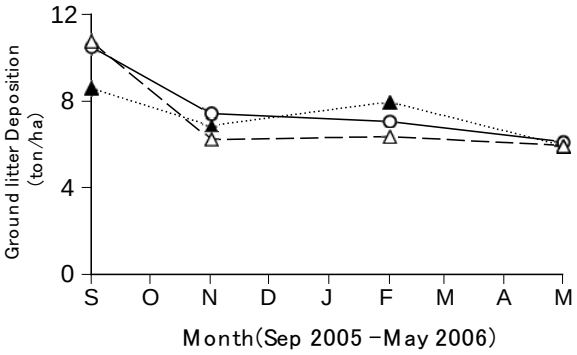

Fig. 5 Seasonal changes in the mass of litter deposition on the forest floor for UF (open circle), DF (shaded triangle), and RF (open triangle)

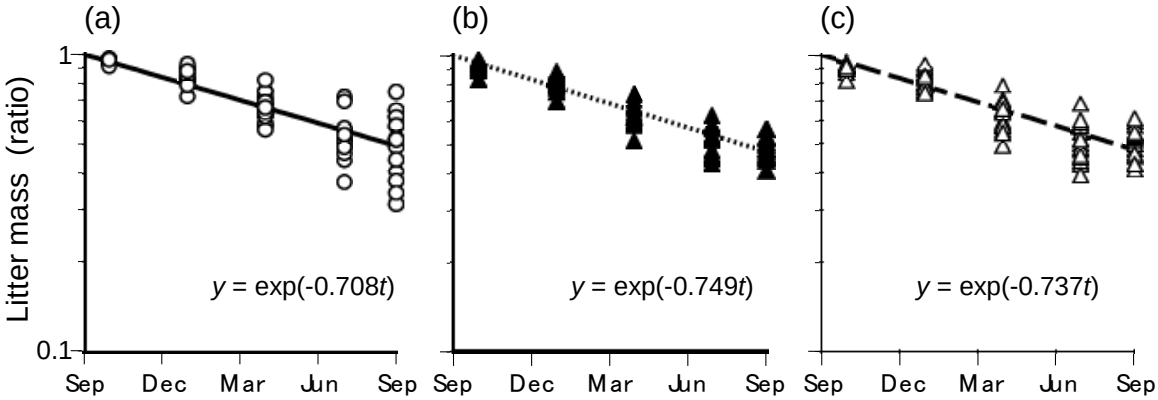

Fig. 6 Changes in the dry weight of *Combretcarpus rotundatus* leaf litter during the decomposition experiment for UF (a: open circle), DF (b: shaded triangle), and RF (c: open triangle)

According to the model estimation, peat deposition increased in UF, whereas it decreased in DF and RF. The thickness of the acrotelm layer rose to 4.9, -1.2, and -2.2 cm 5 years later in CF, DF, and RF, respectively. The amount of peat layer increased to 3.46, -1.60, and -2.86 kg/m^2 5 years later in UF, DF, and RF, respectively (Fig. 7).

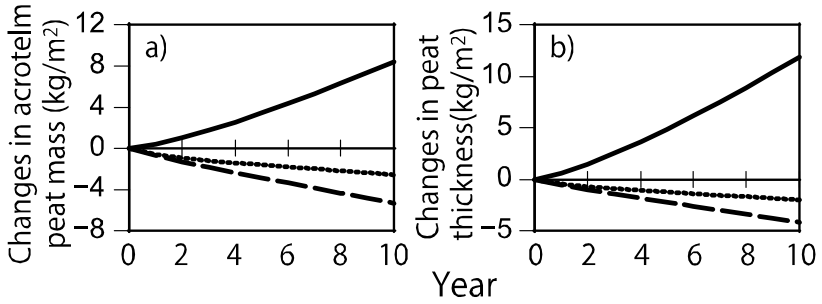

Fig. 7 Changes in a) peat deposition and b) peat surface height within 10 years as simulated by the model for UF (solid line), DF (dotted line), and RF (broken line)

DISCUSSION

The results of this study showed that the difference in mean annual GWL between DF and RF was 5.6 cm. Compared with the GWL of UF, which was near the peat surface during the wet season, the GWL of RF did not improve significantly. This is in line with the results of a previous study (Jauhiainen et al., 2008). This result was attributed to water seeping away from the dam surrounding the peat. The estimated volumetric soil moisture showed a trend similar to that of GWL. Soil moisture at the RF site was higher than that at the DF site, although it was far lower than that at the UF site. These results indicate that both GWL and surface soil moisture improved to some extent upon dam construction but did not return to pre-drainage levels.

Above-ground litter production was significantly higher in the DF site than in the RF site, whereas it was lower in RF than in UF. We do not know exactly if dam construction reduced the surface production to such an extent. One possible explanation for the decrease in production is the increase in flooding stress in RF. In general, flood tolerance may have a physiological cost because anaerobic conditions under the water level require oxygen transportation from above-ground organs. In addition, a lowered water table level puts peat under aerobic conditions and promotes decomposition. As peat decomposes, the plant-available nutrients are released. As a result, above-ground production increases. A higher water table level caused by dam construction possibly masked these effects and led to a decrease in above-ground production at the RF site. However, this does not explain why the UF site has a higher litter production than the RF site, despite having the highest water table. This possibly be explained by the condition of the UF site. The UF site is remote from the other two sites and is less intact. Therefore, the above-ground biomass is slightly higher than the other two sites (Neishi et al., unpublished data). It is possible that this difference in above-ground biomass may have led to the difference in litterfall volumes.

Belowground production was highest at the UF site, where the GWL was the highest. This result seems to contradict the case of above-ground production. Trees in wetland forests often allocate more to root biomass than other forms of forests, which can be attributed to their tolerance against water-saturating conditions (Khan et al., 2009). Thus, the flooding stress associated with the higher water table at the UF site increased the belowground production.

The higher water table level at the UF site is assumed to have reduced aerobic decomposition, resulting in a large amount of undecomposed litter deposits. However, neither the leaf litter decomposition constant nor above-ground litter deposition showed a significant effect on the sites. We are not sure why a significant difference in the decomposition constant was not found. In general, aerobic decomposition requires an appropriate humidity range. If this range is exceeded, the rate of decomposition decreases significantly. The sites where the experiments were conducted were on the peat surface and above the mean GWL, and it is possible that this is because none of the sites deviated from the appropriate humidity range. If there is a difference in the decomposition process among the sites, it would have been detected in the belowground process.

CONCLUSION

We found that restoration of peatlands by dam construction did not increase carbon storage. The possible reasons for this result are a decrease in above-ground production and no change in the decomposition rate at the peat surface. On the other hand, we found that dam construction led to some improvement in water levels and surface peat moisture content, which possibly reduced the fire risk to some extent. In addition, this study indicates the importance of organic matter dynamics in the subsurface area, particularly at the height where the water table changes due to dam construction; this was not investigated. Further studies are required to better understand the effects of dam construction on peat restoration.

ACKNOWLEDGEMENTS

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Research article

Crop Growth Model for Hydroponic Cultivation of *Solanum lycopersicum* (Tomato) in a Semi-automated System

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Abstract Hydroponics can be integrated into Controlled Environment Agriculture (CEA), in combination with greenhouses. They can successfully optimize the use of fertilizers and water for arid zones. Elevated costs of this type of agriculture lead farmers to implement semiautomated systems and use recyclable materials to stabilize plant productivity. This paper discusses the different growth ratios of tomato plants estimated with logistic curves when tap water with fertilizer (T1), reclaimed water (T2), and renewable water (T3) are used; additionally, a new module is presented to avoid underestimation of plant height when fertilization is carried out at the flowering stage. This model was adapted only for treatment 1. Logistic curves were created with low RMSE values using the least-square method. Despite presenting better mass volume and fruit quantity on reclaimed water treatment at the final stage of the plant, a t-test revealed that there is not a significant difference among treatments of renewable and reclaimed water for the height of plants. The adjustment of a logistic equation with the inclusion of a linear module allowed to decrease in the RMSE from 73 to 21 mm.

Keywords logistic models, tomato, hydroponics, wastewater, semi-automated systems

INTRODUCTION

Hydroponics and Wastewater

Controlled Environment Agriculture (CEA) is getting attention due to high productivity and adaptation to environmental changes. Saving resources is the main advantage of the direct application of nutrients to the plant's roots (Benke and Tomkins, 2018). To ensure this, automatic systems are installed to monitor water, air, CO_2, and other parameters; the higher the technology, elevation of the costs are inevitable. In automated systems, the balance of nutrients is usually pumped to the system

considering optimum values of EC and pH values in the water; in others, the amount of nutrients is applied manually depending on the stage of the crop.

Most hydroponic nutrient solutions are based on non-renewable sources, which eventually will cause depletion and/or inaccessibility by some farmers (Mikkelsen, 2019). The inclusion of wastewater in hydroponic systems offers an alternative use for wastes and has been analyzed from different perspectives, such as nutrient absorption or as a purifying system (Carvalho, 2018; Ottoson, 2005). However, it has been found that the use of wastewater in hydroponics is not enough to complete a crop cycle but can be achieved with the addition of fertilizers (Magwaza et al., 2020; Cifuentes-Torres et al., 2021; Da silva et al., 2018).

Meselmani (2022) recognizes the importance of a balanced amount of nutrients, pH, and oxygen, and appoints that excessive use of fertilizer is not required to secure crop productivity. Solis et al., (2020) attempted to establish recommendations for nutrient amounts but failed due to the interaction of several parameters engaged in plant growth, nevertheless, they found that the solution replacement periodically provides better results than those systems with single applications.

Tomato plants are known for having an undetermined growth, the ripening of fruits is not uniform, and farmers tend to harvest up to 3 times per season, being able to extend the life cycle of these plants inside greenhouses. In semiautomated systems, the late application of fertilizers combined with a large difference in day and night temperatures may cause the elongation of stems of plants, consequently, it can interfere with harvesting works and spacing inside a greenhouse (Myster and Moe, 1995). Although many authors are investigating the role of wastewater in hydroponics, there has not been integration of logistic models on plant growth. Furthermore, since the difference between reclaimed and recycled water relies on the number of microorganisms keeping it alive, therefore oxygenation and contents of N and P vary.

Crop Growth Models

Growth models also called mathematical models are useful equations to represent physical phenomena of real life. Simulations and predictions can successfully be modeled with the right parameters. Since the growth ratio of the crops is directly related to the nutrient content in the water, sigmoid models have a high accuracy in estimating the growth of crops due to their similar tendency to plant phenology (Di Crescenzo et al., 2021). Within these models, a logistic curve is characterized by a "s" shape; crop growth can be well represented with this type of graph due to slow growth in the early stage, fast vegetative development, and cessation of activities for the end-of-life cycle.

OBJECTIVE

Using a hydroponic system, the purpose of this study is 1) to compare the growth of tomato plants using logistic curves when reclaimed and renewable water is applied and 2) to adjust a logistic equation when additional fertilizer is introduced.

Table 1 Chemical properties of water in every treatment (ppm)

	T-N	T-P	Cations				Anions				
			Na^+	K^+	Mg^+	Ca^+	Cl^-	NO_2^-	NO_3^-	PO_4^-	SO_4^-
T1	1.71	0.47	8.11	2.02	4.81	19.30	6.74	0.19	2.72	0.01	18.80
T2	8.75	1.83	126.50	18.10	10.40	31.40	173.00	0.00	31.10	0.07	92.50
T3	7.46	1.86	115.00	17.10	10.90	31.60	160.50	0.82	21.70	0.17	86.50

Source: Own analysis at the Laboratory of Hydro-structure Engineering, Tokyo University of Agriculture.

METHODOLOGY

The experiment was carried out inside a semiautomated greenhouse located in the facilities of the Hokubu-Daini Wastewater Treatment Plant in Yokohama City, Kanagawa Prefecture, Japan. Tomato seeds were transplanted after 7 days of sown on a portion of a hydroponic plot of 10 m x 1 m. Three

treatments were set: T1) tap water and fertilizers, T2) reclaimed water (with secondary treatment), and T3) renewable water (with tertiary treatment) (Table 1); the composition of the fertilizer applied to T1 is shown in Table 2. Fertilizer applications were made on the 1st and 49th days after transplanting (d). Daily temperature and relative humidity were registered using a Hobo datalogger.

Table 2 Nutrient content in soluble fertilizer OAT House No.1＆ No.2 (ppm)

	TN	AN	NN	P_2O_5	K_2O	MgO	MnO	B_2O_3	CaO	Fe	Cu	Zn	Mo	EC (dS/m)
OAT House No.1 & No.2	260	23	233	120	405	60	1.5	1.5	230	3	0.03	0.1	0.03	2.6

TN=Total Nitrogen, AN= Ammonia Nitrogen, NN=Nitrate Nitrogen, Source: oat-agri.co.jp

The creation of logistic curves was following Eq. 1 (Bacaër, 2011).

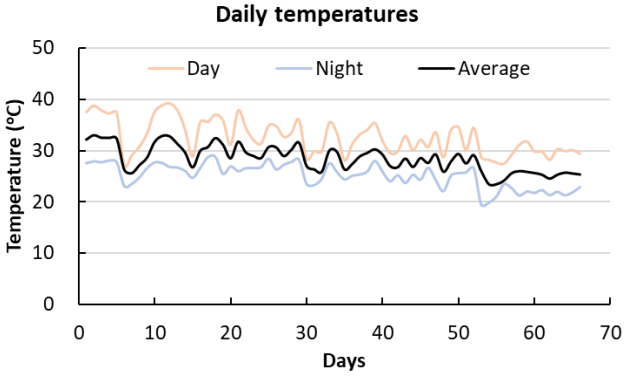
$$y = \frac{k}{1+be^{-cx}} \quad (1)$$

Where y is the dependent variable, k is the upper limit of plant height, x is the independent variable, and b and c are coefficients. Recently Fang et al. (2022) compared Gompertz curves and logistic curves, and even when GDD (growing degree-days) models provide a slightly better performance than those when using DAT (days after transplanting) as independent variables, there is no great difference to be considered as a discriminant for DAT.

RESULTS AND DISCUSSION

Temperature

Daily temperature data in Fig. 3 shows that higher temperatures were recorded at the beginning of the experiment, having peaks of 39℃; on the other hand, the lower temperatures were registered at night by the end of the experiment due to winter proximity. Regimes of CO_2 were kept below 500 ppm during the experiment.



Note: day and night averages were estimated from 6:00 to 18:00 and from 18:00 to 6:00, respectively.

Fig. 1 Temperature recorded with Hobo datalogger

Growing Logistic Models

For height estimation, parameter K in Eq. 1 was substituted by the maximum height measured in every treatment. Coefficient *b* stands for crop growth in the middle of the period, a low value of *b* represents high crop growth, while a high value indicates small growth. The growth ratio of tomato is denoted with a *c* letter in the equation. To find optimal values of *b* and *c*, the Solver function in Excel was selected to calculate them by the least squares method. Height "y" is the dependent variable of "x" which represents the change in days after transplant (d).

When comparing the evolution of crop growth among the two types of wastewaters, it was observed that there are similar values for maximum plant height on T2 and T3 (T2=1,141 mm, T3=1,052 mm), the T-test shows that there was not a significant difference on plant height among T2 and T3 of the data collected weekly. On the other hand, b values represent the amount of crop growth during the middle of the period in observation (35 days), pointing out that the development of crops on T2 was almost two times that of those on T3 (T2: *b*=284, T3: *b*=489) (Table 3). However, regarding crop growth ratio, it is observed that plants under both treatments had a relatively similar *c* coefficient value, showing that there is no significant difference among them.

Table 3 Parameters of logistic equations with single logistic curves for each treatment

	T1	T2	T3
K (mm)	1,506	1,141	1,051
b (adim)	39.7	283.9	489
c (adim)	0.0874	0.1191	0.134
RMSE	73	28	23

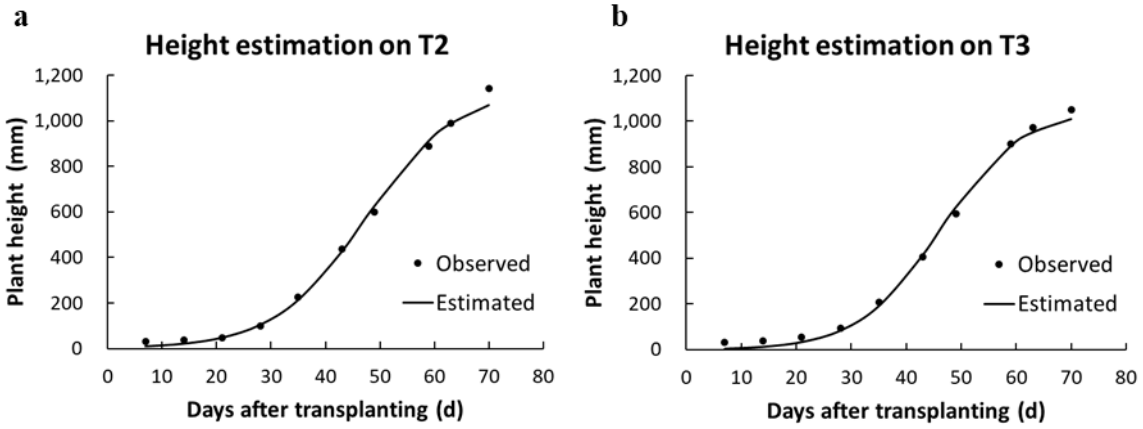


Fig. 2 a) Estimated height for treatment with reclaimed water (T2) and b) Estimated height for treatment with renewable water (T3)

The amount of crop (*b*) and growth ratio (*c*) had much better performance on T1, though a high RMSE was obtained. It was noted that the reason for the high RMSE was derived from the second application of fertilizer in this treatment, therefore a new module was adapted to the equation to be able to simulate this event. The new module was integrated with the difference between the last measure previous the application of fertilizer and the estimated height with a logistic curve. For the new logistic curve, K, which represents the maximum plant growth, was taken as the maximum height before the application of fertilizer. The module resulted in a linear equation after the second fertilization. The parameters of the equations are shown in Table 4.

Table 4 Adjustment parameters for the combined model

	Original Logistic curve	Adjusted logistic curve	Linear module	Combined equations
K (mm)	1506	898.8	-	898.8
b (adim)	39.7	212	-	212
c (adim)	0.0874	0.1785	-	0.1785
d (adim)	-	-	27.76	27.76
e (adim)	-	-	159.87	159.87
	RMSE=73	RMSE=18	R^2=0.98	RMSE=21

To estimate the plant height after transplant (y) and the height after second fertilization (y_1) in T1, it is necessary to introduce the values of days after transplant (x) and days after second fertilization (x_1). Eq. 2 can be used to estimate plant height before fertilization while Eq. 3 includes Eq. 2 to obtain estimations after fertilization.

$$y = \frac{898.8}{1+212^{-0.1785x}} \tag{2}$$

$$y_1 = y + 27.76x_1 + 159.87 \tag{3}$$

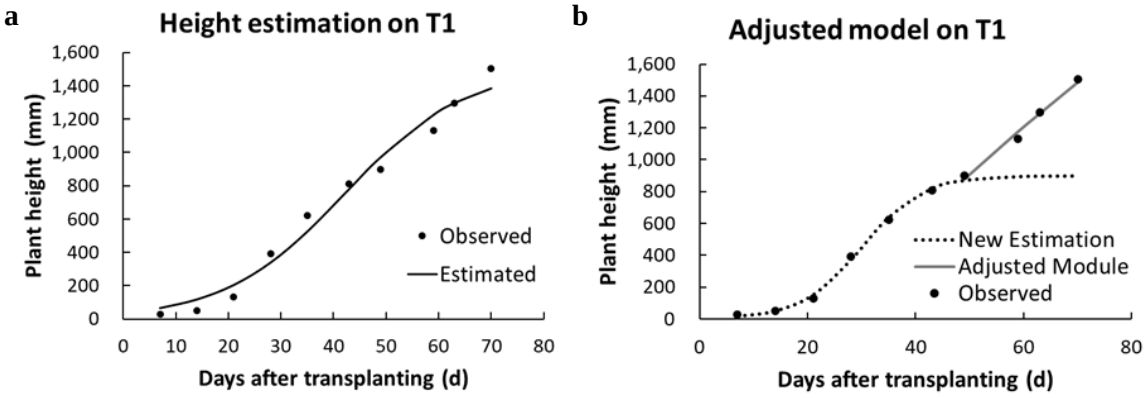


Fig. 3 a) Height estimation with a single logistic curve and b) Adjustment of estimation model after fertilization

With the modified equations, RMSE was improved from 73 to 21 mm (Table 4), therefore the inclusion of the new module significantly improved the estimation of plant height when sudden fertilization is considered.

Despite the constant decrease of temperature from the beginning until the end of the season (Fig. 1), the estimation of plant height when being irrigated either by renewable water or reclaimed water can be predicted with a single logistic curve (Figs. 2a, 2b). The growth of plants with wastewater is a great opportunity for the reuse of Nitrogen and Phosphorus, the correct implementation of the nutrient is necessary to avoid the overgrowth of steam, moreover, fertilizer application should be selected based on the nutrient content to enhance fruit development and considering the proper stage of the crop.

CONCLUSION

In principle, the use of logistic curves can highly estimate the growth of tomato plants in semiautomated systems when being irrigated either by renewable or reclaimed water and when their natural phenology is not perturbed; despite having notable differences in the amount of growth by the middle of the period there were no significant differences in the growth ratio among these two treatments. When sudden fertilization occurs, a logistic curve can be expanded with a new module that estimates the plant height according to the days after fertilization. This model can improve height estimation for these plants under greenhouses and can be used to avoid the overgrowth of plants inside these facilities. Since the "x" variable on the modified logistic curve depends directly on the daily phenology performance in each crop, this module can be studied and adopted in similar crops such as shrubs, herbs, and other vegetables.

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Research article

Physical Structure Assessment of Rivers Used by Grazing Livestock

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Abstract In recent years, the demand for meat has increased due to changing dietary habits as well as global population growth. In response to the increased demand for livestock products, grassland ecosystems are increasingly used for grazing and feed crop production, raising concerns about the negative environmental impacts caused by the expansion of livestock production. The author has studied a beef cattle farm that is one of the few farms in Japan that uses forest grazing. There have been concerns about the negative impact of farming grazing livestock near water bodies. When considering sustainable grazing livestock farming, the challenge is to conserve water quality and propose appropriate habitat design to conserve biodiversity. River ecosystem studies require an assessment of the physical environment and surveys of the number of organisms. RHS-HQA is a method developed in the UK and is a relatively easy survey method for obtaining information. This study investigated how grazing cattle use the rivers present in their pastures. A physical environment survey using the RHS-HQA was also carried out to investigate the status of the river on the grazing land. Based on these results, the environmental design of pastureland for sustainable grazing livestock production was discussed, with particular attention to rivers and other riparian areas. The results of the RHS-HQA showed that the river flowing through the target farm was maintained in its natural state, with diverse flow and bed material and a suitable bank environment for biological habitat. Also, the results suggest that by maintaining riparian forest between the grazing land and the river, riverbanks are less likely to become bare or collapse even when grazing cattle use rivers.

Keywords physical structure assessment, RHS-HQA, forest-grazing, pasture-based livestock

INTRODUCTION

There is no question that one of the international challenges we face today is the food problem. Developing countries, the main areas of population growth, have reported a change in diet, shifting from a grain-based diet to a growing demand for meat. The FAO has projected meat consumption to 2050 based on trends in meat consumption from 1961 to 2013; meat consumption is projected to increase rapidly from 376 million tons in 2013 to 557 million tons in 2050.

Jiaguo et al. (2017) investigated the sustainability of current land use and management practices in the Asian Dry Belt, where grassland ecosystems are increasingly used for grazing and forage crop production to meet the increasing demand for livestock products. As a result of their survey, they reported that "While current approaches alleviate the urgent need for short-term livestock production, they need to long-term vulnerability in food security. Trade-offs between short gains and long-term losses, between food for humans and animals, and between agricultural intensification and environmental degradation need to be holistically examined for the region's sustainable development". The relationships between different ecosystem services are very complex; improving the function of one ecosystem service may have "synergies" that enhance the function of other ecosystem services but may also cause "trade-offs" that reduce the function of other ecosystem services.

The author has studied a beef cattle farm that uses forest grazing as one of the few examples in Japan. A small waterway and part of a river flow through the farm, and grazing cattle can also use these water bodies. There have been concerns about the negative impact of grazing livestock farming on water bodies. When considering sustainable grazing livestock farming, the challenge is to conserve water quality and propose appropriate habitat design to conserve biodiversity.

River ecosystem studies require a physical environment assessment and surveys of the number of organisms. The European Water Framework Directive (WFD) aims to improve all water bodies to good ecological and environmental status; the ecological assessment includes biology, hydrogeomorphology, and chemical physics assessment items. Several countries and institutions have proposed river physical environment surveys, with HABSDORE, AUSRIVAS, and SEQ-MP being prominent. RHS-HQA is a method developed in the UK (Raven et al., 1998), which has been implemented in many cases (Costa and Vieila, 2021; Stefanidis et al., 2022) and is a relatively easy survey method for obtaining information. RHS-HQA has been applied in Japan by Oishi et al. (2006) and Nakajima et al. (2010); this study used this assessment method in a stream survey in a forest grazing area.

OBJECTIVE

This study investigated how grazing cattle use the rivers present in their pastures. A physical environment survey using the RHS-HQA was also carried out to investigate the current status of the river on the grazing land. Based on these results, the environmental design of pastureland for sustainable grazing livestock production was discussed, with particular attention to rivers and other riparian areas.

METHODOLOGY

Overview of Forest Grazing

The research target is the beef cattle grazing farm (K Farm), located in the eastern part of Hokkaido, Japan. The site covers an area of approximately 100 ha and includes pastureland, grassland, forests, rivers and waterways, a former cattle barn (no longer used as a barn), and storage facilities. The farm is raised with Aberdeen Angus and, as of 2020, had a stock of approximately 100 head. The pasture is open from April to November, and grass harvested from the K Farm's meadows is fed from December to March, as snow cover prevents grass from foraging on pasture. In addition, the pastures and forests are separated by roads and rivers on the property (Fig. 1(a)).

Behavior Survey of Grazing Cattle

Fifteen sensor cameras (Ltl-6210 PLUS, Zhuhai Ltl Acorn Electronics Inc.) were installed on grazing cattle movement routes and at gates on the property to observe cattle behavior. The sensor camera was fixed at a height in the pasture, such as a tree or gate, where cattle could not reach, using a belt attached to the camera. Day and night still images were taken in infrared sensor mode. Sensor cameras have been installed continuously since 2018, but this report only presents the results of one sensor camera installed in the river (the location is shown in Fig. 1) from April to November 2020.

River Habitat Quality Assessment (RHS) with Habitat Quality Assessment (HQA)

The RHS-HQA was conducted on the river (the S River) flowing through the K Farm. The S River is a class B river in Hokkaido, with a channel length of 19.0 km and a catchment area of 2,029 km^2. In this report, a 500 m section of the S River (red line in Fig. 1(a); Fig. 2(b)), where the K Farm's pasture (Pasture-R1 and Pasture-R2 in Fig. 1(a)) is adjacent, was the study site.

The RHS is a system to assess the characteristics of the river environment based on indicators of the physical environment. The RHS is carried out along the 500 m length of river channel.

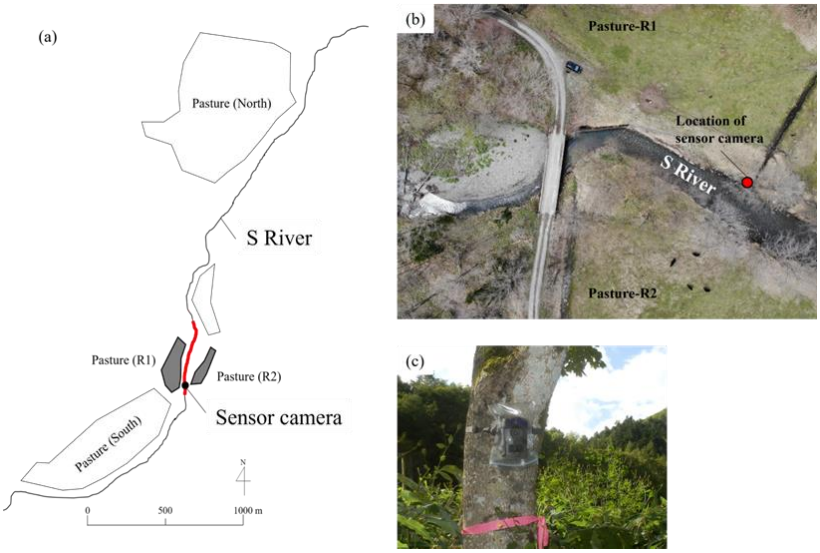

Fig. 1 (a) Schematic diagram of the K Farm; (b) Aerial images of the target site of the RHS; (c) Sensor camera installed in a tree near the S River

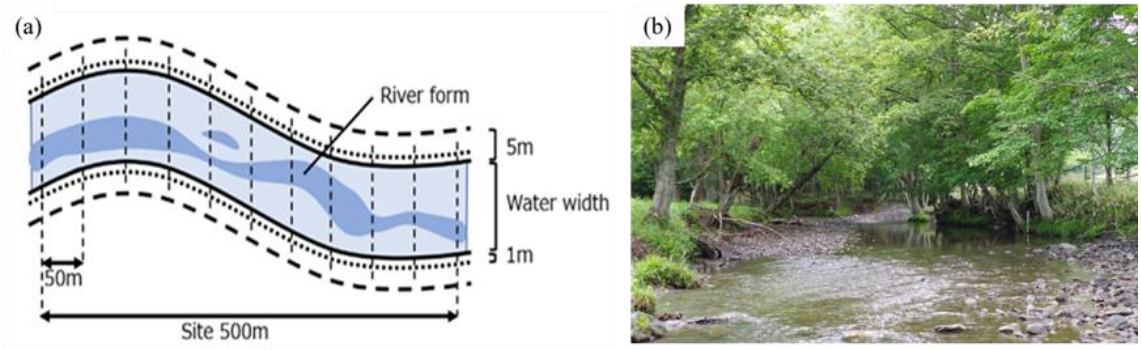

Fig. 2 (a) Dimensions for spot-check; (b) View of the S River taken from near the sensor camera

Observations are made at ten equally spaced spot-checks along the channel, whilst information on valley form and land-use in the river corridor provides additional context (Fig. 2(a)). Spot-checks are designed to record predominant channel, bank, and river corridor features at 10 locations spaced evenly along the 500 m RHS site. In this study, observations were made on six of the RHS survey sections (C, E-H and J). Section C records the cross-sectional shape of the river and the number of riffles, pool, unvegetated point bar, and vegetated point bar. Section E and F records physical attributes and bank top land-use vegetation structure on each spot-check points. Sections G records channel vegetation types on each spot-check point. Section H records land-use within 50 m of bank top on each spot-check point. Section J records the extent of trees and associated features of 500 m RHS site.

The results of the RHS are scored according to the HQA scoring system. The HQA is designed to assess the diversity and naturalness of the physical structure of biological habitats and is a system for assigning scores to items relating to the natural environment obtained from the RHS at a single site. The HQA gives a higher score if there are many spots with different attributes within the RHS site, or if the site has physical environment attributes that are important for riverine organisms.

RESULTS

Actual Use of Rivers by Grazing Cattle

Figure 3 shows the total number of daily photographs of the sensor cameras installed on the rivers took from April to November 2020. Note that the sensor camera was set up so that the sensors responded at five minutes intervals after taking a picture. Therefore, if grazing cattle stay in one location for an extended period, multiple photos are taken in an hour. Here, the total number of pictures taken within an hour was converted into one shot to investigate daily usage around the river during the grazing period. Grazing cattle were observed to move between other pastures on the property, appearing in the riverside pasture at approximately one-month intervals, staying there for about two weeks, and then moving back to other pastures. The number of days spent in each grazing area is thought to depend on the grass condition, but in 2020 the grazing areas by the river were used more frequently compared to other pastures. Next, the total number of shots by time is shown in Fig. 4. Here, the number of shots taken within an hour was directly tabulated to consider the time spent around the river. Grazing cattle were active from sunrise to sunset, with many shots taken between 4:00 and 18:00. Noon showed the highest frequency and duration of stay. Still, there was no significant tendency to use the river area at a specific time. Therefore, grazing cattle freely enter and leave the rivers while staying in the pasture around them.

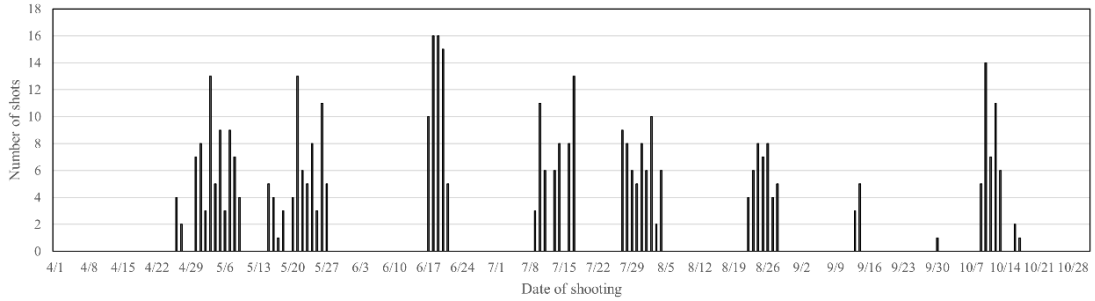

Fig. 3 The total number of daily photographs of the sensor camera

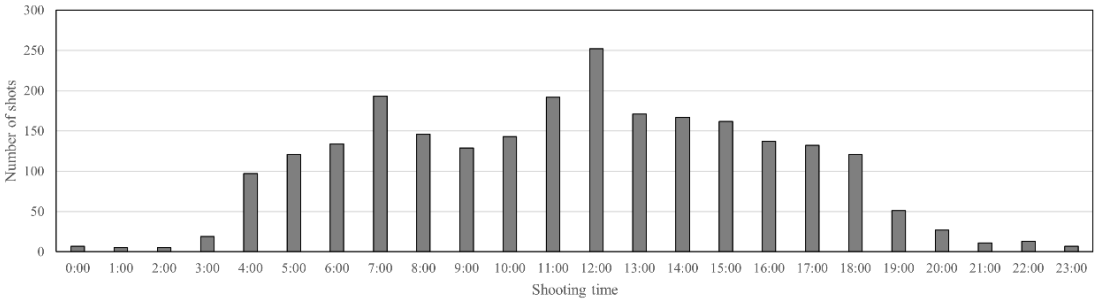

Fig. 4 Total number of photographs of the sensor camera by time

Survey Results of the Physical Environment of the River in the Grazing Area

The RHS-HQA scores of the S River are shown in Table 1. The total score of the S River was 60. This score is higher than those reported for other rivers in Japan (Oishi et al., 2006; Nakajima et al., 2010) and can be regarded as a physical environment in which the natural environment is maintained. High scores in four sections were characterized: flow type in section E1, riverbed morphology in E2, bank features in E4, and land use within 50 m of the bank in H. A wide variety of flow types and riverbed materials were identified at each spot in the S River (Fig. 5(a)). The upper reaches of the S River have many meandering channels (Fig. 5(b)), and many vegetation bars and pools (Fig. 5(c)) were observed. Thus, the meanders of the river, formed by the action of the river's flow, are considered essential elements of the physical environment of the river and are the reason for the high HQA score.

Table 1 The score of the RHS-HQA

Section	Categories	Attributes	Result
C	Number of riffles pools and point bars	The total number of un vegetated and vegetated point bars	2
E1	Flow types	Broken standing waves, un broken standing waves, chaotic floe, smooth, no perceptible flow	8
E2	Channel substrates	Bedrock, boulder, cobble, gravel, sand, silt, clay	8
E3	Channel features	Exposed bedrock/boulders, unvegetated mid-channel bar, vegetated mid-channel bar, mature island	5
E4	Marginal and bank features	Eroding earth cliff, stable earth cliff, unvegetated/vegetated point bar, unvegetated/vegetated side bar	19
F	Bank vegetation structure	Each bank of bankface and banktop are scored. Only simple or complex vegetation structure score.	6
G	In-stream channel vegetation	Liverworts and mosses, emergent broad-leaved herbs, emergent reeds/rushes/sedges, floating-leaved, free floating and amphibious, submerged broadleaved, submerged liner and fine-leaved	2
H	Land-use within 50m	Each bank is scored separately. Only broadleaf woodland (or native pinewood), moorland/heath, and wetland score.	7
J	Trees and associated features	Each bank is scored separately. Extent of tree and associated features. Associated features are overhanging boughs, exposed bankside roots, under water tree roots, coarse woody debris and fall on trees	3

Fig. 5 (a) Variety of flow types and riverbed materials; (b) Meandering channels; (c) Vegetation bars

DISCUSSION

The results of the physical environment survey showed that the S river in the pasture was maintained in its natural state, with diverse flow and bed material and a suitable bank environment for biological habitat. Here, we discuss the relationship between rivers and grazing livestock production.

First, using water troughs is a method of supplying water to livestock in grazing. In contrast, using rivers or waterways in pastureland, as in the K farm, can save labor in providing water to water troughs and allow grazing cattle to always drink fresh water (Fig. 6(a)). This can be evaluated as a synergistic effect of the river functions on the supply of livestock products by forest grazing.

Using the river by grazing cattle may have adverse effects, such as soil erosion due to trampling and bare banks due to foraging. No river repairs or other improvements were observed in the study section of this report, where grazing cattle frequently used the river. Also, there is no bare bank or severely eroded condition. One factor contributing to these is the riparian forest. The study section maintains a riparian forest of about 3-5 m in width between the grazing land and the river (Fig. 6(b)). The opening part of this riparian forest set up a cattle movement route like a gate. The riparian forest restricts the movement of cattle, and the path of movement of the grazing area of the river is fixed. This may inhibit cattle from staying in the river and inside the riparian forest for long periods, thereby preserving the river environment. On the other hand, there is also concern that the presence of riparian forest within the grazing area may represent a trade-off for vegetation within the grazing area. In R1 and R2 pastures, grass declined on the edge of the riparian forest, and an invasion of bamboo and wildflowers was observed (Fig. 6(c)). Grazing cattle did not use the part of bamboo grass encroachment during high pasture growth season from May to September. However, they have also been observed to forage for weeds in April, when pasture grasses have not grown sufficiently immediately after the snow melts, and in October and November, when pasture grass growth is

suppressed due to lower temperatures because they cannot forage for sufficient grass in the pasture. In addition, forest floor vegetation in woodlands, including riparian forests, tends to be maintained even when pasture biomass is reduced due to a lack of sunlight or insufficient rainfall. The establishment of riparian forests in grazing areas may be described as securing an alternative food resource to pasture grasses.

Fig. 6 (a) Cattle using the S River; (b) Riparian Forest on the S River; (c) Invasion of bamboo into the riparian forest

CONCLUSION

The forest grazing of the K farm can both maintain the physical environment as a habitat for diverse organisms and use it for grazing. One of the factors contributing to this was the preservation of riparian forests. In the future, a comprehensive assessment of the river environment should be carried out, including analysis of river water quality and biological surveys. In addition, a more detailed analysis of the synergies/trade-offs of ecosystem services from forest grazing should also be carried out to accumulate knowledge on sustainable forest grazing.

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Research article

Effects of Aeration and pH on the Performance of Lactic Acid Bacteria-Attached Carbon Fiber Electrode

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Abstract Lactic acid bacteria (LAB) and iron ions dissolved from steelmaking slag (SS), when attached to an electrode surface, improve the performance of carbon fiber electrodes. However, the electrode potential decreases during the attachment (fermentation without aeration), leading to decreased electrode performance when used as a cathode. Additionally, SS dissolution increases the solution pH, which can affect the survival rate of LAB. This study examines the effects of aeration on an electrode potential and solution pH on the survival rate of LAB in solution during fermentation. In the experiments, SS, LAB beverage, bamboo powder, and carbon fiber electrodes were placed in a bottle with and without aeration. Temporal measurements of the solution pH, iron ion concentrations, adenosine triphosphate (ATP), and electrode potential were performed. The results showed that aeration could prevent a 0.5-fold decrease in the electrode potential due to fermentation. The solution pH temporarily increased and exceeded eight during the fermentation, suggesting that SS had been dissolved. ATP began to decrease when the solution pH exceeded 8, indicating that the solution pH influences the survival rate of LAB. It is recommended that the fermentation should be conducted within three days. Furthermore, to improve the performance of a sediment microbial fuel cell (SMFC), the electrodes with and without aeration should be used as the cathode and anode of SMFC, respectively.

Keywords Carbon fiber electrode, steelmaking slag, lactic acid bacteria, aeration, pH

INTRODUCTION

Microbial fuel cell technology (MFCT), which can be used to treat organic waste, household sewage, and agricultural wastewater, as well as supply electricity to homes and recycle resources back on farmlands, has drawn the interest of many researchers. It is believed that MFCT will provide numerous benefits for addressing and solving social issues such as organic waste disposal and energy scarcity, particularly in developing countries. However, the performance of MFCT remains low and must be improved before it can be used in practice. Increasing electrode performance is one way to improve the MFCT performance. According to Yamasaki et al. (2018), various potential losses occur during electron flow to an electrode. One of these is activation loss, which significantly impacts electrode performance. Pretreating the electrode is widely used to minimize activation loss.

Adsorption of bacteria or metal ions on an electrode surface is one way to improve electrode performance. Wang et al. (2009) successfully enhanced electrode performance by activating bacteria at the electrode, resulting in lower potential losses. The improved electrode performance caused by bacterial attachment and biofilm formation has been widely studied using cyclic voltammetry (Carmona-Martinez et al., 2011; Kang et al., 2012). Nishimura et al. (2018) reported that ferric ions

dissolved from steelmaking slag (SS) improved sediment microbial fuel cell (SMFC) performance. Using SS and lactic acid bacteria (LAB) in the anode of SMFC could enhance SMFC performance (Touch et al., 2020).

On this basis, research into the changes in the performance of carbon fiber electrodes caused by the attachment of iron ions (Fe) dissolved from SS and LAB on the electrode surface has begun (Touch et al., 2022). The performance of the carbon fiber electrode improved after attaching (fermentation without aeration) LAB and Fe dissolved from SS on the electrode surface. However, the electrode potential decreases during the fermentation without aeration, decreasing electrode performance when used as a cathode. Therefore, aeration should be provided during the fermentation. Additionally, the dissolution of SS increased the solution pH, which may impact the survival rate of LAB.

OBJECTIVE

This study investigates the effects of aeration on an electrode potential and solution pH on the survival rate of LAB in the solution during fermentation. Changes in the electrode potential owing to the fermentation are subsequently investigated. Moreover, polarization (current–voltage relation) is measured to detect alterations in SMFC performance when the fermented electrodes are used as the cathode and anode for the long-term current generation.

METHODOLOGY

Experimental Materials and Procedures

Touch et al. (2022) proposed a simple attachment process of iron ions dissolved from SS and LAB on the surface of carbon fibers. An attachment process similar to Touch et al. (2022) was used in this study.

Three liters of tap water were filled into cylindrical bottles with inner diameters and heights of 158 and 193 mm, respectively. Fig. 1 shows a schematic of a bottle with a 20-mm depth of SS and a 10-mL lactic-fermenting beverage (a commercial product). 3g of bamboo powder was added to the bottles, and fermentation reduced the solution pH. This process facilitates the dissolution of iron from SS, and nutrients from bamboo powder can activate LAB. An air stone was placed on the SS layer in the case with aeration, and carbon fiber electrodes were positioned 90 mm from the bottle bottom.

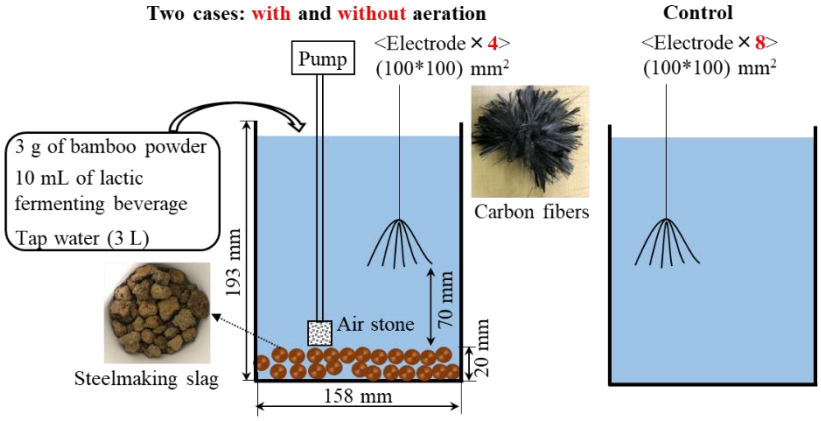


Fig. 1 Experimental devices and materials

Carbon cloth (News Company, PL200-E) was used as the electrode material, and it was preheated at 500°C for 1 h to improve its performance (Nagatsu et al., 2014). The heated carbon cloth with a 100-mm width and length was separated into fibers to form a brush-type electrode (Fig. 1).

Four electrodes were placed in a bottle without aeration, four electrodes in a bottle with aeration, and eight electrodes in a bottle filled with only tap water (Fig. 1, Control).

Operations and Measurements

Experiments were conducted for 22 days following the schematic in Fig. 2. At 3, 7, 10, and 22 days after the experiment began, the potential of each electrode was measured using a voltmeter and an Ag/AgCl reference electrode.

The pH, redox potential (ORP), Fe concentration, and adenosine triphosphate (ATP) of the solution were measured on the day of measuring electrode potential. The pH and ORP were measured using a pH/ORP meter (Horiba, D-50), Fe concentration was measured using PACKTEST (Kyoritsu Corp., WAK), and ATP was measured using a lumitester (Kikkoman, Lumitester-Smart).

The fermented and control electrodes extracted from the bottles on Day 3 were used as the cathode and anode of SMFCs to examine the long-term performance of SMFCs for electricity generation (Fig. 2b). For the electrical current generation, an external resistance of 1 Ω was loaded between the anode and cathode. Several polarization measurements were performed throughout the electricity generation using the circuit in Fig. 2a to examine the performances of SMFCs. In the polarization measurement, an external resistance with 1 Ω–9.1 kΩ was loaded between the anode and cathode. Cell voltage was recorded 1 min after loading each external resistance and used to calculate the current according to Ohm's law: $I = U/R_{ex}$, where U [V] is the voltage, I [A] is the current, and R_{ex} [Ω] is the external resistance. The power P was calculated using $P = IU$. Current and power densities were obtained by dividing these values by the surface area of the electrode, i.e., 0.01 m^2. The maximum current density was also determined using polarization, as Nagatsu et al. (2014) described.

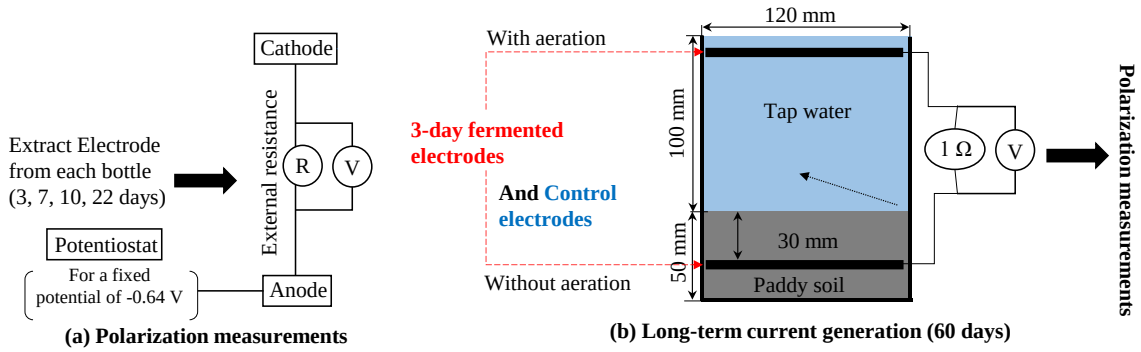


Fig. 2 Operation and measurement methods

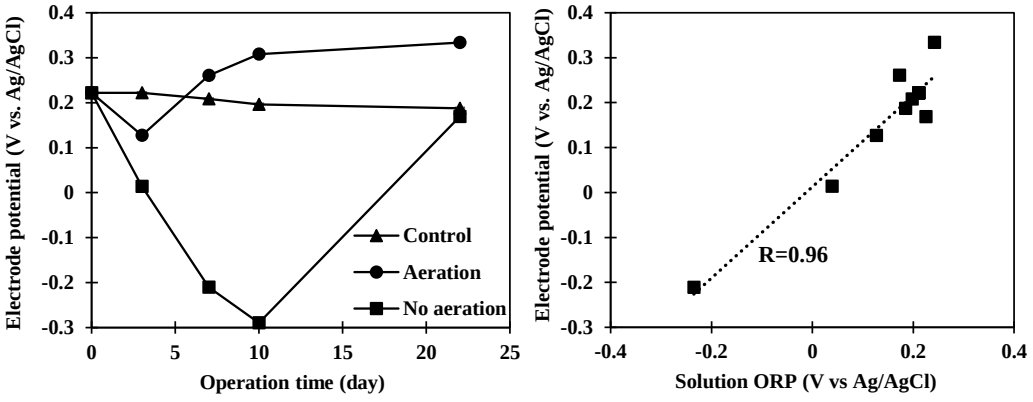
RESULTS AND DISCUSSION

Effects of Aeration on the Electrode Performance

Touch et al. (2022) discovered that the electrode potential decreased during fermentation without aeration. However, they were unclear about the decreasing characteristics of the electrode potential under the fermentation with and without aeration. Fig. 3 showed a comparison of the electrode potential and the solution ORP.

The electrode potential was 0.21 V on average for the control electrode during the experiment. On Day 3, the electrode potential decreased to 0.13 and 0.01 V for the electrodes fermented with and without aeration, respectively (Fig. 3a). Although aeration was performed, electrode potential decreased due to the fermentation of the bamboo powder. However, a 0.05 V decrease in the electrode potential was observed when aeration was performed, whereas a 0.11V decrease in the electrode potential was observed without aeration. Without aeration, the electrode potential further decreased to − 0.29 V (on Day 10) but increased to 0.31 V (on Day 10) when aeration was performed.

As expected, aeration can reduce the decline in electrode potential caused by fermentation. Interestingly, the electrode potential with aeration was high compared to that of the control electrode, suggesting that the higher performance of the electrode was due to the adsorption of LAB and iron ions on the electrode surface when aeration was conducted. Although without aeration, the electrode potential increased from -0.29 to 0.17 V (Day 10 to 22), suggesting that the fermentation of bamboo powder intensively occurs during only the first ten days. Furthermore, it was observed that the electrode potential had a high correlation (R = 0.96) with the solution ORP (Fig. 3b), indicating that the electrode potential depends on the characteristics of the solution. The electrode potential decreased when the electrode was place in a solution with a low ORP.

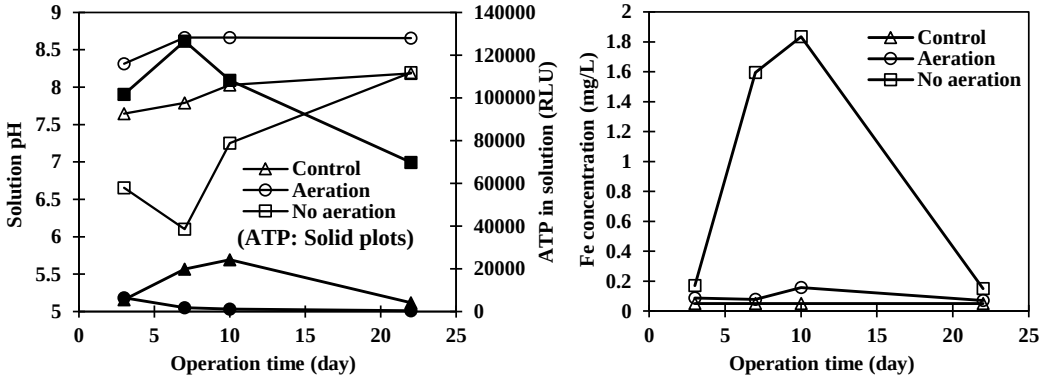


(a) Electrode potential (b) Correlation of solution ORP with electrode potential

Fig. 3 Electrode potential under different conditions and its relationship with solution ORP

Effects of Dissolution of Steelmaking Slag on LAB

Figure 4 depicts the temporal changes in the solution pH, ATP, and Fe concentration. On Day 3, the solution pH for the control case was 7.6, for the aerated case was 8.3, and for the unaerated case was 6.7 (Fig. 4a, open plots). The solution pH differed due to bamboo fermentation (acidification) and dissolution of SS (alkalization).



(a) Solution pH and ATP in solution (b) Fe concentration in solution

Fig. 4 Temporal changes in pH, ATP, and Fe concentration

The pH of a solution generally rises when SS is dissolved, whereas it decreases due to the release of organic acids during bamboo fermentation. With aeration, the SS dissolution was significant in changes the solution pH because the released organic acids were oxidized. This is the cause of the increase in solution pH in the aerated case. However, without aeration, the solution pH decreased to 6.1 on Day 7 due to the release of organic acids. When the fermentation was completed, the

accumulated organic acids started to oxidize. In addition to the SS dissolution, this oxidation contributed to the increasing pH, as shown in Fig. 4a.

Fe concentration increased in both cases with and without aeration (Fig. 4b), indicating SS dissolution during fermentation. Remarkably, a 20-fold high in Fe concentration was observed in the unaerated case compared with that of aerated case, suggesting that fermentation without aeration can effectively facilitate the dissolution of Fe from SS.

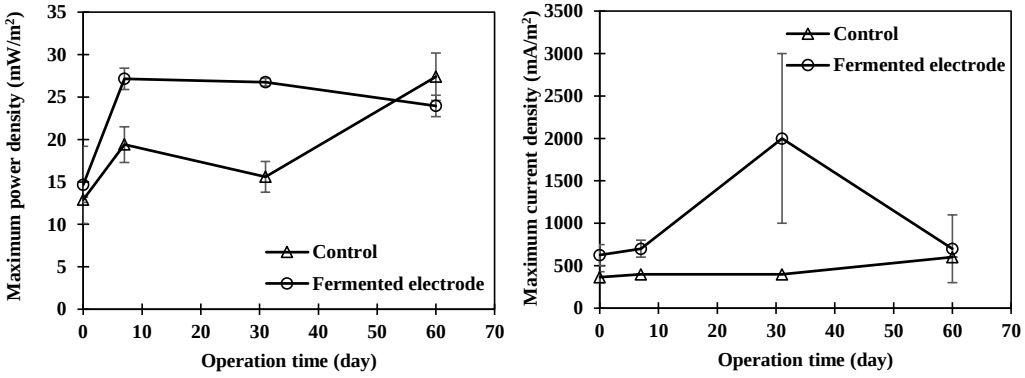
The decreasing ATP appeared when the pH was 8.0 for the control case, 8.3 for the aerated case, and 7.3 for the aerated case (Fig. 4a, solid plots). This ensured that an increase in solution pH influenced the survival rate of LAB. It is thought from this result that pH should be kept at less than 8, and preferably in an acidic state during the fermentation.

Overall, the fermentation period should be less than three days, especially if aeration is used. To increase the performance of SMFC, the electrode fermented with aeration should be used as the cathode, and the electrode fermented without aeration should be used as the anode. As shown in Fig. 2, experiments were conducted to verify our suggestion, and the experimental results are discussed in the following section.

Long-Term Performance of the Fermented Electrode

Figures 5a and 5b show the comparison of performance (power and current density) of SMFCs when using the electrodes with and without fermentation. As expected, the maximum power density (P_{max}) and current density (I_{max}) of SMFCs that used fermented electrodes were higher than those that used control electrodes (without fermentation). When fermented electrodes were used, P_{max} was 27 mW/m^2 (Fig. 5a) and I_{max} was 2000 mA/m^2 (Fig. 5b) on Day 31. Compared with those that used control electrodes, a 1.7-fold increase in P_{max} and a 5-fold increase in I_{max} were observed. As discussed earlier (Fig. 3), the cathode is more effective when fermented with aeration, and the anode is more effective when fermented without aeration. This increased electromotive force, which increased the current density.

However, the performance was approximately the same on Day 60, suggesting that the fermented electrode is still effective within 60 days. Generally, the quality of cathode water temporally varies along with electricity generation, specifically an increase in pH (Touch et al., 2017). It is assumed that the increase in pH of cathode water influences the survival rate of LAB attached on the cathode, leading to a decrease in SMFC performance.



(a) Maximum power density (b) Maximum current density

Fig. 5 Temporal variations of maximum power and current densities

CONCLUSION

This study used laboratory tests to confirm the impact of aeration on electrode potential and solution pH on the survival rate of LAB in the solution during fermentation. Although aeration was conducted during the fermentation, a 0.05 V decrease in the electrode potential was observed. However, this

decrease was smaller than without aeration (a 0.11 V decrease). Interestingly, fermented electrode potential was higher than without fermentation when aeration was conducted for more than seven days. The increase in solution pH during the fermentation affected the survival rate of LAB. Based on these results, it is recommended to complete the fermentation within three days, particularly in the case of aeration. Furthermore, during the fermentation, the solution pH should be kept at or less than 8 and preferably in an acidic state. It was also found that a decrease in pH during the fermentation aided the dissolution of Fe from the SS. Using electrodes fermented with and without aeration as the cathode and anode, respectively, it was possible to improve the SMFC performance. However, the improved performance was kept within 60 days due to changes in the quality of cathode water caused by long-term electricity generation.

ACKNOWLEDGMENTS

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Research article

Discussion on Influencing and Limiting Factors on Sustainable Grape Farming in Yamanashi Prefecture of Japan

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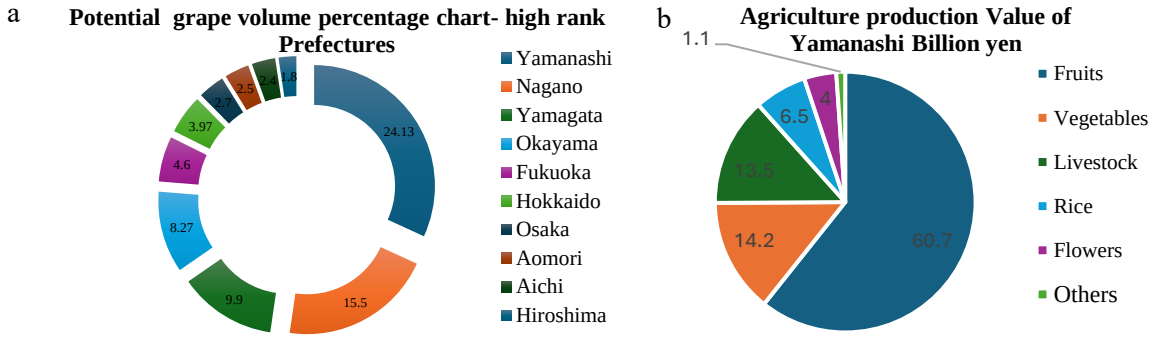
Abstract Viticulture has been an important agricultural sector throughout history in many countries. In Japan, grape-growing areas cover 17,800 ha, and the estimated annual grape production is 172,700 tons. The leading prefecture for grape production and winemaking is Yamanashi Prefecture. The land area under grapevine cultivation in Yamanashi Prefecture is around 3,780 ha with an estimated production of 36,900 tons per year, while grape production and winemaking are two key sources of income for local farmers. However, despite many advances in grape and wine production, these sectors face significant challenges both in Yamanashi Prefecture and across Japan, including a shortage of qualified labor. There is a lack of information and studies that focus on examining factors impacting the grape and wine industry in Yamanashi Prefecture. The objectives of the current study were 1) to examine the economic characteristics of grape farmers in Yamanashi Prefecture, 2) to evaluate factors influencing and limiting the contribution of grape farming to household income, and 3) to assess challenges facing grape farmers and wine producers in the study area. Field surveys in the form of structured and semi-structured questionnaires were conducted with grape farmers and wine producers during the ripening and harvesting grape season in 2022. Data were analyzed descriptively using SPSS software. The result indicated that on average, 80% of farmers in Yamanashi Prefecture were part-time farmers and had 1 to 3 ha of land, of which 40% was under grape cultivation and 60% under peach cultivation. The majority of respondents (88%) had a university education, while 12% had only a high school education, with female grape growers predominating (60%). The majority of the produced grape (80%) was sold fresh and only 20% was used for making wine. Most of the grape growers used the pergola method for training vines and preferred sandy and silty soil, with 90% of respondents using sprinkler irrigation. The results indicated that key environmental factors affecting grape bunches were light exposure, temperature, humidity, wind, rainfall, and the physiology of the grapevine by water and nutrients. The result showed that initial investments, labor inputs, small size of land parcels, and the depopulation of rural areas are the core factors that influence and limit the contribution of grape farming to household income. Therefore, if these issues are not considered, the long-term viability of sustainable grape production and winemaking in Yamanashi Prefecture will be at risk.

Keywords grapevine, challenges, influences, and limiting factors, Yamanashi Japan

INTRODUCTION

Viticulture has been an important agricultural arm throughout history in many countries. The main reason is that it can economically evaluate table grapes as fresh food, dried fruit, fruit juice, wine, and other processed products. Like other crops, grape growing is impacted by environmental conditions, such as soil and climate (Helder et al., 2019). The environmental conditions play an

important role in determining yields and grape quality potential (Cornelis et al., 2019). Also, climate is an important influencing and limiting factor on grapevine physiological development, vegetative growth, phenology, and production, and consequently on grape quality and sustainable grape farming (Petrie et al., 2017). In Japan Yamanashi prefecture is one of the leading grape producers and people are mainly farmers and they economically depend on agriculture. Grape production and making wine are two of the sources on which their income depends (Fig. 1a). In Yamanashi Prefecture the revenues from agricultural production are driven largely by yield and table grape price was around 3,000 to 3,500 yen per kilogram and wine price can vary from 1,000 up to 4,000 per bottle. According to Figure 1b, in Yamanashi Prefecture of Japan, the annual grape production value is 60.7 billion yen and Yamanashi, Nagano, Yamagata, and Okayama are the main grapes producing Prefectures. Although prosperous and full of facilities, Yamanashi Prefecture consists of major problem that exists in the whole agricultural society of Japan. The aging issue in the agricultural society and low birth rates is a huge and growing problems in Japan. In Yamanashi Prefecture, the total population is 817,192, and the geographic area is 4,465 km^2. In 2019, the population aged 65 years and above Yamanashi was 250,000 persons 2019 growing at an average annual rate of 1.94% (Statistics hand of the book of Japan, 2021). Hiring has become an issue at vineyards and wineries, although wine grape cultivation is not as laborious as table grapes cultivation. As they mentioned, an experienced farmer can only manage up to 1 ha of vineyard.



Source: Ministry of Agriculture, Forestry and Fisheries

Fig. 1 (a) Main grape producing Prefectures in Japan and (b) Agriculture production value

The output of grape production in terms of yield and quality can be optimized through the choice of plant material, such as variety, clone, and rootstock, and through the choice of viticulture techniques, such as training system, and Production costs can be reduced largely through mechanization. Based on Table 1 the average grapes yield was 10.47 tons/ha, and according to the interviewer's response the quantity and quality of grapes were significantly affected by rainfall rate and humidity. Temperatures have become increasingly warmer during the period of grape ripening. This resulted in differences in annual production and quality. Additionally, as increased temperatures increase the evaporative demand driving both vine transpiration and soil evaporation, the soil water balance over the season will become increasingly dry (Jackson, et al., 1993). Grape growers and stakeholders should become aware of this problem to timely plan and adopt these measures to ensure the future sustainability of this important crop.

Table 1 grape growing areas and production of five years all prefectures of Japan

Production years	Growing areas (ha)	Fruiting areas (ha)	Production (ton)
2015	18,100	17,100	180,500
2016	18,000	17,000	179,200
2017	18,000	16,900	176,100
2018	17,900	16,700	174,700
2019	17,800	16,600	172,700
Average yield in five years			10.47

Source: Annual Report, MAFF 2019

OBJECTIVE

The people of Yamanashi prefecture of Japan are mainly farmers, They economically depend on agriculture. Grape production and making wine are two of the sources on which their income depends. Therfore the objectives of this study were 1) to examine the social economic characteristics of grape farmers, 2) to find factors influencing and limiting the contribution of grape farming to household income, and 3) to assess challenges facing grape farmers and wine producers in the area.

METHODOLOGY

The research study was conducted during the harvesting season of grapes in 2022 in Katsunuma, one of the nine main grape-producing districts of Koshu city in Yamanashi Prefecture, Japan. As you can see in Fig. 3, which is located near the center of Honshu. Katsunuma has a favorable climate that nurtures the grapevine. The main material of the study was the data collected from grape-producing households and wine producers in the village of Kami Kuribara in the Katsunuma district. The total number of grape-producing households was 50 in the study area. The data were obtained randomly from 30 head of grape-producing households through face-to-face interviews using pre-prepared structured and semi-structured questionnaires related to socio-demographic characteristics of the grape-producing household, farm size, yield, farm management, and influencing and limiting factors (questionnaires translated into Japanese).

Source: https://www.nippon.com/en/guide-to-japan/pref19/

Fig. 3 Map of the study area

RESULTS AND DISCUSSION

Increasing grapevine farms will cause difficulty in the capability of managing the grape farms. According to table 2 result indicated that the average age of those involved in grapevines and wineries is above 60 years old, with a minimum of 30- to 40-year-old. This can quickly become a problem for vineyards and get more serious in the coming years. On top of this, skill and knowledge are only strengthened at maturity age so, if these experienced farmers passed away the next generation will feel short of knowledge. Another problem was emigration, the majority of the younger generations immigrated to the cities in finding better job opportunities. In addition, grapevines take on average three to five years before their harvest can be made. During this period no profit can be made from the harvest. Profits are only earned at a later stage and may not be enough at the beginning.

According to Table 2, the majority of grape producers (76%) were aged 50-60 years and 24% were less than 40 years. Grape farming was more predominantly 60% female activity, 40% male, followed by married individuals who constituted 80%. On the other hand, political and economic obstacles, such as licenses and taxes make it harder for young generations to join which was expressed during interview by grape producers. The majority of the respondents (88%) had university education, while (12%) had high school. Household members less than 3 constitute (80%) of farmers and 4 and above were (20%). Compare with Afghanistan grape producers; in Japan, grape growers

are highly skilled, constantly updating their knowledge of cultivating and management, and are interested in adopting new technologies and practices (Yusufi, 2019).

There is a comprehensive education program at all levels. Many universities are active in the field of practical skills of grape cultivators, and government agricultural agencies properly introduce education in new ways and technology arising from research centers. It proved that knowledge and skill, research, and extension are the core influencing factors for sustainable grape farming.

Table 2 Socio-demographic characteristics of grape farmers

Variable	Grape farmers of Kabul N=30	Grape farmers of Yamanashi N=30
Age		
30-40	10(33.3)	12(24)
50-60	20(66.0)	38(76)
Sex		
Male	25(83.3)	12(40)
Female	5(16.60)	18(60)
Marital status		
Married	20(66.6)	24(80)
Single	10(33.3)	6(20)
Education		
None	12(40)	0(0)
High school	15(50)	9(12)
University	3(10)	21(88)
Household size		
<= 3	10(33.3)	24(80)
4 and above	20(66.6)	6(20)

Source: Field survey, 2022 (Parentheses shows percentage)

According to Table 3, in Yamanashi Prefecture around 80% of farmers were part-time farmers and land size was between 1 and 3 ha (40%) of the land was covered by vineyards and (60%) by peach. Distance between rows and plants 7x10 meters and plantation of 50 up to 100 plants per ha was common and the majority of the farmers prefer sandy and silt soil for grapevine with the application of 1 to 3 tons of chemical, organic, and compost fertilizer per ha only one time in the winter season. Most of the grapevines trained Pergola with sprinkler irrigation method which was very popular and gave good results for grape production, especially varieties such as Kyoho, Muscat Bailey A, Koshu, Delaware, Merlot, and Chardonnay.

In this connection, (80%) of produced grape was used as fresh grapes and only (20%) of the total grape was used for winemaking. Regarding grapes, the yield result indicated an average of 10.47 tons per ha with approximately 90 kg per vine. Despite existing problems, the contribution of grape farming to annual household income was around (20%).

Average Rank Formula

Descriptive statistics, particularly tabulation, were used to summarize the data. To determine the constraints and factors that influenced decline in agricultural production, average ranking for each of the ranked causes was used to determine the most influential factors using the formula given below.

$$\text{Average rank} \quad P_a = \frac{X_1P_1+X_2P_2+X_3P_3+\cdots+X_nP_n}{Total\ response\ count} \tag{1}$$

Where xi is the response count for each choice and Pi is the ranked position.

Based on Table 4 the results revealed that initial investment, resistant seedling to pests and diseases, influence of climate and shortage of labour average rank were 1.3, 1.3, 1.6, 1.6 respectively and the severest problems which were expressed by (80%) of grape growers followed by high planting materials 70%, high cost of fertilizer 63.3%, replacement of varieties 66.6%, and high cost

of fertilizer 63.3% average ranked were 1.5, 1.5, 1.6, 1.6, respectively. Pests' leafhoppers and spider mites, and major diseases were powdery mildew and downy mildew. All above factors had significant influence on growth, yield, quality of grapes and sustainable grape farming.

Table 3 Shows respondents results in Yamanashi Prefecture

Characteristics of grape farms	Respondents' results
Occupation	Occupation of majority (80%) of the grape farmers was agriculture
Size of land per grape farmer	Most of farmers had from 1 to 3 hectares, and 60% land was for peach
Part time farmers	80% of farmers are part time farmers
Purpose of grape production	Table grape consumption and making wine
Share of grape to annual income household	Contribution of grapes to annual income of household is 20%
Fresh grape consumption	Majority (80%) grape is produced used as table grape consumption
Grape to process to wine	Only 20% of the total grape production is used for making wine
Wineries	In Yamanashi Prefecture 39 wineries are producing wine
Varieties of grape cultivated in Yamanashi	Kyoho, Muscat Bailey A, Koshu, Delaware, Merlot, Chardonnay
Grapevine training method	Most of grape farmers used Pergola method for training of vines
Distance between rows and plants	7 x 10 with plantation of 50 to 100 plants per hectare is common
Grapevine age	Most of the grapevines were between 10 to 30 years old
Yield of per grapevine	The average yield per grapevine was 90 kg
Good yield giving age grapevine	Over 5 years old
Kinds of soil is good for grapevines	Majority of the respondents prefer sandy and silt soil for grapevine
Kind of fertilizer apply in grapevine	Chemical fertilizer, organic fertilizer, and compost
Amount of fertilizer apply in grapevine	Commonly 1-3 tons applied each year in grapevines
Appropriate season to apply fertilizers	The best season to apply fertilizer is winter season
Noticed of pests and insects	Nematode, powdery mildew
Source of irrigation	Surface water such as river, lake, and rainfall
Method of irrigation	Majority 90% use sprinkler irrigation method in grapevines

Source: (Field survey, 2022)

Table 4 Shows the most influential and limiting factors experienced by grape farms

Constraints	Rank				
	1st	2nd	3rd	4th	Average
High initial investment	24(80.0)	3	2	1	1.3
High cost of planting materials	21(70.0)	4	3	2	1.5
Replacement of variety is very difficult	20(66.6)	5	4	1	1.5
High cost of fertilizer	19(63.3)	5	4	2	1.6
Shortage of labour	18(60.0)	7	3	2	1.6
Pests and diseases	16(53.3)	6	5	3	1.8
High cost of new agriculture technologies	15(50.0)	10	3	2	1.7
High resistant seedling to pests and diseases	23(76.6)	4	2	1	1.3
Impacts of climate (rain and humidity)	22(73.3)	3	3	2	1.6
Limited access to quality seedlings	12(40.0)	8	7	3	2.3
Limited access to financial services	10(33.3)	8	7	5	1.9
Land fragmentation	17(56.6)	7	4	2	1.7
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Land fragmentation	17(56.6)	7	4	2	1.7

Source: field survey, 2022 (Parentheses indicate the percentages) (Average rank low number shows severe problems)

Environmental conditions play an important role in determining not only yield but also grape quality potential. In winegrowing regions, growers have historically adjusted their plant material

selections and viticulture techniques through trial and research to achieve the best possible compromise between yield, quality, and production costs. In each location environmental conditions are different, so there is no general recipe that can be applied everywhere. This explains why plant materials and viticulture techniques vary so much across grape-growing regions of the world. According to Table 5, in July 2012 there were 167.2 sunshine hours while in July 2020 total sunshine was 78.5 hours the rainy season was long, and the precipitation was so heavy in July 2020. Therefore, the respondent mentioned that the harvested grapes were good that year, but the yield was relatively low because the rainy season was long, and the precipitation was so heavy in July. The quality of harvested grapes was good, but the yield was relatively low because of heavy rainfall around 317 mm more in 2020 in comparison with the rainfall in July 2012.

Table 5 Effects of rainfall, temperature and sunshine on grape yield and quality

2020	Total rainfall (mm)	Average temperature			Total sunshine (hrs.)
		Daily Max. temperature	Daily Min. temperature	Daily Ave temperature	
July	432.0	33.9	18.0	23.8	78.5
Aug	50.0	39.3	20.9	28.0	245.8
Sep	48.5	35.8	9.9	23.4	125.7
2012					
July	115.5	31.3	21.4	25.3	167.2
Aug	23.0	34.8	21.8	27.0	238.6
Sep	22.0	30.6	18.5	23.5	173.8

Source: Ministry of Agriculture, Forestry and Fisheries, 2020

CONCLUSION

Grape is one of the important economic fruit crops found in the Yamanashi Prefecture of Japan. Findings indicated that in Yamanashi Prefecture around (80%) of farmers were part-time farmers and had between 1 and 3 ha of land which (40%) of the land was cultivated grape and (60%) peach. The majority of the respondents (88%) had university education, while (12%) had high school. Female grape growers were (60%) more predominantly than male farmers and (80%) of the produced grape was used fresh and only (20%) for making wine. Most of the grape growers used the Pergola method for training vines and prefer sandy and silt soil with (90%) of responders using sprinklers irrigation. Results on influencing and limiting factors indicated initial investment, resistant seedlings to pests and diseases, heavy rainfall and humidity, shortage of labor, high cost of fertilizer (63.3%), replacement of varieties (66.6%), and high cost of planting materials (70%), were the core influencing and limiting factors on sustainable grape farming which were expressed by (80%) of grape growers. The use of late-ripening and humidity-resistant plant material (varieties, clones, and rootstocks) is an environmentally friendly and cost-effective tool for adaptation and sustainable grape farming in Yamanashi Prefecture of Japan.

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Research article

The Current Situation of Farmers' Practice of Rice Seed Use in Cambodia: An Exploratory Study in Takeo Province

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Abstract Rice productivity in Cambodia has increased dramatically in recent decades. The main factor behind this breakthrough has been the spread of irrigation and modern rice varieties. However, the formal rice seed supply system is still not well established, and most farmers use seed collected by themselves. In this situation, it is difficult to maintain the new varieties' field performance. This study investigated the current situation of farmers' rice seed treatment practices and the concern that these practices hinder the improvement of rice productivity in Cambodia. Data for this study were collected from 80 conveniently selected farmers in irrigated and rainfed areas in Takeo Province of Cambodia. Farmers in the irrigated area cultivated modern varieties and sold most of their production, while farmers in the rainfed area grew traditional and improved varieties and used them for home consumption. In both areas, farmers procured rice seed through self-collection, and when they changed the variety cultivated, they mostly procured seed from relatives or neighboring farmers. This fact suggested that most farmers did not purchase formally produced seeds. The seed used per hectare in the irrigated area was two times higher than in the rainfed area. In addition, the rice yield per seed used in the irrigated area was lower than in the rainfed area, even though farmers in the irrigated area were growing modern varieties.

Keywords seed renewal, variety adoption, irrigation access, farmer-to-farmer transaction

INTRODUCTION

In recent decades, rice productivity increased rapidly in Cambodia. Even though the unit rice yield was 2.06 ton/ha in 2001, the unit yield rose to 3.75 ton/ha in 2020 (FAOSTAT). This rapid growth was due to the diffusion of modern varieties, increased use of fertilizer and improvement of irrigation access (Cramb et al., 2020; Kodo et al., 2021). Even these agricultural inputs increased and/or improved, supplying good quality rice seeds was one of the remained subjects of rice production in Cambodia. Although the significance of investment for rice seed was confirmed to increase productivity, most farmers prepare rice seeds by self-collection (ADB, 2014).

In Cambodia, the formal rice seed supply system was composed of Agricultural Quality Improvement Program (AQIP) seed company established by the Ministry of Agriculture, Forestry and Fisheries (MAFF), Tuol Samrong seed farm established by the World Bank project, and some other private seed producers (Chamroeun et al., 2015). The Cambodia Agricultural Research and Development Institute (CARDI) distribute the breeder's seeds to the seed producers and they multiple seeds and sell them to farmers, retailers and millers. However, the production of rice seeds cannot satisfy the demand of formally produced rice seeds at present. Against this situation, some programs aiming to improve rice seed quality used by farmers and to establish the system of seed

certification were launched in 2022, which were supported by overseas institutions (APSA, 2022; GAFSP, 2022).

Regarding the established seed supply system, participation of rice farmers is one of the important requirements. No matter how good seeds are provided, if farmers prefer to obtain seeds by self-collection or farmer-to-farmer transaction to reduce cost, rice productivity should not be improved. To consider how to involve farmers in the refined seed supply system, it is necessary to understand the present farmers' practices of rice seed use.

OBJECTIVE

To find some implications for the refinement of rice seed supply system in Cambodia, we set the following objectives: 1) Grasp an actual situation regarding the practice of rice seed use among farmers in a rice production area in Cambodia, and 2) Explore concerns regarding rice production due to the present practices of farmers' seed use.

METHODOLOGY

The data for this study was collected through face-to-face interviews with farmers using a structured questionnaire. To grasp the farmers practices under the different precondition of rice production, we selected 2 survey sites: Borei Cholsar district as an irrigated area and Tam Kak district as a rainfed area, both located in Takeo Province in southern Cambodia which is one of the major rice production areas in the nation (Chhun et al., 2020). Since this study was intended as an exploratory study base on the objectives, we adopted a convenience sampling method and selected 40 farmers in each site. The survey was conducted in January and February of 2022. The contents of the questionnaire were as follows: land possession and use, income sources, methods and outputs of rice production, and treatment of rice seed. We collected information on 3 cropping seasons: wet season (WS) in 2021, early wet season (EWS) in 2021, and dry season (DS) in 2020-21.

Table 1 Overview of labor and land possession among surveyed farmers

Area	N	Family member (person)	Family farm labor (person)	Family off-farm labor (person)	Own farmland		Rent-in paddy (ha)	Total farmland (ha)	Labor-land ratio (person/ha)
					Paddy (ha)	Others (ha)			
Irrigated	40	4.3	1.7	0.8	2.3	0.0	1.0	3.3	0.9
Rainfed	40	4.6	2.4	1.2	0.8	0.4	0.4	1.6	4.1

Source: Made by authors with the data of the survey in January 2022

Table 2 Annual income of surveyed farmers by each income source (Unit: US$*/year)

Area	N	Agriculture				Off-farm income	Total in 2021
		Rice	Non-rice crop	Livestock	Farm labor		
Irrigated	40	4,349	0	175	0	1,105	5,629
Rainfed**	39	305	82	105	157	2,789	3,438

Source: Same as Table 1.

** Exchanged from "Riel" with the rate on November 17th, 2022: 1 US$ = 4,150 Riel.*

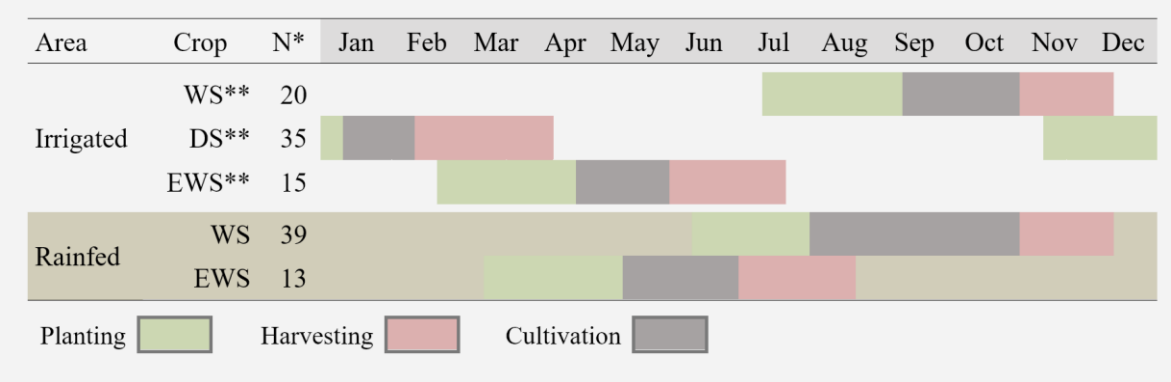
*** From the averages in Tam Kok, we exclude one farm which the rice income was abnormally high.*

RESULTS AND DISCUSSION

Rice Production among Surveyed Farmers in Irrigated and Rainfed Area

Table 1 gives an overview of the labor and land holdings of the farmers surveyed. Although the amount of land owned in the irrigated area was more than twice that of the rainfed area, the amount of labor in the irrigated area was less than that in the rainfed area. Thus, there was a large difference

in the labor-land ratio between the irrigated area (0.9) and the rainfed area (4.1). Regarding the source of income (Table 2), the sale of rice was the main source of income for farmers in the irrigated area. In contrast, income from rice was much lower for rainfed farmers than for irrigated farmers, and off-farm income was a major source of income for most of them.



Source: Same as Table 1.
*Remarks) * Frequency of farmers who conducted each type of rice crop in 40 farmers in each area.*
*** WS = Wet season, DS = Dry season and EWS = Early wet season.*

Fig. 1 Crop calendar of rice production among surveyed farmers in 2020-21

Table 3 Water access, variety, and scale of rice production among the surveyed farmers

Area	Crop	N	Irrigation (Freq.*)			Variety adoption (Freq.*)			Cultivated area (ha) ***
			Rain-fed	Surface water	Ground water	Modern variety**	Improved variety**	Traditional variety**	
Irrigated	WS	20	0	19	1	20	0	0	2.15
	DS	35	2	33	1	35	0	0	2.78
	EWS	15	1	14	0	15	0	0	1.56
	Annual	40							4.19
Rainfed	WS	39	33	6	0	0	33	14	1.22
	EWS	13	6	10	0	9	4	1	0.43
	Annual	40							1.33

Source: Same as Table 1.
*(Remarks) * Frequencies of farmers in the number of who practiced each crop, shown in the "N" column. If farmers usemore than one type of irrigation, we count them for all. "Surface water" includes canals, pond, lake and river.*
*** "Modern variety" is which bred by IRRI and mainly cultivated in Vietnam, e.g., IR504 and OM5451. "Improved variety" is a pure line of traditional variety, which is generally processed by CARDI, e.g., Phka Malis and Phka Rumduol*
**** Averages of the farmers producing rice in each cropping season.*

The rice cropping schedule of the surveyed farmers is described in Fig. 1. In the irrigated area, farmers cultivated rice in all 3 cropping seasons in a year. The main cropping season in the irrigated area was DS. On the other hand, farmers in the rainfed area cultivated rice in WS and EWS in a year and most farmers cultivated rice in WS. Almost all farmers used direct seeding in the wetland and hired contractors with combine harvesters for harvesting. The average number of rice crops in a year by area was 1.75 and 1.30 in the irrigated and rainfed areas, respectively.

Table 3 shows the status of water access, variety adoption and land use in relation to rice production among the farmers surveyed. In the irrigated area, most farmers had annual access to irrigation water from canal, pond, lake and river, and all farmers cultivated the modern varieties that were photoperiod insensitive and short maturing, such as IR504 and OM5451. These modern varieties are popular in Vietnam and most of their production is exported to Vietnam (Chhun et al., 2020). In contrast, farmers in the rainfed area cultivated rice with rainwater in WS, but most farmers cultivating rice in EWS used surface water irrigation. The rice varieties grown were traditional varieties and improved varieties (pure line of traditional varieties) in WS, and in EWS the farmers

grow modern varieties as in the irrigated area. Regarding the rice cultivated area, the aggregated area planted in the irrigated area (4.19 ha) was three times greater than that in the rainfed area (1.33 ha).

Table 4 shows the rice yield and its disposal among the farmers surveyed. The production and yield of rice in the irrigated area was higher than in the rainfed area. While farmers in the irrigated area sold almost 90% of their rice yield, farmers in the rainfed area disposed of half of their yield for consumption. In both areas, about 10% of production was saved as rice seed. Although the total sales of rice were higher in the irrigated area than in the rainfed area, the unit price of rice was lower in the irrigated area than in the rainfed area. For EWS in the rainfed area, the price was closer to that in the irrigated area than for WS. This indicated that the price of modern varieties such as IR504 and OM5451 was lower than traditional and improved varieties. Kodo (2021) mentioned that farmers produce varieties that are popular in Vietnam because they are easy to sell. Rice traders buy rice for Vietnam from farmers at a low price, but always buy the entire quantity brought by farmers, regardless of its quality. From the above, farmers in irrigated areas made rice production more commercial than rainfed areas, and they adopted the strategy to sell large number of modern varieties even if the price was lower than traditional and improved varieties.

Table 4 Yield and disposal of rice production by each area and cropping season

Area	Crop	N	Production (ton)	Yield (ton/ha)	Disposal of rice yield (%)				Unit rice price (US$/ton)	Total rice sales (US$*)
					Sold	For home	For seed	Animal feed		
Irrigated	WS	20	11.2	4.7	79.7	6.7	12.4	1.2	195.4	1,975
	DS	35	14.4	5.0	85.8	2.2	11.1	0.8	205.8	3,047
	EWS	15	7.2	4.3	75.7	6.7	17.7	0.2	198.9	1,227
	Annual	40	21.2	4.8	87.2	2.7	9.4	0.7	201.7	4,349
Rainfed	WS**	38	3.1	3.0	34.3	51.3	11.9	1.4	285.2	275
	EWS	13	0.9	2.3	34.4	42.4	12.6	10.0	241.0	113
	Annual**	39	3.4	2.8	34.9	49.6	12.3	2.0	278.6	305

Source: Same as Table 1.
*(Remarks) *Exchanged from "Riel" with the rate on November 17th, 2022: 1 US$ = 4,150 Riel.*
***From "WS" and "Annual"in Tam Kok, we exclude one farm which the unit price and total sales are abnormally high.*

Rice Seed Use and Procurement among Surveyed Farmers

The amount of seed used per unit in the irrigated area was twice that of the rainfed area (Table 5). While farmers in the rainfed area collected their own rice seed, farmers in the irrigated area bought half of their seed from other farmers and/or material dealers. In addition, the rice yield per unit seed input differed between the areas (Table 6). The rice yield per unit seed use in the irrigated area (12.3 kg/1 kg seed) was lower than in the rainfed area (16.0 kg/1 kg seed). However, the yield per seed use was not significantly different in the EWS and the difference was more significant in the WS than in the annual aggregation. This result suggests that the difference in yield per seed between modern and traditional and improved varieties was clearly observed.

Table 5 Usage and sources of rice seed by each area

Area	Total usage of seed (kg)*	Unit usage of seed (kg/ha)				Ratio of seed source (%)*		
		Annual*	WS**	DS**	EWS**	Self-collection	Other farmers	Material dealers
Irrigated	1,676	408.3	413.6	417.4	391.0	50	37	13
Rainfed	206	215.1	194.8	-	261.8	91	9	-

Source: Same as Table 1.
*(Remarks) *Average of 40 farmers in each area.*
***Average of the farmers producing rice in each cropping season.*

In terms of sources of rice seed, farmers in the irrigated area renewed half of their seed, but the main source of renewed seed was farmer-to-farmer transactions, and the proportion of rice seed procured from material dealers was only 13% (Table 5). And in the rainfed areas, there were no farmers who bought rice seed from dealers, and most rice seed was produced by self-propagation.

Even when a new variety was introduced, most farmers in both areas bought seed from other farmers (Table 7). Table 8 shows farmers' perceptions of the negative effects of rice seed spoilage. Most farmers recognized the problems caused by contamination of rice seed by other varieties and weed seed. Regarding variety mixture, while farmers in the irrigated area emphasized the reduction in yield, most farmers in the rainfed area mentioned difficulties in selling due to low grain quality.

Table 6 Rice production per seed use by each area and cropping season

Cropping season	Annual		WS		DS	EWS	
Area classification	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Irrigated	Rainfed
No. of farmers	40	40	20	39	35	15	13
Production per seed use (kg/1kg seed)	12.3*	16.0*	12.1**	17.0**	12.5	11.0	10.8

Source: Same as Table 1.
*(Remarks) *p < 0.05 and **p < 0.01 on a paired t-test between Borei Cholsar and Tam Kak.*

Table 7 Transactions of new varieties' seed

Area	Counterpart	Buy in cash	Buy in kind	Ex-change	Gift
Irrigated	Farmer	16	2	5	9
	Supplier	14	1	1	0
	Government	4	0	0	2
	Others	1	0	0	0
	N**	27	3	6	11
Rainfed	Farmer	21	2	9	5
	Supplier	0	0	0	1
	Government	4	2	0	0
	Others	2	0	0	0
	N**	25	4	9	6

Source: Same as Table 1.
*(Remarks) *Multiple answer question.*
***Numbers of farmers who answered that get seeds in each way from any counterpart.*

Table 8 Negative effects of contamination

	Reasons of negative effects*	BC**	TK**
By variety mixture	Low yield	25	7
	Difficult to sell	8	25
	Low price	1	2
	Difference of growth	0	3
	Others	0	3
By weed seed	Hard to control weed	17	27
	Increase of herbicide	13	3
	Low yield	7	3
	Difficult to sell	1	3
	Others	0	2

Source: Same as Table 1.
*(Remarks) *Categories based on the answers of open questions. **Frequencies in 40 farmers in each are any counterpart.*

CONCLUSION

This study explored the actual situation of farmers' practices of rice seed procurement and use in an irrigated and a rainfed area, and discussed the concerns of rice production driven by farmers' practices. The situation of rice production was clearly different between the irrigated and rainfed areas due to the accessibility of irrigation. Farmers in the irrigated area grew rice in both the wet and dry seasons, adopted modern varieties and produced rice commercially. In contrast, farmers in the rainfed area produced rice only in the rainy season, using traditional varieties, and more than half of the production was used for their own consumption.

Rice seed procurement and use practices also differed between the irrigated and rainfed areas. Farmers in the irrigated area used much more rice seed per unit of planted area and procured half of the seed from external sources: specified material suppliers and other farmers. On the other hand, farmers in the rainfed area mostly used rice seed they collected themselves. Even though farmers in the irrigated area used the modern varieties and achieved higher land productivity than that in the rainfed area, the rice yield per seed use in the irrigated area was significantly lower than in the rainfed area. In addition, the yield per seed use in EWS in the rainfed area was also lower than in other seasons, and farmers cultivated modern varieties in this season. Therefore, the yield per seed use of modern varieties was lower than that of traditional and improved varieties among the farmers surveyed. The reasons for this situation were considered to be low quality and overuse of rice seed. The farmers surveyed in both areas procured most of their seed through self-collection or farmer-to-farmer transactions, even when new varieties were introduced. Farmers recognised the following effects of using low quality seed: reduced yield, falling farmgate prices, severe weed problems and increased use of herbicides. In addition, farmers in irrigated areas achieved high rice yields by increasing the planting density of modern varieties. In general, high planting densities interfere with

plant uptake of light and nutrients. This is considered a major cause of low yield per seed input in the irrigated area.

In this study, we found the possibility that the benefits of modern varieties have not been fully demonstrated, and the situation caused by the overuse of their seeds. If most farmers always use too much rice seed, meeting the demand for good quality seed becomes a difficult challenge for the government. In order to confirm this hypothesis, we need to conduct further studies on the sample representing the farmers growing modern varieties in the surveyed area.

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Research article

Efficiency of No-till Transplanter Use in Conservation Agriculture Tomato (*Solanum lycopersicum* L.*)* Production Systems in Battambang Province, Cambodia

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Abstract Cambodian farmers have gradually started growing no-tilled vegetables, but production is low due to manual practices. No-till transplanter use in conservation agriculture (CA) can boost small-holder vegetable production and decrease production costs. Thus, this paper aimed (1) to compare the working capacity of a no-till vegetable transplanter with a punch planter work in CA (Conservation agriculture) and hand planting in CT (Conventional tillage) and (2) to assess the economic performance of the equipment. The experiment was conducted in Battambang province, Cambodia, from January to August 2022. The experiment was arranged in RCBD with three treatments, plating using a no-till vegetable transplanter, punch planter, and manual or hand plating, each replicated four times. Tomato seedlings were used for this experiment. As a result, the no-till vegetable transplanter's working capacity was shown to be 16 h/ ha, or nearly three times faster than punch plater and hand plating and could transplant 10 seedlings per minute. Plant spacing and density were similar for all the treatments at 0.8 m, and the plant density of the hand planter and punch planter was 11,660 plants/ha compared to the no-till transplanter at 9,921 plants/ha. Economic recovery is attainable at the break-even point of 18.20 ha/y for the transplanter.

Keywords conservation agriculture, cover crop, economic recovery, machinery, sunn hemp

INTRODUCTION

Farmland areas in Cambodia increased from 27% in 2000 to 32.8% in 2020 (176,520 km^2) (World Bank, 2022); however, the main local vegetable market is dependent on imports, which represent more than 65% of the domestic demand (Chea, 2022). Some challenges that have been identified include labor force outflows from the agricultural sector to the construction and industrial sectors, and the lack of mechanization to support farm work, with annual labor demand in vegetable production reaching 169.85 days/ha (World Bank, 2015). Conventional tillage (CT) practices in

vegetable production may cause soil disturbance, soil nutrient loss, and unsustainable farming. To minimize these issues, conservation agriculture (CA) is practiced in line with three principles: minimum tillage, permanent soil organic cover, and crop diversification. These components work well with the support of farm machinery and tools, which can address labor shortages, improve productivity, and save time and cost. Sustainable mechanization considers economic, social, environmental and cultural aspects, when contributing to the sustainable agriculture production (FAO, 2022). In Cambodia, CA was established in 2004 and launched as a key development target in Battambang province (CASIC, 2020), and later adopted in vegetable production (Manuel, 2015). A priority target of mechanization is the propagation of no-till vegetable transplanter (NVT) by the National Soil Dynamic Laboratory (NSDL). An NVT funded by USAID was imported to Cambodia for adaptation with small-holder farmers (Jones et al., 2019). The performance of the NVT has demonstrated high field effectiveness, eases planting labor in CA, and is economically affordable for small and medium-sized farmers.

OBJECTIVE

The objectives of this study were (1) to compare the working capacity of a no-till vegetable transplanter with a punch planter work in CA and hand planting in CT and (2) to assess the economic performance of the no-till vegetable transplanter.

METHODOLOGY

The experiment was conducted in the upland area in Ratanak Mondul district, Battambang province, Cambodia (12.93062, 102.85632) from January to August 2022, where average temperature and rainfall were from 25.80°C to 29.60°C and 14 mm to 200 mm, respectively (Climate Data, 2021). The soil type is clay loam, with a pH range from 7.00 – 7.15.

Experimental Design

The whole experimental plot was 175 m^2 and planted with a mixture of two cover crops: sunn hemp (*Crotalaria juncea* L.) and millet (*Cenchrus americanus* L.) at the rate of 25 and 15 kg/ha, respectively. The experimental design was a randomized complete block design (RCBD) that consisted of three treatments, namely NSDL NVT, no-till punch planter, and CT hand planting, each of which had four replicates. Thus, at the age of 60 days, the cover crop was crimped for no-till plots and plowed for CT plots. The size of each replicate was 5 m x 25 m, with a row space of 2 m for easy tractor turning. One month after crimping/disking, tomato seedlings (*Solanum lycopersicum* L.) were prepared for planting at the age of 6 weeks for all the treatments.

No-Till Vegetable Transplanter and Oggun Tractor

The NVT is a single-row transplanter mounted with a tractor and was designed by the no-till vegetable transplanter. In operation, it needs two people, one driving the tractor and one operating the no-till vegetable transplanter. In the process, the no-till planter is working dependent mechanisms, as the main power source of the transplanter is a DC electric motor with a speed control box. The motor transmits force by a roller chain link to a rack and pinion gear, which transfers the rotational motion to the linear motion of a stainless-steel bar comprising six vertical rack holders. The seedling bar continues to travel from left to right when the toggle switch of the control box shifts, and the direction also changes automatically. In addition, the ports that are attached to the rack hold the seedling until the bottom spring-loaded door is opened to allow the seedlings to fall by gravity into the kicker chamber. The spring-loaded kicker positions the plant in the furrow previously opened by the no-till disc coulter and double disk openers. The two closing wheels press the sides of the furrow to the plant to provide sufficient root-to-soil contact for optimum growth of the seedling (Kornecki and Kichler, 2018).

The Oggun II tractor is an open-source design with special consideration for small-scale farming applications. The tractor is operated by a hydraulic system for rear-wheel drive, weighing around 725 kg, and uses as its power source a 16.5-kW Honda GX690 gasoline engine (Think Oggun, 2020). The dimensions of the tractor are 3.71 m long x 2 m wide, with 0.73 m ground clearance and mid-mount implement clearance of 1.15 m for a clear view of the front working implement during operation (Kornecki et al., 2012).

Punch Planter

The punch planter used in the experiment was the Weasel Bulb Planter, designed to work easily with a comfortable T-bar grip. The process starts with pushing the handle and placing a foot on the footplate to press the sharp blade cylinder and pointed tip into the ground, allowing it to slide into the ground effortlessly and the cores to pop out with ease. The Weasel Bulb Planter weighs less than 1.24 kg and is about 0.90 m long (Garden Weasel, 2022).

Data Collection

During the operation of NVT, transplanting speed, field capacity, number of plants per minute, plant density, plant angle, plant spacing, missing plant, and fuel consumption of tractor were collected for calculating variable cost. The speed was measured by recording three forward times in each plot, which were converted to operation speed. The field capacity depends on the total time of full operation and working width for converting to a hectare (FAO, 1994). Fuel consumption on each plot was measured by every vegetable transplanter after finishing each plot; firstly, the gasoline tank was filled fully after finishing the operation, and the tank was refilled by the measuring glass (Hancock et al., 1991).

$$\textit{Field capacity (ha h}^{-1}\textit{)} = \frac{Total\ cultivation\ land\ (ha)}{Total\ cultyvation\ time\ (hr)} \quad (1)$$

The number of plants per minute was selected from four rows in 25 m to count the plants in each row and divided by time spent in each row. Plant density was measured by counting the number of plants in each plot and selecting two samples in each plot to report in a hectare. Plant angle was measured in ten samples by using an angle ruler. Plant spacing was measured in 10 samples, and if the plant spacing was bigger than 1.5 meters, it was counted as one missing plant. Missing hills refers to the percentage of seedlings damaged or wrongly planted in each row.

Break-Even Point

Break-even point analysis (BEP) is the relationship between fixed costs, variable costs, and returns. A BEP is defined as an investment that generates a positive return and can be determined graphically or with simple mathematics. BEP computes according to the following formula:

$$\textit{BEP (ha y}^{-1}\textit{)} = \frac{Total\ fixed\ costs\ (USD\ y^{-1})}{(Service\ Fee\ (USD\ ha^{-1}) - variable\ cost\ (USD\ ha^{-1})} \quad (2)$$

Fixed costs include equipment depreciation, interest costs, TIH (Taxes, insurance, and housing), and general overhead expenses. Depreciation cost depends on a salvage value of 10%, a lifespan of 10 years, and a new condition value, and to simplify calculation TIH: 1% is determined lumped together. The variable cost includes the cost of goods sold or production expenses such as labor and power costs, feed, fuel, and other capital asset investments (Edwards, 2015; Gutierrez and Dalsted, 2012).

Data Analysis and Interpretation

The collected data was analyzed by using analysis of variance (ANOVA) in R (version 4.2.2) and RStudio 4.1.0, which are free software and available online. If the test was significantly different,

the least significant distance (LSD) was performed to separate the means in each treatment with an error level of 5% (confidence level of 95%).

RESULT AND DISCUSSION

Transplanting Speed and Field Capacity

According to Table 1, transplanting speed was significantly different ($p<0.001$). The average speed of hand-planting, punch-planter, and NVT was 0.140 km/h, 0.150 km/h, and 0.625 km/h, respectively. The result indicated that using the NVT was 3 times faster than other methods, while the speed of punch-planter and hand-planting was similar. However, the operational speed of the NVT used in this study was lower when compared to an automatic tomato transplanter studied by Zamani et al. (2016), whose operation was in the range of 1-2 km/h.

The field capacity of NVT was significantly ($p<0.001$) faster than the hand and punch planter at 0.07 ha/h, 0.01 ha/h, and 0.02 ha/h respectively (Table 1). The labor requirement for planting tomatoes a hectare per day using the NVT corresponded to 16 h/ha. Meanwhile, hand planting and punch planter required 68 h/ha (Table 1). In line with our study, other study also mentioned the benefits of a transplanter; for instance, the field capacity of a single-row walking transplanter was found to be 22 h/ha, which is equivalent to an 88% labor reduction over hand planting (Park et al., 2005). Likewise, another study revealed that the field capacity was approximately 0.0343 ha/h (Dhupal and Sahu, 2020).

Number of Plants per Minute and Plant Density

Planting rate was shown that the transplanter provided the highest number of seedlings, mostly 10 plants min^{-1}, significantly ($p<0.001$) from hand, and punch planter was planted approximately 2.80 plants min^{-1} (Table 1). Based on observations, transplanting mechanization improved the time seeding rate compared to man work (manual work).

The difference in plant density was significant ($p<0.001$); the transplanter planted fewer seedlings than hand planting and the punch planter at 9,921 plants/ha, 11,666 plants/ha, and 11,666 plants/ha, respectively (Table 1). However, the plant population still followed the recommended tomato planting density of between 8,000 and 14,000 plants/ha (Jones, 1999).

Plant Angle and Plant Spacing

The plant angle was significantly different ($p<0.001$) between the tested methods. The hand planting and punch planter had a bigger angle than the NVT (Table 1) with angles of 76.40^{o}, 79.70^{o}, and 58.80^{o}, respectively. The reason the NVT made smaller angles was that the angle was affected by the seedling root being soft with gravitational drop off about 1 meter high into the furrow, making the seedling unstable. Another reason is that the soil clods on the surface were not broken into small pieces properly or smoothly; when the closing wheel turned the soil to fill the roof in action, the plant moved the geometry.

The difference in plant spacing was not significant among the planting treatments, and spacing was around 0.80 m for each treatment (Table 1). It was bigger than the FAO standard for tomato plant spacing in the field, which ranges from 0.30 m to 0.60 m. The serial performance of a two-wheel tractor mounted with a row no-till plant transplanter evaluated between 2017 and 2019 delivered tomato spacing of between 0.59-0.70 m (Kornecki and Reyes, 2020).

Missing Plant Ratio and Fuel Consumption

Missing plant ratio (plant damage) was measured in NSDL NVT plots that after planting had spacing between rows larger than 1.5 m, and was 15.83% per hectare. Dhupal and Sahu (2020) recorded a

missing plant ratio of less than 5.33% at three different speeds 0.29 km/h, 0.28 km/h, and 0.27 km/h. Fuel consumption during operation was at 4.20 L/hr at 90% power.

Table 1 Performance and plant physics for different planting methods

Residue retention	Speed (km/h)	No. of plants (per min)	Plant no. (plants/ha)	Field capacity (ha/h)	Plant angle (°)	Plant spacing (m)
Hand planter	$0.14^{b} \pm 0.00$	$2.73^{b} \pm 0.18$	$11{,}666^{a} \pm 5$	$0.01^{b} \pm 0.00$	$76.35^{a} \pm 7.73$	0.80 ± 7.73
Punch planter	$0.15^{b} \pm 0.00$	$2.82^{b} \pm 0.13$	$11{,}666^{a} \pm 8$	$0.02^{b} \pm 0.00$	$79.70^{a} \pm 7.17$	0.80 ± 7.17
NSDL NVT	$0.61^{a} \pm 0.03$	$9.84^{a} \pm 2.34$	$9{,}921^{b} \pm$	$0.07^{a} \pm 0.00$	$58.85^{b} \pm 17.6$	0.80 ± 17.6
p-value	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	0.95
CV (%)	7.43	25.76	11.41	11.41	16.47	N/S
Overall mean						0.79

** Means significant at p<0.05, ** significant at p<0.01, *** significant at p<0.001,*
Different alphabetic letters are used to denote significant differences between the treatments

Break-even Point (BEP)

The initial investment cost of the Oggun tractor was 12,500 USD (Table 2). Its annual working hours were determined at 150 h/year for 15 years of economic life with a salvage cost of 10% per year, accounting for a depreciation cost of 1,125 USD/y. The service fee sum of the total operation and ownership cost was 213.75 USD ha^{-1}, in terms of 10 USD/day of labor cost (Carter et al., 1997). The investment cost of the NSDL NVT was 3,000 USD for a unit in new condition with a 6-year life span, 50 annual hours, and a depreciation cost of 450 USD/ha. The break-even area of the Oggun tractor-mounted NVT was 18.20 ha/y. Hin et al. (2020) found a similar result with a break-even area was 18.30 ha/y.

Table 2 Calculation of annual break-even area for the Oggun mounted transplanter

BE	Unit	Oggun	NVT	Total
Investment cost	USD	12,500.00	3,000.00	15,500.00
Salvage value	USD	1,250.00	300.00	1,550.00
Economic life	y	10.00	6.00	-
Annual hour	h/y	150.00	50.00	-
Total FC	USD/y	1,443.75	526.50	1,970.25
Total VC	USD/ha	105.52	-	-
Service fees	USD/ha	213.75	-	-
BE area	ha/y	18.20	-	-

CONCLUSION

An important trend in promoting sustainable labor and vegetable production in Cambodia is the widespread implementation of CA by small-scale farmers while employing small and mid-size agricultural machinery. The NVT arrangement on an Oggun tractor showed that it may cut hard labor and time by a factor of three when compared to manual labor. The planting experiment's findings showed that, in comparison to punch and hand planters, the NVT method's shortcomings included a higher percentage of missing plants and smaller plant angles. However, from an economic standpoint, the result was still acceptable. The break-even point – a measure of the method's economic performance – is the most crucial component in determining the viability of conservation agricultural gear. According to the study, the tested NVT setup's break-even point was 18.20 ha/y with a service price of 213 USD/y. This suggests the NVT owner should have more planting space than is necessary or the option to provide NVT services to other farmers.

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Research article

Improving the Farm Business and Resilience of New Farmers: Case of a Greenhouse Tomato Farmer in H City, Tokyo

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Abstract Among new farmers, farming discontinuation within a few years is prevalent due to various issues, including difficulty securing farmland, insufficient technology adoption, low income, and weak branding. In recent years, the importance of recruitment and support services for new farmers has been gaining recognition. Therefore, studies that can provide insights and innovations to improve the business operations and resilience of each new farmer are relevant and timely. Tomato is the most common fruit vegetable consumed fresh or processed in Japan. For new farmers, tomatoes are considered one of the favored high-value commodities for production. In response to the needs of a young female new farmer who ventured into greenhouse tomato farming in H City, Tokyo, this study aims to clarify the consumption and purchasing behavior satisfaction and brand familiarity of randomly selected tomato consumers. We conducted a consumer survey from May to June 2022. Although we had 470 respondents, we only utilized responses from 213 consumer-respondents to capture the characteristics and preferences of those who experienced buying tomatoes from the selected farm (NF Farm). Through this case study approach, the survey revealed that supermarkets (31%) were the main place of purchase for fresh tomatoes due to convenience, followed by direct stores (28%) and unmanned stores (17%) owing to both convenience and good product quality. Results indicated that cherry tomatoes were the most widely consumed across all seasons, while summer was the season with highest consumption of all tomato types, with prices ranging between 101 JPY and 500 JPY (1 USD = 133.9 JPY). After only 5 years in business, NF Farm seemed to have gained a fan base. Unfortunately, 63.8% of consumer-respondents indicated no knowledge of the farm logo. Most related the farm to the name of the farmer. Thus, there is a need for NF Farm to re-evaluate its farm brand (e.g., logo, farm name, labeling) so that it will be properly recognized even by its long-time customers.

Keywords new farmers, preference, brand familiarity, farm resilience, women farmer

INTRODUCTION

Japanese agriculture faces various challenges, including the need for more farmer successors and an increasing number of aging farmers. Among new farmers, farming discontinuation within a few years is prevalent due to various issues (MIC Japan, 2019), including difficulty securing farmland, insufficient technology adoption, low income, and weak branding. In recent years, the importance of recruitment and support services (including financial and technical aspects) for new farmers has been gaining recognition (McGreevy et al., 2019; Fujisaki and Saitou, 2020). There are also studies focusing on the challenges of support systems for new farmers during the entry process into agriculture (Okamato and Miyake, 2022) and the roles of marketing-related policy support (Yoshida and Yagi, 2019).

According to the Ministry of Agriculture, Forestry and Fisheries (MAFF Japan, 2022b), the number of new farmers is experiencing a decrease from 55,670 persons in 2017 to 52,290 persons in 2021. New farmers aged 49 years old and younger showed a similar downtrend from 20,760 persons in 2017 to 18,420 persons in 2021. On the other hand, the number of new female farmers has been on the increase, with the number of newly employed and newly applied female farmers increasing by 6.9% and 11.1%, respectively.

Tomato is the most common fruit vegetable consumed fresh or processed in Japan. In terms of agricultural income produced, tomatoes had the highest share (10%) among vegetables (MAFF Japan, 2023). For new farmers, tomato is considered one of the preferred high-value commodities for production. However, with a wide variety of tomatoes available in the market, new farmers seemed to face various issues related to price, market competitors, market channels, sweetness, production management, and brand recognition. These same challenges may influence a new farmer's decision to continue or discontinue farming. Therefore, studies that will provide insights and innovations to improve farm business operations and resilience of each new farmer are relevant and timely. Resilience is vital for farmers for adapting to the current and changing environment (Shimoguchi and Mojica, 2016). The provision of accessible markets may encourage these farmers to continue farming (Shimoguchi et al., 2020).

It should be noted that this study has been conducted in consultation with the young female new farmer in H City to address her inquiries and concerns about her venture into greenhouse tomato farming, including understanding her consumers and clarifying brand status, with an aim of improving her farming business and resilience.

OBJECTIVE

This study aimed to identify the characteristics of consumers, determine their fresh tomato purchasing and consumption behavior in general, and clarify consumer satisfaction and their brand familiarity with the greenhouse tomato farm (thereafter, NF Farm) managed by a young female farmer in H City, Tokyo.

METHODOLOGY

Based on an interview conducted in March 2022, it became clear that NF Farm needed assistance in determining its consumer base, identifying their perception of the taste and price of tomatoes, evaluating their satisfaction level, and clarifying their farm recognition. A total of 470 consumer-respondents were collected from the fresh tomato consumer survey conducted from 1 May to 30 June 2022 in H City, Tokyo. To capture a wide range of consumers, this study was conducted in the places where the tomatoes of NF Farm are being sold, specifically a *mujin hanbai* store (which refers to an unmanned store using an honor system for payment and located on the farm premises), three (3) retail stores, SNS, and events. We utilized three survey methods using a structured questionnaire, namely: face-to-face survey, online survey via quick response (QR) code shown in in-store point-of-purchase (POP) displays, and online survey via near-field communication (NFC) tag placed on POP displays. The structured questionnaire consisted of three parts: (1) consumer profile, (2) fresh tomato

purchasing and consumption behavior, and (2) knowledge, tomato preference, and recognition of the NF Farm logo. Moreover, a four-point Likert scale was used to determine their satisfaction level with NF tomatoes.

After identifying those who have experienced buying tomatoes from our selected farmer, survey results from 213 consumer-respondents were utilized and analyzed using descriptive analysis.

RESULTS AND DISCUSSION

Profile of NF Farm

NF Farm was established in 2019 by a young female aspiring farmer. Under the provisions of the revised Law on Productive Green Areas (also known as *seisan ryokuchi ho* in Japanese), she was able to rent a 2,000 m^2 plot of land in 2018, where she operates a greenhouse for tomato production (including cherry, medium size, and large size tomatoes), produces seasonal vegetables (e.g., cabbage, zucchini) on an open-field, and processes some of the harvested tomatoes into puree. Freshly harvested vegetables are sold at an unmanned store (commonly known as *mujin hanbai* in Japanese) located on the farm. In addition to this *mujin hanbai*, NF Farm also sells via JA direct stores, supermarkets, specialty retail stores, events (e.g., Marche, weekend markets), and its own online store.

Characteristics of the Consumer-respondents

Based on survey results from the 213 consumer-respondents, the average age was 52 years old. In terms of gender, there were fewer males than females. Regarding the distribution by age and family structure, Fig. 1 indicates a wide age range of consumer-respondents. Family structures have four types: couples with children, couples living alone, and extended family. Most respondents are couples with children in the age range of 30 to 59 years, followed by couples and those living alone.

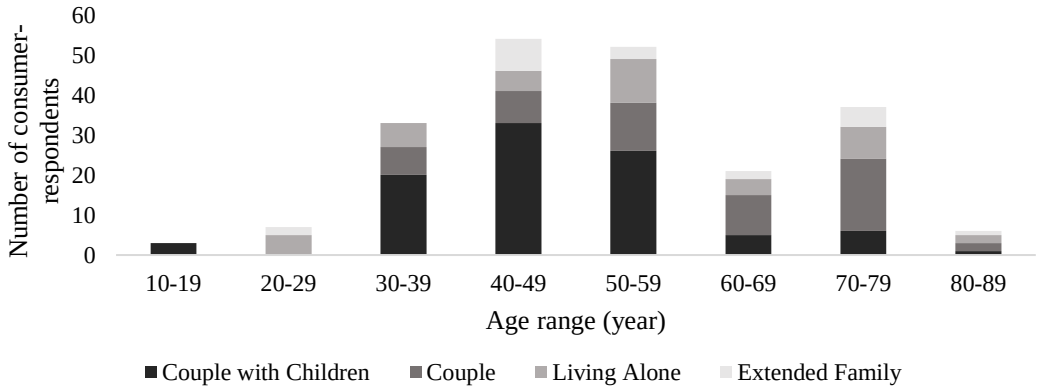

Fig. 1 Number of tomato consumer-respondents by age range and family structure (n=213)

Purchasing and Consumption Behavior of the Tomato Consumer-respondents

Table 1 shows the consumer-respondents' purchasing behavior in terms of preferred place of purchase for fresh tomatoes and the reason for choosing that place. There were four types of places of purchase: supermarket, direct store, *mujin hanbai*, and other, and four types of reasons: convenience, quality, price, and other. Regarding choice of place of purchase, the supermarket was their top choice (66 consumer-respondents, 31%) in purchasing fresh tomatoes, followed by direct store (60 consumer-respondents, 28%) and *mujin hanbai* (38 consumer-respondents, 18%). Most of the consumer-respondents chose the supermarket due to convenience. The direct store was preferred by 32 and 16 consumer-respondents due to good quality and convenience, respectively. Similar to

the reason for choosing direct stores, consumer-respondents valued convenience and quality for choosing *mujin hanbai*. The results also indicate that affordability was not a primary reason for purchase. We assume that there were no significant price gaps among these stores for fresh tomatoes. Moreover, convenience and quality seemed to be more important when choosing a place of purchase. Some consumer-respondents mentioned that they purchase NF Farm tomatoes as their way of supporting this young female farmer.

Table 1 Number of tomato consumer-respondents by place of purchase and reason for choosing the place (n=213)

Reason for choosing the place	Place of purchase				Total
	Supermarket	Direct store	*Mujin hanbai*	Other	
Convenience	41	16	17	13	87
Good quality	9	32	19	16	72
Affordable price	2	1	1	0	4
Other	14	11	1	20	46
Total	66	60	38	49	213

Notes: Mujin hanbai refers to an unmanned store with an honor system for payment.
Pearson's Chi-squared test (p-value = 6.201e-07)

Regarding the frequency of purchasing fresh tomatoes, cherry tomatoes seemed to be purchased on a regular basis (74% of the consumer-respondents) compared to medium size (irregular basis 48%) and large size (59%) tomatoes (p-value = 7.341E-14). If the consumer-respondent purchases once a week, cherry tomato was their main choice (49%). This is expected, since cherry tomatoes are often used in lunch boxes and salads in Japan.

In Japan, tomatoes are produced all year round. However, it is assumed that consumers have a specific preference for the type of tomato to purchase and how it is utilized depending on the season. Figure 2 shows the utilization of tomatoes by type and season. This information is important for farmers in planning what type of tomatoes to produce by season. Types of tomatoes were categorized into cherry, medium size, large size, and combination, while utilization was divided into salad, lunch box, cooked, and others. For all seasons, cherry tomatoes showed to be the main type consumed, and mostly used for salads. Since this finding is in line with MAFF Japan's (2022a) report that cherry tomato is the most commonly produced tomato, accounting for 21% of total harvested volume, it can be said the cherry tomatoes are still popular for both consumption and production. Moreover, summer is an exception, with the high consumption frequency of all tomato types can be seen when comparing with all seasons. In terms of tomato utilization, tomato salads had the highest frequency in both types and seasons.

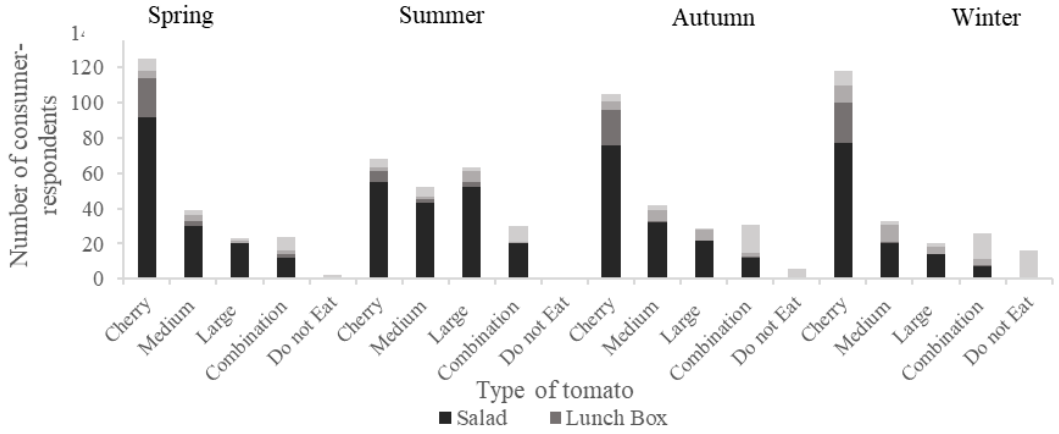

Fig. 2 Utilization of tomato by type of tomato and season (n=213)

Level of Satisfaction with NF Farm Tomatoes and Preferred Price

Table 2 shows the satisfaction level of consumer-respondents with the NF Farm tomatoes based on various factors: freshness, color, taste, size, acidity, hardness of peel, sweetness, and price. Looking at the average satisfaction level calculated using the Likert scale, consumer-respondents were satisfied with all factors, with freshness (3.52) as the top factor, followed by color (3.43), taste (3.38), and size (3.38). Since NF Farm harvests tomatoes daily and supplies them to most of its clients on the same day, consumer-respondents seemed to acknowledge that the tomatoes are freshly harvested. Moreover, price is the least important for them, conveying that some of them purchase tomatoes as part of supporting the initiatives of this young female farmer.

Table 2 Satisfaction level with NF Farm tomatoes (n=213)

Factors	Average	SD
Freshness	3.52	0.54
Color	3.43	0.56
Taste	3.38	0.60
Size	3.38	0.54
Acidity	3.27	0.57
Hardness of peel	3.25	0.58
Sweetness	3.23	0.60
Price	3.07	0.60

Note: Satisfaction level is based on the following scale: 1 – very unsatisfied, 2 – unsatisfied, 3 – satisfied, 4 – very satisfied

Table 3 shows the cross-tabulation between the price range of tomatoes and taste satisfaction among the consumer-respondents. Price categories ranged from 100 JPY and below to 1,001 JPY and above. Most of the consumer-respondents (94%) were either very satisfied or satisfied with the NF Farm tomato taste, especially those consumer-respondents paying a price range of “101 to 300” JPY and “301 to 500” JPY. This may also convey that the NF Farm needs to keep the tomato price ranging between 101 JPY and 500 JPY.

Table 3 Tomato price range and taste satisfaction for NF Farm tomatoes (n=213)

Tomato price range (JPY)	Taste satisfaction				Total
	Very satisfied	Satisfied	Unsatisfied	Very unsatisfied	
100 and below	1	0	0	0	1
101 to 300	33	40	2	1	76
301 to 500	37	50	4	0	91
501 to 700	13	6	1	0	20
701 to 1,000	9	3	1	0	13
1,001 and above	0	1	1	0	2
No Answer	0	9	1	0	10
Total	93	109	10	1	213

Notes: (1) Pearson's Chi-squared test (p-value =0.0390),
(2) Exchange rate is 1 USD = 133.9 JPY (June 2022, MUFG Bank)

Brand Familiarity of the Consumer-respondents

Table 4 explains the consumer-respondent’s familiarity with NF Farm and its brand. Cross tabulation was conducted between sources of initial NF Farm and length that the respondents know about the farm. Among the listed information sources, “living nearby and *mujin hanbai*” was the most common reason followed by “media”, “SNS and event”, and "acquaintance”. The majority of the consumer-respondents have known NF Farm more than a year ago. Although “living nearby and *mujin hanbai*” seemed to be an effective way as initial source of information, there is a need to determine the impact of SNS and other publicity as a method of disseminating information about the farm.

Table 4 Number of consumer-respondents by first knowledge and purchase, recent tomato purchase and brand recognition of the NF Farm (n=213)

Particular factors	First time to know about the farm and purchase tomato			Total
	One year ago, and above	Between less than one year and six months ago	Within six months	
Source of Information				
Living nearby and *mujin hanbai*	111	22	14	147
Media (TV and newspaper)	20	1	4	25
SNS and event	14	3	5	22
Acquaintance	15	2	2	19
Most recent purchase				
Within a week	72	6	9	87
Few weeks ago	48	13	11	72
Few months ago	24	8	3	35
One year ago	13	0	0	13
Others	5	1	0	6
Brand recognition				
Yes	60	10	7	77
No	102	18	16	136
Total	162	28	23	213

Notes: Mujin hanbai refers to unmanned stores.

For those people who knew the farm longer than a year, their most recent purchase of NF Farm tomatoes was within a week or a few weeks ago. This implies that the longer consumer-respondents knew about NF Farm, the more frequently they purchased NF Farm tomatoes. However, despite the familiarity and purchasing behavior among the consumer-respondents, they seemed not to recognize the brand by logo and name (63.8%). Instead of a logo, consumer-respondents knew the farm by the name of the farmer. This offers additional evidence for the lack of brand recognition among the consumer-respondents, and that the publicity efforts through SNS and other information sources are not sufficiently effective in raising recognition of NF Farm and its products.

CONCLUSION

Consumer-respondents were mostly female (77%) with an average age of 52.2 years old. Couples with children (44%) were the most common, followed by couples (27%). In purchasing fresh tomatoes, the supermarket (31%) was the main place of purchase due to convenience, followed by direct stores (28%) and *mujin hanbai* (17%) because of convenience and good quality. Cherry tomatoes seemed to be the most widely consumed of all seasons, and summer was the season with the highest consumption of all tomato types.

With regard to NF Farm tomatoes, consumer-respondents were most satisfied with their freshness. This is a given factor, since tomatoes are shipped to retails stores immediately after harvest. Price had the lowest satisfaction rating, conveying that consumer-respondents seemed do not mind the price as an act of support to the farmer initiative. With only a few years in business, NF Farm seemed to have gained a fanbase. Unfortunately, 63.8% of consumer-respondents indicated no knowledge regarding the farm logo. Most related the farm to the name of farmer.

This study recommends that NF Farm increase and improve production of cherry tomatoes because of their apparent all year-round demand, while keeping the price within the 101 to 500-yen range. Since most consumer-respondents consider convenience and good quality when choosing a place of sale, NF Farm needs to increase its supply to supermarkets.

For further study, there is a need to re-evaluate the NF Farm brand (e.g., logo, farm name, labelling) so that it will be properly recognized by consumers. Moreover, determining the

characteristics of NF Farm's repeat customers may give further insights on how to maintain good relationships with them while achieving sustainability of its farm business.

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Research article

Effect of Pollination by the *Apis mellifera* on Yield and Fruit Productivity Quality of Greenhouse Produced Sweet Net Melon in Cambodia

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Abstract Sweet net melon (*Cucumis melo* L.) is an annual climbing plant famous for its delicious fleshy fruit. It is one of the most widely cultivated and consumed worldwide. This study aimed to investigate the efficacy of pollination employing *Apis mellifera* L. (Hymenoptera: Apidae) on yield and growth in greenhouse conditions, compared to the traditional method of hand cross-pollination and self-pollination. The experiment was laid out using a completely randomized design (CRD) with 3 treatments and one hundred replications: T1 represented self-pollination, T2 – hand cross-pollination, and T3 – *Apis mellifera* pollination. Plant growth, fruit yield, and sugar content were analyzed by using a portable refractometer. Results revealed that the *Apis mellifera* pollination had resulted in a significantly greater fruit set of sweet net melon than hand cross-pollination and self-pollination (100%, 74%, and 62%, respectively). Furthermore, *Apis mellifera* had significantly enhanced fruit yield compared to self-pollination and hand cross-pollination. In addition, self-pollination, hand cross-pollination, and *Apis mellifera* pollination were not significantly different in terms of sweetness, fruit thickness, fruit weight, number of seeds per fruit, and fruit size. Therefore, pollination by *Apis mellifera* can be used to increase fruit yield and ensure food security, in line with Cambodia's National Strategy for Food Security and Nutrition from 2019 to 2023. In addition, pollination by *Apis mellifera* may be one of the most powerful tools for agricultural adaptation to climate change.

Keywords: *Apis mellifera*, pollination, thickness, flower

INTRODUCTION

Sweet net melon (*Cucumis melo* L.) is an annual climbing plant. It is widely cultivated and consumed in flesh fruit (Kesh and Kaushik, 2021; Revanasidda and Belavadi, 2019; Silva et al., 2020). The reports indicated that world melon production increased by 9% between 2012 and 2016, the cultivated area increased by 9000 ha, and the fruit yield increased from 24.6 tons/ha-1 to 25 tons/ha-1 (FAOSTAT, 2017). Nut et al. (2019) have reported that, in Cambodia, tens of thousands of melons are produced every year by local farmers. Melon plants have a shorter life, about 3 and 4 months, where anthesis and pollination occur 30 to 35 days after sowing. Following pollination, fruit development and growth are harvested 70 days after sowing (Azmi et al., 2019). Flowers of melon plants tend to be monoecious (Grumet et al. 2007) – in fact, they are either male or female, and both occur on the same plant. Generally, plants with monoecious flowers need pollinators, especially insects, to ensure enough pollination (Azmi et al., 2019; Dasgan et al., 1999).

Melon is typically grown in greenhouses; however, inadequate pollination prevents the highest levels of output and quality because suitable insects cannot enter the enclosed greenhouses, preventing pollinators from entering (Kwon and Saeed, 2003; Dasgan et al., 1999). To solve these

pollination problems, staff are employed to hand-pollinate melon flowers, but this approach is more inefficient and economically costly than the use of insects as natural pollinators to increase crop yield and quality (Azmi et al., 2019). For melon fresh fruit, quality is what mostly influences consumers' conduct and formulates recurring buying habits and brand loyalty within a reasonable price (Kyriacou et al., 2018).

Many greenhouses' crops depend on bee species for pollination (Sadeh et al., 2007). The European honeybees (*Apis mellifera* L.) are the most frequent floral visitor of crops worldwide (Hung et al., 2018). The foraging behavior of honeybees, which collect nectar and pollen to maintain their colonies, provides multiple benefits to plant pollination (Young et al., 2007). Thus, honeybees are the main pollinators for increasing crop yields, where they provide commercial pollination services to plants grown in greenhouses (Lee et al., 2018).

OBJECTIVE

The aim of the study is to investigate the effect of pollination by *Apis mellifera* L. (Hymenoptera: Apidae) on the yield and quality of net sweet melon in the greenhouse, compared with hand cross-pollination and self-pollination.

METHODOLOGY

Experimental Conditions

Sweet net melon plants (*C. melo* var. mellon sweet net 77) were cultivated from seed on the seed trays in a 24 × 32 m greenhouse at the Faculty of Agriculture and Food Processing, National Meanchey University (NMU), Cambodia, which is located at latitude of 13°34'52.2"N and longitude of 102°55'50.3"E from February 1st to April 23rd, 2022. Seeds were purchased from Known-You Seed co, ltd, a company product in Taiwan. The seed was soaked in 40-degree water within one and a half hours to two hours and planted in moist peat moss in the seed tray and covered with Green Garden Shade Net. After 10 days, germinated seedlings were transplanted into white grow bags consisting of (40 × 40 × 50 cm) that contained 5 kg of coco peat and placed in the greenhouses. Each grow bag was fertilized with 5 g of amino acid 5% + 12.3.3 + OM 35% and irrigated by a dripping fertigation system (A and B Solid Fertilizer recommendation). Branches were removed to allow growth of the main stem, and supporting red plastic ropes were provided at each grow bag to facilitate plant climbing to supporter wires. The colonies of *Apis mellifera* were provided by the Khmer Beekeeping Farm, with more than 30,000 adults per hive. Two hives of *Apis mellifera* were used in the greenhouse while experimenting.

Treatments and Experimental Design

The experiments were laid out using completely randomized design (CRD) with a hundred replications. There were 300 plots, and each plot size was 0.8 × 1 m. There were two rows in each plot with a plant spacing of 0.4 × 0.4 m, and the plant population per plot was 4 plants. The experimental plots were divided into three treatments as the following:

Table 1 Treatment and adaptation of the pollination control

Treatment	Pollination method	Control
Treatment 1	Self-pollination	Uncontrolled
Treatment 2	Hand cross-pollination	Human pollinator
Treatment 3	*Apis mellifera*	Bee pollinator

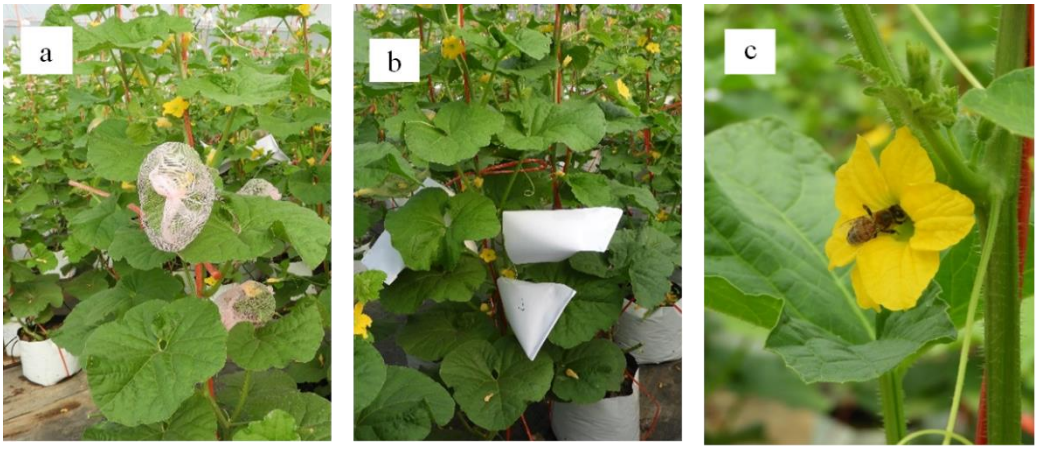

Fig. 1 T1 Self-pollination: use net size 3 × 3 mm to cover female flowers to protect against contamination by bees (a), T2 Hand cross-pollination: use white paper to cover female flowers to protect against contamination by bees and self-pollination (b), T3 *Apis mellifera*: use bees to pollinate (c)

Data Collection

Ten days after pollination, the fruit set on 100 plants from different treatments was recorded. The sweet net melons were harvested at 70 to 75 days using sharp knives or scissors. Generally, the ripe sweet net melons have senesced tendrils (Relf and Mcdaniel, 2020), and the minimum recommended sugar level for this fruit is 8 Brix. Below that level, the melons are not usually suitable for the market (Villanueva et al., 2004). Average fruit yield from 100 plants per treatment was also recorded, and 100 fruits from each of the 100 replication plants were chosen for weight, size, average number of seeds per fruit, and total soluble solids (TSS) content as a measure of sweetness. We measured the average number of seeds per fruit because a higher number of seeds leads to larger and heavier fruits (Cruz et al., 2005). First, the fruits were weighed (kg) using an electronic balance, and size (cm) was measured using a measuring tape. Then, the seeds were cut open to remove seeds. The thickness of the fruit flesh was cut into two wedges and measured the thickness. TSS content (Brix) of the fruit was tested from extracted juice, where a drop of juice from each cube was pipetted onto a screen panel of a portable refractometer.

Data Analysis

Data were collected from all samples of the three treatments and entered into Microsoft Excel. The data were statistically analyzed using R software (version 4.1.3).

RESULTS AND DISCUSSION

Sweet Net Melon Production

Table 2 shows that the average fruit set (%) of sweet net melon in treatment T3 = 100% was significantly different compared to other treatments. Thus, honey bees are the main pollinators for increasing crop yields. This probably provided commercial pollination services to plants grown in greenhouses (Lee et al., 2018). Meanwhile, T1 = 62% and T2 = 74% were not significantly different. This phenomenon may result from greenhouse cultivation, where high yields of sweet net melons are hindered by insufficient pollination due to the restricted access of pollinating insects within the enclosed structure. Pollinators are unable to enter greenhouses (Kwon and Saeed, 2003; Dasgan et al., 1999), necessitating manual pollination by staff. However, this approach is less efficient and more expensive than utilizing natural pollinators to enhance crop yield and quality (Azmi et al.,

2019). Besides, the average yield of sweet net melon in treatment T1 = 0.66 kg and T2 = 0.78 kg per fruit were not significantly different from each other, but if compared with treatment T3 = 1.05 kg, it was significantly different. It indicates that the yield of sweet net melon is related to the fruit set.

Table 2 Effect of pollination method on fruit set and yield of sweet net melon fruit

Treatment	Fruit set (%)	Average yield (kg per plant)
T1 = Self-pollination	62 ± 0.49^{a}	0.66 ± 0.53^{a}
T2 = Hand cross-pollination	74 ± 0.44^{a}	0.78 ± 0.49^{a}
T3 = *Apis mellifera*	100 ± 0.00^{b}	1.05 ± 0.18^{b}

Note: Data are meant ± SD. Different letters within a column indicate treatment differences at P < 0.05 (n = 100)

Sweet Net Melon Quality

Table 3 shows that the average total soluble solids were not significantly different, respectively. TSS is a genuine indicator of melon-consuming quality, with a minimum standard of ten percent recommended. The effect of the irrigation schedule was also considered with respect to increasing melon quality. To date, the recommended practice has been to cause an irrigation deficit close to fruit harvest, with the intent of drying out or stressing the plant to bring on maturity and increase sugar accumulation. Irrigation showed that keeping plants stress-free close to harvest and during harvest facilitated the production of sweet fruit (Long, 2005) from the same variety applied in the experiment (Albuquerque et al., 2006).

Table 3 Effect of pollination method on TSS content, flesh, weight, seed production, and size of sweet net melon fruit

Treatment	TSS (Brix)	Flesh (cm)	Weight (kg)	Number of seeds per fruit	Size (cm)
T1	13.49 ± 1.59^{ns}	3.9 ± 0.54^{ns}	1.03 ± 0.19^{ns}	393 ± 77.24^{ns}	38.24 ± 2.16^{ns}
T2	13.20 ± 1.92^{ns}	3.78 ± 0.41^{ns}	1.02 ± 0.16^{ns}	388 ± 64.04^{ns}	38.39 ± 2.01^{ns}
T3	13.24 ± 1.89^{ns}	3.8 ± 0.44^{ns}	1.06 ± 0.20^{ns}	400 ± 68.16^{ns}	38.82 ± 2.70^{ns}

Noted: Data are means ± SD. Different letters within a column indicate treatment differences at P < 0.05 (n = 100).

The average fruit thickness in treatment T1 = 3.9 cm, T2 = 3.78 cm, and T3 = 3.8 cm were not significant amounts in treatment. This phenomenon may arise from using the same variety (Albuquerque et al., 2006) and the fertilizer, irrigation, and cultivation conditions applied in the experiment (Simsek and Comlekcioglu, 2011).

All the treatments have the average weight, T1 = 1.03 kg, T2 = 1.02 kg, and T3 = 1.06 kg, number of seeds per fruit, T1 = 393, T2 = 388, and T3 = 400, and size, T1 = 38.24 cm, T2 = 38.39 cm, and T3 = 38.82 cm, were not significantly different. Cultivars of melons with an average weight of 0.6 - 2.5 kg planted in greenhouses have been in high demand overseas (Lyan et al., 2021).

CONCLUSION

In conclusion, this study showed that Apis mellifera pollination produced a greater fruit set of sweet net melon than hand cross-pollination and self-pollination. Pollination by *Apis mellifera* produced a higher yield than self-pollination and hand cross-pollination. Self-pollination, hand cross-pollination, and *Apis mellifera* pollination did not affect the sweetness, thickness of the fruit flesh, weight, number of seeds per fruit, and size of sweet net melon fruits.

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Research article

Impact of Technology Adoption on the Economic Well-being of Rice Farmers in Cambodia

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Abstract Variety is a key factor in the quality and productivity of paddy rice. In 2010, the Royal Government of Cambodia promulgated a paddy/rice policy that introduced 10 high-yielding rice varieties to farmers. This study investigated the socio-economic factors influencing farmers' decisions to adopt these high-yielding rice varieties while examining the impact of their adoption on yields and profits. Probit regression and propensity score matching methods were applied for analysis. The empirical results of the probit regression indicated that factors such as gender (male), paddy field size, and distance to a paved road had a significantly positive influence on farmers' adoption of the improved rice varieties. Meanwhile, household size, the number of paddy field plots owned, car ownership, off-farm job engagement, and the number of cows owned had a significantly negative effect. The results from propensity score matching methods revealed that farmers who had adopted high-yielding rice varieties experienced a significantly positive impact on yields and profits.

Keywords technology adoption, economic well-being, high-yielding rice varieties, Cambodia

INTRODUCTION

Agriculture is a vital sector for economic growth and development in Cambodia. Paddy rice in Cambodia is grown mainly under rainfed conditions, and the adoption of high-yielding rice varieties is generally limited. Constraints in policy promotion and technology dissemination have led to the low uptake of new technologies and the corresponding limitation in rice yield (FAO, 2010). The average rice yield in Cambodia in 2013 was 3.3 t/ha, the lowest among selected ASEAN countries. Vietnam led with an average paddy rice yield of 6.2 t/ha, followed by Indonesia (5.7 t/ha), Lao PDR (4.1 t/ha), and Thailand (3.5 t/ha), respectively (ADB, 2014). In an effort to boost rice production and enhance the net farm income of farmers, the Royal Government of Cambodia introduced a total of 10 high-yielding rice varieties. According to research conducted by CARDI (2011), all 10 rice varieties yielded higher than traditional varieties, with the total average being 18 percent higher. Generally, farmers tend to abstain from adopting new farming technology due to the risks and uncertainties it may pose. However, once they observe improvements in outcomes resulting from its use, they become more willing to adopt it, leading to faster diffusion (Feder and Umali, 1993).

To assess the effects of adopting new technology, a simple comparison between adopters and non-adopters without controlling for differences in characteristics can lead to biased estimations (Faltermeier and Abdulai, 2009). Therefore, this study utilizes the propensity score matching method to control variations in farmers' characteristics.

OBJECTIVE

This case study aims to identify the socio-economic factors influencing farmers' decisions to adopt high-yielding rice varieties and to examine the effects of adoption on their economic well-being in Bati district, Takeo province, Cambodia.

METHODOLOGY

A two-stage sampling technique was employed in this study. The first stage involved purposive sampling, wherein two communes in the Bati district of Takeo province were selected. In the second stage, random sampling was conducted using a random integer generator website (Randomness and Integrity Services Ltd., 2010). Farmers cultivating any of the 10 high-yielding rice varieties were categorized as adopters, while those still cultivating traditional varieties were classified as non-adopters. This selection, initially proposed as a 'dichotomous choice' by Feder et al. (1985), was followed (Awotide et al., 2011). Consequently, 151 adopter farmers and 151 non-adopter farmers, totaling 302 farmers, were selected as the respondent household sample. The field survey took place from late August to early October 2014, and semi-structured face-to-face interviews were conducted.

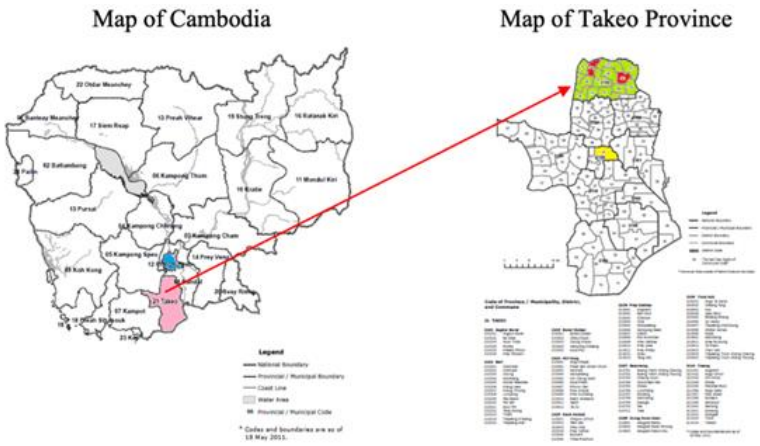

Fig. 1 Map of the study area

Farmers' adoption of technology may be influenced more by their individual characteristics than by their farming practices. A straightforward comparison without accounting for these varying characteristics can lead to biased estimations. Therefore, the study utilized a propensity score matching method to control for differences in farmers' characteristics. Following Beker and Ichino (2002), a two-step procedure was employed for propensity score matching. In the first step, a probability model was estimated to determine the propensity scores of each farmer. In this study, the probit model was defined as Eq. (1):

$$D_i = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n + \varepsilon_i \quad (1)$$

where D_i is a dummy dependent variable indicating the adoption of the improved rice varieties, X is the independent variable to be estimated, β represents the coefficients to be estimated, α_0 is the intercept term, and ε_i is the error term. Moving on to the second step, each farmer in the adopter group was paired with a traditional rice farmer having similar propensity score values to estimate the average treatment effect. The propensity score matching equation is written as Eq. (2):

$$P_{score} = 1 / (1 + e^{-Di}) \quad (2)$$

In this matching method, both single nearest neighbor matching (NNM) and kernel-based matching (KBM) were employed. The covariate balance test is typically necessary to ensure the quality of the matching. Asfaw and Shiferaw (2010) introduced overall covariate balance test criteria both before and after matching. Sianesi (2004) proposed that the pseudo R^2 should decrease after

matching to validate the success of the matching process, and joint significance should be rejected post-matching. Additionally, the mean bias should decrease after matching to affirm the quality of the matching. Rosenbaum and Robin (1985) recommended the use of mean absolute standardized bias (MASB), where a standardized difference should be less than 20% to confirm the success of the matching process.

RESULTS AND DISCUSSION

Descriptive Results

Table 1 presents the summary statistics of the basic profile of the respondent farmers and the results of t-tests indicating statistical differences between the two farmer groups. Several variables indicate that the adopter group has significantly lower values than the non-adopter group. These variables include household size, the number of paddy field plots owned, ownership of cars, ownership of cows, off-farm job engagement, livestock sales, income from off-farm activities, farming labor, and the receipt of extension service. The non-adopter farmers leverage larger family sizes to engage in more off-farm jobs and raise more livestock, leading to increased income. The non-adopters, with significantly higher off-farm income and livestock sales, and a greater percentage of households owning a car, appear to be economically wealthier than the adopters in terms of their non-farm economic status. Additionally, the non-adopters own more paddy field plots than the adopters. This higher number of plots for rice cultivation may require more farming labor, making it challenging for the non-adopters to embrace labor-intensive new technology as their family members are significantly committed to off-farm activities. Furthermore, limited contact with extension service is observed among the adopters due to the scarcity of extension officers in the communities.

Table 1 Socio-economic and demographic profile of the respondent farmers

Variables	Unit	Adopters (n=151)		Non-adopters (n=151)		Difference	t-Test
		Mean	SD	Mean	SD		
Household size	No. person	4.54	1.43	5.03	1.68	-0.49***	2.73
Age	Years	47.95	12.84	47.09	12.61	0.86	0.59
Education	Years	5.17	3.08	5.00	3.43	0.17	0.46
Gender (1=men)	Dummy	0.83	0.38	0.70	0.46	0.13***	2.73
Paddy field size	Ha	0.99	0.64	0.81	0.52	0.19***	2.79
Number of paddy field plots	Number	1.66	0.83	2.35	1.42	-0.70***	5.19
Distance to paved roads	Km	4.85	2.29	3.64	1.99	1.22***	4.93
Distance to the market	Km	6.84	1.67	6.23	1.66	0.61***	3.18
Own cars (1=yes)	Dummy	0.02	0.14	0.09	0.29	-0.07***	2.77
Own motorbikes (1=yes)	Dummy	0.76	0.43	0.68	0.47	0.08	1.54
Own cows	Number	1.27	1.34	1.68	1.41	-0.41***	2.30
Engage in off farm job (1=yes)	Dummy	0.14	0.35	0.70	0.46	-0.56***	11.83
Livestock sales	USD/year	55.76	290.14	169.17	713.84	-113.41*	1.81
Farmgate price per kg (rice)	USD/kg	0.31	0.02	0.25	0.03	0.06***	20.53
Off farm income	USD/year	101.17	391.82	747.92	1,223.29	-646.75***	6.19
Sell rice (1=yes)	Dummy	0.92	0.71	0.42	0.49	0.50***	10.96
Has source of water (1=yes)	Dummy	0.17	0.37	0.09	0.28	0.08**	2.09
Farming labor	No. person	2.91	1.05	3.95	1.33	-1.04***	7.54
Receive extension service (1=yes)	Dummy	0.08	0.27	0.25	0.44	-0.17***	4.12
Yield	t/ha	3.25	0.79	2.02	0.61	1.23***	15.10
Gross revenue	USD/ha	980.48	634.72	385.60	253.10	594.88***	10.70
Fixed cost	USD/ha	51.84	75.50	14.95	20.99	37.38***	5.79
Total variable cost	USD/ha	554.18	285.64	301.95	161.97	252.23***	9.44
Profit	USD/ha	426.30	392.24	83.65	137.33	342.65***	10.13

Source: Own survey, 2014

*Note: $p < 0.01$***, $p < 0.05$**, $p < 0.1$*; family labor cost has been included in the calculation; 1 USD was equivalent to 4,065 Riel (National Bank of Cambodia as of 1 September 2014)*

Meanwhile, the variables for which the adopter group in Table 1 exhibited a significantly higher value than the non-adopter group are gender, paddy field size, distance to paved roads, distance to the market, farmgate rice price, whether selling rice or not, and accessibility to water source. The adopter farmers have significantly more males than the non-adopters, probably because this pertains to the more labor-intensive features of improved rice farming, such as land preparation and application of synthetic pesticides, than traditional rice farming. Additionally, the adopter farmers own a significantly larger paddy field than the non-adopter farmers. This is likely because high-yielding rice varieties are more commercially oriented than traditional varieties in terms of market demand, and their benefits are better cultivated by growing them in a larger paddy field. The commercial orientation of the high-yielding varieties is also evident in the higher farmgate price received by the adopters compared to the non-adopters. The adopter farmers have a longer distance to paved roads and markets than the non-adopter farmers, probably because buyers tend to visit their rice farms to make purchases, while the non-adopter farmers must sell their rice themselves at the nearest market. The dummy results for 'sell rice' suggest that significantly more adopter farmers cultivate rice for commercial purposes, whereas significantly more non-adopter farmers focus on subsistence purposes only. Additionally, the adopter farmers have significantly better access to water than the non-adopters, possibly because high-yielding rice varieties generally require much more water than traditional rice varieties. Education and age are not statistically significant.

The yield, gross revenue, and profit generated by the adopter farmers from paddy rice farming are 1.23 t/ha, 594.88 USD/ha, and 342.65 USD/ha higher, respectively, than those by the non-adopter farmers. The fixed cost and total cost incurred by the adopter group are significantly higher than the non-adopter group because improved rice varieties require more labor and other inputs. Additionally, improved rice farming serves as their main household income source, with off-farm income accounting for only about 9.4% of their total household income. However, from this simple comparison, we cannot yet conclude that the farmers who adopted any of the improved rice varieties had a positive impact on yields and profits. This is because the better performance of the adopted farmers might have been influenced by certain characteristics that differ from the non-adopter farmers. Hence, it is necessary to control for these differences through propensity score matching.

Propensity Score Matching Results

Table 2 shows the results of the probit regression for factors influencing the probability of adopting any of the 10 high-yielding rice varieties. The results align with the findings from the descriptive analysis. Gender, paddy field size, and distance to paved roads are positively associated with the adoption of improved rice farming. This implies that a unit increase in each of these variables will lead to a higher adoption of the high-yielding rice varieties, as explained in the previous section. Additionally, household size, the number of rice plots owned, the number of cars owned, the number of cows owned, and off-farm job engagement show a significantly negative association with the adoption of improved rice varieties. This suggests that a unit increase in each of these variables will lead to less adoption of the high-yielding rice varieties, as mentioned above.

Table 3 shows the results of the effects of improved paddy rice farming on the economic well-being of farmer households. The adopter farmers obtained significantly higher yields than the non-adopter farmers, with differences ranging from 1.34 t/ha to 1.43 t/ha. This result is consistent with previous studies by Wiredu et al. (2010) in Northern Ghana, and by Saka and Lawal (2009) in Southwestern Nigeria. Regarding the effect on profits (net farm income), the differences are also positive and statistically significant in favor of the adopter farmers for all four matching methods, ranging from 324.27 USD/ha to 333.98 USD/ha. These results suggest that the adopter farmers achieved significantly higher economic well-being from paddy rice farming than the non-adopters. This finding aligns with some previous studies, such as Hossain et al. (2006) and Mendola (2006) in Bangladesh.

Moreover, Nguezet et al. (2011) from Nigeria, Wiredu et al. (2014) from Northern Ghana, and Wang et al. (2012) from six provinces of Cambodia identified relevant results, such as a significantly positive impact of improved paddy rice farming on the gross revenue from it. In contrast, Rahnam (2003) from Bangladesh showed that commercial rice production based on the use of high-yielding

varieties exhibited a sheer lack of efficiency, as the profit was little due to a combination of technical and allocative inefficiencies in modern rice production.

Table 2 Results of probit regression for the determinants of adoption

Adoption	Coeff.	Std. Err.	z	P>z
Household size	-0.18***	0.07	-2.66	0.01
Age	0.01	0.01	0.90	0.37
Education	0.04	0.03	1.17	0.24
Gender	0.57**	0.25	2.25	0.02
Paddy field size	0.72***	0.21	3.47	0.00
Number of paddy field plots	-0.50***	0.11	-4.38	0.00
Distance to the paved road	0.20***	0.05	3.97	0.00
Distance to market	0.04	0.06	0.59	0.55
Own cars	-1.21**	0.47	-2.55	0.01
Own motorbikes	0.21	0.22	0.93	0.35
Own cows	-0.13*	0.07	-1.86	0.06
Engage in off-farm job	-1.54***	0.20	-7.71	0.00
Constant	-0.21	0.72	-0.29	0.77
Number of observations				302.00
Log likelihood				-117.93
LR chi^2				182.81
Pro>Chi^2				0.00
Pseudo R^2				0.44

Source: Own survey, 2014
*Note: p < 0.01***, p < 0.05**, p < 0.1**

Table 3 Average treatment effects of technology adoption on yields and profits

Outcome	Matching method	ATT			
		Adopters	Non-adopters	Diff.	t-stat
Yield	NNM (1)	3.25	1.83	1.42	7.84***
	NNM (5)	3.25	1.82	1.43	9.35***
	KBM (0.03)	3.25	1.89	1.35	8.45***
	KBM (0.06)	3.25	1.91	1.34	8.72***
Profit	NNM (1)	374.00	47.06	326.94	6.42***
	NNM (5)	374.00	40.02	333.98	7.81***
	KBM (0.03)	374.00	48.08	324.27	7.25***
	KBM (0.06)	374.00	43.69	330.31	7.71***

*Note: p < 0.01***, ATT: average treatment effect on treated; Yield: Paddy rice yield (t/ha); Profit: from paddy rice farming (USD); family labor cost has been included in the calculation; 1USD was equivalent to 4,065 Riel; NNM (1): single nearest neighbor matching with replacement and common support; NNM (5): five nearest neighbor matching with replacement and common support; KBM (0.03): kernel-based matching with bandwidth 0.03 and common support; KBM (0.06): kernel-based matching with bandwidth 0.06 and common support.*

Table 4 presents the results from covariate balancing tests for matching processes. The pseudo-R^2, indicating how well the covariates explain the probability of improved technology adoption, was 44% before matching. After matching, the values decreased by only about 2-4%. The small differences before and after matching suggest no systematic differences in the distribution of covariates between the adopter and non-adopter groups. Additionally, the *p*-values of the likelihood ratio tests consistently indicated that the joint significance of the covariates was rejected after matching.

Furthermore, the results of the overall covariate balancing tests in Table 4 show that the standardized mean differences for the covariates used in the estimation process were 39.40% before matching. After matching, they decreased in the range of 8.30-9.30%. Through the matching process, the total bias was reduced by 76.40-78.93%. Significant bias still exists, and addressing it may require an increase in the sample size. The combination of a low pseudo-R^2, insignificant *p*-values of the likelihood ratio test after matching, low mean standardized bias, and high total bias reduction

suggests that the specification of the propensity score estimation process successfully balanced the distribution of covariates between the adopters and the non-adopters.

Table 4 Matching quality indicators before and after matching

Matching method	Pseudo R^2		LR chi^2 (p-value)		Mean standardize bias		Total % bias reduction
	Before	After	Before	After	Before	After	
NNM (1)	0.44	0.04	182.81 (0.000)***	15.56 (0.212)	39.40	9.30	76.40
NNM (5)	0.44	0.02	182.81 (0.000)***	9.70 (0.642)	39.40	9.10	76.90
KBM (0.03)	0.44	0.02	182.81 (0.000)***	9.37 (0.671)	39.40	8.30	78.93
KBM (0.06)	0.44	0.02	182.81 (0.000)***	7.44 (0.828)	39.40	8.70	77.92

*Source: Own survey, 2014; Note: p < 0.01***; NNM (1): single nearest neighbor matching with replacement and common support; NNM (5): five nearest neighbors matching with replacement and common support; KBM (0.03): kernel-based matching with bandwidth 0.03 and common support; KBM (0.06): kernel-based matching with bandwidth 0.06 and common support.*

CONCLUSION

The results from the propensity score matching methods revealed that the farmers who adopted high-yielding rice varieties had a positive impact on yields and profits from paddy rice production. We recommend that the Government of Cambodia prioritize rice farmers with smaller households and larger paddy sizes, especially those with limited off-farm opportunities, in their efforts to promote the adoption of high-yielding rice varieties in the nation. Careful support and training should be provided to female-headed farmer households to encourage women's involvement in improved rice farming, addressing issues such as poor access to information, limited skills due to low education, and a shortage of farm labor. Additionally, establishing an agricultural land policy to commercialize agricultural land and improving infrastructure for water access and market connectivity should be considered.

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Research article

Consumption of the *Elaeocarpus hygrophilus* Kurz Fruit in Cambodia: An Exploratory Study

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Abstract In Cambodia, most historical materials have been lost due to the genocide and the book-burning policy under the Pol Pot regime, and therefore, limited scientific records of the names, raw materials, manufacturing methods, and ingredients of traditional foods exist today. Current changes in the Cambodian lifestyle, such as the westernization of eating habits and increased food safety awareness, are driving factors that may result in the gradual disappearance of traditional foods. The *Elaeocarpus hygrophilus* Kurz fruit, known as *Madenh* or *Romdenh* in Khmer, is one example of a traditional food under pressure from changing eating habits. This study aimed to identify the consumption trends of *Elaeocarpus hygrophilus* Kurz and its processed products. The field survey revealed six ways of eating *Elaeocarpus hygrophilus* Kurz, including pickled, smashed-in-sugar, raw, caramelized, pickled-in-honey, and pickled-in-rice liquor. Additionally, the results of interviews with 514 customers in the local market about their habits regarding the product showed that younger customers tended to consume more pickled, smashed-in-sugar, and fresh fruit than the older generations. Further studies on the nutritional content of these products are needed to explore their relationship with eating habits and to prevent the decline in traditional food preferences.

Keywords consumption, Elaeocarpus hygrophilus Kurz, Cambodia, traditional foods

INTRODUCTION

From ancient times, Khmer residents used a variety of indigenous foods in their staple diets, including rice, fish, fruits, edible flowers, a pungent fermented paste called *Prohoc*, and fermented alcoholic beverages (Tully, 2005). Although these foods are an important aspect of Cambodia's national culture, they are mostly served only in traditional festivities such as Phcum Ben and the Khmer New Year, or weddings and funerals (Deth et al., 2020). The daily eating habits and traditional processing methods of the ubiquitous *Prohoc* and fermented alcoholic wines have been visibly

passed from generation to generation. For example, most Cambodian residents living in rural areas frequently catch fish from the Tonlé Sap Lake and nearby streams during the pick seasons to process *Prohoc* (LeGrand et al., 2020). The Ethnic Khmer groups including Khmer Khork, Suoy, Kuy, Kroung, Kravet, Lun, Tampuan, Phnong, and Kachok residing in the northern-eastern part of Cambodia still use traditional homemade starter culture for making fermented rice (*Tapae* in Khmer), rice liquor, and palm liquor (Yamamoto and Matsumoto, 2011). The local varieties of fermented (pickled) vegetables such as cucumber, mustard green, carrot, bean sprouts, cabbage, and daikon radish are popular (Chrun et al., 2017). The types of fermented meat include fish sauce, fish paste, shrimp paste, sour fermented paste, and salted fish, among others (Ly et al., 2020). A major fruit product in Cambodia is a pickled olive-like green fruit called *Madenh* or *Romdenh* in Khmer. In Cambodia, the scientific name *Planchonella obovata* is often used for this fruit and tree because the local Khmer-English dictionary uses the name. However, it was necessary to identify the species because neighboring countries such as Vietnam and Thailand use different scientific names for similar products with almost the same color, shape, and way of eating. This paper uses the scientific name *Elaeocarpus hygrophilus* Kurz as the result of identification by herbarium specimen using samples from several provinces in Cambodia[1]).

The fruit is mostly harvested from flooded areas and Cambodian people commonly use it as a traditional remedy, with pregnant women in particular consuming it after baby delivery to improve blood circulation (Dy, 2000). In Vietnam, the *Elaeocarpus hygrophilus* Kurz fruit is processed through fermentation, into jam, and pickled with rice wine; these products are highly consumed by rural and urban Vietnamese people because of the specific taste (Giang, 2023). In Thailand, it is used as a traditional medicine for reducing body overheating and stimulating saliva secretion (Kuria et al., 2021). Although these products are widely sold at wet markets in Cambodia and highly consumed, the available varieties and consumption trends of the fruit have not yet been examined. In particular, current changes in the Cambodian lifestyle, including the Westernization of eating habits and increased awareness of food safety, are enhancing the risk that such traditional foods may disappear unnoticed.

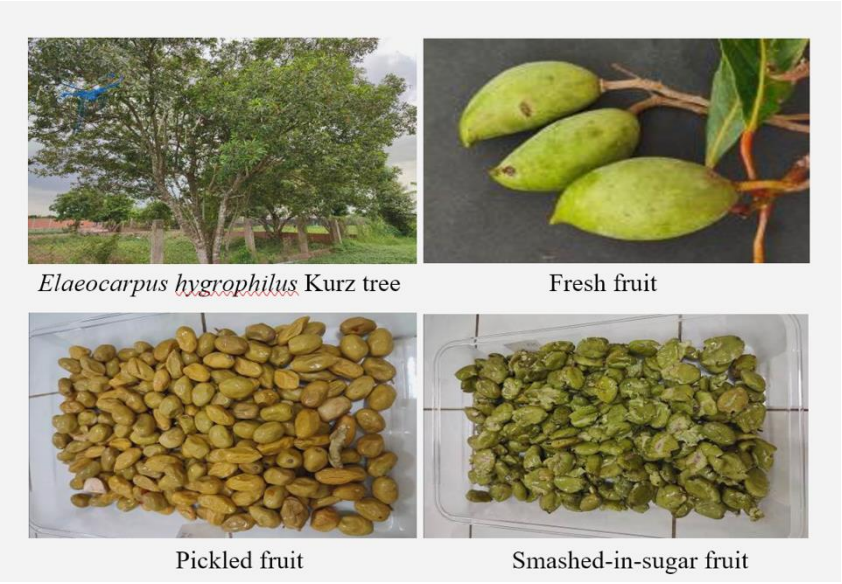


Fig. 1 *Elaeocarpus hygrophilus* Kurz tree and related products

OBJECTIVE

This study aimed to identify the existing varieties and consumption trends of the *Elaeocarpus hygrophilus* Kurz fruit products in Cambodia by examining the consumption habits and demographic characteristics of Cambodian residents.

METHODOLOGY

A total of 514 participants were selected from 25 provinces in Cambodia, covering two markets per province and at least 10 to 12 customers per market. Face-to-face interviews were conducted from September to October 2022.

A two-pronged analysis method was employed. First, descriptive statistics were used to explore the respondents' demographics – age group, gender, religion, and nationality; motives – sensory characteristics and product type awareness; consumption habits – product types, eating location, and occasion; and the consumption frequency of *Elaeocarpus hygrophilus* Kurz products. Second, ordered probit models were used to investigate the relationship between consumption frequency and participants' demographics, consumption habits, and motives for consuming *Elaeocarpus hygrophilus* Kurz products. These models were not used for interpreting the consumption frequencies (never, low, medium, and high); therefore, marginal effects were used to predict the probability of such levels.

Before starting the ordered probit models, the main variables of demographics, consumption habits, and motives, which were included as dummy variables and displayed as independent variables, were examined carefully for multicollinearity with the consumption frequency (dependent variable) of *Elaeocarpus hygrophilus* Kurz products; if the values of variance-inflating factors (VIF) are higher than 5 to 10, multicollinearity might occur among the independent variables in the regression models. However, in this study, the VIF values with the ordered probit model were between 1 and 1.81, which was acceptable (Shrestha, 2020). Therefore, the final suitable independent variables used after checking VIF included demographics – age groups (Age 1—Age 5), gender – product type, eating location, occasion (Pchum Ben, Khmer New Year, wedding, water festival, and recreation), and motives (taste, smell, color, appearance, and health benefit), independently.

Consumption frequency (dependent variable) was measured on a scale from "0" (never) to "high" (every day or two to three times per week; low = once every three months or one to two times a year; medium = once per week or month). This scale was further used to measure the consumption of four popular products of *Elaeocarpus hygrophilus* Kurz fruit, including fresh, pickled, smashed-in-sugar, and caramelized. Thus, the ordered probit models generalized the consumption frequency of each product by changing a unit whenever an independent variable unit increased or decreased. Age 6 and Age 7 showed high collinearity; therefore, they were excluded from the ordered probit models. A detailed description of the variables is presented in Table 1.

According to Lanfranchi (2019), the ordered probit model was formed as follows Eq. (1).

$$y_i^* = \beta x_i + \varepsilon_i \quad (1)$$

Where y_i^* is an unobserved dependent continuous variable (consumption frequency) of i (i = 0 (never), 1 (low), 2 (medium), 3 (high)), x_i, a matrix of known values of independent explanatory variables (demographics, consumption habits, and motives of respondents), β is a vector of unknown slop parameters to be estimated, and ε_i, a vector of stochastic error-term (standard normal distribution). The variable y is observable and the relationship between y and μ_i is referred to as the threshold point function (cut-off points; y_i^*) that is predicted along with the regression coefficient.

Consumption frequency (y = 0, 1, 2, 3) was determined following Eq. (2).

$$y = 0 \text{ if } y^* \leq 0,\ y = 1 \text{ if } 0 \leq y^* \leq \mu_1,\ y = 2 \text{ if } \mu_1 \leq y^* \leq \mu_2, \text{ and } y = 3 \text{ if } y^* \leq \mu_2 \quad (2)$$

Where μ_1 and μ_2, ($0 < \mu_1 < \mu_2$) are threshold parameters of y^* that are predicted with β. The form of probability of consumption frequency was estimated according to Eq. (3):

$$Prob\ (y=0) = \Phi\ (-\beta x),\ Prob\ (y=1) = \Phi\ (\mu_1 - \beta x) - \Phi\ (-\beta x), \ldots,\ prob\ (y=3) = 1 - \Phi\ (\mu_2 - \beta x) \quad (3)$$

Where Φ is the normal cumulative distribution function. The ordered probit model was predicted by using maximum likelihood estimation (Gebre and Rahut, 2021). The interpretation was based on the β parameters through the independent variable impact on consumption frequency. In the post-estimation, marginal effects were used to estimate the different scales of consumption frequency levels by estimating a change in its probability concurrently with a change in the unit of an

independent variable (Cantillo et al., 2021). All data were analyzed using the STATA version 13 statistical software.

Table 1 Variable description

Type of variable	Description of variable	Category	Expected sign
Dependent variable			
Food consumption frequency	0 = never; 1 = low; 2 = medium; 3 = high	Continuous	
Independent variable			
Demographics			
Age 1	1 = if age is less than 19 years; 0 = otherwise	Dummy	+/-
Age 2	1 = if age is between 20–29 years; 0 = otherwise	Dummy	+/-
Age 3	1 = if age is between 30–39 years; 0 = otherwise	Dummy	+/-
Age 4	1 = if age is between 40–49 years; 0 = otherwise	Dummy	+/-
Age 5	1 = if age is between 50–59 years; 0 = otherwise	Dummy	+/-
Age 6	1 = if age is between 60–99 years; 0 = otherwise	Dummy	+/-
Age 7	1 = if age is more than 70 years; 0 = otherwise	Dummy	+/-
Gender	1 = male; 0 = otherwise	Dummy	+/-
Consumption habit			
Production type	1 = if the consumer processes *Elaeocarpus hygrophilus Kurz* themselves; 0 = otherwise	Dummy	+
Eating location	1 = if the consumer eats such products at home; 0 = otherwise	Dummy	+
Occasion festivities			
Pchum Ben	1 = if consumed during Phcum Ben festival; 0 = otherwise	Dummy	+
Khmer new year	1 = if consumed during Khmer New Year; 0 = otherwise	Dummy	+
Wedding	1 = if consumed during wedding; 0 = otherwise	Dummy	+
Water festival	1 = if consumed during water festival; 0 = otherwise	Dummy	+
Recreation	1 = if consumed during recreation; 0 = otherwise	Dummy	+
Motives			
Taste	1 = if taste is important; 0 = otherwise	Dummy	+
Smell	1 = if smell is important; 0 = otherwise	Dummy	+
Color	1 = if color is important; 0 = otherwise	Dummy	+
Appearance	1 = if appearance is important; 0 = otherwise	Dummy	+
Health benefit	1 = if health is important; 0 = otherwise	Dummy	+

RESULTS AND DISCUSSION

Table 2 displays the detailed demographic characteristics of the respondents. Their age groups included 50 years and older (200 respondents; 38.10%), those of 30-49 years old (185 respondents; 35.99%), and younger than 30 years (129 respondents; 25.10%). The number of female respondents was 383 (74.51%); most were Buddhists (511; 99.41%) and all of them were Cambodian by nationality.

Table 3 shows respondents' motives for consuming *Elaeocarpus hygrophilus* Kurz based on sensory characteristics and product type awareness. A total of 449 consumers (87.35%) preferred the taste of *Elaeocarpus hygrophilus* Kurz products.

Table 4 shows the consumption habits of *Elaeocarpus hygrophilus* Kurz products. A total of six available products were identified in this study, including pickled, smashed-in-sugar, fresh, caramelized, pickled-in-honey, and pickled-in-rice liquor. Among all the products, the former four products were consumed the most. The number of consumers who bought pickled *Elaeocarpus hygrophilus Kurz* from markets was 415 (80.73%), whereas only 26 respondents (5.05%) made it

themselves. The smashed-in-sugar products were bought by 355 respondents (69.06%). A total of 238 respondents (46.30%) tended to consume store-bought pickled *Elaeocarpus hygrophilus* Kurz and 215 respondents (41.82%) bought smashed-in-sugar products. As consumers today may not have enough time to make these products by themselves, purchasing and eating both products out-of-home were likely more desired. According to Mihalopoulos and Demoussis (2001), consumers facing time constraints mostly opt for eating out, rather than home cooking. During the Pchum Ben festival, 220 (42.80%), 123 (23.93%), and 73 respondents (14.20%) reported eating the pickled, smashed-in-sugar, and fresh varieties, respectively, while during the Khmer New Year, wedding ceremonies, and the water festival, 52 (10.11%), 31 (6.03%), and 54 respondents (10.50%), respectively, consumed these products. The pickled, smashed-in-sugar, and fresh products were commonly consumed as a snack during break times at work or during Cambodian festivities, suggesting that a high frequency of snack consumption is based on occasional festivities, location, and food availability (Mackenbach et al., 2022).

Table 5 shows the consumption frequency of these products, indicating three, based on consumer preference, including the pickled variety (12 respondents; 2.33%), smashed-in-sugar variety (13 respondents; 2.52%), and the fresh fruit (four respondents; 0.77%), which they consume every day among other products. These findings indicate that the high consumption frequency of *Elaeocarpus hygrophilus* Kurz products is relatively related to people's tastes. Therefore, taste is the primary driver of food preference, and it is the most important factor influencing food choices based on individual judgment (Chan and Zhang, 2022).

Table 2 Demographics of respondents

Classification	Description	Frequency (%)	
Age group	≤29	129	(25.10)
	30-49	185	(35.99)
	≥50	200	(38.10)
Gender	Male	131	(25.48)
	Female	383	(74.51)
Religion	Buddhist	511	(99.41)
	Muslim	1	(0.19)
	Christian	2	(0.38)
Nationality	Cambodian	514	(100.00)

Table 3 Motives in *Elaeocarpus hygrophilus* Kurz

Classification	Frequency (%)	
Sensory characteristic		
Taste	449	(87.35)
Smell	37	(7.19)
Color	24	(4.66)
Appearance	150	(29.18)
Health benefit	21	(4.08)
Product type awareness		
Pickled	485	(94.40)
Smashed-in-sugar	337	(65.60)
Fresh	152	(29.60)
Caramelized	70	(13.60)
Pickled-in-honey	1	(0.02)
Pickled-in-rice-liquor	3	(0.60)

Figure 2 illustrates the consumption trends of *Elaeocarpus hygrophilus* Kurz products by province. Regarding the relationship between consumption trends and geographical areas, we found six products available in Cambodia. The pickled product showed the highest number and ratio in all provinces of Cambodia, being chosen by 441 respondents (85.80%), implying that it was 75%–100% available for consumption in all provinces. The fresh fruit was moderately consumed, based on a

0%–24% to 75%–100% availability. Hence, three products – pickled, smashed-in-sugar, and fresh fruit – might be consumed more based on their availability, especially in markets, in all Cambodian provinces. While the caramelized product might also be available, only 48 respondents (9.34%) consumed it, demonstrating less interest in the product. The other two products – pickled-in-honey and pickled-in-rice liquor – showed less consumption in each province, implying that they were less commercial and more homemade products that some prepared when having spare time. Therefore, four available products – pickled, smashed-in-sugar, fresh, and caramelized – were used for analysis.

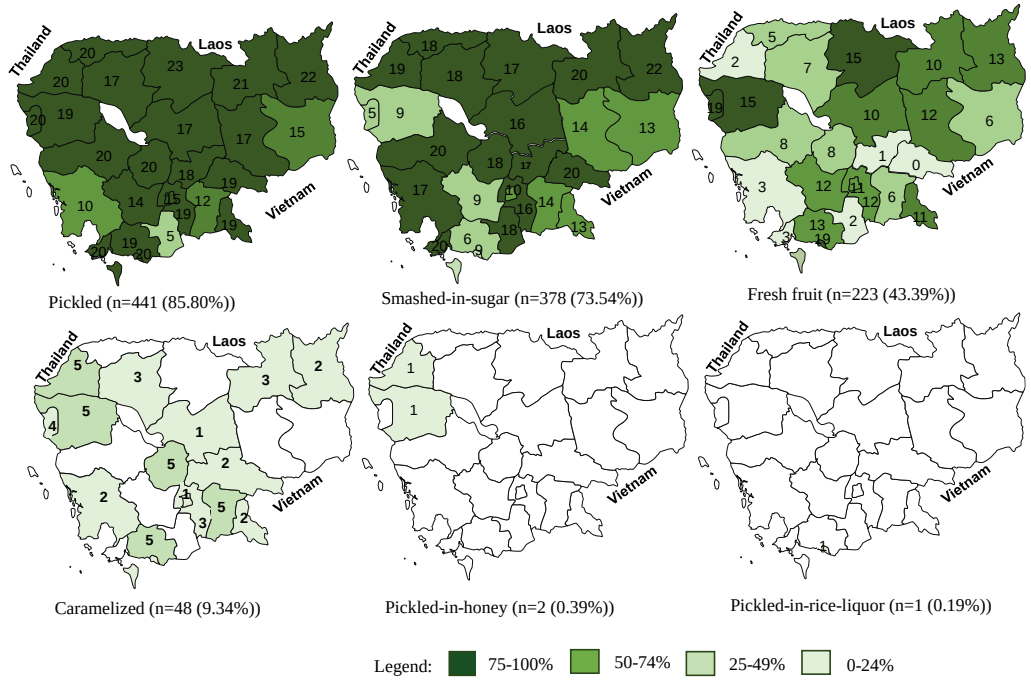


Fig. 2 Consumption trends of *Elaeocarpus hygrophilus* Kurz in all Cambodian provinces

Table 4 Consumption habits related to *Elaeocarpus hygrophilus* Kurz products

	Pickled (%)		Smashed-in-sugar (%)		Fresh (%)		Caramelized (%)		Pickled-in-honey (%)		Pickled-in-rice liquor (%)	
Product types												
Buy	415	(80.73)	355	(69.06)	208	(40.46)	43	(8.36)	0	(0.00)	0	(0.00)
Own processing	26	(5.05)	21	(4.08)	16	(3.11)	5	(0.97)	2	(0.38)	1	(0.19)
Eating location												
At home	202	(39.30)	160	(31.12)	129	(25.09)	17	(3.30)	2	(0.38)	1	(0.19)
Outside	238	(46.30)	215	(41.82)	92	(17.89)	27	(5.25)	0	(0.38)	0	(0.00)
Occasions												
Pchum Ben	220	(42.80)	123	(23.93)	73	(14.20)	29	(5.64)	0	(0.00)	0	(0.00)
Khmer new year	52	(10.11)	4	(3.51)	19	(3.69)	19	(3.69)	0	(0.00)	0	(0.00)
Wedding	31	(6.03)	19	(3.69)	9	(1.75)	9	(1.75)	0	(0.00)	0	(0.00)
Water festival	54	(10.50)	56	(10.89)	23	(4.47)	5	(0.97)	0	(0.00)	0	(0.00)
Recreation	213	(41.43)	121	(23.52)	92	(17.89)	40	(7.78)	0	(0.00)	0	(0.00)

Table 6 shows the results of the ordered probit model on consumers' habits and demographic characteristics. The chi-squared statistics from the models were statically significant ($P < 0.00$; χ^2 (18) = 184.70, 155.02, 388.04, and 105.81, Pro > chi-square = 0.00) for each product, suggesting that the models have a good fit (Oyetunde-Usman et al., 2021). We found that four group ages (Age 1–

Age 4) were positively significant at 1% and 10% with the pickled and smashed-in-sugar products of Elaeocarpus hygrophilus Kurz, respectively. Although the fresh fruit was not statistically significant, it showed a positive sign. Therefore, these age groups were more likely to eat more pickled, smashed-in-sugar, and fresh fruit. However, the coefficient was negative for the Age 4 and Age 5 groups with the caramelized product. Furthermore, consumers older than 49 years were less likely to eat the caramelized product, which may be determined by health problems. Interestingly, production type was positively and significantly correlated with the caramelized, pickled, and smashed-in-sugar variants at 1%, 5%, and 10%, respectively, meaning that consumers who considered making these products at home were more likely to eat them than those who purchased. This shows that home producers seemed to be overly concerned about food safety if they purchased these products from local wet markets, as they have no expiry date and labeling.

Table 5 Consumption frequency of *Elaeocarpus hygrophilus* Kurz products

Consumption frequency	Pickled (%)		Smashed-in-sugar (%)		Fresh (%)		Caramelized (%)		Pickled-in-honey (%)		Pickled-in-rice liquor (%)	
Never	73	(14.20)	138	(26.84)	291	(56.61)	465	(90.66)	512	(99.61)	513	(99.81)
1-2 times per year	66	(12.84)	52	(10.11)	51	(9.92)	30	(5.83)	2	(0.38)	1	(0.18)
1 time per three months	126	(24.51)	86	(16.73)	70	(13.61)	9	(1.75)	0	(0.00)	0	(0.00)
1 time per month	140	(27.23)	107	(20.81)	66	(12.84)	6	(1.16)	0	(0.00)	0	(0.00)
1 time per week	64	(12.45)	79	(15.37)	23	(4.47)	0	(0.00)	0	(0.00)	0	(0.00)
2-3 times per week	33	(6.42)	39	(7.58)	9	(1.75)	2	(0.38)	0	(0.00)	0	(0.00)
Every day	12	(2.33)	13	(2.52)	4	(0.77)	1	(0.19)	0	(0.00)	0	(0.00)
Total samples	514	100	514	100	514	100	514	100	514	100	514	100

Eating location was shown in a positively significant correlation at 1% with all four product types. Consumers tended to eat these products at home rather than outside. Regarding occasions, Pchum Ben, the water festival, and recreation were positively and significantly correlated at 1%, 5%, and 10% with the fresh fruit, smashed-in-sugar, and pickled products, respectively. Furthermore, consumers who considered these events important were more likely to consume the products. In addition, the taste and appearance of the fresh and pickled fruit were positively and significantly correlated at 1% and 10%, respectively, implying that consumers who perceived them important tended to have more on both fresh and pickled fruit compared to those who did not. However, consumers were less likely to eat the caramelized item for reasons such as unwanted sweetness and food abstention. Thus, the pickled and fresh fruit seemed to gain more interest from consumers because of health benefit reasons.

In the post-estimation of the ordered probit model, the marginal effect results of the pickled, smashed-in-sugar, fresh, and caramelized products are shown in Tables 7–10, respectively. In this part of the study, the overall probabilities of low, medium, and high consumption were estimated for all products of *Elaeocarpus hygrophilus* Kurz. We found that age groups were significantly associated with all levels of consumption frequency of the pickled product (Tables 7–10, Fig. 3), with the probability of low consumption decreasing by age group (Age 1 = 12.00%, Age 2 = 10.00%, Age 3 = 8.00%, Age 4 = 9.00%, Age 5 = 1.00% less likely of a low consumption). Regarding the smashed-in-sugar product (Fig. 3), age groups were significantly associated with consumption frequency, meaning that the average consumption increased by age group (Age 1 = 7.00%, Age 2 = 10.00%, Age 3 = 9.00%, Age 4 = 9.00%, Age 5 = 6.00%). These results indicate that younger people are more likely to eat pickled and smashed-in-sugar products than the older population. The latter may deal with health problems in terms of chronic diseases, such as high blood pressure or food allergies, resulting in fermented food abstention. Health conditions and dietary requirements are the main factors leading to changes in food consumption habits in older generations (O'Mahony et al., 2023).

Table 6 Ordered probit including consumer habits and demographic characteristics

Variables	Pickled		Smashed-in-sugar		Fresh fruit		Caramelized	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Age 1	1.12***	(0.23)	0.47*	(0.22)	0.50	(0.27)	0.25	(0.38)
Age 2	0.77***	(0.17)	0.62***	(0.16)	0.16	(0.19)	0.33	(0.27)
Age 3	0.62***	(0.17)	0.50***	(0.15)	0.03	(0.19)	0.19	(0.25)
Age 4	0.67***	(0.17)	0.57***	(0.16)	0.42*	(0.19)	-0.01	(0.30)
Age 5	0.03	(0.19)	0.33	(0.19)	0.02	(0.23)	-0.12	(0.34)
Gender	0.10	(0.13)	-0.12	(0.12)	-0.13	(0.15)	0.14	(0.20)
Production type	0.70**	(0.25)	0.53*	(0.26)	0.30	(0.31)	2.66***	(0.63)
Eating location	0.62***	(0.12)	0.84***	(0.12)	1.60***	(0.14)	2.64***	(0.34)
Pchum Ben	0.55***	(0.12)	0.35*	(0.14)	1.06***	(0.17)	-0.65	(0.54)
Khmer new year	-0.01	(0.09)	0.10	(0.15)	0.24	(0.15)	-0.11	(0.32)
Wedding	0.22	(0.09)	0.04	(0.98)	0.13	(0.15)	-1.52	(87.70)
Water festival	0.15**	(0.05)	0.11*	(0.05)	0.21***	(0.07)	-0.84	(81.22)
Recreation	0.09***	(0.02)	0.12***	(0.28)	0.23***	(0.03)	0.08	(0.07)
Taste	0.34	(0.18)	0.31	(0.17)	0.49*	(0.22)	0.11	(0.29)
Smell	-0.25	(0.25)	0.23	(0.24)	-1.29***	(0.38)	-0.48	(0.37)
Color	0.38	(0.28)	0.03	(0.26)	-0.11	(0.34)	0.65	(0.34)
Appearance	0.28*	(0.14)	-0.15	(0.14)	0.63***	(0.16)	0.32	(0.22)
Good health	0.45	(0.29)	-0.09	(0.27)	0.90**	(0.29)	-3.36***	(1.03)
Cut points								
cut 1	0.31***		0.40***		1.69***		1.91***	
cut 2	0.95***		0.78***		2.24***		2.71***	
cut 3	3.38***		2.68***		4.66***		3.74***	
Log-likelihood	-441.43		-515.32		-323.72		-146.46	
LR chi^2 (18)	184.70		155.02		388.04		105.81	
Prob > chi^2	0.00		0.00		0.00		0.00	
Pseudo R^2	0.17		0.13		0.37		0.27	

, **, and * indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.*

In Table 9 and Fig. 3, Age 1 and Age 4 were positively and significantly associated with fresh fruit consumption frequency, showing that consumers older than 19 were 2.00% more likely to have a low consumption of fresh fruit than those younger than 19 years. Interestingly, the Age 1 group were 17.00% more likely to have an average consumption of fresh fruit. Consumers in the Age 4 group (over 49 years) were 3.00% more likely to have low consumption of fresh fruit, surprisingly, being 13.00% more likely to reach the average consumption. Although other age groups were not significantly correlated with the fresh fruit, positive trends were observed. Older adults were more likely to eat the fresh fruit of *Elaeocarpus hygrophilus* Kurz. Younger ages habitually prefer to consume young fresh fruits, for example, young mango or wooden apple. This habit may not change when they become older, because of their adopted food experience and taste preferences from their childhood (Brady et al., 2022).

However, in Table 10 and Fig. 3, Age 4 was negatively and significantly correlated with the consumption frequency of the caramelized product of *Elaeocarpus hygrophilus* Kurz; Age 5 showed a similar negative trend but was not statistically significant. Results showed that older adults (in both age groups) were 1.00% less likely to have a low consumption. The sweet taste of the caramelized product determines adults over 49 years to consume it less, especially if they are faced with serious health consequences (e.g., diabetes), which usually result in diet restrictions on the consumption of confectionary and sugary products (Cheah et al., 2023).

Our findings showed that production type was significantly correlated with all levels of consumption frequency of the pickled and smashed-in-sugar *Elaeocarpus hygrophilus* Kurz, meaning that consumers who made these products at home were 9.00% and 4.00%, respectively, less likely to manifest low consumption of both products than those who purchased the products (Tables 7 and 8). However, the home producers were 11.00% (pickled) and 7.00% (smashed-in-sugar) more likely to have high and medium consumption of these products than purchasers. Consequently,

although the number of product purchasers was higher than that of home producers (for all products), the latter may show higher consumption because they make these products in large amounts, enjoying them with their families or friends. In contrast, while the number of purchasers is higher than that of home producers (Table 4), they seem to consume a smaller amount, as a small amount of money needs to be paid. Moreover, in Cambodia, those who make and consume their homemade products may care more about food safety issues, as the products sold in local wet markets lack labels, and expiry dates, are freely open-cover, and may contain unknown food additives, presenting health risks through food-borne diseases. Purchasing unhealthy foods may cause serious health problems due to microbial and chemical hazards (Ishra et al., 2022).

The eating location was shown to have the same trends as the production type. It was significantly associated with all levels of consumption frequency of pickled, smashed-in-sugar, and fresh fruit.

This means that consumers who preferred eating at home in the pickled and the smashed-in-sugar products increased the probabilities 8.00% and 6.00% each from low consumption to 10.00% and 14.00%, respectively, of moderate consumption compared to those who preferred eating out. Surprisingly, consumers who ate the fresh fruit at home were 52.00% more likely to achieve the average consumption than those eating out. Those who preferred eating the pickled, smashed-in-sugar, and fresh fruit at home tended to exhibit a positive emotional experience regarding food safety than those who did not; hence, their preference for processing these products by themselves at home, and freely enjoying their consumption. This result is similar to Lu et al.'s (2011) study, which concluded that consumers' positive emotional experiences in eating meals at home in North America were due to engaging in healthier meal choices because of ensuring food safety and long-term health benefits.

Regarding occasions, we found that Pchum Ben, the water festival, and recreation were significantly associated with pickled, smashed-in-sugar, and fresh fruit. Consumers who regarded Pchum Ben as important were 7.00% and 2.00% less likely to register a low consumption of pickled and smashed-in-sugar fruit, respectively, than those who did not. This may be because some Cambodian people changed their habitual food consumption by adopting quality and safety standards for their foods, leading to lower consumption of unstandardized local foods. Moreover, the new lifestyle and better-off income of local consumers stimulate them to change their habitual consumption. For instance, consumers with a high income living in South Korea prefer to consume organic foods because of an enhanced quality of life (Han and Lee, 2022). Furthermore, the pickled and smashed-in-sugar products were respectively 10.00% and 7.00% more likely to reach the medium level of consumption than others. Pchum Ben showed the highest probability (37%) of consumers reaching medium consumption of the fresh fruit product, followed by the water festival and recreation (Table 8). This implies that those with low income are less concerned about food safety compared to those with better-off income; therefore, they may purchase any available or cheaper food, regardless of its poorer quality or safety. In particular, when celebrating occasions in Cambodia, consumers gather with their families and enjoy these products as snack foods. Similarly, during the Chinese New Year, the Chinese food known as *Chap Chye* is consumed in large quantities due to family reunions for dinner (Chien and Karim, 2016).

Our findings showed that gender was not significantly correlated with any level of consumption frequency of the pickled, smashed-in-sugar, fresh, and caramelized products of *Elaeocarpus hygrophilus* Kurz; however, the coefficient showed positive and negative trends (Tables 7–10). Males were 2.00% and 1.00% more likely to have a moderate consumption of the pickled and caramelized products, respectively, and 1.00% more likely to have a high consumption of both, compared to females (Tables 6 and 9). However, they were 3.00% less likely to have a moderate consumption of the smashed-in-sugar and fresh fruits, and 1.00% less likely to have a high consumption of these products compared to females. The taste of smashed-in-sugar and fresh fruit of *Elaeocarpus hygrophilus* Kurz is a little sour and bitter, which makes them more appreciated by women as they are usually consumed with dried or fresh spicy chili, which are considered the favorite foods of Cambodian women (Yang et al., 2018). Moreover, in Cambodian culture and tradition, women have an active role in food preparation and are more likely to know about fermented foods than men; therefore, they may feel more interested in food consumption than men (Ganiyusufoglu et al., 2022).

Table 7 Marginal effects of consumption frequency on the pickled product

Variables	Consumption frequency of the pickled product							
	Never		Low		Medium		High	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Age 1	-0.08***	(0.01)	-0.12***	(0.02)	-0.01	(0.05)	0.22**	(0.07)
Age 2	-0.08***	(0.02)	-0.10***	(0.02)	0.07***	(0.01)	0.11***	(0.04)
Age 3	-0.07***	(0.02)	-0.08***	(0.02)	0.07***	(0.01)	0.08**	(0.03)
Age 4	-0.07***	(0.02)	-0.09***	(0.02)	0.06***	(0.02)	0.09**	(0.03)
Age 5	-0.01	(0.03)	-0.01	(0.03)	0.01	(0.04)	0.01	(0.02)
Gender	-0.01	(0.02)	-0.01	(0.02)	0.02	(0.02)	0.01	(0.01)
Production type	-0.06***	(0.02)	-0.09***	(0.03)	0.04	(0.03)	0.11*	(0.06)
Eating location	-0.08***	(0.02)	-0.08***	(0.02)	0.10***	(0.02)	0.06***	(0.02)
Pchum Ben	-0.08***	(0.01)	-0.07***	(0.02)	0.10***	(0.02)	0.05***	(0.02)
Khmer new year	0.01	(0.01)	0.01	(0.01)	-0.01	(0.02)	-0.01	(0.01)
Wedding	-0.03	(0.01)	-0.03	(0.01)	0.04	(0.02)	0.02	(0.09)
Water festival	-0.02**	(0.01)	-0.02**	(0.01)	0.03**	(0.01)	0.01**	(0.01)
Recreation	-0.01***	(0.04)	-0.01***	(0.00)	0.01***	(0.01)	0.01***	(0.00)
Taste	-0.06	(0.04)	-0.05	(0.03)	0.08	(0.05)	0.02*	(0.01)
Smell	0.04	(0.05)	0.03	(0.04)	-0.06	(0.07)	-0.02	(0.02)
Color	-0.04	(0.03)	-0.05	(0.04)	0.04**	(0.02)	0.05	(0.05)
Appearance	-0.04*	(0.02)	-0.04*	(0.02)	0.05	(0.02)	0.03	(0.02)
Good health	-0.05*	(0.02)	-0.06	(0.04)	0.05***	(0.01)	0.06	(0.05)

, **, and * indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.*
"0" represents the lowest frequency (never), "1" represents low (once every three months or one to two times a year), "2" represents medium (once a week or once a month); "3" represents high (every day or one to two times per week); variable inflation factor (VIF) < 1.48.

Table 8 Marginal effects of consumption frequency on the smashed-in-sugar product

Variables	Consumption frequency of the smashed-in-sugar product							
	Never		Low		Medium		High	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Age 1	-0.11**	(0.05)	-0.03	(0.02)	0.07***	(0.02)	0.08	(0.05)
Age 2	-0.15***	(0.03)	-0.05***	(0.02)	0.10***	(0.02)	0.10**	(0.03)
Age 3	-0.13***	(0.04)	-0.03**	(0.01)	0.09***	(0.02)	0.07*	(0.03)
Age 4	-0.14***	(0.03)	-0.04**	(0.02)	0.09***	(0.02)	0.09*	(0.04)
Age 5	-0.08	(0.05)	-0.02	(0.02)	0.06	(0.03)	0.05	(0.04)
Gender	0.03	(0.04)	0.01	(0.01)	-0.03	(0.03)	-0.01	(0.01)
Production type	-0.12**	(0.05)	-0.04	(0.02)	0.07***	(0.02)	0.09	(0.06)
Eating location	-0.21***	(0.03)	-0.06***	(0.01)	0.14***	(0.02)	0.13***	(0.03)
Pchum Ben	-0.09**	(0.04)	-0.02*	(0.01)	0.07**	(0.02)	0.05*	(0.02)
Khmer new year	-0.03	(0.04)	-0.01	(0.01)	0.02	(0.04)	0.01	(0.02)
Wedding	-0.01	(0.03)	-0.01	(0.01)	0.09	(0.02)	0.01	(0.01)
Water festival	-0.03	(0.01)	-0.01*	(0.00)	0.02*	(0.01)	0.01*	(0.01)
Recreation	-0.03***	(0.01)	-0.01***	(0.00)	0.03***	(0.01)	0.02***	(0.00)
Taste	-0.10	(0.06)	-0.01	(0.01)	0.08	(0.05)	0.03*	(0.02)
Smell	-0.06	(0.06)	-0.01	(0.02)	0.04	(0.04)	0.03	(0.04)
Color	-0.01	(0.08)	-0.01	(0.02)	0.01	(0.06)	0.01	(0.03)
Appearance	0.04	(0.04)	0.01	(0.01)	-0.04	(0.04)	-0.02	(0.02)
Good health	0.02	(0.09)	0.01	(0.02)	-0.02	(0.07)	-0.01	(0.03)

, **, and * indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.*
"0" represents the lowest frequency (never), "1" represents low (once every three months or one to two times a year), "2" represents medium (once a week or once a month); "3" represents high (every day or one to two times per week); variable inflation factor (VIF) < 1.53.

Food color showed a significant correlation with the consumption frequency of the pickled product, suggesting that consumers who perceived its color as important were 4.00% more likely to reach medium consumption than others (Table 7). Taste and appearance (Table 9) showed a significant correlation with the consumption frequency of fresh fruit: consumers who considered the taste and appearance of the product as important were 5.00% and 4.00%, respectively, more likely to have a low consumption of this product. Additionally, those who perceived the taste and appearance

of the fresh fruit as important were 12.00% and 20.00%, respectively, more likely to have a medium consumption of it. Perhaps, Cambodian people tend to prefer the pickled and fresh fruit of *Elaeocarpus hygrophilus* Kurz because they seem interested in the fresh color, adoptable taste, and good appearance of the products. A relevant study found that consumers in the Netherlands preferred consuming carrots with an attractive color suggestive of freshness and naturalness (Schifferstein et al., 2019). Furthermore, eating fresh fruits is simply a habit for some Cambodians, as they have done this since childhood. High consumption of specific foods is closely related to taste pleasantness and food familiarity (Gumussoy and Rogers, 2023).

Among sensory attributes, the smell was negatively significant in all levels of consumption frequency of the fresh fruit of *Elaeocarpus hygrophilus* Kurz, meaning that 15.00% of the consumers who considered the smell of fresh fruit important were less likely to have low consumption, and 23.00% were less likely to reach the medium consumption of this product compared to those who did not. Perhaps, consumers who do not consider the smell of fresh fruit important intend to eat more of it as their focus may be on its taste and appearance, which is similar to the case of mandarins, as their taste and appearance are the main drivers of fruit preference and acceptance by eaters (Gámbaro et al., 2021). Additionally, whether young or mature, this fruit does not have a strong smell, resulting in a low focus on this aspect. In our study, older age groups (Table 9) are likely to consume less fresh fruit because of unwanted tastes, health issues, and strong smell recognition ability, leading them to have less interest in its consumption than the younger generations. As shown in prior studies, people of older ages have a stronger ability to recognize smell than younger people due to different brain functioning, thereby choosing high-quality food for consumption (Honnens et al., 2023).

Table 9 Marginal effects of consumption frequency on the fresh fruit product

	Consumption frequency of the fresh fruit product											
	Never			Low			Medium			High		
Variables	Coef.		Std. Err	Coef.		Std. Err	Coef.		Std. Err	Coef.		Std. Err
Age 1	-0.19		(0.11)	0.02	***	(0.01)	0.17		(0.10)	0.01		(0.00)
Age 2	-0.06		(0.08)	0.01		(0.01)	0.05		(0.06)	0.01		(0.00)
Age 3	-0.02		(0.07)	0.01		(0.02)	0.01		(0.06)	0.01		(0.00)
Age 4	-0.17		(0.07)	0.03	**	(0.01)	0.13	*	(0.07)	0.01		(0.00)
Age 5	-0.01		(0.01)	0.01		(0.02)	0.01		(0.07)	0.01		(0.00)
Gender	0.05		(0.06)	-0.01		(0.01)	-0.03		(0.04)	-0.01		(0.00)
Production type	-0.12		(0.12)	0.02		(0.01)	0.10		(0.11)	0.01		(0.00)
Eating location	-0.57	***	(0.04)	0.02		(0.02)	0.52	***	(0.04)	0.02	*	(0.01)
Pchum Ben	-0.39	***	(0.05)	0.02		(0.02)	0.37	***	(0.06)	0.01	*	(0.01)
Khmer new year	-0.09		(0.06)	0.02		(0.01)	0.07		(0.05)	0.01		(0.00)
Wedding	-0.05		(0.06)	0.01		(0.01)	0.04		(0.04)	0.01		(0.00)
Water festival	-0.09	**	(0.03)	0.02	**	(0.01)	0.06	***	(0.02)	0.01		(0.00)
Recreation	-0.09	***	(0.01)	0.02	***	(0.00)	0.07	***	(0.01)	0.01		(0.00)
Taste	-0.18	*	(0.07)	0.05		(0.03)	0.12	**	(0.05)	0.01	*	(0.00)
Smell	0.37	***	(0.06)	-0.15	***	(0.04)	-0.23	***	(0.32)	-0.01		(0.00)
Color	0.04		(0.01)	-0.01		(0.04)	-0.03		(0.09)	-0.01		(0.00)
Appearance	-0.25	***	(0.10)	0.04	***	(0.01)	0.20	***	(0.06)	0.01	*	(0.00)
Good health	-0.33	***	(0.09)	0.01		(0.02)	0.31	**	(0.11)	0.01		(0.01)

, **, and * indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively.*
"0" represents the lowest frequency (never), "1" represents low (once every three months or one to two times a year), "2" represents medium (once a week or once a month); "3" represents high (every day or one to two times per week; variable inflation factor (VIF) < 1.41.

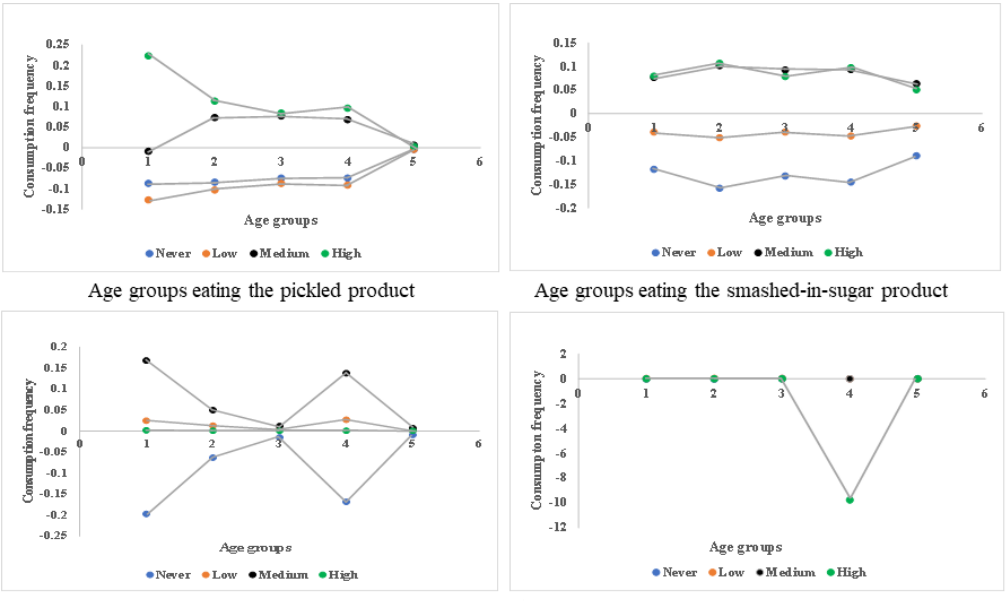
Interestingly, we found that good health benefits were positively significant in the consumption frequency of the pickled (Table 7) and fresh fruit (Table 9) of *Elaeocarpus hygrophilus* Kurz. Consumers who perceived pickled products as having health benefits were 5.00% more likely to reach medium consumption, and surprisingly, 31.00% more likely to reach the medium consumption of fresh fruit compared to those who did not. It seems that in Cambodia, some of the local people take into account that the *Elaeocarpus hygrophilus* Kurz plant is used as a traditional remedy for curing some ailments, including fever, and flu, or improving women's blood circulation after giving

birth. Moreover, it enriches the essential vitamin intake. Therefore, consuming this fruit relates to self-care and health awareness. The awareness of the health benefits of foods stimulates consumers to pay increasing attention to their food consumption (Yang et al., 2023). Moreover, in Cambodia, fresh fruit consumption depends on people's attitudes and regional location; for example, consumers may adopt their friend's and relatives' consumption patterns of eating pickled and fresh fruits for pleasantness. The social environment and influence of other people have a direct impact on food choices (Pluck and Morrison-Saunders, 2022).

Table 10 Marginal effects of consumption frequency on the caramelized product

Variables	Consumption frequency of the caramelized product							
	Never		Low		Medium		High	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Age 1	-0.02	(0.25)	0.02	(0.18)	0.01	(0.07)	0.01	(0.01)
Age 2	-0.03	(0.32)	0.02	(0.23)	0.01	(0.10)	0.01	(0.01)
Age 3	-0.01	(0.17)	0.01	(0.13)	0.03	(0.05)	0.01	(0.00)
Age 4	0.01*	(0.03)	-0.01*	(0.02)	-0.01	(0.01)	-9.77	(0.00)
Age 5	0.01	(0.10)	-0.01	(0.08)	-0.01	(0.02)	-0.01	(0.00)
Gender	-0.01	(0.13)	0.01	(0.10)	0.01	(0.03)	0.01	(0.00)
Production type	-0.77	(1.01)	0.24	(1.14)	0.35	(0.69)	0.17	(1.46)
Eating location	-0.76	(1.15)	0.25	(1.01)	0.34	(0.81)	0.15	(1.35)
Pchum Ben	0.04	(0.39)	-0.03	(0.30)	-0.01	(0.08)	-0.01	(0.00)
Khmer new year	0.01	(0.11)	-0.01	(0.08)	-0.01	(0.03)	-0.01	(0.00)
Wedding	0.13*	(6.77)	-0.11*	(5.65)	-0.02	(1.09)	-0.01	(0.05)
Water festival	0.07*	(6.87)	-0.06*	(5.66)	-0.01	(1.16)	-0.01	(0.05)
Recreation	-0.01	(0.07)	0.01	(0.06)	0.01	(0.02)	0.01	(0.00)
Taste	-0.01	(0.10)	0.01	(0.07)	0.01	(0.02)	0.01	(0.00)
Smell	0.03	(0.32)	-0.02	(0.25)	-0.01	(0.07)	-0.01	(0.00)
Color	-0.09	(0.73)	0.07	(0.46)	0.02	(0.25)	0.01	(0.03)
Appearance	-0.03	(0.30)	0.02	(0.22)	0.01	(0.08)	0.01	(0.01)
Good health	0.05	(0.63)	-0.04*	(0.50)	-0.01	(0.12)	-0.01	(0.01)

, **, and * indicate that the coefficient is statistically significant at the 10%, 5%, and 1% levels, respectively. "0" represents the lowest frequency (never), "1" represents low (once every three months or one to two times a year), "2" represents medium (once a week or once a month); "3" represents high (every day or one to two times per week; variable inflation factor (VIF) < 1.81.*



Age groups eating the pickled product | Age groups eating the smashed-in-sugar product

Age groups eating the fresh fruit product | Age groups eating the caramelized product

Fig. 3 Marginal effects of age groups and consumption of *Elaeocarpus hygrophilus* Kurz

CONCLUSION

This study analyzed six products of the *Elaeocarpus hygrophilus* Kurz fruit that are found in Cambodia, including pickled, smashed-in-sugar, fresh, caramelized, pickled-in-honey, and pickled-in-rice liquor products. The pickled, smashed-in-sugar, fresh, and caramelized *Elaeocarpus hygrophilus* Kurz products were found more likely to be consumed. Most consumers purchase them from markets rather than processing them at home, and they tend to eat more of the pickled, smashed-in-sugar, and fresh fruits. Younger people tended to have a medium consumption of pickled, smashed-in-sugar, and fresh fruits, while older generations tended to eat less caramelized products because of their unwanted sweet taste and health risks. Men tended to have a medium consumption of pickled and caramelized products compared to women because they preferred the sweet taste preference; however, women tended to have a medium consumption of smashed-in-sugar and fresh fruits due to their preferences for acidic, bitter, and spicy foods. The consumers who prepared pickled and smashed-in-sugar products at home showed a medium consumption of both products. Home-food eaters showed a similar trend. Regarding occasions, those who considered Pchum Ben important tended to have a medium consumption of pickled, smashed-in-sugar, and fresh fruits. Consumers perceiving taste and appearance as important tended to show a medium consumption of fresh fruit. All products widely sold at local markets lack expiry dates, proper packaging, and labeling. Therefore, future research should focus on consumer knowledge, behavior, and existing issues on consumption to find the challenges in developing effective strategies to improve such products. The basic nutritional facts and bioactive compounds of the *Elaeocarpus hygrophilus* Kurz products have not yet been identified, which could explain the difficulty in improving labeling for homemade food processors. Hence, nutritional evaluation and physiochemical properties, especially for fresh fruit should be identified as they serve for functional ingredient information, traditional product labeling enhancement, and consumer health promotion.

Note)
1) The unknown plant specimens were investigated by using archived herbarium specimens (Belhumeur et al., 2008. The fresh plant specimens such as leaves, flowers, fruits, and branches were collected from Svay Rieng province, Cambodia, in September 2023. They were dried in a micro-oven for 48 hours at 80 ℃; however, the fruits were dried for 72 hours with the same temperature set to remove water inside. Then the dried specimens were taken photographs and packed into folders with right labels. After that, a common approach was used in plant species identification; meanwhile, unknown dried segments of plant were checked their shapes with the known species in herbarium specimens that were kept and preserved in long time. Both were shown in the same characteristics in shapes of leaves, flowers, or fruits; thereby, verifying in genuine species as Elaeocarpus hygrophilus Kurz.

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Research article

Considering Environmental Standards Based on Soils and Water Quality in the Biotopes around Urban Areas in Japan

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Abstract Biotope, where the ecosystems have been lost due to industrial development and urbanization, should be restored to rehabilitate the organisms of the original inhabitants. Although there are more than 1,500 school biotopes in Japan, few research have been conducted for evaluating their soil and water quality. Compared to lakes and rivers, biotopes have problems as there is less data on soil and water quality. Furthermore, there were no 'environmental standards for biotopes,' so it was hard to evaluate if their soil and water conditions are appropriate for biotopes. Accordingly, the aims of this study are to determine soil and water quality in several biotopes and to develop a draft of environmental standards for biotopes. Various surveys were conducted by disseminating questionnaires to elementary school students on current management systems and their perception of the function of biotopes. Also, soil and water samples were collected from a public park and four elementary schools in Tokyo and Kanagawa Prefectures for quality analysis. As biological characteristics, coliforms and *E. coli* were measured from soil samples. Also, total nitrogen (TN), total phosphorus (TP), pH, EC, SS, coliforms and *E. coli* were measured from water samples. The results of TN and TP tended to increase in summer due to the increase in algae. The school that keeps bantams and goats near the biotope detected coliforms and *E. coli*. The excrement of these animals may cause contamination. However, the results from the questionnaire survey indicated that the water appears to be clean. Accordingly, there was a difference in their perception and water quality condition. Therefore, the draft of environmental standards, TN and TP values may be consistent with the standards for the lakes, although there are size differences between lakes and biotopes. However, the standards on coliforms and *E. coli* should be more restricted, since children often play with biotopes.

Keywords biotope, environmental standards, *E. coli*, Tokyo

INTRODUCTION

Biotopes are places designed for the restoration and rehabilitation of organisms that have been lost by industrial development and urbanization. The term 'biotope' was introduced by a German scientist in the early the 20th century and additional concept of 'biocenosis' was formulated in German. This concept ('ecosystem = biotope + biocenosis') became accepted in German, French, Russian and other Europe gradually. The new interpretation of the term ('biotope = habitat + community') appeared in the United Kingdom in the early 1990s while classifying 'marine habitats' of the coastal zone. Since then, this meaning was also used in international European environmental documents (Olein and Ducrotoy, 2006).

In Germany, biotopes have been attracting attention since the 1970s, when environmental problems happened by industrialization became more serious. In Japan, biotopes have been made in

various places since the end of the 20th century, including water areas such as tidal flats, wetlands, lakes, and rivers, as well as forests and grasslands. This concept, which had begun in Germany and other European countries, has spread to Japan. Recently in Japan, schools, NPOs, NGOs, and companies have been making various efforts to make biotopes. Not only naturally occurring biological environments, but also artificially created spaces can be said to be biotopes. Since they are environmentally closed water systems, they are prone to water pollution and need to be improved. Although there are more than 1,500 school biotopes in Japan since 2002 by Ministry of Education, Culture, Sports, Science and Technology, few research have been conducted for evaluating their soil and water quality. Also, research for biotopes is not more than that for lakes and rivers. In Japan, the environmental standards for lakes and rivers were made by Ministry of the Environment but not suitable to biotopes.

OBJECTIVE

The aim of this study is to investigate the biotopes' soil and water quality, as well as to understand the public's perception of it, in order to develop a draft of environmental standards for biotopes.

METHODOLOGY

Soil and water samples were collected at 4 different locations: Kuwabukuro Biotope Park, Toho Gakuen Primary School, Aikawa Elementary School, Todoroki Elementary School, and Komatsugawa Elementary School, which are in Tokyo and Kanagawa Prefectures. These schools were nominated for Biotope Competition by Ecosystem Conservation Society, Japan. Since the biotope in Komatsugawa Elementary School doesn't have the area for water, only soil was sampled.

The sampling was conducted in three seasons April to May (spring), July to September (summer) and November (autumn). From soil samples, biological characteristics such as coliform and *E. coli* were measured. For water samples, the biological and chemical characteristics such as total nitrogen (TN), total phosphorus (TP), pH, electric conductivity (EC), suspended solids (SS), *E. coli* and coliform were measured. Water velocity was also measured in each biotope. TN and TP were measured by the spectrophotometric method and coliforms and *E. coli* were used in the dilution plate method. Additional surveys were conducted by disseminating the questionnaire sheets to 70 students in Toho Gakuen Primary School on current management systems and their perception of the function of biotopes.

RESULTS AND DISCUSSION

In the most sampling sites, SS indicated high values during the summer. The presence of algae in the water resulted higher SS values. For Todoroki, tap water was introduced at any time, lower SS were observed than other sites. As some biotopes are closed, the pH values sometimes exceeded 8.0 (Fig. 1). In Kuwabukuro and Aikawa, SS and EC were high, as they received rainwater directly.

Figure 2 showed the results of total nitrogen (TN) and total phosphorus (TP) in each season in 5 biotopes. The indicators of eutrophication are the value higher than 0.2 mg/L for TN and higher than 0.02 mg/L for TP (Kudo and Watanabe, 2014). Based on the criteria of TN and TP values, Toho, Kuwabukuro and Aikawa were identified as eutrophication. The accumulation of nutrients from surface runoff with rainfall and dead vegetation may promote eutrophication. Nitrogen and phosphorus are nutrients for phytoplankton, phytoplankton also increases with nutrients in biotope. Additionally, organic pollution happened with organic matters such as dead plants and animals.

From the results indicated in Fig. 2, TN and TP as well as SS tended to increase in summer due to the increases in algae. Although the water in the Kuwabukuro, which has an area at 1,800 m^2, is connected with river water, the water velocity observed was 0 m/s as well as other biotopes. TN during the summer in the biotope of Toho Gakuen Primary School was 9.18 mg/L. It was because of the pesticide applied for eliminating rats during the summer. Also, Aikawa indicated the highest in TP, as no in-flow was observed in this biotope.

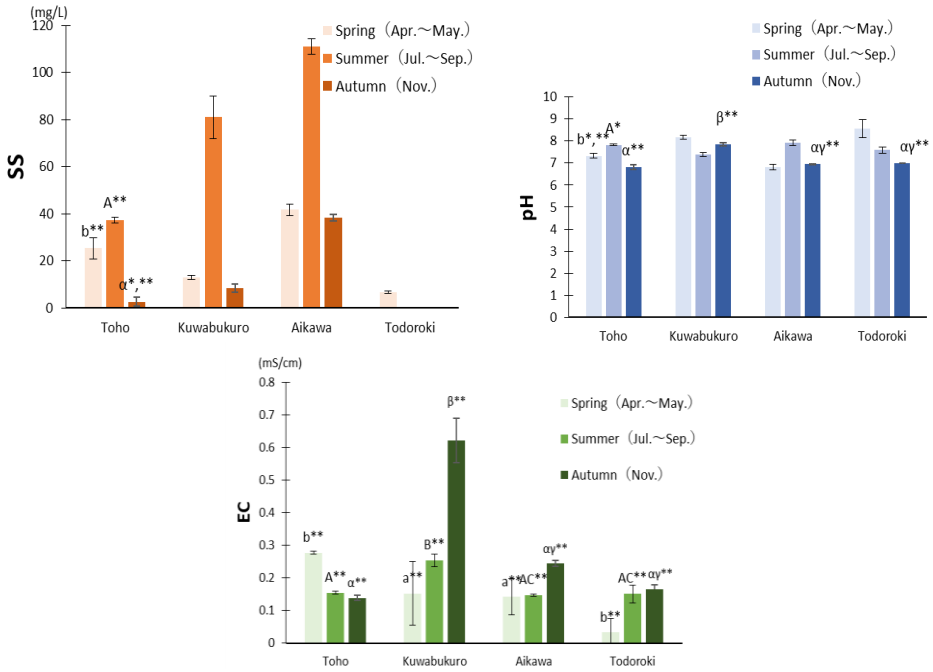

Fig. 1 Suspended solids (SS), pH and EC in biotopes

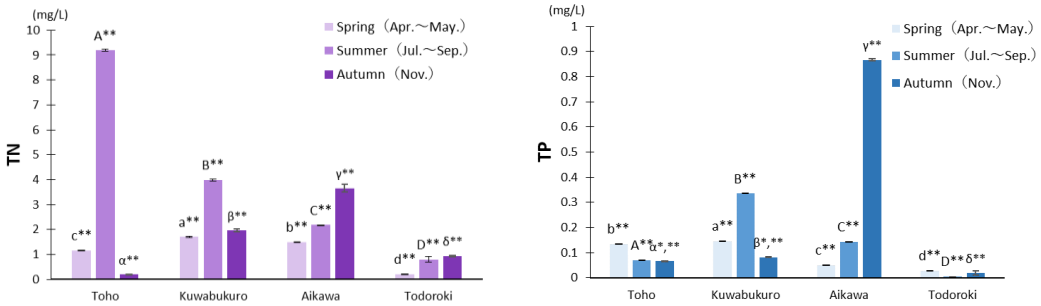

Fig. 2 Total nitrogen (TN) and total phosphorus (TP) in biotopes

Table 1 Coliforms and *E. coli* in biotopes

Sampling Area	season	Soil		Water	
		Coliform (cfu/g)	*E. coli* (cfu/g)	Coliform (cfu/ml)	*E. coli* (cfu/ml)
Toho	Spring	3.9×10^4	5.5×10^3	5.7×10^4	3.0×10^4
	Summer	7.2×10^3	ND	ND	ND
	Autumn	5.9×10^4	4.7×10^3	ND	ND
Aikawa	Spring	ND	ND	9.3×10^5	ND
	Summer	ND	ND	4.1×10^5	4.5×10^3
	Autumn	5.2×10^3	4.5×10^3	ND	ND
Todoroki	Spring	ND	ND	ND	ND
	Summer	ND	ND	ND	6.3×10^3
	Autumn	ND	ND	ND	ND
Kuwabukuro	Spring	ND	ND	ND	ND
	Summer	1.7×10^5	9.3×10^3	6.0×10^3	8.0×10^3
	Autumn	1.2×10^4	5.0×10^3	ND	ND
Komatsugawa	Spring	5.7×10^3	2.6×10^3	—	—
	Summer	1.4×105	1.3×105	—	—
	Autumn	5.1×10^5	1.2×10^5	—	—

ND : Non Detected, — : No sample

There were no water samples in Komatsugawa because this biotope doesn't have water areas. In all of the sampling biotope locations, animals such as goats, rabbits, chickens, and monkeys were kept or wild animals such as cats, birds and raccoon dogs were observed. Therefore, the excrement of these animals may affect the results of Table 1.

At Toho Gakuen Elementary School, no *E. coli* was detected in August 2021. In the case of Aikawa, there was no animal shelter, but wild animals often visited the biotope. Additionally, there is no history of changing the water in this biotope, accordingly the survival of coliforms and *E. coli* were detected. These results indicated high risks of contamination for humans, especially children. However, at the biotope in Todoroki Elementary School, no coliforms and *E. coli* were detected except during the summer, as the water in the biotope was changed several times per year using tap water. Additionally, wild birds were observed near a sampling point in Kuwabukuro Biotope Park since summer, so coliforms and *E. coli* were detected in summer and autumn.

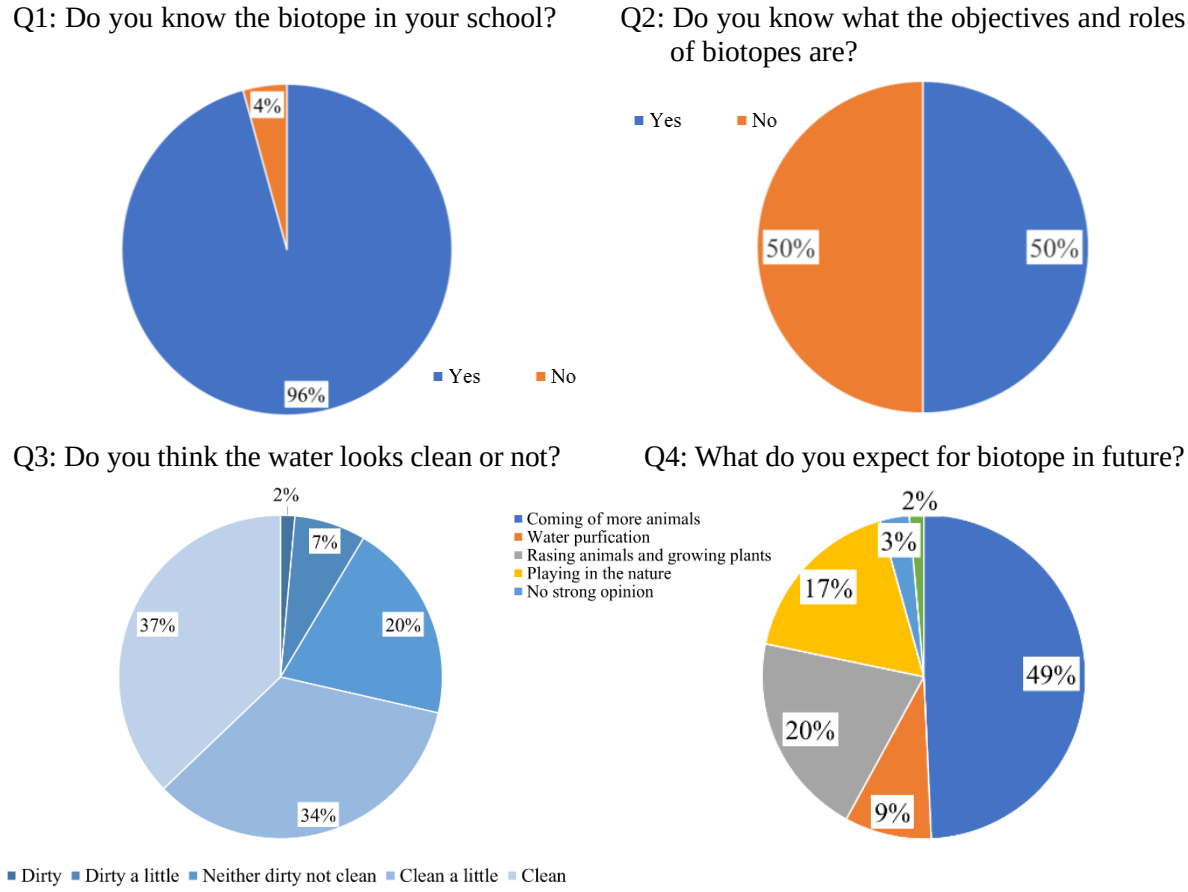

Fig. 3 Results of Questionnaire Q1, Q2, Q3, and Q4

According to Q1 in Fig. 3, almost all students in Toho Gakuen Primary School knew their biotope. However, only 50% of students understood the objectives and roles of the biotope from the results of Q2. They have been keeping bantams and goats near biotopes, and they have become the primary source of coliforms and *E. coli*. However, more than 70% of students thought the water looked almost clean from the results of Q3. Accordingly, there was a difference in their perception and water quality condition. From the results of Q4, it was clear that around 70% of students tended to be concerned with biodiversity and nature protection. In fact, the answers of water purification were only 17%. On the other hand, Q5 which was free answer question in the questionnaire. Certain number of respondents answered, 'I would like to ask the people who visits our biotope not to throw away garbage.' and 'I want to try water purification.' This indicated that they are willing to work on environmental issues including water pollution.

Table 2 Draft of environmental standards in biotopes

Evaluation	TN (mg/L)	TP (mg/L)	SS (mg/L)	pH	*E. coli* [90%] (cfu/100ml)
AA	0.2 or less	0.02 or less	1 or less	6.5 or more 8.5 or less	0
A	0.5 or less	0.05 or less	5 or less	6.5 or more 8.5 or less	20 or less
B	1.0 or less	0.10 or less	15 or less	6.5 or more 8.5 or less	300 or less
C	2.0 or less	0.20 or less	30 or less	6.0 or more 8.5 or less	1000 or less
D	3.0 or less	0.25 or less	45 or less	6.0 or more 8.5 or less	-
E	3.5 or less	0.30 or less	60 or less	6.0 or more 8.5 or less	-

On the basis of the experimental results, the draft of environmental standards for biotopes was proposed as shown in Table 2. The values of TN and TP may be consistent with the standards for the lakes, although there are size differences between lakes and biotopes. However, since children often play with water in biotopes, the standards for coliforms and *E. coli* should be more restricted.

CONCLUSION

School biotopes are prone to eutrophication due to the accumulation of nutrients with rainfall and dead plants because the water is not changed frequently (Kudo and Watanabe, 2014). The values of TN and TP showed that eutrophication is progressing. The sources of supplying nutrients are various, such as domestic wastewater, industrial wastewater, chemicals for water treatment, drainage through gravity outlets, dead vegetation from forests, carcasses and excrements of wild animals, underground water, sediments, aquatic animals and plants, rainfall, fallen ash, etc. In this case, the effective measures against increasing nutrients seem to be removing sediments and changing water frequently.

For the draft of environmental standards, TN, and TP values may be consistent with the standards for the lakes, although there are size differences between lakes and biotopes. However, the standards on coliforms and E. coli should be more restricted, since children often study and play with biotopes.

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Research article

Effects of Adding Coconut Charcoal on Soil Physical Properties and Maize Performance

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Abstract Tonga is a tropical nation that faces susceptibility to the effects of climate change, with one of the primary challenges for its agricultural sector being the impact of El-Nino leading to prolonged periods of drought. The resulting economic crisis in the region was notable during the 2015-2016 drought season, leading to food shortages and a subsequent increase in food prices. This necessitated the importation of more expensive perishable goods to supplement locally produced items. This study aimed to investigate the use of coconut charcoal as a soil water amendment to mitigate water scarcity during drought periods. The findings demonstrated that incorporating 10 % of coconut charcoal with particle sizes of less than 1 mm into the soil can enhance soil physical properties, particularly in terms of maintaining optimal soil water levels of 50 kPa to 100 kPa for plant vegetative growth and grain growth 100 kPa to 1200 kPa. This amendment was found to alleviate plant water stress by prolonging the period before soil dryness occurs, benefiting vegetative growth and grain development stages. In conclusion, the incorporation of coconut charcoal as a soil amendment showed significant improvement in overall plant performance, such as an average increase in leaf area from 33.7 cm^2 to 93.9 cm^2. This suggests that coconut charcoal can be a viable recommendation as a soil amendment, aiding in the conservation of water resources and reducing irrigation costs and other expenses for small-scale farmers. This approach could enhance the resilience of Tonga's agricultural sector and small farmers in coping with drought conditions attributed to El-Nino. Consequently, this strategy could help diminish the need for importing perishable agricultural products from abroad during drought periods.

Keywords El-Nino, drought, coconut charcoal, optimal soil water levels, soil water amendment

INTRODUCTION

Tonga, situated within the Pacific Island Countries, encompasses a collection of 172 coral and volcanic islands positioned between latitudes 15° to 24° degrees South and longitudes 173° to 177° degrees West. The country experiences a tropical climate characterized by an average annual rainfall of 1,728 mm, and an annual mean humidity of 77%, with temperatures ranging from a minimum of 8.7°C to a maximum of 33.1°C. This region faces agricultural challenges during El-Nino, leading to prolonged periods of drought. The El-Nino event from 2015 to 2016 resulted in a significant reduction in annual precipitation, adversely affecting agricultural production in Tonga. The consequent lack of rainfall during this period led to water scarcity for irrigation, prompting an economic crisis that escalated food prices and jeopardized food security in the region.

The food deficit in Tonga has necessitated the importation of perishable goods, leading to higher prices compared to local produce. For instance, the cost of 1 kg of local tomatoes at USD 0.60 was notably cheaper than imported tomatoes at USD 6.00, resulting in market inflation (Finau, 2015). Despite this, only a few commercial farmers have made substantial investments in installing effective

irrigation systems relying on underground water sources (Waterloo and Ijzermans, 2017). This study aimed to address these challenges by focusing on preserving water in the soil, making it more accessible for agricultural use. The predominant soil type on the main island of Tongatapu is andosol clay soil, covering 90% of the land due to volcanic eruptions (Gibbs, 1976). Tongatapu's coconut production accounts for approximately 99 million nuts annually (Manu, 2018). It is noted that charcoal can influence soil water retention and aggregate stability, thereby improving crop water availability (Piccolo et al., 1996).

Tryon (1948) examined the impact of charcoal additions on soil moisture availability in soils with different textures. The experiment utilized coconut charcoal from Sri Lanka on Japanese andosol clay soil, similar to the texture of Tongatapu's andosol clay soil. Coconut charcoal, readily available in Tonga and other tropical regions, has the potential to enhance agricultural practices. In Tonga, many households have coconut charcoal residue from their underground ovens (ngoto ‘umu), primarily used for cooking rather than agricultural purposes. This research aimed to demonstrate the beneficial effects of coconut charcoal residue on soil physical properties and plant performance. It highlighted that coconut charcoal residue is not a waste product but a valuable resource that can be utilized by the agricultural sector, particularly during drought seasons, as a soil water amendment.

OBJECTIVE

The main objective of this study was to evaluate the effects of adding coconut charcoal on soil physical properties and plant performance.

METHODOLOGY

Preparation of Coconut Charcoal

The process of preparing coconut charcoal involves heating the coconut residue raw materials to a temperature that increases gradually until it reaches 350°C within 15 minutes. The ratio of raw materials used is 2.5:1.0 for coconut charcoal production (Perera et al., 2013). The charcoal is then pounded and crushed into small particles, which are sieved to obtain different particle sizes of 3 mm, 2 mm, 1 mm, and less than 1 mm.

Preparation of Pot Plants

In the preparation of pot plants for the current study, the same andosol soil was added to each pot, along with crushed coconut charcoal in varying particle sizes of 3 mm, 2 mm, 1 mm, and less than 1 mm. Different application rates of coconut charcoal, such as 2.5%, 5.0%, 7.5%, and 10%, were mixed into the soil in each pot. One pot served as the control group, containing only andosol soil without any added coconut charcoal.

Direct Sowing the Corn Seeds

Corn seeds were directly sown in each pot, with three seeds planted to ensure germination. Thinning was done subsequently, leaving one seedling to grow for visual observation purposes throughout the study. This experimental setup aimed to assess the impact of different particle sizes and application rates of coconut charcoal on plant growth and soil physical properties in comparison to the control group without charcoal amendment.

Irrigation

As part of the irrigation process used in the experiment, hand irrigation was conducted using a spring can with an amount of 500 ml of water per pot plant, totaling 10 L for the 20 pot plants. Irrigation

was applied as needed for optimal plant growth. When the soil indicated dryness below the comfort range, irrigation was applied to maintain soil moisture for the plants.

Experimental Layout

The experimental layout followed the Random Complete Block Design (RCBD) methodology proposed by Clewer and Scarisbrick (2001). The design involved five treatments that were replicated four times, with the coconut charcoal mixtures applied at a depth of 10 cm in the pots. The experiment was carried out in a glasshouse at the Tokyo University of Agriculture, as indicated in Fig. 1, below, to ensure controlled environmental conditions and accurate data collection. This experimental layout allows for the systematic comparison of the different treatments and their effects on plant growth and soil physical properties.

Treatment 1 (T1) : Soil (97.5%) + Charcoal (2.5%, 3 mm)
Treatment 2 (T2) : Soil (95.0%) + Charcoal (5.0%, 2 mm)
Treatment 3 (T3) : Soil (92.5%) + Charcoal (7.5%, 1 mm)
Treatment 4 (T4) : Soil (90.0%) + Charcoal (10.0%, <1 mm)
Treatment 5 (T5) : Soil (100.0%) Control (without charcoal)

Fig. 1 Experimental layout

Installation of Sensor

In the experiment, soil water content was monitored using TEROS 21 sensors to provide a more comprehensive understanding of soil moisture dynamics. Unlike traditional sensors that measure water content alone, the TEROS 21 sensor measures water potential, indicating the availability of water to plants and its movement within the soil (Campbell et al., 2010). Additionally, S-SDM-M005 sensors were used to measure water content percentages in the soil.

Five TEROS 21 sensors were installed at a depth of 5 cm, while S-SDM-M005 sensors were placed at a depth of 10 cm in each pot of the five treatments. This setup allows for detailed monitoring of soil and water conditions at different depths. Data collection was done using Zentra Utility and HOBO Ware software for accurate and reliable measurements throughout the experiment.

Measuring Leaf Area

Leaf area measurements were taken using a measuring tape to determine the length and width of the leaves in centimeters, following the method described by Chanda and Singh (2002). These measurements were recorded to compare the leaf area among the different treatments and analyze any significant differences that may indicate the impact of coconut charcoal on plant growth and development. The leaf area calculated was given by the following Eq. (1).

$$Leaf\ area\ (LA) = leaf\ width\ (W) \times leaf\ length\ (L) \quad (1)$$

RESULTS AND DISCUSSION

Statistical analysis was conducted using ANOVA Single Factor, as displayed in Table 1 below, revealing that treatment 4 (T4) has the highest average leaf area of 93.9 cm^2. This indicates that the addition of coconut charcoal has positively contributed to increasing the size of the leaves, ultimately enhancing plant performance in terms of leaf development.

On the other hand, the control treatment, or treatment 5 (T5), which did not involve the addition of coconut charcoal, exhibited the lowest average leaf area of 33.7 cm^2. This suggests that plants in this treatment had smaller leaves compared to those treated with coconut charcoal, emphasizing the potential beneficial effect of coconut charcoal on leaf size and, by extension, plant growth and performance.

Table 1 Average leaf area for each treatment

Groups	Count	Sum	Average (cm^2)	Variance
T1	4	251.8	62.950	84.94
T2	4	246.6	61.650	199.53
T3	4	162.9	40.725	113.96
T4	4	375.6	93.900	128.04
T5	4	134.8	33.700	306.81

ANOVA single factor average leaf area

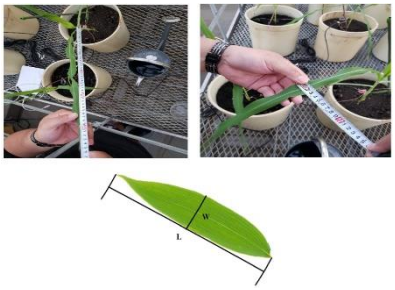

Fig. 2 Measuring of leaf area

Table 2 displays the comparison of the P-values for the average leaf area among the different treatments. The results indicated that there was a significant difference in leaf area among the treatments, except for the comparisons between T1-T2, T2-T3, and T3-T4, where no significant difference was observed. This suggests that the impact of treatments on leaf area varied, with specific treatments showing distinct effects on leaf development and size. Further analysis of the data can provide insights into the specific effects of each treatment on plant performance and growth.

Table 2 Compared P-value of average leaf area for each treatment

Treatment	P-value	Highly significant (H.S) Significant (S) Non-significant (N.S)	Escalation / Abbreviation
T1 vs T2	0.535256248	N.S ≥ 0.05 (5 %)	d (N.S)
T1 vs T3	0.019770135	S ≤ 0.05 (5 %)	b* (S)
T1 vs T4	0.011535978	S ≤ 0.05 (5 %)	b* (S)
T1 vs T5	0.025427129	S ≤ 0.05 (5 %)	b* (S)
T2 vs T3	0.054299548	N.S ≥ 0.05 (5 %)	e (N.S)
T2 vs T4	0.014394010	S ≤ 0.05 (5 %)	c* (S)
T2 vs T5	0.047533118	S ≤ 0.05 (5 %)	c* (S)
T3 vs T4	0.000566231	H.S ≤ 0.001 (.1 %)	a** (H.S)
T3 vs T5	0.518949725	N.S ≥ 0.05 (5 %)	f (N.S)
T4 vs T5	0.000493836	H.S ≤ 0.001 (.1 %)	a** (H.S)

ANOVA single factor P-value comparison

The bar graph in Fig. 3 demonstrates an evident and statistically significant difference in the average leaf area between treatment groups T3-T4 and T4-T5, with a P-value of less than or equal to 0.001 (0.1%). Furthermore, the confidence interval for this difference is 99.99%. Additionally, comparisons between treatment groups T1-T3, T1-T4, T1-T5, T2-T4, and T2-T5 also revealed statistically significant differences, with a P-value of less than or equal to 0.05 (5%) and a confidence interval of 95%.

Table 3 shows that Treatment 4 (T4) exhibited a notably high average soil water matric potential, making it a suitable option for farmers looking to use soil water amendments (Fig. 4). This range aligned with the favorable/comfort range of soil water matric potential conducive to maize growth, typically falling between 50 - 1200 kPa (Campbell et al., 2010).

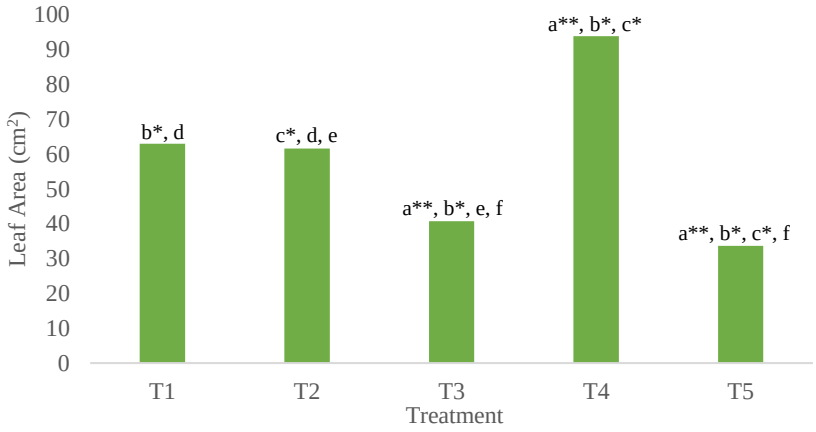

Fig. 3 Average leaf area for each treatment

Table 3 Average soil water matric potential for each treatment

Groups	Count	Sum	Average (kPa)	Variance
T1	228	-760074.51	-3333.66013	9570332.2
T2	228	-703200.3	-3084.21186	9548436
T3	228	-439837.87	-1929.11346	6001146.4
T4	228	-148724.54	-652.300595	1117680
T5	228	-732918.35	-3214.55417	7508437.7

ANOVA single factor average soil water matric potential

The ANOVA single factor statistical analysis comparing T1-T2 and T1-T5, as well as T2-T5, revealed no significant differences with a p-value greater than or equal to 0.05. However, contrasts between T1-T3, T2-T3, T3-T5, T1-T4, T2-T4, T3-T4, and T4-T5 exhibited highly significant differences with a p-value of less than or equal to 0.001 in terms of soil water matric potential kPa.

Fig. 4 Measuring of soil water matric potential

In Fig. 5, the impact of the various treatments on both soil temperature and soil water matric potential is depicted. The measurements suggested that an increase in soil temperature, particularly within the range of 30 to 40 degrees Celsius, had led to a decrease in the soil water matric potential measured in kilopascals. The average values for T1 were 3333.66 kPa, T2 - 3084.21 kPa, T3 - 1929.11 kPa, T4 - 652.30 kPa, and T5 - 3214.55 kPa over a specific period. It was observed that all treatments experienced rapid drying within a few days, except for T3 and T4, which exhibited a slightly slower drying rate.

Table 4 Compared P-value of soil water matric potential for each treatment

Treatment	P-value	Highly significant (H.S) Significant (S) Non-significant (N.S)
T1 vs T2	0.389458216	N.S ≥ 0.050 (5.0%)
T1 vs T3	1.23E-07	H.S ≤ 0.001 (0.1%)
T1 vs T4	1.50172E-30	H.S ≤ 0.001 (0.1%)
T1 vs T5	0.6636359	N.S ≥ 0.050 (5.0%)
T2 vs T3	1.21916E-05	H.S ≤ 0.001 (0.1%)
T2 vs T4	4.81429E-26	H.S ≤ 0.001 (0.1%)
T2 vs T5	0.63391606	N.S ≥ 0.050 (5.0%)
T3 vs T4	2.12078E-12	H.S ≤ 0.001 (0.1%)
T3 vs T5	1.99896E-07	H.S ≤ 0.001 (0.1%)
T4 vs T5	8.69324E-34	H.S ≤ 0.001 (0.1%)

ANOVA Single Factor P-value Comparison

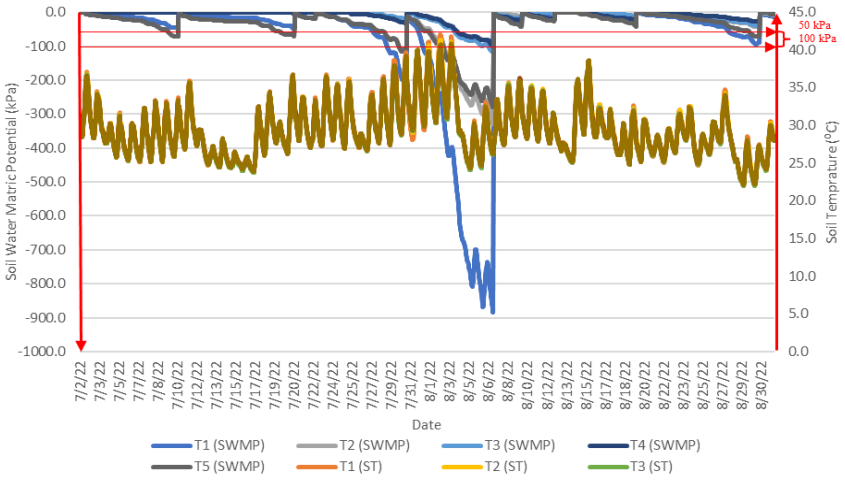

Fig. 5 Soil water matric potential and soil temperature

CONCLUSION

The comprehensive findings suggested that incorporating 10% coconut charcoal with a particle size of less than 1mm as a soil amendment can enhance the soil's physical properties, leading to improved water-holding capacity and a reduction in plant water deficit. Furthermore, the inclusion of coconut charcoal as an amendment can boost overall plant performance, particularly in terms of leaf area, which saw an increase from 33.7 cm^2 to 93.9 cm^2.

As a result, coconut charcoal emerged as a recommended soil amendment that not only aids in conserving water resources but also helps diminish financial burdens related to irrigation and other associated expenses like the installation of irrigation systems, ultimately reducing labor time for small-scale farmers. Additionally, with the agricultural sector in Tonga and small farmers able to provide an ample supply for the local market, the daily basic needs of the populace can be adequately met. This proactive approach can help avoid excessive imports of perishable agricultural products from overseas during periods of drought, particularly those triggered by phenomena such as El-Nino.

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Research article

Impact of Agricultural Certification for Silk Farmers: Case Study of Khon Kaen Province, Northeast Thailand

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Abstract Despite rapid economic growth, income inequality between rural and urban areas remains an important social issue in Thailand. In 2020, the disparity between the Northeast region, which has the lowest GRP per capita, and the East region, which has the highest GRP per capita, was approximately 5.05 times. Northeast Thailand is an agricultural area and is famous for silk production. According to the Queen Sirikit Department of Sericulture, in 2017 sericulture silk yarn production in the Northeast region was 520 metric tons and engaged 82,071 households (or approximately 80% of all households in the region). Improving the silk industry in the Northeast is essential for economic development in this region. Obtaining certifications that guarantee quality is considered one effective way to increase farmers' income. Hence, this study aimed to clarify the factors that play a role in obtaining certification and the impact of obtaining certification on farmers' profits from silk weaving. We examined the case of farmers in Khon Kaen province in Northeast Thailand and focused on four certifications: Organic Thailand, Geographical Indication (GI), OTOP, and Peacock. We conducted both quantitative and qualitative analyses based on the primary data collected through in-person interviews with 103 farmers from October to November 2022. The results showed that the important factors affecting profits from silk weaving are design, the type of dyestuffs, and the ability to access markets where products fetch high prices. To identify the key factors to obtain certification, we used logistic regression, and to evaluate the impact of the certifications, we conducted a two-sample t-test. Statistical analysis results revealed that joining a farmers' community and the number of processes involved in sericulture are two important factors in obtaining certifications and that farmers who have certifications tend to earn more income compared to non-certificated farmers.

Keywords agricultural certification, sericulture, logistic regression, two-sample t-test, Thailand

INTRODUCTION

In Thailand, economic inequality between rural and urban areas is an important social problem. In 2020, the economic gap between the Northeast, the region with the lowest GRP per capita, and the East, the region with the highest GRP per capita, was approximately 5.05 times (Gross Regional and Provincial Product Chain Volume Measure 2020 Edition). The main industry in the Northeast is agriculture, which accounts for about 20% of the region's gross domestic product. Therefore, improving agriculture is necessary to reduce the economic gap.

To increase farmers' income, we can consider the following three methods. The first is to increase farmers' land, and the second is to increase the yield. The last one is increasing the price per unit of the crop. In Thailand, almost all the arable land is already used, and the expansion of agricultural areas is no longer relevant. Further, many farmlands have environmental problems

because of the overuse of chemical fertilizers (Tirado et al., 2008). Hence, of the three methods, the first two are not feasible in considering environmental conservation. Therefore, producing high-value crops is essential to improve farmers' income. Furthermore, high quality with agricultural certifications or labels is one promising method for farmers to take. The last decades have seen a rise in the public interest in the consumption and production of ethical foods, such as organic food and fair trade (Vermeir and Verbeke, 2006). Acquiring agricultural certification also often has positive impacts on farmers' net income. However, the crops that have been studied are limited, such as chocolate, fruits, and coffee (Meemken, 2020).

Thailand is known for its silk production, and in 2020 the amount of production of silk yarn was 520 metric tons, ranking fifth in the world (International Sericultural Commission, 2020). According to the report of Queen Sirikit's Department of Sericulture, the Northeast area is one of the main production areas of silk. In 2017 sericulture practices covered 57 out of the total 77 provinces in Thailand. The mulberry area was 7,553 ha and 82,071 households conducted sericulture. Around 80% of households conducting sericulture lived in Northeast Thailand. The origins of the Thai silk industry are not known in detail but according to the ASEAN GI database, 2024, in Chonnabot district, Khon Kaen, silk was used as a gift for King Rama I (1737-1809) as early as in the 18th century.

OBJECTIVE

This paper studies the silk sector and agriculture certifications, taking the case of Khon Kaen province in Thailand. In this paper, we focus on four certifications. The first label is Organic Thailand which is organic certification in Thailand. The second is Geographical Indication (GI), certified to protect the locality and traditionality of the product. The third one is OTOP which means One Tambon One Product. Tambon means village in Thai and this certification encourages rural development, and the last certification is Peacock which is an exclusive certification that indicates the quality of Thai silk.

METHODOLOGY

We have two research questions: what factors are related to obtaining certification and what kind of impact does the certification bring to silk farmers' annual income from silk weaving? To clarify those two research questions, we conducted face-to-face interviews and questionnaire surveys in Khon Kaen province, Northeast Thailand (Fig. 1). Black dots indicate the locations of the farmers who were interviewed. We conducted two rounds of fieldwork. The first survey was from August 1st to August 5th, and the second survey was from October 23rd to November 11th. The total number of farmers who answered our questionnaire was 103.

To examine determinants to obtain certificates, we chose variables as such years of education completed, gender, and whether to join farmers' communities (Table 1). We conducted a logistic regression to examine the important factors of obtaining certifications.
We used the following model Eq. (1) varying the number of control variables in the five models we conducted.

$$Y = f(X'\beta) \quad (1)$$

Where Y is equal to 1 if the farmer has certification and zero otherwise, and X is a vector of independent variables, which includes *education, age, experience, area_ha, full-time, seripeople, and steps*, depending on the models.

Comparing the mean values between certified and non-certified farmers, the three areas with particularly large differences in mean values were experience, land area, and the number of sericultural processes conducted in their households (Table 2). We will analyze using logistic regression whether those factors are statistically significant.

In addition, to determine the certification's effect on silk farmers, we conducted a two-sample t-test. We examine each research question not only by quantitative analysis but also by qualitative analysis based on information obtained through interviews and other means.

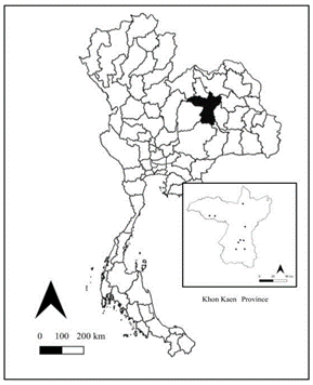

Fig. 1 The map of the study site

Table 1 List of independent variables

age	Farmer's age
edu	Years of education completed
gender	= 1 if the farmer is a woman, = 0 otherwise
experience	Years of agricultural experience
fulltime	= 1 if the farmer is a full-time silk farmer, = 0 otherwise
family number	Number of family members
Area ha	Size of land that the farmer owns (ha)
seripeople	Number of family members who are involved in sericulture
steps	Number of processes in silk production that the farmer is engaged in
community	= 1 if the farmer belongs to a community, = 0 otherwise

Table 2 List of independent variables' mean and standard deviation

	Group	Obs.	Mean	Std. dev.
Age	1	46	56.08	10.34
	0	24	58.54	10.94
Difference			-2.56	
Education	1	46	7.74	2.74
	0	24	6.54	1.98
Difference			1.2	
gender	1	43	0.9	0.29
	0	24	0.92	0.28
Difference			0	
experience	1	34	30.74	15.53
	0	20	26.1	18.44
Difference			4.64	
fulltime	1	33	0.73	0.45
	0	18	0.83	0.38
Difference			-0.11	
area_ha	1	40	3.3	3.54
	0	20	1.37	1.33
Difference			1.94	
seripeople	1	44	1.7	1.49
	0	19	1.42	0.69
Difference			0.28	
steps	1	46	3.76	1.88
	0	24	2.38	1.95
Difference			1.39	

Note: Group=1 means the farmer joins the community and Group=0 means the farmer doesn't join the community

RESULT AND DISCUSSION

From the result of the regressions, the steps were statistically significant, indicating that it is an important factor in obtaining certifications (Table 3). We estimated Average Marginal Effects (AME). If a farmer adds one more process, the probability of certification increases by 8.84% (Model 5). In sericulture, there are six main processes to make silk weaving. These are mulberry cultivation, silkworm bleeding, reeling yarn, dyeing, weaving, and selling.

From the interviews, we found that some farmers who perform a smaller number of processes are concerned by the recent increase in the cost of purchasing raw silk while the purchase price remained the same for finished silk fabrics. However, raising silkworms requires skills, and it is difficult for some farmers to increase the number of processes if they are also engaged in non-farming jobs in cities or growing other crops. In addition, opportunities to learn the skill to raise silkworms are also limited as these skills are often taught in communities or in an area where sericulture is traditionally practiced.

Table 3 Results of logistic regression

	Model 1 Obs:54 GOF: -34.24		Model 2 Obs:48 GOF: -26.78		Model 3 Obs:38 GOF: -24.91		Model 4 Obs: 49 GOF: -29.22		Model 5 Obs: 54 GOF: -31.4	
	AME	P>|z|	AME	P>|z|	AME	P>|z|	AME	P>|z|	AME	P>|z|
edu	0.02	0.37	0.00	0.52	0.04	0.30	0.02	0.45	0.00	0.45
age	0.00	0.63	0.00	0.57	0.00	0.63	0.00	0.39	0.00	0.86
experience	0.00	0.24	0.00	0.17	0.00	0.72	0.00	0.17	0.00	0.24
area_ha			0.12	0.12						
fulltime					-0.01	0.96				
seripeople							0.00	0.761		
steps									0.08	0.02**

*Note p>0.01 ***, p>0.05 **, p>0.1**

The community variable was not included in the regressions because the variable is concerned with endogeneity, but we determined it to be an important factor as a result of the interviews. The importance of being part of a community can be discussed from two aspects. The first is that one must join the community to obtain OTOP, and the second is that the Queen Sirikit Department of Sericulture (QSDS) offers technical improvement workshops for certification, but these are offered on a community basis. The main purpose of the community is to provide technical training so if the farmer doesn't join any community, the farmer finds it difficult to improve their sericulture skills. From our survey, 54 of the farmers joined some kind of community and out of 46 farmers who have certifications, 44 of them belong to the community while out of 24 non-certificated farmers, 1 of them joined the community.

We also examine the impact of agricultural certification on farmers' annual income from silk textiles[1]. Table 4 reports the results of the t-tests between the certified and non-certified farmers. We find that certified farmers tend to obtain 15,702 THB more income annually, and the difference is statistically significant at the 1% level.

Table 4 Results of two sample t-tests

Group	Obs.	Mean	Std. err.	Std. dev.
Non-certified	13	19692.31	2923.87	10542.17
Certified	36	35394.44	3305.6	19833.62
Difference		-15702.1		
				t = -2.71

[1] We do not use regressions to examine the impact of certification on income due to the issue of endogeneity of certification variable and unavailability of instrumental variables to correct for this bias.

Focusing on each certification, there were significant differences in the number of certifications obtained by farmers. The certification with the highest number of farmers obtaining it was OTOP, with 26 farmers obtaining it. Peacock was next, with 17 holders. On the other hand, GI and Organic Thailand had two each. While OTOP and Peacock are popular certifications among silk farmers in Khon Kaen, Organic Thailand and GI are not as popular. In the interview, the leader of the farmers' community that has GI and Organic Thailand said GI is not easy to obtain because the certification is one of the international labels that have many requirements.

We find that certifications positively impact farmers' income and joining farmers' communities and conducting more processes of sericulture contribute to obtaining certifications. However, many farmers still find it difficult to join the community and obtain certifications. There are mainly two reasons. Firstly, lack of connection with the community that conducts training and information exchange about silk. In our survey, one community welcomes anyone who wants to join while another community refuses new members because they are concerned about their relationships with existing members and village residents. In addition, because joining the farmer's community is a common culture in Thailand, while farmer communities are already organized, the types of communities are diverse, and farmers can be found belonging to more than one community. This leads to the next reason we will discuss for the lack of time to take training.

Secondly, the time constraints for farmers to join communities. Sometimes farmers leave the community because of a lack of time they need to give to take training. Moreover, silk has traditionally been a sideline business for farmers, and many farmers grow silk apart from engaging in non-agricultural work or growing other crops.

One type of support that may help farmers in such situations is to offer financial assistance such as microfinance. While they start engaging more with the sericulture sector to join communities and learn skills, they may rely on this assistance to supplement the loss of income that may otherwise have been realized with their non-farm work. If the government can offer such assistance until the farmers' sericulture business takes off, the farmers may be able to upgrade their products and obtain certifications to benefit from higher income. In addition, in the private sector, where silk is consumed, it is important that buyers and others properly understand certification and promote it to consumers to encourage consumption.

CONCLUSION

In this study, we conducted an interview and questionnaire survey with silk farmers in Khon Kaen, Northeastern Thailand to identify the important factors in acquiring a certification and the effects of certification. The results showed that increasing the process of sericulture and community participation are two important factors for obtaining certifications. We also found that certification has a statistically significant positive impact on farmers' income. Certified farmers earn 15,702 THB higher annual income from silk weaving than non-certified farmers. On the other hand, improving technology is important to increase the number of processes, and one way to improve technology is to belong to the community and attend training. However, farmers face challenges such as a lack of connections to join communities and a lack of time to attend training. Therefore, the government needs to provide more financial support to farmers and information on how to attend training.

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Research article

Extension Needs of Farmers Engaged in Buffalo Raising around Kaeng Lawa Reservoir Wetland, Ban Phai District, Khon Kaen Province, Thailand

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Abstract Buffalo raised by smallholder farmers play important roles for agricultural production, including providing draught power and fertilizer. Buffalo are suited to poor feeding management and adapt to hot-humid tropical climate conditions. Recently the swamp buffalo population of Thailand has been declining. The objectives of the current study are to examine the socio-economic background of Thai farmers engaged in buffalo raising, buffalo raising practices, and farmer needs in terms of extension work focused on buffalo raising. Data collection for the study consisted of questionnaires submitted to 45 farmers in May – October 2020 by convenience sampling. SPSS for Windows was used for analysis to determine the percentage, mean, minimum, and maximum values. In-depth interviews were conducted with farmers who were members of a buffalo-raising group, and with several village headmen and local staff in communities around the Kaeng Lawa Reservoir wetland, in Ban Phai District, Khon Kaen Province, Thailand. The results indicated that members of the buffalo-raising group had an average of 23.9 years' experience in buffalo raising, with an average of 8-9 heads of buffalo per household. The majority of farmers (92.1%) sold their buffalo per head to local merchants, while the average annual income from buffalo sales was 63,233.71 baht per household. Additionally, farmers sold buffalo manure by 20 kg bag for 20-25 baht, earning 2,000 – 3,000 baht a year. The extension work on buffalo raising showed that farmers needed the following: 1) knowledge, in particular on selecting and buying female breeders, breeding improvements, keeping buffalo manure and added value of buffalo manure; 2) training; 82.22% of farmers wanted training provided at the village level, while 75.56 % requested livestock officers as training facilitators; and 3) support, in particular with buying high-quality breeders from government organizations, services on injections for animal health, provision of vaccinations and prevention of disease.

Keywords buffalo raising, agriculture extension, buffalo raising extension

INTRODUCTION

Thai people's livelihood in the past depended on buffalo labor for agriculture. Historically, buffalo are part of Thai people's lives. Currently, the role of buffalo is changing and being replaced by modern technology arising from farm mechanization. As a result, the significance of the past role of buffalo is being lost, and the buffalo population, as a critical part of the rice farming industry has declined rapidly. The value and price of buffalo has also declined (Bangkok Post, 2019). The Provincial Livestock Office and Office of Agriculture Economics (2021) reported that statistics of buffalo in Thailand has decreased from 1.70 million in 2000 to 1.26 million in 2020In some areas

buffalo raising is still a valued agricultural animal activity for small householders, but the production has unfortunately declined in recent decades (Pineda et al., 2021). Moreover, buffalo have become a niche market, conservation activity and hobby.

The Kaeng Lawa Reservoir wetland, located in Ban Phai District, Khon Kaen Province, Thailand currently has about 2,000 buffalo around the reservoir, and is the biggest group of buffalo in Northeast Thailand (Department of Livestock, 2022). About 120 farmers in a community enterprise there may help to drive the agriculture in the region sustainably as well as providing socio-economic outputs farmers and their practices on buffalo raising. Thus, the study on needs for agriculture extension on buffalo raising of farmers in Kaeng Lawa reservoir wetland, Khon Kaen was needed.

OBJECTIVE

The objective of this research was to study some selected social and socio-economic backgrounds of Thai buffalo raising farmers, practices on buffalo raising and needs for extension on buffalo raising of farmers around Kaeng Lawa reservoir wetland, located in Ban Phai District, Khon Kaen Province, Thailand.

METHODOLOGY

The study was conducted by individual interviews to 45 buffalo raising farmers around Kaeng Lawa reservoir wetland in Ban Phai District, Khon Kaen Province, Northeastern Thailand (Figures 1 and 2). The population details were collected by questionnaire in May - October 2020 by convenience sampling. A questionnaire was created by generating from the literature review. The instrument consisted of three parts. The first part was related to the farmers' background (education background, experience, and number of buffalo). The second part was focused on practices on buffalo raising. The third part was related to the needs for extension on buffalo raising of farmers. All parts of the questionnaire contained multiple choices, fill in the blank, and choose all were used. The answers were from individual farms. SPSS for Windows was used for analysis of data to determine percentage, mean, minimum and maximum. An in-depth interview was done with 5 village headmen who live near the Kaeng Lawa reservoir and the local staff.

Fig. 1 Kaeng Lawa reservoir wetland

Fig. 2 Herd of buffalo in the wetland

RESULTS AND DISCUSSION

Socio-economic Background of Surveyed Farmers

The results indicated that farmers were a mean of 56.40 years old. Most farmers (82.22%) had finished primary school level, 15.56% of them had finished high school, and 2.22% of them had no education. Kudting and Wongsaman (2010) stated that farmers with low education level had no

problems and dissents for raising the buffaloes, and the main things were the experiences and the knowledge passing from earlier generations. The main career of farmers was rice farming (66.67%). Farmers in the region received revenue mainly from rice production (71.11%), livestock production (17.78%), and other sources (11.11%). The majority of farmers raised buffalo as the second career (74.61%) more than the first career (25.39%). The land for raising buffalo was free areas around Kaeng Lawa Reservoir wetland (80.00%) and their own land (20.00%) and 23.90 years' experience on buffalo raising (Table 1).

Table 1 Socio-economic background of buffalo raising farmers around Kaeng Lawa Reservoir, Khon Kaen Province, Thailand

Personal information	Number (n=45)	Percent (%)
1. Age (year)		
- ≤ 50	7	15.56
- 51-60	31	68.88
- >60	7	15.56
Mean 56.40, Maximum 73, Minimum 39		
2. Education level		
- No education level	1	2.22
- Primary school	37	82.22
- High school	7	15.56
3. Main career		
- Rice farming	30	66.67
- Buffalo rising	6	13.33
- Fisherman	5	11.11
- Employment	4	8.89
4. Main income		
- Rice production	32	71.11
- livestock production	8	17.77
- Other sources	5	11.11
5. Buffalo rising land		
- free areas around Kaeng Lawa Reservoir wetland	36	80.00
- their own land	9	20.00
6. The experience on buffalo raising (year)		
- ≤ 10	3	6.97
- 11-30	33	73.33
- > 30	9	20.00
Mean 23.90, Maximum 63, Minimum 33		

Buffalo Raising Practices

Farmers had buffalo for the average of 8-9 heads per household. Most farmers did not use any feed concentrate, and no feed that was used with another to improve the nutritive balance (92.16%). Only 7.84% of farmers sometimes used concentrate to feed their buffaloes because source of roughage was from natural grassland (89.47%), grown by themselves (10.53%). The primarily farmers raised buffalo by natural pasture (100%). About 71.33% of farmers gave supplemental minerals to their buffaloes, those supplemental minerals from department of livestock support. Some farmers preferred to breed their buffaloes by natural matching (60.38%), more than artificial insemination (39.62%) because most of the buffaloes were in the field. Almost all buffaloes got vaccination (97.78%) and all buffaloes were treated against parasites. The majority of them (92.1%) sold their buffaloes per head to local merchants and earned the annual income of 63,233.71 baht per household. Farmers dried some buffaloes manure from the pen and sold it for 20-25 baht a bag (Figs. 3 and 4), earning 2,000 – 3,000 baht a year (Table 2).

Table 2 Buffalo-raising practices of farmers around Kaeng Lawa Reservoir, Khon Kaen Province, Thailand

Practices	Number (n=45)	Percent (%)
Number of buffaloes (head)		
- <5	6	13.33
- 5-20	30	66.67
- >20	9	20.00
Mean 8.56, Maximum 47, Minimum 2		
Feeding the concentrate food		
- Yes	4	7.84
- No, feeding only roughage	41	92.16
- free natural grassland	(37)	(89.47)
- grow grassland	(4)	(10.53)
Giving supplemental minerals		
- Yes	33	73.33
- No	12	26.67
Breeding		
- Matching by natural	27	60.38
- Artificial insemination	18	39.62
Vaccination		
- Yes	44	97.78
- No	1	2.22
Market place		
- Local merchant	41	92.16
- Meat selling	4	7.84
Buffalo annual income (baht)		
- ≤20,000	11	24.44
- 20,000-50,000	29	64.44
- >50,000	5	11.11
Mean 63,233.71, Maximum 800,00 Minimum15,000		

Fig. 3 Buffaloes in the pen with their manure

Fig. 4 Bags of buffalo manure for sale

Farmer Extension Needs with Regard to Buffalo-Raising

Regarding the extension on buffalo raising, it was found that farmers had needs in the following: 1) Knowledge aspect; having the high level (>70%) of needs in the topics; selecting and buying female breeder (95.56), breeding improvement (100%) for reducing genetic disorder and also improving the productivity related to Na-Chiangmai (2000) who stated that development of buffalo breeding schemes in Thailand have shown higher performance of calves after breeding program by the National Buffalo Breeding and Research Program, keeping buffalo manure and added values of buffalo manure (100%); 2) Training course aspect; 82.22% of farmers needed training provided at the village, 75.56% would like have livestock officers to be resource person of training; and 3) Support aspect; the farmers had high level of needs in the items; 71.11% of buying good breeder

from government organization, 82.22% of service on injection for animal health, 82.22% of providing vaccination and prevention of disease (Table 3).

The in-depth interview found reproduction of buffalo under intensive farm management conditions, farmers raised buffalo by natural pasture which less feeding in flooding rainy season, buffaloes breeding were in their herds with closed blood and buffalo manure was released to the environment; water and air pollutions, because numbers of buffaloes around Kaeng Lawa reservoir was clumped in small upper areas. The situation was different than that indicated in the report of Food and Agriculture Organization (FAO, 2022) on buffalo in Thale Noi wetland, wide area in the southern Thailand found essential part of wetland ecology, maintaining water quality.

Table 3 Needs for extension on buffalo raising of farmers around Kaeng Lawa Reservoir, Khon Kaen Province, Thailand

Needs	Number (n=45)	Percent (%)
Knowledge aspect		
- selecting and buying female breeder	43	95.56
- breeding improvement	45	100.00
- keeping buffalo manure and added values of buffalo manure	45	100.00
Training course aspect		
- training provide at the village	37	82.22
- livestock officers to be resource person of training	34	75.56
Support aspect		
- buying good breeder from government organization	32	71.11
- service on injection for animal health	37	82.22
- providing vaccination and prevention of disease	37	82.22

CONCLUSION

Most farmers who raise buffalo have a high level of needs with regard to breeders and breeding improvement. Although the National Buffalo Breeding and Research Program in Thailand was established in 1981, a program suitable for free-range buffalo as well as for intensive buffalo raising by smallholder farmers is still needed, particularly due to the aging of the farming population. Moreover, storage of buffalo manure and added value of buffalo manure is a major aspect of the Bio-Circular-Green' Economy Model (BCG Model), which aims to develop high-value products and services that are eco-friendly and require less resource input, while conserving natural and biological resources. One way of creating added-value organic fertilizer from buffalo manure is via vermi-technology, i.e., by utilizing earthworms for composting organic material. This can reduce waste and increase the income of buffalo-raising farmers.

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Research article

Factors Influencing Adoption of Ecosystem-Based Adaptation Practices: The Case of Small-Scale Maize Farming in Morogoro Region, Tanzania

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Abstract Maize is the main staple crop in Tanzania; it is produced in almost all agroecological regions of the country, with production dominated by small-scale rain-fed farming. Maize production in Tanzania is constrained by climate change impacts such as rises in temperature, changes in rainfall patterns, and increases in plant diseases, insects, pests, floods, and droughts. Small-scale maize farmers have low climate change adaptation capacity, as the majority still use unsustainable farming practices such as monoculture, intensive tillage, and burning of crop residues, all of which increase the farmers' vulnerability to climate change impacts. Sustainable farming practices, in particular Ecosystem-based Adaptation (EbA) practices such as the ones considered in this study, are believed to contribute significantly to restoring and conserving agroecosystems, increasing maize productivity and resilience towards climate change. This study aimed to identify the common EbA practices adopted by farmers in Tanzania and to determine the factors influencing adoption of EbA practices in maize farming. The study was conducted in the Kilosa district of the Morogoro region of Tanzania. Both primary and secondary data were used in the study. Primary data was collected through key informant interviews with the agricultural extension officers and a semi-structured questionnaire survey administered to 350 farmers. The T-test and the Tobit regression model were used for data analysis. Based on the T-test results, commonly adopted EbA practices included crop rotation, maize-legume intercropping, and improved seeds. Based on the Tobit regression analysis, farm size, household income, land ownership, access to climate information, labor, knowledge of EbA practices, and membership in the farmer field schools were found to significantly influence the adoption of EbA practices in maize farming. This study highlighted the importance of the government's role in increasing EbA knowledge dissemination to the farmers through improving the training facilities in the farmer field schools and increasing opportunities for the farmers to have access to credit from financial service providers, allowing maize farmers to boost their income and become able to adopt more EbA practices.

Keywords maize farming, climate change, ecosystem-based adaptation practices, Tobit regression model

INTRODUCTION

Maize is an important food crop in Tanzania as it accounts for over 70% of the national starch requirement for human consumption (Mkonda and Xinhua, 2017) and approximately 65% of the smallholder farming households depend on maize for the provision of both food and income (Anderson et al., 2016). Between 65% and 85% of maize produced is consumed by the household producing it while only 20% to 35% is used for commercial purposes (Lana et al., 2017). According to USAID (2010), maize is produced in almost all agroecological regions in the country. It is characterized by small-scale production (Baregu et al., 2015) and is mainly rain-fed as only 3% of the total planted area is irrigated (URT, 2016). In most African countries including Tanzania, maize production is affected by climate change effects as approximately 70% to 80% of maize losses are caused by droughts and floods (Amondo and Simtowe, 2018). Furthermore, with the increasing adverse impacts of climate change, maize yield in Tanzania has been predicted to decline at the local level by 37% in 2050 (Msongaleli et al., 2015). This decrease in the maize yield will affect the household food security and income of the most rural households in the country.

According to the Intergovernmental Panel on Climate Change (IPCC, 2018), Tanzania is among the countries that are most vulnerable to climate change as most of the farmers are suffering from its negative impacts. In addition, the country is ranked among the 13th countries with weak adaptation capacity to climate change (IPCC, 2014). Most of the farmers still employ unsustainable farm practices such as monoculture, intensive tillage, and burning or removal of crop residues after harvest from the farmland, which degrades the health of the agroecosystem (Agula et al., 2018) and exposes the farmers to be more vulnerable to climate change impacts.

The farmers need to use sustainable farm practices which are considered as Ecosystem-based Adaptation (EbA) practices in this study. EbA refers to the use of ecosystem services and biodiversity as part of an overall adaptation strategy to help people adapt to the adverse impacts of climate change (Nalau et al., 2018). EbA practices ensure sustainable management, conservation, and restoration of natural resources and ecosystems that support and protect agricultural livelihoods such as nutrient cycling provision, soil formation, water infiltration, pollination, pest and disease regulation, and carbon sequestration (Abdelmagied and Mpheshea, 2020; Daigneault et al., 2016). The common example of EbA practices at the farm scale is the use of agroforestry to combat the effects of high temperatures, heavy rains, and other climate change impacts on crops and livestock (Siles et al., 2010) and has the potential to tackle food insecurity and increase the resilience of the farmers towards the impacts of climate change (Catacutan et al., 2017). Despite the importance of maize farming and the benefits of EbA practices in the cultivated ecosystems, less is known about the common EbA practices adopted by small-scale maize farmers and the factors influencing the adoption of EbA practices in maize farming in Tanzania. Based on various literatures, eight EbA practices were selected for this study which were crop rotation, maize-legume intercropping, agroforestry, mulching, improved seeds, organic manure, zero tillage, and planting maize on contour ridges.

Description of the Eight Selected EbA Practices in Maize Farming

Crop rotation is the practice of growing a sequence of crops on the same land cycle after cycle (Dury et al., 2012). Maize-legume intercropping is the cultivation of maize intercropped with legumes such as common beans, soybeans, groundnuts, or cowpeas for a specific period or the entire growing season. Agroforestry practice in maize farming is the integration of trees and maize crops in the same land. Mulching in this study is a practice that consists of leaving a layer of crop residues on the soil surface for soil and water conservation. The use of improved seeds as an EbA practice in this study is the use of improved maize seeds in maize farming because they are high-yielding and tolerant to diseases and drought compared to recycled seeds. The use of organic manure in maize farming either from plant or animal sources helps to improve soil fertility. Zero tillage is a practice in which seeds are placed into untilled soil by opening a narrow slot, trench, or hole of only sufficient width and depth to obtain proper seed placement and coverage (Derpsch et al., 2014). Planting maize on contour ridges involves the construction of small earth structures across the slopes on cultivated land to decrease runoff, increase water infiltration, and capture rainfall close to the crop root system.

OBJECTIVE

The general objective of this study was to analyze the factors influencing the adoption of EbA practices in maize farming. The specific objectives were to identify the common EbA practices adopted by farmers and to determine the factors influencing the adoption of EbA practices in maize farming.

METHODOLOGY

Study Area, Data Collection and Analysis

The study was conducted in the Kilosa district of the Morogorogo region in the eastern part of Tanzania. The district is characterized by a semi-humid climate with an average annual rainfall between 800 mm to 1,600 mm and an average annual temperature ranging from 19℃ to 30℃. The study area was selected because most of the smallholder farmers are engaged in maize farming and the district experiences climate change impacts (Vatn et al., 2017). According to the population census conducted by the United Republic of Tanzania in 2022, the total population of Kilosa district in 2022 was 617,032 people of which 80% are framers (URT, 2022). With the support of the district agricultural extension officer, purposive sampling was used to select 10 divisions in the Kilosa district with potential for maize farming and with many smallholder maize farmers. The 10 selected divisions were Kidete, Zombo, Madoto, Kimamba B, Msowero, Ulaya, Mhenda, Masanze, Magomeni and Rudewa divisions. From each division, 35 farmers were randomly selected which made a total of 350 farmers. This study employed a cross-sectional research design in data collection. Primary data were collected between January 7th to February 11th in 2023 through key informant interviews with the agricultural extension officers and a semi-structured questionnaire survey administered to 350 farmers who were randomly selected. Data analysis was conducted using the T-test and Tobit regression model.

RESULTS AND DISCUSSION

Ecosystem-based Adaptation Practices Adopted in Maize Farming

Table 1 shows that the common EbA practices adopted in maize farming were crop rotation (115 adapters), maize-legume intercropping (205 adapters), and improved seeds (127 adapters). Maize-legume intercropping had the largest number of adopters which shows that most small-scale maize farmers prefer this practice because it reduces the risk of total crop failure as when one crop fails, farmers can still benefit from another crop on the farm.

Table 1 T-test result of EbA practices adopted on maize farming (n=350 farmers)

No.	EbA practices adopted	Adopters (farmers)	Non-adopters (farmers)	Yield of adopters (kg/ha)	Yield of non-adopters (kg/ha)	*p*-value
1	Crop rotation	115	235	3,490	1,132	0.000
2	Maize-legume intercropping	205	145	2,754	709	0.000
3	Agroforestry	39	311	4,600	1,569	0.000
4	Mulching	70	280	3,673	1,465	0.000
5	Planting maize on contour ridges	9	341	3,011	1,878	0.050
6	Improved seeds	127	223	3,546	973	0.000
7	Zero-tillage	17	333	3,853	1,808	0.002
8	Organic manure	22	328	3,786	1,781	0.000

The result is in line with the study of Rusinamhhodzia et al. (2012) who found that smallholder farmers of Central Mozambique prefer intercropping because it reduces the risk of total crop failure and improves productivity. Table 1 also shows that all the EbA practices have a significant impact on maize yield as adopters of EbA practices have higher maize yield compared to non-adopters. The result is consistent with the study of Abdelmagied and Mpheshea (2020) that EbA practices improve agricultural productivity.

Factors Influencing Adoption of EbA Practices in Maize Farming

The Tobit model, which is also called the censored regression model is designed to estimate linear relationships between variables when there is either left- or right-censoring in the dependent variable (Tobin, 1958). Tobit model uses both the data at the threshold and those above the threshold to estimate the model. The tobit model measures not only the adoption decision but also the intensity of the use of technology once adopted (Tobin, 1958).

In this study, the Tobit regression model was used to analyze the factors influencing the adoption of EbA practices in maize farming. In the Tobit model, the dependent variable Y is ecosystem-based adaptation practices adopted by the farmers on maize farming measured using the adaptive index which was obtained by taking the number of EbA practices adopted by the maize farmers divided by the total number of EbA practices available to the farmers as given in Eq. 1.

$$Y = \beta_0 + \sum_{i=1}^{10} \beta_i X_i + e \quad (1)$$

Where β_0 is the intercept of Y, β_i , i = 1, 2, ...,10 is a regression coefficient with respect to the independent variable X_i and e is the error term. The independent variables used in the model are shown in Table 2.

Table 2 Description of the independent variables used in the Tobit model

Variables	Description
Age	Age of household head (years)
Gender	Dummy (1= male, 0 = female)
Household size	Number of household head size
Farm size	Total maize farm size of the farmer in hectares
Household income	Total annual household income of the farmer from both on-farm and off-farm activities in Tanzanian shillings
Land ownership	Dummy (1 = the farmer own the maize farm, 0 = the farmer rent the maize farm)
Access to climate information	Dummy (1 = the farmer has access to climate information, 0 = the farmer does not have access to climate information)
Access to labour force	Dummy (1 = the farmer has access to family labour or can afford the costs of hired labour, 0 = the farmer does not have access to family labour and can not afford the costs of hired labour)
Knowledge of EbA practices	Dummy (1= the farmer has knowledge of how to use EbA practices and the importance of EbA practices in the farm, 0 = the farmer does not have knowledge on how to use EbA practices and the significance of EbA practices in the farm)
Membership in farmer field school	Dummy (1= the farmer is a member in the farmer field school, 0= the farmer is not a member in the farmer field school)

The discussion of the Tobit regression results in Table 3 is as follows, the model was selected because it had the smallest Akaike Information Criterion, and the value of the log-likelihood was higher which corresponds to a better fit of the data in comparison to other models.

Farm size was statistically significant (p<0.1) with a positive coefficient showing that the increase in farm size increases the likelihood of the farmer to adopt EbA practices in maize farming. Large farm size provides enough space for the farmer to adopt a wide range of EbA practices in the farm like the use of different kinds of crop diversification such as intercropping, and crop rotation compared to farmers with small farm sizes. This is similarly in line with a study by Belay et al. (2017) who found that large farm size provides farmers with an opportunity to practice crop diversification which helps to reduce risks associated with unpredictable weather changes.

Household income had a significant (p<0.001) positive effect on the adoption of EbA practices in maize farming. In this study, the household income was the combination of the income generated by the farmer from both on-farm and off-farm activities. The increase in the household income of the farmer increases the probability of the farmer to adopt more EbA practices in the farm. Small-scale farmers need to have sufficient income to afford the cost of using several EbA practices in the cultivated field. For example, using improved maize seeds, organic manure, cost of controlling weeds in a zero-tilled farm, and labor cost in some of the labour-intensive EbA practices such as planting maize on contour ridges. This result is in line with the previous findings that the increase in income enhances the likelihood of the farmer to invest in more productive farm inputs such as improved seeds and practicing crop diversification in the farm (Kom et al., 2020).

Land ownership had a positive coefficient and statistically significant (p<0.001) influence on the adoption of EbA practices in maize farming indicating that the increase in the access of the farmers to land ownership increases the probability of the farmers being concerned with the conservation and protection of the farmlands for short- and long-term benefits. Hence, the farmers will adopt more EbA practices such as water and soil conservation measures (mulching, organic manure, agroforestry, contour farming, crop rotation, intercropping, zero tillage) compared to the rented farmlands because the farmers do not have full access to the land. The result is consistent with the study of Tran et al. (2019) whose findings showed that land ownership had a positive influence on the adoption of climate-smart agriculture technologies.

Access to climate information influences the adoption of EbA practices in maize farming as it was statistically significant (p<0.001) with a positive coefficient showing that farmers who have access to information regarding climate events such as temperature and rain intensity are more likely to adopt EbA practices to combat the effects of climate variability in farming. For instance, if the farmers know that there will be low rainfall, they will anticipate planting maize on the contour ridges as an in-situ water harvesting technique to increase surface run-off storage near the cropped area. The finding is in line with the study of Rahman et al. (2021) who found that climate information is a crucial factor determining climate change adaptation.

Access to the labour force was statistically significant (p<0.05) with a positive coefficient which indicates that the increase in the access of the farmer to farm labor also increases the probability of the farmer adopting more EbA practices in maize farming. Access to labor implies the ability of the farmer to afford labor costs especially hired labour or the availability of a family labour force to the farmer. Some of the EbA practices are labor intensive such as the application of organic manure in the farm, mulching, planting maize on the contour ridges, and maize-legume intercropping require the farmer to have access to farm labour either family labour, hired labour, or communal labour to help with farm work. This result is consistent with the previous study of Ng´ombe et al. (2017) whose findings showed that the availability of labour was positively correlated with the adoption of conservation agriculture practices in Zambia.

Knowledge of EbA practices significantly (p<0.001) influences the adoption of EbA practices in maize farming. The positive coefficient shows that the more the farmers get knowledge on how to use EbA practices in the farm and the importance of EbA practices in the cultivated ecosystem, the higher the likelihood of adopting EbA practices in maize farming. For instance, if the farmers know the usefulness of EbA practices like mulching, they will not burn or remove crop residues from the field instead they will use it for mulching purposes to increase organic matter and soil moisture content. This finding is similarly in line with the previous study conducted in Ghana by Agula et al. (2018) who found that farmers who know the biological function of ecosystem-based farm management practices have higher probabilities of adoption compared to farmers without adequate knowledge on the usefulness of ecosystem-based farm management practices.

Membership in the farmer field school is an important variable influencing the adoption of EbA practices in maize farming. The coefficient of the farmer field school is positive and statistically significant (p<0.05) indicating that the increase in the participation of the farmers in the farmer field school to gain knowledge from the training on how to use EbA practices in the farm, increases higher chances for the adoption of EbA practices in maize farming. Farmer field schools in the study area train the farmers on several EbA practices such as effective ways of practicing zero-tillage, planting maize on contour ridges, maize-legume intercropping, and agroforestry. This finding is consistent

with the study of Bhutto et al. (2018) who found that participation of the farmers in the farmer field school programs positively influenced the adoption of sustainable agricultural practices.

Table 3 Tobit regression result of the factors influencing adoption of EbA practices (n=350)

Coefficients	Estimate	Std. Error	z value	pr(>|z|)
(Intercept)	-1.812e-01	3.262e-02	-5.557	0.000 ***
Age	3.132e-04	4.935e-04	0.635	0.526
Gender	-3.663e-04	1.471e-02	-0.025	0.980
Household size	-4.916e-03	3.304e-03	-1.488	0.137
Farm size	9.877e-03	5.880e-03	1.680	0.093.
Household income	1.736e-07	2.749e-08	6.316	0.000 ***
Land ownership	1.199e-01	1.461e-02	8.207	0.000***
Access to climate information	1.863e-01	2.052e-02	9.081	0.000 ***
Access to the labor force	3.389e-02	1.395e-02	2.429	0.015*
Knowledge of EbA practices	1.270e-01	1.928e-02	6.585	0.000 ***
Membership in farmer school	5.452e-02	2.301e-02	2.369	0.018 *
Log (scale)	-2.456e+00	7.175e-02	-34.232	0.000***

*Note: ***p< 0.001, **p< 0.01, *p< 0.05 and . p< 0.1, Source: Field survey in Tanzania, 2023*

CONCLUSION

The common EbA practices adopted by the maize farmers in the Kilosa district in Tanzania were found to be crop rotation, maize-legume intercropping and the use of improved seeds. The adoption of EbA practices were found to have significant impact on maize yield, as the adopters of EbA practices had higher maize yield compared to non-adopters of EbA practices. Factors influencing the adoption of EbA practices in maize farming were identified as farm size, household income, land ownership, access to climate information, access to labour force, knowledge of the EbA practices, and membership of the farmers in the farmer field school. This study highlighted the importance of the government's role in increasing EbA knowledge dissemination to smallholder farmers through improving the training facilities in farmer field schools. It is also important for the government to increase opportunities for smallholder maize farmers to have access to credit from financial service providers to boost their income and become able to adopt more EbA practices in maize farming.

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Research article

Nutritional and Cost-Benefit Analysis of Some Traditional Thai Foods and Beverages Prepared from Sacred Lotus

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Abstract In Thailand, the sacred lotus (*Nelumbo nucifera* Gaertn.) is used as an ingredient for healthy food and beverage production and plays a role in Buddhist rituals. In particular, dried lotus petal tea and jasmine rice wrapped in lotus leaves are a staple of traditional food menus, but detailed nutritional information on these products is lacking. Hence, the objective of this research was to standardize some traditional value-added Thai foods and beverages made from lotus and assess their nutritional value. First, a recipe for rice mixed with lotus seed, shrimp, and chicken wrapped in lotus leaves was standardized as a main course, to be served along with lotus petal tea. Subsequently, a nutritional analysis of the two products was carried out for the purpose of nutritional information labeling. The estimated nutritional values in both products were assessed according to the criteria of Percentage of Thai Recommended Daily Intakes for population over 6 years of age (% Thai RDI) with a 2,000-kcal diet. The results showed that the nutritional value of rice wrapped in lotus leaves per net weight of 180 g as a percentage of RDI (excluding a nutritional analysis of the lotus leaves) was 390 kcal (20%) of total energy, 14 g (22%) of total fat, 285 mg (95%) of cholesterol, 18 g of protein, 48 g (16%) of total carbohydrate, 620 mg (31%) of sodium, and vitamin A, B1, and B2. For the nutrition value of a lotus petal teacup per 100 g net weight, only 20 mg (1%) of sodium was found. Lastly, the preliminary results of this study were evaluated based on a value index over five years. The findings revelated that the value addition of sacred lotus represented 8,859 Thai Baht of net present value (NPV), a benefit-cost ratio (BCR) of 1.34, and 8.1% of internal rate of return (IRR), and showed the break-even value of the project budget. Therefore, the result findings are expected to enhance development of sacred lotus products oriented towards green production.

Keywords lotus, traditional food, nutrition information, Thai RDI, green product

INTRODUCTION

Lotus (*Nelumbo nucifera* Gaertn.), commonly known as the sacred lotus, belongs to the Nelumbonaceae family and is a significant aquatic economic plant (Pal and Day, 2013). This species holds religious importance in Southeast Asia, including Thailand, where various parts of the lotus plant, such as the flower, seed, leaf, and rhizome, are utilized as food ingredients and traditional herbs (Dhanarasu and Al-Hazimi, 2013; On-nom et al., 2023). The lotus has been extensively studied for its nutritional composition. For instance, lotus seeds are a rich source of lipids (0.22-3.68%), proteins (10.60-28.19%), carbohydrates (61.3-70.1%), vitamins (0.13-4.6 mg/kg of B1, B2, B6, C, and E), minerals, and bioactive compounds (Shin et al., 1999; Zheng et al., 2003; Indrayan et al., 2005; Wu et al., 2007; Bhat and Sridhar, 2008; Zeng et al., 2011; Luo et al., 2016; Shahzad et al., 2021; Bangar et al., 2022). In Thailand, lotus seeds are commonly used in various food products, such as stir-fried lotus seeds with dried chili paste, lotus seed flour, lotus seed butter, lotus seed cream, and lotus seed milk (Punnaterkoon et al., 2016; Petcharat et al., 2009). For the local people in Pathum Thani province, the sacred lotus holds significance as they utilize it to craft lotus flower and stamen tea. Additionally, the fragrant aromas of its petals and leaves make them suitable for wrapping food (Meesuk, 2001; Changthom, 2021; Ridhowati et al., 2023). Some examples include rice wrapped in lotus leaves, herb appetizers wrapped in sacred lotus petals (Miang Kham), spicy sacred lotus petal salad (Yam), and fried crispy sacred lotus petals. This reflects the cost-effective utilization of different parts of the sacred lotus. However, the products derived from the sacred lotus still lack credibility in terms of quality and have limited reach among consumers. Therefore, there is a need to develop community products that enhance consumer awareness through food analysis, nutrition labeling, and environmentally friendly production.

The country's Bio-Circular-Green (BCG) Economy and Sustainable Development Goals (SDGs) connect the bio-economic system to the cost-effective use of biological resources, generate value-added cultural food menus for community economies, and mitigate environmental problems stemming from food waste—one of the primary sources of GHG emissions from human activities. Estimates suggest that 8-10% of global greenhouse gas emissions are associated with unconsumed food. The UNEP Food Waste Index Report (2021) reveals a household food waste measure in Thailand of 79 kg/capita/year, equivalent to 5,478,532 tons/year. Moreover, the project's outcome and impact pathways are evaluated using the concept of social return assessment (SROI), incorporating techniques such as monetization, benefit transfer, and project cost-effectiveness measurement with the net present value, benefit-cost ratio, and internal rate of return indices. This assessment aims to maximize the cost-effectiveness of budget expenditures.

OBJECTIVE

The objective of this study was to examine the nutritional status and the cost-benefit value of traditional Thai foods and beverages prepared from sacred lotus.

METHODOLOGY

Examine the menus of local food and healthy beverages across all 77 provinces of Thailand. Choose a cultural menu from the sacred lotus that can evolve into a series of single-dish menus and a healthy drink, including rice wrapped in sacred lotus leaves and dried sacred lotus petal tea. Furthermore, these menus should be positioned for promotion as food and beverage options, contributing to the reduction of global warming by evaluating their carbon footprint in the future.

The process for preparing rice wrapped in sacred lotus petals involves the following steps: First, 6.44 mL of vegetable oil, 1.00 g of ground white pepper, 2.66 tsp oyster sauce, 1.44 g of caster sugar, and a 3.33 mL mixture of blac k and light soy sauces. Combine these with a 6.66 g mixture of lotus seeds, 4.44 g of shrimp, 4.44 g of mushrooms, and 37.77 g of steamed jasmine jasmine rice. Next, scoop this mixture onto the middle of sacred lotus leaves, arranging ingredients such as 10 g of pork Chinese sausage, 10 g of salted egg, and 22.22 g of chicken on the rice. Proceed to wrap the sacred

lotus leaves and steam the package for 30 minutes. Each package of rice wrapped in sacred lotus leaves has a net weight of 180 g. Preparing dried sacred lotus petal tea involves separating the sacred lotus flower components, with the stamen section completely dried indoors. Simultaneously, the petals are washed and cut into small pieces of 0.5 centimeters before being dried indoors as well. Each package of dried sacred lotus petal tea has a net weight of 100 g, primarily composed of 60% sacred lotus petals, 20% stamens, and 20% pandan leaves as main components. The product samples were randomly collected: fifteen packages of rice wrapped in sacred lotus leaves with a total weight of 2,700 g and ten packages of dried sacred lotus petal tea with a total weight of 1,000 g. Food analysis and nutritional labeling were done by the Foundation for Industrial Development National Food Institute, Thailand. The processes and analytical methods for food analysis are outlined in Table 1. The nutritional analysis data is utilized to calculate the values of energy, sugar, fat, and sodium in comparison to the corresponding nutrient content per unit package, as specified in Notification No. 182 (1998) of the Ministry of Public Health (2012).

Table 1 Test methods for nutritional analysis

Items	Test methods
Ash	AOAC (2019) 945.38C
Calcium	In-house method T9152 based on AOAC (2019) 984.27
Calories from fat	Methods of analysis for nutrition labeling 1993, chapter 1,5
Cholesterol	In-house method T992 based on the J. of AOAC International, Vol. 76, No.4, 1993
Dietary fiber	In-house method T995 based on AOAC (2019) 985.29
Iron	In-house method T9152 based on AOAC (2019) 984.27
Moisture	AOAC (2019) 945.38B
Protein (N x 6.25)	In-house method T927 based on AOAC (2019) 991.20
Saturated fat	In-house method T974 based on AOAC (2019) 996.06
Sodium	In-house method T9152 based on AOAC (2019) 984.27
Total carbohydrate	Methods of analysis for nutrition labeling 1993, chapter 1,5
Total calories	Methods of analysis for nutrition labeling 1993, chapter 1,5
Total fat	AOAC (2019) 945.38F
Total sugars	In-house method T997 based on AOAC (2019) 982.14
Vitamin A	In-house method T969 based on AOAC (2019) 992.06
Vitamin B1	In-house method T970 based on AOAC (2019) 942.23
Vitamin B2	In-house method T971 based on AOAC (2019) 970.65

The research project at Valaya Alongkorn Rajabhat University under the Royal Patronage Pathum Thani Province has received budget allocation and obtianed the profit from sales at the university market. The study aims to evaluate economic impact through a benefit-cost analysis method, utilizing the ex-ante evaluation model for an additional 5 years. This extended assessment is conducted while the project is ongoing, measuring the investment value with quantitative indices such as Net Percent Value (NPV), Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR).The assessment data is gathered through participant interviews, employing instruments designed to evaluate project cost-effectiveness (Wongjinda, 2021; Jaijit et al., 2017), as represented in Eqs. (1-3).

$$NPV = \sum_{t=0}^{n} (B_t - C_t) / (1+r)^t \quad (1)$$

$$BCR = \sum_{t=0}^{n} B_t / (1+r)^t / \sum_{t=0}^{n} C_t / (1+r)^t \quad (2)$$

$$IRR = \sum_{t=0}^{n} (B_t - C_t) / (1+r)^t = 0 \quad (3)$$

These equations involve variables t (project duration in years), B_t (project benefit in year t in baht per year), C_t (project research cost in year t in Thai baht per year), and r (discount rate in percentage).

Before initiating the research project, the researcher sought certification from the Human Research Ethics Committee of Valaya Alongkorn Rajabhat University under the Royal Patronage Pathum Thani Province. This certification aligns with the ethical guidelines for research involving

human subjects, meeting international standards outlined in COA No. 0049/ 2566 and REC No. 0049/2566.

RESULTS AND DISCUSSION

The results of the nutritional analysis for rice wrapped in sacred lotus leaves and dried sacred lotus petal tea are presented in Table 2.

Table 2 The results of nutritional analysis

Test items	Rice wrapped in sacred lotus leaves					Dried lotus petal tea				
	Amount (per 100 g)		1 pack (per 180 g)		Thai RDI (%)	Amount (per 100 g)		1 glass (250 ml, 5 g)		Thai RDI (%)
Total energy			390.00	kcal				0.00	kcal	
Calories from fat			130.00	kcal						
Total calories	220.00	kcal				1.00	kcal			
Total fate	8.00	g	14.00	g	22			0.00	g	0.00
Saturated fat	2.60	g	4.50	g	23					
Cholesterol	157.00	mg	285.00	mg	95					
Protein	10.20	g	18.00	g		Not detected		0.00	g	0.00
Total carbohydrate	26.70	g	48.00	g	16	0.20	g	< 1.00	g	0.00
Dietary fiber	1.70	g	3.00	g						
Sugar	3.80	g	7.00	g		Not detected		0.00	g	0.00
Sodium	346.00	mg	620.00	mg	31			20.00	mg	1.00
Iron	1.18	mg	2.12	mg	15					
Calcium	57.00	mg	102.60	mg	15	< 9.62	mg			
Vitamin A	51.00	µg	91.80	µg	10					
Vitamin B1	0.05	g	0.09	mg	6					
Vitamin B2	0.13	g	0.23	mg	15	0.10	g			
Ash	1.57	g	2.83	mg		Not detected				
Moisture	53.56	g	96.41	g		99.72	g			

Note: Percent Thai Recommended Daily Intakes for the population over 6 years of age (% Thai RDI) are based on a 2000 kcal diet. Serving size 1 glass (250 ml, 5 g of dried lotus petal tea) and serving size 1 pack (180 g of rice wrapped in lotus leaves)

The findings indicate that rice wrapped in sacred lotus leaves, with a net weight of 180 g, provides a total of 390 kcal. of energy and contains five macronutrient groups for Thai people: 18 g of protein, 14 g (22%) of total fat, 48 g (16%) of total carbohydrate, and minerals: 102.60 mg (15%) of calcium and 1.18 mg (15%) of iron. Additionally, it includes vitamins A, B1, and B2. The product also offers nutrients beneficial to the gastrointestinal tract, such as dietary fiber, while monitoring against overeating includes cholesterol, sodium, saturated fat, and sugar (Surakarnkul, 2011). These monitored nutrients are reported on the Guideline Daily Amounts (GDA) nutritional label, with the maximum daily consumption recommended at 20% of total energy, 11% of sugar, 22% of fat, and 31% of sodium. Regarding the nutrition value of a cup of dried sacred lotus petal tea per net weight of 100 g, only 20 mg (1%) of sodium was found. Both products' nutritional values meet the percentage of Thai recommended daily intakes for the population over 6 years of age (% Thai RDI) based on a 2,000-kcal diet (Ministry of Public Health, 2012). The results suggest that both products can be integrated into food and beverage businesses. In addition to providing nutritional information, they exhibit similar nutrient content to popular Thai foods, such as chicken pad Thai with rice noodles (energy: 159 kcal/100 g, protein: 6.36 g/100 g, total fat: 3.53 g/100 g, total carbohydrate: 24.7 g/100 g) (USDA, 2021). Moreover, the standard recipe developed from jasmine rice wrapped in sacred lotus leaves into a single-dish menu served with dried sacred lotus petal tea can incorporate environmentally friendly ingredients and cater to a diverse consumer base, including Islam, vegetarians, and health enthusiasts. This development can potentially upgrade products from the sacred lotus toward green products in the next phase of the carbon footprint assessment.

The project's results, focused on creating value-added traditional Thai food and healthy drinks from the sacred lotus to green products, initially considered economic returns (income) and evaluated the value index for the next 5 years. The creation of value-added dried sacred lotus petal tea and rice wrapped in sacred lotus leaves demonstrated that the return from this project exceeds the investment, making the investment worthwhile. Specifically, there is a NPV of 8,859 Thai Baht, an IRR of 8.1%, and a BCR of 1.34, indicating that for every 1 Thai Baht invested, 1.34 baht is returned. According to the criteria for measuring the value of capital (NPV > 0, BCR > 0, and IRR > the interest rate of the source of investment (5%) (Vijitsrikamol, 2021)), the evaluation results affirm the value of spending the project budget. However, in the future, at the end of the project, a Social Return on Investment (SROI) evaluation for the sustainable development of the Thai traditional food and beverage from the sacred lotus project should be conducted.

CONCLUSION

In the initial phase of the research project, the goal was to transform jasmine rice wrapped in sacred lotus leaves into a single dish, served with royal lobster tea, with a focus on standardizing the recipe. This standardized recipe can be adapted to incorporate local, environmentally friendly ingredients and cater to a diverse range of consumer groups. The product includes a nutritional information label adhering to GDA and Thai RDI criteria. Additionally, it boasts a nutrient content comparable to popular Thai dishes, contributing to the acceptance and creation of value-added traditional Thai menus and healthy drinks from the sacred lotus over the next five years. This represents the outcome of the cost-effectiveness evaluation of the budget expenditure, yielding indices of NPV, IRR, and BCR. In conclusion, it is essential to conduct a SROI evaluation. This evaluation should further extend to green products through a carbon footprint assessment. Products obtained from using lotus plant components do not create food waste and can generate income for the community. This linkage aims to connect the bio-economy system and reduce GHG emissions from food production.

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Research article

Co-digestion of Ensiled Napier Grass and Commercial Bakery Wastewater for Bioenergy Production

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Abstract Bioenergy derived from anaerobic digestion has gained attention for a decade because of its ability to convert waste into biogas. The advantages of this biotechnology could substitute conventional energy, lower greenhouse gas emissions, and produce less biodegradable waste. This study focused on methane production from ensiled Napier grass (Pak Chong 1) by co-digestion with anaerobic mixed cultures of an Expanded Granular Sludge Bed (EGSB) from a bakery factory. The ratio of co-digestion between ensiled Napier grass feedstock and inoculum (F/I ratio) was 1:1 and 1:3 based on volatile solids (VS). The potential of methane production was evaluated using a batch experiment for 30 days in the laboratory at room temperature (32–35 ± 5 ºC). To enhance biogas production, an alkaline pre-treatment of Napier grass was prepared by adding 1% NaOH. The results demonstrated that the methane production potential of the F/I ratio at 1:1 and 1:3 was 311.11 ± 29 and 255.56 ± 91 mL CH_4/g COD, respectively. The maximum energy production based on methane production was approximately 9.17 kJ/L. The range of pH was 6.96 ± 0.2 to 9.93 ± 0.2 and the percentage of SS, TS, and COD removal were 60.10, 24.69, and 48.63, respectively. The results of this study indicated that the feedstock and inoculum ratio (F/I) including pretreatment of feedstock and inoculum is necessary for biogas potential production. The potential biogas production of the CSTR reactor and its economic feasibility should be further considered.

Keywords anaerobic co-digestion, methane production, Napier grass, bakehouse wastewater

INTRODUCTION

Currently, biogas obtained from waste conversion has gained substantial attention due to its benefits. Biogas can be used as a substitute for fossil fuels, and it can reduce the CO_2 and greenhouse gas emissions of the waste treatment process. Anaerobic digestion is one of the traditional technologies for the biological treatment of organic waste (Ren et al., 2018). Previously, anaerobic digestion, in which organic compounds are degraded and converted to biogas in the absence of O_2, was generally used in many single biodegradable feedstocks including domestic or industrial waste, kitchen waste, and agricultural waste (Zarkaya et al., 2013; Pandey et al., 2019). Agriculture residues or crops are the second feedstocks that are utilized as sources of renewable energy. The complex substrates such

as cellulose and hemicellulose contain primarily glucose and xylose which could be fermented to produce bioenergy using the process of microorganisms. Lignocellulosic biomass could provide approximately 10% of the world's energy. (Zhang et al., 2007; Sawadeenarunat et al., 2016).

Napier grass (Pennisetum purpureum) has considerable attention as a promising crop for energy production, due to the fact that it is fast-growing, easy to harvest, has a high biomass, is highly lignocellulosic, and is environmentally friendly (Mehmood et al., 2017). Although it is native to Africa, it has been cultivated in many tropical regions of the world, including Thailand. Napier grass (Pakchong 1 strain) is not only one of the available biomass sources in Thailand (approximately 221,760,000 tonnes) but also has a high potential for bioenergy production from perennial grasses (Waramit and Chaugool, 2014; Sawasdee and Pisutpaisal, 2021). However, the anaerobic digestion of a single lignocellulosic feedstock has limitations including low biogas production efficiency, long duration, and acidification. Several studies have shown later that co-digestion results in higher biogas production compared to using a single feedstock. Successful research demonstrated that co-digestion of dairy manure with wheat straw and chicken manure produced more methane than using a single feedstock (Wang et al., 2012). Wall et al., (2014) reported that co-digestion of silage and dairy slurry yielded the highest specific methane yield of 349 L CH_4/kg VS. Typically, pretreatment is also considered an advanced option to enhance the biogas production of anaerobic digestion because it is necessary to break down lignin to hydrolyze cellulose and hemicellulose. Pretreatment methods are generally categorized as physical (grinding or milling), chemical (acid and alkaline), and biological methods (Vargas et al., 2015). Furthermore, grass silage is one of the appropriate options to minimize the feedstock preparation costs and provide adequate raw materials for biogas production operations. Grass ensiling is a simple preservation method that is implemented in biomass to extend the storage time (Pahlow et al., 2003). The bakery factory or bakehouse industry typically consumes an amount of water and energy while wastewater from the processes also causes environmental impacts. On the other hand, this kind of wastewater contains highly biodegradable and organic compounds including nutrients, carbohydrates, and lipids which are suitable for bioenergy production of anaerobic digestion (Ali et al., 2017; Pilarska, 2018).

OBJECTIVE

The study aimed to investigate the methane production potential and the energy recovery from the co-digestion of ensiled Napier grass with commercial bakery wastewater in a batch experiment to achieve optimal proportions of substrates for further scale-up experiments.

METHODOLOGY

This study investigated the methane production potential of the co-digestion of ensiled Napier grass with commercial bakery wastewater on a laboratory scale as follows:

Inoculum and Feedstocks

In this study, anaerobic sludge obtained from an expanded granular sludge bed (EGSB) from a bakehouse wastewater treatment process (Bangkok, Thailand) was provided as an inoculum. It was preserved in the refrigerator at 4 ºC. Before use, the anaerobic mixed culture was activated by adding 5% CH_3COOH under anaerobic conditions for a week. In this experiment, the 1:1 and 1:3 ratios of co-digestion between ensiled Napier grass feedstock and inoculum (F/I ratio) were investigated, while the initial pH of this was adjusted to a neutral level.

Preparation of the Ensiled Napier Grass

Napier grass (*Pennisetum purpureum*) Pakchong 1 strain was collected from the Lamtakhong demonstration field of the Thailand Institute of Scientific and Technological Research (Nakhon Ratchasima, Thailand). The grass was harvested at 70 days old and delivered to the laboratory. The

fresh grasses were chopped into small pieces (1-2 cm) by machine. Afterwards, 1L of the compressed-grass extraction was ensiled in the laboratory reactor and sealed airtight with a screw top for 60 days. Before the experiment, the ensiled Napier grass suspension was passed through a 47 mm filter to remove all the debris. The physiochemical characteristics of ensiled Napier grass were evaluated, including pH, TS, SS, TKN, TP, and VFA. In addition, alkaline pre-treatment of ensiled Napier grass was applied in this study by adding 1% NaOH (W/V) for 1 hour.

Methane Production and Analytical Method

Methane production was conducted in a batch experiment in the laboratory. The biological methane potential (BMP) was evaluated using the following 1:1 and 1:3 ratios of F/I with an initial pH of 6.8–7.2. The headspace of the BMP bottle was flushed with nitrogen gas for 5 minutes to displace the air, and the bottle was sealed with a rubber stopper. All BMP experiments were set up at a temperature of 32–35 ± 5 ºC for 30 days. During the experiment, the daily methane gas was measured using the wetted gas syringe method (Owen et al., 1979). Methane production potential was calculated as the following equation (Eq. 1), while the energy production was calculated from the maximum methane converting to energy unit (kJ/L) (Sittijunda, 2015). All treatments were carried out in triplicate. The results are given as average values with standard deviations.

$$Methane\ production\ potential = \frac{Total\ CH_4\ production\ (mL)}{g\ COD\ of\ substrate} \quad (1)$$

pH was measured using a pH meter (Hach 1130, USA). Concentrations of COD, TS, and VS were analyzed according to the standard methods of water quality (APHA, 2015). The energy production in this study was estimated based on methane production and its heating value (Sittijunda, 2015).

RESULTS AND DISCUSSION

An ensiled Napier grass was applied to co-digestion with commercial bakery wastewater in this study. The ensiled Napier grass characteristics, including pH, TS, SS, COD, and VFA, were 4.08 ± 0.1, 32.2 ± 0.38 g/L, 12.53 ± 0.38 g/L, 45.28 ± 0.44 g/L, and 3.52 ± 0.29 g/L, respectively. Due to the low pH of ensiled Napier grass, which could affect the hydrolysis reactions, 1% NaOH was provided to neutralize the pH level. The initial pH values were 6.8-7.2 and gradually increased to 8.1-9.3 at the end of the experiment. The increase in pH might relate to the concentration of NH_3 in the systems, which affected methanogen bacteria and the methane production potential. As in the previous study, Sompong (2019) reported that the high concentration of NH_3 influenced the methanogenic bacteria and tended to decrease methane production. Thus, pH values during anaerobic digestion processes including VFA should be considered for enhancing the methane production yields.

The daily methane production of both F/I ratios is shown in Figure 1. The maximum methane production of the 1:1 ratio was 230 ± 15 mL on the day 15th and 170 ± 20 mL of the 1:3 ratio at the day 14th. The COD removal percentages of 1:1 and 1:3 ratios were 48.63 and 43.11, while the percentages of SS and TS removal for the 1:1 ratio were 60.10 and 24.69, and 55.70 and 23.85 for the 1:3 ratio of F/I, respectively (Table 1). The energy production was determined based on the conversion of the maximum methane production, the density of methane, and its heating value (Sittijunda, 2015). The energy production of 1:1 and 1:3 F/I ratios were 9.17 and 6.81 kJ/L, respectively.

The results suggested that the co-digestion of feedstock and inoculum showed better methane production potential than a single substrate. According to a study by Sirirote et al. (2014), the highest cumulative biogas production of 26.25 L was obtained using a ratio of Napier grass and inoculum of 1:2. Comparing the previous study, the methane production potential of this co-digestion study (255.56 and 311.11 mL CH_4/g COD) showed higher methane production than single Napier grass digestion (122.4 mL CH_4/g TVS) (Sawasdee and Pisutpaisal, 2021). Many studies reported the

methane production yields of different feedstocks and inoculums, for instance, the co-digestion of USAB granular and hydrolysate Napier grass (1:1) produced 40.9 percentage of methane yield (Sittijunda, 2015), and the sludge digested with ice cream wastewater was provided 320-340 mL CH_4/g COD (Ince, 1998). This indicated that the presence of organic materials is a crucial factor in the process of biogas production through anaerobic digestion. In a previous study, Sittijunda (2015) noticed that the amount of methane produced is affected by variables such as the organic loading rate, the particular substrate utilized, and the temperature at which the process is carried out. Furthermore, several pre-treatment methods of feedstocks are selected to enhance the biogas production yields. Grass ensiling is a method selected to make feedstock preparation more cost-effective, promote biomass degradation, and increase methane production (McEniry et al., 2014). The results suggested that ensiled Napier grass digested with commercial bakery wastewater can produce biogas and reduce greenhouse gases. However, it is necessary to conduct further research on scaling up the systems to obtain the required energy, using double-batch or CSTR reactors and investigating economic feasibility.

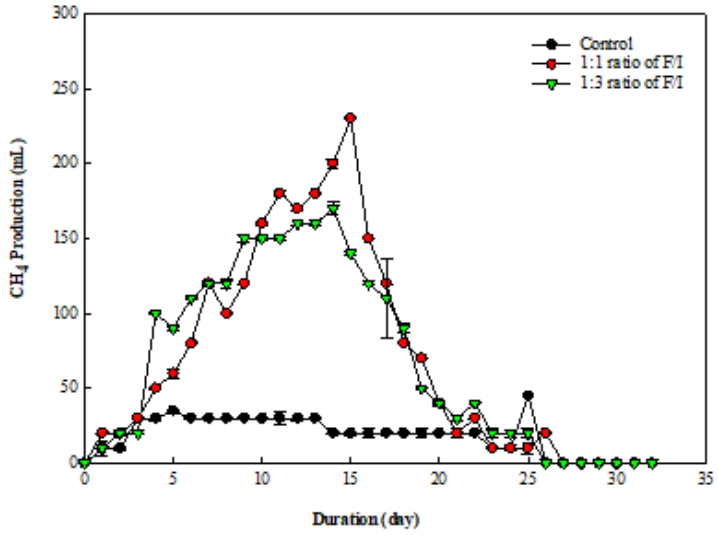

Fig. 1 The methane production of 1:1 and 1:3 ratios of F/I

Table 1 The removal percentage of COD, SS, TS, methane production potential, and energy production of the co-digestion of ensiled Napier grass and commercial bakery wastewater

F/I ratio	% COD removal	%SS removal	% TS removal	CH_4 production potential (mL CH_4/g COD)	Maximum CH_4 production (mL)	Energy production (kJ/L)
1:1	48.63	60.10	24.69	311.11 ± 29	230 ± 15	9.17
1:3	43.11	55.70	23.85	255.56 ± 91	170 ± 20	6.81

CONCLUSION

The results demonstrated that the co-digestion of ensiled Napier grass and commercial bakery wastewater can produce methane and energy. The study determined that the optimal feedstock and inoculum ratio was 1:1, resulting in a methane production potential of 311.11 ± 29 mL CH_4/g COD and energy production of 9.17 kJ/L. Additionally, it was found to remove 43.11 to 48.63% of COD, 55.70 to 60.10% of SS, and 23.85 to 24.69% of TS. Therefore, this study indicated that co-digesting of ensiled Napier grass with commercial bakery wastewater can generate biogas and reduce

greenhouse gas emissions. To enhance the methane production yield, pH, VFA, and methanogen bacteria dynamics could be necessarily considered for further research.

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Research article

Farmers' Perspectives on Ecosystem Services Provided by Tree Windbreak System in Ovche Pole Region, Macedonia

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Abstract Ovche Pole Region is the second largest agricultural area in Macedonia. It is a plain with a dry climate, characterized by low precipitation and high ambient temperatures during the growing period and prevailing winds which are frequently present throughout the year. During the 1950s, the government took a large-scale operation for the establishment of tree windbreaks (field shelterbelts) that would reduce wind velocity, protect agricultural land, and increase crop productivity. Even though these systems perform important functions, approximately half of the initial tree windbreak area is lost mainly due to land use change. Today a significant area of the existing tree windbreak belts is damaged. Actions for the protection, rehabilitation, and restoration of these systems are needed, however, without active support and understanding of farmers' perspectives on tree windbreak systems, any activity would be without major and long-term success. Therefore, the objectives of this study are to: (1) examine farmers' attitudes toward the tree windbreak system and their rehabilitation, and (2) assess farmers' awareness and perceptions of ecosystem services provided by the tree windbreak system. In this aim a semi-structured questionnaire was developed and following the convenience sampling method distributed to 72 farmers to gather the needed information. Data analysis showed that in general farmers have positively valued the tree windbreak systems and agreed that rehabilitation and restoration are needed. Regarding the ecosystem functions, the results indicate that farmers gave uniform answers in some cases, the farmers had split perceptions. According to farmers' responses, the most important ecosystem service provided by the tree windbreaks is climate regulation, this is followed by the reduction of soil erosion and runoff and the source of provisional materials function.

Keywords tree windbreak systems, ecosystem services, farmer's perceptions, attitudes

INTRODUCTION

Tree windbreaks, shelterbelts, and hedgerows are linear barriers that usually consist of a single row or multiple rows of trees, and shrubs mainly used to protect the land from the adverse effects of wind (Alemu 2016; Brandle et al. 2021). Besides the wind protection effect, these systems perform multiple ecosystem functions such as microclimate regulation, soil protection, biomass production, wildlife habitat, recreational and cultural sites, etc. (Ruppert et al, 2020). On a larger scale, windbreaks provide societal benefits both locally and on a regional scale (Brandle et al. 2021) Weninger et al (2021) in their systematic review of 222 studies concluded windbreak ecosystem services showed a clear dominance of effects that are considered positive by a major part of society. Because of the many benefits, tree windbreaks were extensively established across the world, especially in Australia, Argentina, and northern parts of China, North America, Russia, and some former USSR republics as well as other countries in Europe (Brandle et al. 2021; Jose et al 2029; Ruppert et al. 2020; Sarah et al 2021). However, many recent studies report a decline in the windbreak area and a subsequent loss of landscape functionality (Enrica et al. 2023; Weninger et al

2021). During the 1950s, the government of Macedonia, at that time part of the Socialist Federal Republic of Yugoslavia, took a large-scale operation for the establishment of tree windbreaks across the country. Among several others, in the Ovche Pole Region – the area of interest in this study, there was a massive action for the establishment of tree windbreak systems. In total 556 hectares of land were planted. Even though these systems perform important functions, approximately half of the initial tree windbreak area is lost mainly due to land use change. Today a significant area of the existing tree windbreak belts is damaged. Actions for the protection, rehabilitation, and restoration of these systems are needed. (Onchevski et al, 2022). Without the active support of stakeholders of farmers' perspectives on tree windbreak systems, any activity would be without major and long-term success (Camilli et al. 2018; García de Jalón et al. 2018; Khatri et al 2023; Ruppert et al.2020; Rois-Díaz et al. 2018; Thevs et al. 2017). Because there are no research studies, little is known about farmers' perspectives on agroforestry practices in Macedonia so far, in particular the tree windbreaks.

OBJECTIVE

To fill the gap mentioned in the introduction, the objectives of this study are to (1) examine farmers' attitudes toward the tree windbreak system and their rehabilitation, and (2) assess farmers' perceptions of ecosystem services provided by the tree windbreak system.

METHODOLOGY

Research Area Description

Ovche Pole Region is a plain located in the east-central part of Macedonia taking an area of 649 km^2 (Fig. 1). It is the second largest agricultural region in Macedonia, part of the semi-arid and sub-humid agroecological zone of the country (Aksoy et al. 2020).

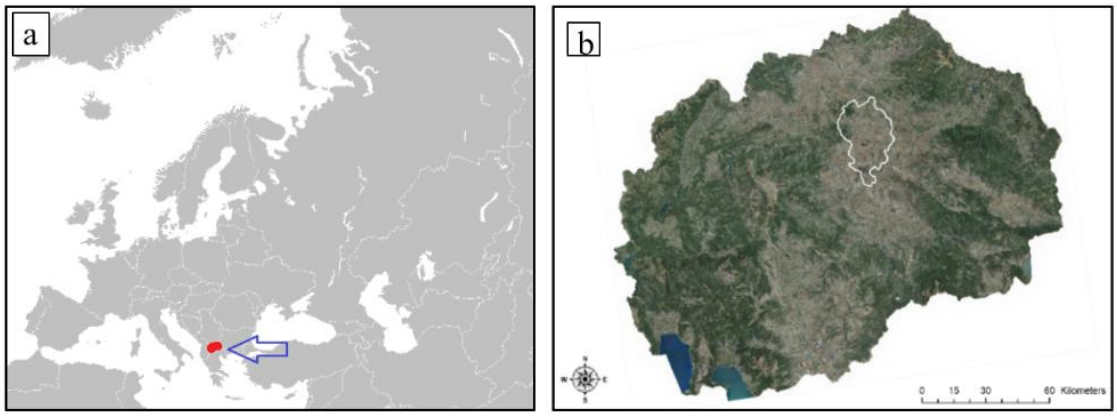

Fig. 1 Geographical position of Macedonia (a) and research area (b)

The regional climatic conditions are dry and are characterized by low precipitation and high ambient temperatures during the growing period as well as year-round prevailing winds. Northern winds are most dominant, blowing throughout the entire year, with an average frequency of 188% and an average speed of 4.6 m/sec. Tree windbreaks are planted in the southwest to northeast direction perpendicular to the direction of the prevailing northwest winds. and take around 555.66 ha in total. The rows of trees are 10 to 20 meters wide with different lengths starting from 0.5 km for the shortest and 15 km for the longest. They are forming a rectangle grid pattern and agriculture parcels that are approximately 1000 m in length and 250 m in width. The dominant and most distributed tree species in the windbreaks are the Black locust (*Robinia pseudoacacia*), followed by Field elm (*Ulmus minor*), Ash (*Fraxinus ornus*), Almond (*Prunus amygdalus*), and others.

Fig. 2 Photos showing the tree windbreaks in the research area

Data Collection and Analysis

The study was conducted from the 7th of September to the 7th of October 2019. A semi-structured questionnaire was developed and distributed to farmers to gather primary data. Using the convenience sampling method, 72 farmers took part in the questionnaire survey, out of a population of 375 registered farmers. The questionnaire was designed to have three sections. The first section contained questions related to the socioeconomic characteristics of farmers. The second section captured farmers' attitudes toward the tree windbreak system in general and the third section captured farmers' awareness and perceptions of ecosystem services provided by the tree windbreak. In this section, farmers were asked to answer one Likert scale question and one raking question. The first question was composed of 12 statements that referred to an ecosystem service. In the second question, farmers were asked to rank the ecosystem services by importance. Simple descriptive statistics such as frequency distribution and percentage were used to interpret and present data. Secondary data on climate/weather, land use, soils, and demography were obtained from published or unpublished sources. The number of registered farmers was provided by The Ministry of Agriculture, Forestry and Water Management (MAFWM). In addition to the primary data, relevant literature on agroforestry, tree windbreaks ecosystem services, and farmers' perceptions were reviewed.

RESULTS AND DISCUSSION

Table 1 provides an insight into the socio-demographic characteristics of the respondents. The results show that most of the respondents were middle-aged to old males with high education levels. These results reflect the average age of farmers in Macedonia since the number of young people who decide to work in the agriculture sector is declining. Almost all of them produce grain crops like wheat, ray, and corn, however, most of the respondents produce additional products such as vegetables, animal fodder (alfalfa), grapes, etc. The average size of the land for the individual farmers is around 5 hectares. To avoid biased and false impressions on the average land size results, an agriculture company that manages a land area of 1300 ha was excluded from the calculations.

Table 1 Socio-demographic characteristics of respondents

Characteristics of respondents (Total number of respondents: n=72)	
Average age	57.9 (range 29 to 80 years)
Gender	Female = 4 / Male=68
Level of education	no formal education = 0 / primary school degree = 2 / high school degree = 26 / university degree = 9 / vocational qualifications = 16
Average size of farmland(ha)	5.33 ha
Purpose of agricultural production	commercial = 48 / own needs = 15 / commercial and own needs = 10

The results of the survey show that the majority of the farmers have positive attitudes towards the tree windbreaks. On the other side, the respondents who expressed negative feelings mainly

complained that the trees compete with the crops for water, make shade, and are not well maintained by the public forest enterprise. Results are summarized in Table 2. In opposite, Ruppert et al. (2020) for their study area in Kyrgyzstan reported that more than 50% of the respondents had negative attitudes toward the windbreaks. In their case, the respondent's main concerns were the shading, possible potential conflicts with neighbors, spreading of diseases, small land area, harmful roots, etc. The results analysis from the second questionnaire section is presented in Figure 3. shows that there is a strong agreement and high awareness among respondents that the tree windbreaks: add to the aesthetic of the landscape; provide protection and habitat for pollination insects; provide shade and shelter for animals; reduce runoff; positively influence the local microclimate; and provide wood, fruits, fodder, nuts, and other materials.

Table 2 Questions reflecting the farmers' attitudes towards the tree windbreak

Question	Number of respondents (Percentage of total %)		
	Positive[1] / Yes[2,3]	Negative[1] /No[2,3]	Neither positive nor negative[1] / I do not know[2]
1) What is the general impact of the field protection belts on the land production process?	58 (79%)	3 (4%)	12 (16%)
2) Do you think that field protection belts should be removed?	4 (5%)	69 (95%)	0 (0 %)
3) Do you think that field protection belts should be restored and extended to other areas?	59 (81%)	9 (12%)	5 (7%)

[1,] *Answer applicable to number 1 question.*
[2,] *Answer applicable to number 2 question.*
[3,] *Answer applicable to number 3 question.*

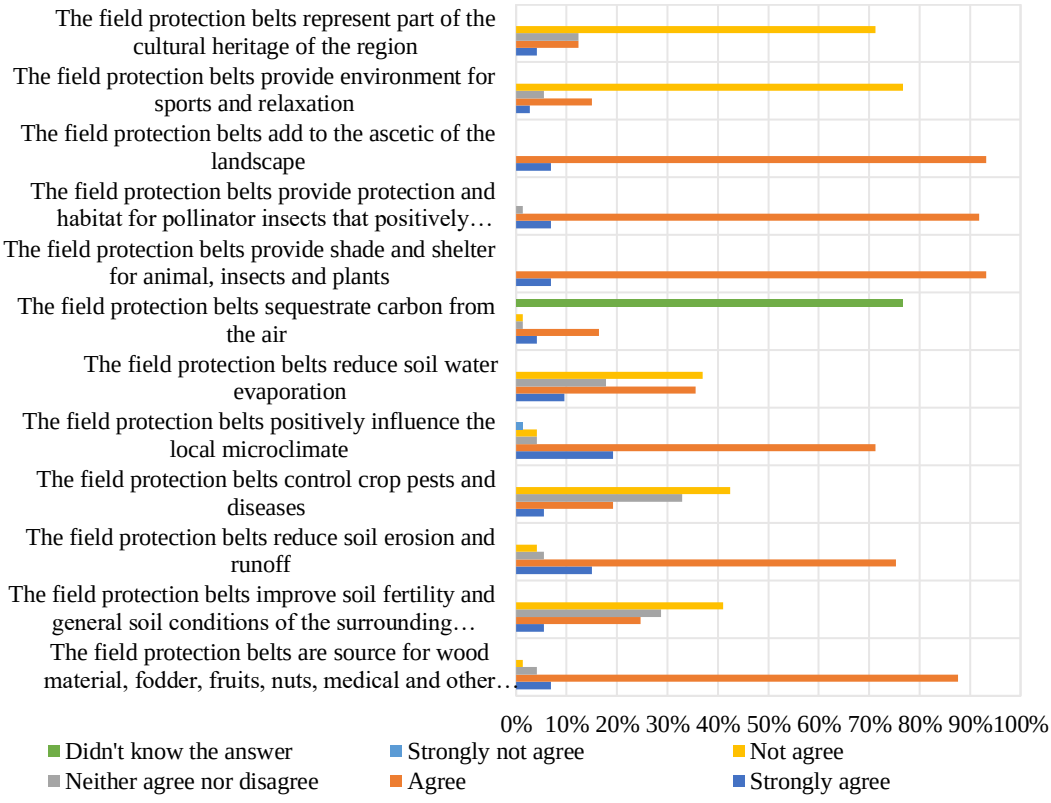

Fig. 3 Farmers' awareness and perceptions of the ecosystem service provided by tree windbreaks

Furthermore, most farmers did not agree that tree windbreak systems represent part of the regional cultural heritage, and that they provide an environment for sports and recreation. On the other hand, for some ecosystem services farmers' responses were not uniform. It is worth noting that there was strong disagreement among farmers regarding the ability of windbreaks to reduce soil water evaporation, which is their primary function. The results showed that 36% of respondents agreed that windbreaks reduce soil water evaporation, 37% disagreed and 18% neither agreed nor disagreed. In addition, farmers' perceptions were ununiform on the statements that tree windbreaks improve soil fertility and soil conditions as well as control pests and diseases.

Most of the farmers did not know how to answer regarding the carbon sequestration function of the systems, keeping in mind that tree carbon sequestration is a phenomenon that the general and old population does not completely understand and is aware of, these results are not surprising. When farmers were asked to rank the ecosystem services by importance, 55 % stated that the most important is the microclimate regulation service provided by tree windbreaks (Fig. 4). The second most important is the reduction of soil erosion and runoff, and the third is the windbreaks to provide wood material, fodder, fruits, nuts, and other products. In this case, Ruppert et al. (2020) reported similar results. In their research area farmers' most appreciated benefits from windbreaks were the provision of construction material, wind reduction, and firewood provision.

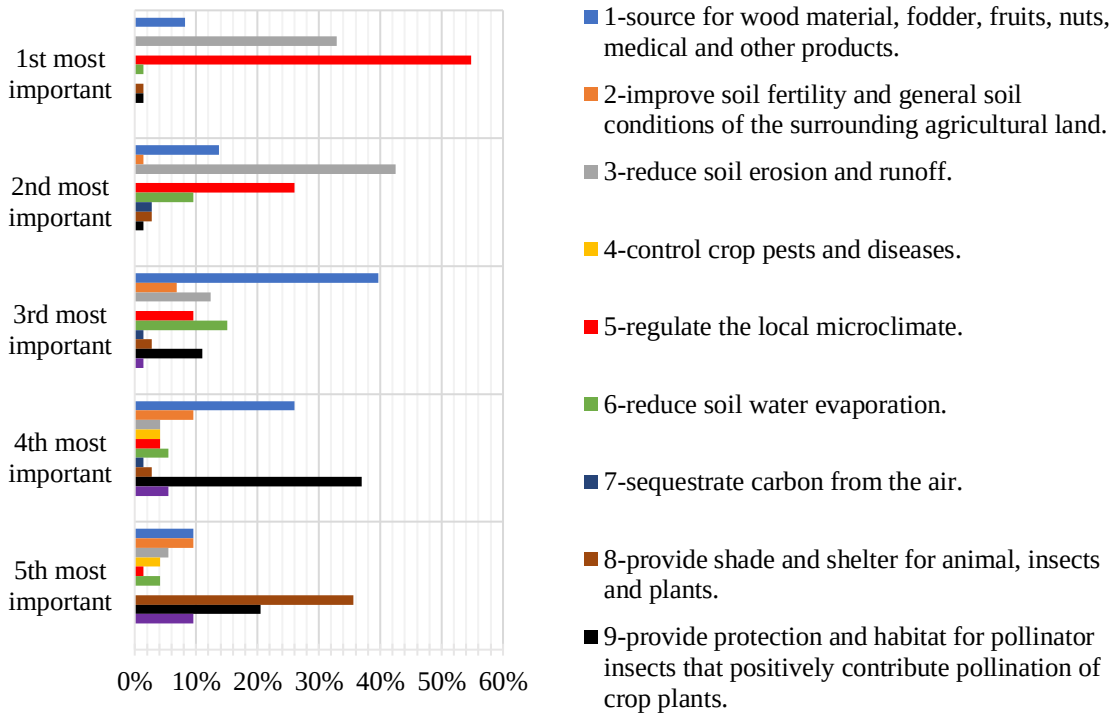

Fig. 4 Ranking of ecosystem services provided by tree windbreaks

CONCLUSION

This research brings valuable insight into the attitudes and perceptions of the local population on tree windbreaks which is key to the successful implementation of protection and restoration projects and programs. The results showed that farmers, in general, have positive attitudes toward windbreaks, however, it also showed that more than half of the respondents were not convinced that windbreaks can reduce soil water evaporation and improve fertility and general conditions of soils. This belief can be a potential reason for any reluctant behavior and hesitation from farmers towards the restoration and extension of tree windbreaks to new areas. Data derived from scientific studies can be used as proof to contra arguments and shift negative perceptions. Therefore, extensive scientific studies, that will investigate and quantify the ecosystem services provided by the tree windbreaks are

needed, especially studies that assess the effect of tree windbreaks on evapotranspiration, soil fertility, and crop yields. Besides the presentation of specific data on paper, it is important that farmers can get to know a realistic picture and proper management practices on demonstration sites. On top of that, there are many other provided benefits, that are not acknowledged entirely. These should be communicated and promoted to the local population as well as the public in the country.

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Research article

Factors Influencing Accounting Practices for Biological Assets: The Case of Selected Agritourism Farms in the Philippines

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Abstract The IAS 41 accounting standard for agriculture aims to standardize the accounting practices among entities engaged in agricultural production. However, there has been limited awareness and adoption of the standard, especially in the agritourism sector. This study examined accounting practices of selected agritourism farms in Region IV-A, Philippines, and aimed to identify the factors that influence their accounting practices. Interviews were conducted with eighteen farms and their financial records were reviewed. A descriptive analysis composed of mean and median rating and odds ratio analysis were performed. Additionally, sentiment analysis was conducted to evaluate the attitudes of the respondents toward the factors that influence their practices. Results indicated that most farms did not adhere to the established accounting standards for recognizing and measuring biological assets, instead relying on current practices. Only five farms recognized biological assets composed of living animals and plants, and only three farms maintained a Biological Asset account and measured it using the fair market value approach. The study highlighted that owner or management preferences, and the ease of calculation contributed very significantly to the farm's accounting practices. Training in finance and accounting and recommendations of external auditors increased the likelihood of farms adopting the standard. Notably, sentiment analysis revealed a positive score for training, while recommendations of the auditors received a moderately positive score. The study recommends enhanced education on accounting for agriculture. A framework on how to record and measure biological assets must be developed to improve the accounting practices of agritourism farms and their compliance with accounting standards.

Keyword agritourism, accounting practices, biological assets, odds ratio analysis, sentiment analysis

INTRODUCTION

Managing an asset throughout its useful life, from its acquisition to its disposal, contributes to sustained operational excellence (Maletic et al., 2020) as it allows business entities to make better financial decisions and enhance asset performance and overall productivity. Efficient management of assets is essential to achieve competitive advantage, especially in agriculture, as it encompasses biological assets that include living animals and plants.

Agritourism, a form of farm diversification offering tourism activity conducted in rural areas (RA 10816 Sec. 3, 2016), has gained prominence as a strategic approach to farms' financial sustainability while showcasing different agricultural activities that can be done within the farm. Diverse agricultural and fishery-based activities attract visitors to experience and learn about farm life while having outdoor recreation and relaxation (Ohe, 2020). Asset management in agritourism farms involves the management of biological assets such as crops, livestock, and other agricultural products. Farm owners strategically plan cultivation cycles, integrate different farming practices, and

implement effective risk management (Tew and Barbieri, 2012) to safeguard these assets that constitute the core of the agritourism experience.

Asset management includes recording or accounting biological assets essential for financial reporting, decision-making, and compliance with governing bodies. However, farmers typically do not engage in accounting practices due to their lack of expertise, the incompatibility of some accounting principles with their specific type of business, and the complexity and cost associated with implementing such practices (Argilés and Slof, 2001). Proper financial accounting is not maintained in agriculture, as farmers only record monetary transactions that involve revenues and expenses (Doğan et al., 2013). In addition, financial literacy, land holding size, and farm income also affect the decision of the farmers to maintain farm accounting records (Prajapati et al., 2015; Tackie et al., 2022).

Farms should keep a comprehensive set of financial records to easily assess the operational and financial efficiency of their agricultural operations (Sharma, 2012). Implementing proper accounting enhances decision-making, improves profitability, and allows farmers to identify their strengths and weaknesses to manage changes and improvements in farm management. Records should be organized based on their respective activities and departments (Sharma, 2012). It is necessary to have distinct accounts for products, livestock, crops, and their associated items. The production cost per unit and the cost of the finished product must be accurately represented. Moreover, both the depreciable assets and biological assets should have proper documentation. Accurate recordkeeping provides a clear picture of the financial status of the farm. If all assets are not accounted for in the financial statements, like the nonrecording of the biological assets, it may lead to misstatements such as overstatements or understatement of farm assets and profits (Miranda and Ohe, 2024).

Accounting for biological assets is guided by the International Accounting Standard (IAS) 41, the accounting standard for agriculture. In the Philippines, the IAS 41 was adopted as the Philippine Accounting Standard 41 (PAS) 41, which has the same objective of prescribing the accounting treatment, financial statement presentation, and disclosures related to agricultural activities, including biological transformation and harvest of biological assets for sale or conversion into agricultural produce or another biological asset. Biological assets are initially measured at fair market value less cost to sell, except for cases where fair value cannot be measured reliably (IAS 41:12). The harvested produce is also measured at fair market value less cost to sell at the point of harvest (IAS 41:13). In addition, subsequent measurements due to biological transformation may result to changes in the fair market value and must be included in profit or loss (IAS 41:26-29).

The adoption of accounting standards is influenced by various factors such as awareness of the owners, educational competency, organizational structure, accounting infrastructure, mandatory compliance, and the users and their needs for accounting information and its cost-and-benefit relationships (Rahman et al., 2002; Hai, 2015; Miranda et al., 2017) and choosing the applicable accounting practices can also be affected by these factors. Factors such as preferences of owners or management and ease in calculation have been considered because farm owners prefer simplicity and familiarity with accounting practices. They want simplified calculations that minimize the chances of errors and save time and resources. In addition, learnings from training, seminars, and workshops they have attended, as well as practices introduced in the industry or sector they belong, also influence what practices they will apply in their farm operations. Industry practices play a crucial role in establishing standardized norms within the agricultural sector, serving as benchmarks for operational and reporting standards. As the farms weigh the practices to be adopted, cost and benefit considerations take place, like using software, which will entail additional costs for the farms. Furthermore, external auditors' recommendations carry significant weight in shaping accounting procedures. They contribute to the adherence to accounting standards and regulatory requirements while offering insights into enhancing internal controls and risk management practices. External users such as investors, lenders, regulators, and government agencies rely heavily on farms to provide relevant and reliable financial information. This information is critical for their decision-making processes, investment evaluations, credit assessments, and adherence to regulatory mandates, underscoring the importance of sound accounting practices aligned with external user needs.

Regardless of the size, all entities must produce financial reports adhering to standards to allow users to assess the organization's performance and compare the financial results (Van Biljon, and

Scott, 2019). Furthermore, it is crucial to correctly grasp the situation of farm resources for sustainable utilization in both farm production and agritourism. Accounting for biological assets empowers farmers to understand the status of the farm resources and helps rational planning for the sustainability of farm activities with broader perspectives. However, limited studies were conducted on how these resources should be accounted for. This study addresses the gap by evaluating and harmonizing the accounting practices of agritourism farms in the Philippines, aiming to create a comparable financial record that decision-makers can use. A system must be established for recordkeeping that will track not only the cost, resource use, and income, but also align with the purpose of planning and budgeting, which are very critical in attaining sustainability in farm operations.

OBJECTIVE

The primary objective of this study is to evaluate the accounting practices implemented by selected agritourism farms in the Philippines. Additionally, the study aims to identify the factors that play a role in shaping the accounting practices of these farms. The findings of this study will contribute to the creation of a framework for applying accounting standards for agriculture in the agritourism sector.

METHODOLOGY

A mixed-method approach was employed, integrating primary and secondary data to explore the accounting practices of eighteen agritourism farms in Region IV-A, Philippines. Purposive sampling was applied to select the farms, and the data collection involved a semi-structured questionnaire administered between August – October 2022 and 2023. Mean and median ratings were used to determine which factors were used extensively by the farms. Odds ratio analysis was performed to compare the likelihood of recording biological assets between two groups. Group 1 consists of farms that record biological assets, while Group 2 is composed of farms that do not record biological assets. An odd ratio of greater than 1 means a positive association while an odds ratio of less than 1 means a negative association (Kalra, 2016). Qualitative insights from the respondents were analyzed using Sentiment Analysis. Sentiment analysis involves identifying and extracting subjective information from a text by assessing its level of positivity or negativity (Kearney and Liu, 2014). Utilizing NVivo 14, a qualitative data analysis software, individual responses were assigned a sentiment score from -1 to 1. A positive score reflected a positive sentiment, while a negative score indicated a negative sentiment.

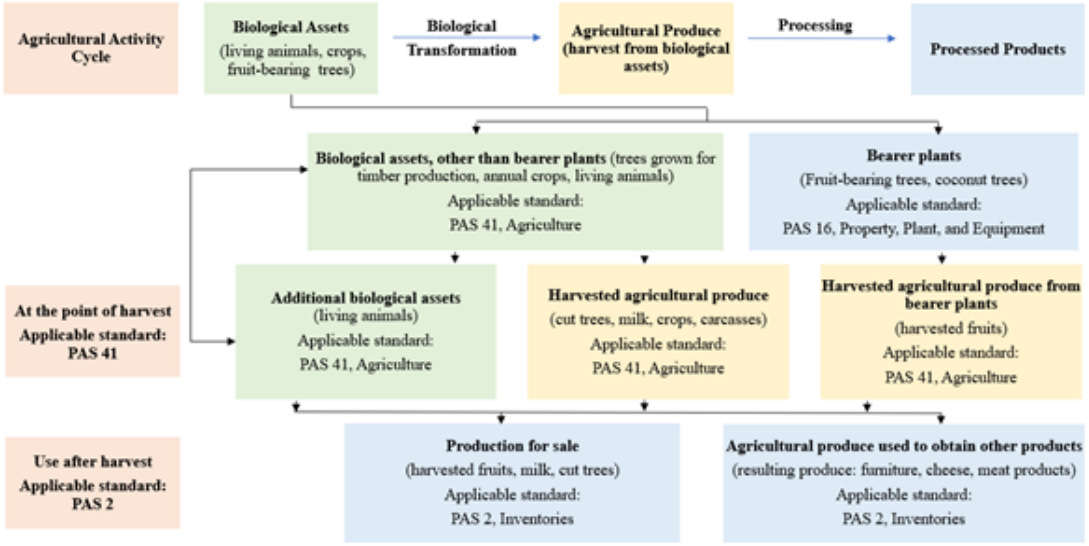
RESULTS AND DISCUSSION

Accounting Practices

Initially, conventional farms concentrated on agricultural production but later diversified to tourism by incorporating tourism services such as farm tours, real farm work experience, animal feeding activities, pick and pay, farm stay, outdoor activities, and events reception. The accounting practices of these farms involve a simple recording of the revenues and expenses with assets and liabilities also being documented. However, the accounting for biological assets used for agricultural production and tourism activities is notably absent.

Biological assets comprising living animals and plants are categorized as consumable and bearer biological assets. In the surveyed agritourism farms, consumable assets, including annual crops (vegetables, herbs) potted plants, and cut flowers, have a shorter life and can be sold once harvested. The bearer biological assets comprise fruit-bearing trees, mahogany trees, dairy cows, and goats. The recognition, measurement, and disclosure of these assets depending on their classification, are guided by PAS 41 - Agriculture, PAS 2- Inventories, and PAS 16 – Property, Plant, and Equipment. The

biological assets undergo biological transformation through growth, degeneration, and procreation (IAS 41:7) potentially yielding a change in quantity and quality change such as giving birth to another biological asset or an agricultural produce to be harvested. Figure 1 illustrates the agricultural activity cycle of the biological assets, classification, and relevant accounting standards to be used. Based on the survey conducted, all farms recognize biological assets in the form of agricultural produce, but only five farms recognize and record living animals and plants. Among these, only three record it under the account name Biological Assets.



Source: Adapted from Gughea and Iordache, 2017

Fig. 1 Agricultural activity cycle of biological assets, its classification, and applicable accounting standards

Table 1 shows how each farm conducts its accounting practices. The majority of the farms produce crops and livestock, 11 farms (61.11%) produce both crops and livestock, two farms (11.11%) raise livestock only such as dairy cattle and goats, two farms (11.11%) produce crops only while one farm (5.56%) is engaged in both livestock and floriculture, one (5.56%) engaged in floriculture only, and lastly one farm (5.56%) engaged in crop, livestock, and floriculture production. Ten (55.56%) farms are registered as corporations, while eight (44.44%) farms are registered as sole proprietors. Only one farm uses a software-based accounting system, while the rest manually record all farm transactions. Accounting transactions on the farm include revenue from the tourist entrance fee, sales from agricultural produce and processed products, and farm operating expenses. These transactions are recorded manually in their record or logbooks and later transferred to Microsoft Excel. In the case of Farm K, they use the software Quickbooks. All transactions are recorded daily, which are subsequently sent and transferred to Quickbooks every month. Farm K is a participant in a *Paiwi* program, which entails the leasing of livestock. Given the presence of multiple sub-farms in this program, the auditor recommended that the use of software be adopted to ensure uniformity in the structure of their financial reports. All farms registered as corporations prepare and submit a complete set of financial statements for compliance with the Securities and Exchange Commission. On the other hand, two farms registered as Sole Proprietorship also prepare a complete set of financial statements, and they use it to avail loans and grants. In comparison, six farms only prepare Income Statements to be submitted for tax compliance.

Only four farms demonstrated awareness of the accounting standard. Among them, Farms F, I, and J applied PAS 41, as recommended by their auditors, while Farm E, though have heard of the standard, chose not to implement it as of this moment since he does not fully understand it. Out of the 18 surveyed farms, only Farms A, F, I, J, and K recognized and documented biological assets in accordance with PAS 41 and PAS 2. For Farm A, engaged in goat farming, live goats are recorded in inventory at the lower cost or net realizable value, while crops are valued based on the market

price. Farms F, I, J, and K value the assets using the market value and disclose them under the account name "Biological Assets" except for Farm F, which records them as "Other Assets." The remaining 13 farms do not record living animals and plants and only record the agricultural produce when it is harvested or sold using the most recent market price. Additional biological assets like calves and kids are recorded in the inventory reports.

Table 1 Characteristics of surveyed agritourism farms and their accounting practices (n=18)

Farms	Agricultural Production	Legal Structure	Accounting system	Accounting Records Maintained	Awareness of PAS 41	Recognize Biological Assets	Valuation Method
A	C & L	Corp	Manual	CFS	No	Yes	LoCNRV, MP
B	C & L	Corp	Manual	CFS	No	No	MP
C	C & L	Corp	Manual	CFS	No	No	MP
D	C & L	Corp	Manual	CFS	No	No	MP
E	C & L	Corp	Manual	CFS	Yes	No	MP
F	L	Corp	Manual	CFS	Yes	Yes	MP
G	C & L	Corp	Manual	CFS	No	No	MP
H	C & L	Corp	Manual	CFS	No	No	MP
I	F & L	Sole	Manual	CFS	Yes	Yes	MP
J	C & L	Sole	Manual	CFS	No	Yes	MP
K	L	Corp	Software	CFS	Yes	Yes	MP
L	C & L	Corp	Manual	CFS	No	No	ACE
M	C & L	Sole	Manual	IS	No	No	IV
N	F	Sole	Manual	IS	No	No	MP
O	C	Sole	Manual	IS	No	No	MP
P	C & L	Sole	Manual	IS	No	No	MP
Q	C, L, & F	Sole	Manual	IS	No	No	MP
R	C	Sole	Manual	IS	No	No	MP

Source: Field Survey, 2022 and 2023
Notes: Agricultural Production: C = Crops, L = Livestock, F = Floriculture
Legal Structure: Corp. = Corporation, Sole = Sole Proprietorship
Accounting Reports: CFS = Complete Financial Statements; IS = Income Statement;
Valuation Method: MP = Most Recent Market Price; LoCNRV = Lower of Cost or Net Realizable Value; ACE = Accumulated costs and expenses; IV = Independent valuation

Factors Influencing Accounting Practices

The financial accounting of agritourism farms is affected by different factors such as the training, preferences of the owners or management, cost-benefit, ease in calculation, industry practices, recommendation of the auditor, and the needs of the external users for decision making. Using the mean and median rating analysis presented in Table 2, the owners' preference (4.83) and ease of calculation (4.61) are considered to be the factor that very extensively affects the farm's accounting practices. The owners and management have the authority and responsibility for the financial decisions and policies on farm management. Since most farms are unaware of the accounting standard and only know about basic accounting, proper accounting of the biological assets is omitted. Moreover, they prefer simplicity in the recording because it is more efficient and cost-saving. The only biological asset-related transaction recorded in their books is when they harvest it and sell it to the consumers. Industry practices (4.44), cost-benefit (4.28), training in finance and accounting (3.83), and recommendations from external auditors (3.61) extensively influenced the accounting practices of the farms. Industry practices provide a benchmark or a common standard for accounting policies. However, based on the survey, the agritourism industry has no established accounting practices. Moreover, applying the standard may be costly since they might hire a new staff in charge of the valuation. For the training, all farms attended training provided by different government agencies, such as the Department of Tourism (DOT) that provide training on financial management,

focusing on tour packaging, costing, and farm development funding. In addition, the Department of Trade and Industry (DTI) and Department of Agriculture (DA) also give training on Entrepreneurial Accounting and Financial Management that covers basic accounting and financial management. This training does not include accounting for biological assets. On the other hand, farms registered as corporations value the recommendations given by their auditors and use them to enhance the accuracy of the farm's financial reporting and align it with the regulatory requirements. Their auditors are key in advising them on recording and measuring biological assets. The needs of primary external users were given a rating of 3.11 or fairly extensive since the financial records they produce are for compliance purposes only.

Table 2 Factors influencing the accounting practices of the surveyed agritourism farms (n=18)

Factors	Mean rating	Median rating	Odds ratio
Preference of the owners or management	4.83	5.0	undefined
Ease in calculation	4.61	5.0	undefined
Industry practices	4.44	5.0	undefined
Cost and benefit	4.28	4.5	undefined
Training in finance and accounting	3.83	4.5	1.2857
Recommendations of external auditors	3.61	4.0	1.2857
Needs of primary external users	3.11	4.0	0.7778

Scale (adopted from Joyno, 2003)
4.51 – 5.00 – Very Extensive, 3.51 – 4.50 – Extensive, 2.51 – 3.50 – Fairly Extensive, 1.50 and below – Very Poor in Extent, 1.51 – 2.50 – Poor in Extent
Source: Field Survey, 2023

Among the five farms that recognize biological assets, only Farm K, engaged in dairy cattle farming, has a comprehensive recording process that covers the acquisition of biological assets, the birth of new calves, the harvest of agricultural produce, and the disposal of assets as recommended by their auditor. As shown in Fig. 2, the farm bookkeeper, in cooperation with their auditor, diligently records and monitors all expenses related to each process. The fair market value approach has been used to value the assets and the monthly changes in the fair market value are regularly documented. These changes are disclosed in their financial statements as FV Gain or Loss on Initial Recognition of Biological Assets and FV Gain or Loss on Remeasurement of Biological Assets. Moreover, the farm owners strictly enforced the recommendations of the auditor in relation to the farm recording which includes records from the breeding process, calving, milking, and medication and treatments. The farm auditor emphasized the importance of recordkeeping, he stated that *"Proper documentation of biological assets is the key to effectively account the biological assets in accordance with PAS 41. The updated record of all biological assets as to its changes will be helpful in accounting."* On the other hand, the farm practices in relation to processing activities were influenced by industry practices and the training they attended.

Using the odds ratio analysis, the farms were grouped into two – Group 1 are the farms recording biological assets (Farms A, F, I, J, K). At the same time, Group 2 are the farms not recording (Farms B, C, D, E, G, H, L, M, N, O, P, Q, R) biological assets. A ratio of 1 and above indicates a greater likelihood that the farm will modify or be affected by its accounting practices if the factor is present. Conversely, a ratio of below 1 suggests a lower likelihood of changing their accounting practice. Based on the odds ratio analysis, there is a higher odd that agritourism farms will practice the recording of biological assets if there is training in finance and accounting (1.2857) provided to owners and key accounting personnel, as well as those in charge of the valuation of the biological assets. Recommendations of the external auditors (1.2857) contributed to the possibility that agritourism farms will practice recording biological assets. Among the five farms that record biological assets per accounting standard, one farm stated that they changed their accounting practice upon consulting with their external auditor. In contracts, the needs of primary external users (0.7778) have a lower odd that farms will practice recording biological assets if needed by primary external users. Since most farms are family corporations, the financial statements they produce are submitted to government agencies for compliance. Some farms use their financial statements to get grants or

funds from government agencies requiring financial reports. On the other hand, preferences of the owners or management, ease in calculation, industry practices, and cost and benefit resulted in an undefined odds ratio because one of the groups has no occurrences of recording biological assets.

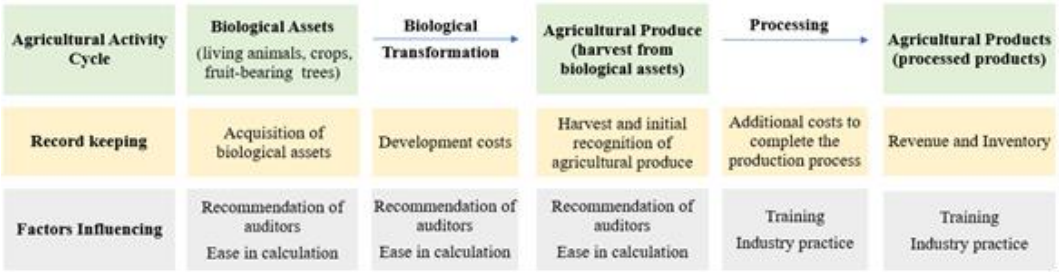


Fig. 2 Accounting practices of Farm K

The sentiment analysis performed also supported the odds ratio analysis results. Based on the qualitative remarks from the respondents, training in finance and accounting was given a positive rating, while the auditors' recommendations received a moderately positive rating. Conducting training related to accounting, especially on how to value the biological assets method, is seen to have a positive sentiment since it will be helpful to them and will reflect the actual status of their farm assets. Most of the training they attended only included discussions on recording sales and expenses, but the valuation for biological assets was not even highlighted. Training in finance and accounting is just a part of their entrepreneurship or business-related training. One respondent shared, *"Actually, the accounting practices I am doing on the farm are based on what I learned from the training conducted by DTI; I have attended training about the cash proforma. Basically, it is just cash in and cash out, balance, description of transactions, and I think it is beneficial."* Farm R also stated, "*Training is important and needed; however, some trainers on accounting cannot explain in layman's terms what accounting is all about that can be easily understood by the farmers. It is very technical. The farmers cannot appreciate why they need to do it, but I understand it because I know it."* All of the farms agreed on the importance of recording the biological assets and compliance with the standard; according to them, they might consider using it if there is training or available manual on how to do it.

For the recommendations of the external auditor, the majority of the farms are registered as corporations and hire an external auditor to check their financial records. External auditors give recommendations to improve the farm operation. Even the farms registered as sole proprietors see the importance of auditors' suggestions, Farm I shared, "*The auditor suggested fixing the bookkeeping and petty cash system. Right now, I want to have traceability of the cash flow because I do not remember anymore how much I have given for the operation, so we need to establish a separate bank account for the farm even though I am having an issue with the banking system in our area."* The auditor's recommendations may have a positive sentiment. However, some farms still prefer to use their method, particularly in recording and measuring their biological assets. Also, some recommendations were not well explained to the lower management like in the case of Farm B, *"We prepare all the reports needed by the board, and it will be reviewed by the auditors; however, if the auditor gives recommendations, the board failed to discuss it to us, so we do not directly experience it."* While most farms have diverse farm management practices, they acknowledge the importance of the recommendations of their auditors. Communicating and integrating their recommendations into their current practices may pose a challenge, but they still find it helpful, especially if it enhances their management practices.

On the other hand, factors such as the preference of owners or management, ease in calculation, industry practices, cost and benefit, and needs of the external users were given a score that fell in the neutral range. Despite the absence of a positive or negative sentiment in those factors, the respondents still believe that recognizing and measuring biological assets is significant in farm operations. They expressed openness to adopting new practices provided that they will get support from the concerned implementors.

CONCLUSION

The study focused on the accounting practices of agritourism farms, explicitly addressing the recognition and measurement of biological assets according to accounting standards for agriculture. While these standards prescribe fair market-based measurements and require disclosure of biological transformations, the observed practices varied among farms, with only a minority adhering to the standards. At the same time, the majority of surveyed farms relies on practices that are simpler and more efficient. Findings suggested that training in finance and accounting and recommendations from external auditors significantly increase the likelihood of agritourism farms recording biological assets.

Harmonizing the accounting practices for agritourism is necessary for producing comparable financial records that decision-makers could use. A recordkeeping system must be put in place to monitor not only the costs and income but also the inventory of assets along with their respective value. Therefore, tailored training programs, collaborative efforts with external auditors, and industry-specific accounting standards are needed to promote standardized and informed accounting practices within the sector. A comprehensive assessment of a farm's current accounting practices must be done to identify the gaps and areas for improvement. This will be the foundation for creating tailored training modules that may cover topics such as farm recordkeeping, valuation, cost allocation, revenue recognition, and inventory management. Government agencies and members of the academe have the capacity to take the lead in carrying out these initiatives. In addition, they may collaborate with accounting and auditing firms that have expertise in agricultural accounting. In order to establish an industry-specific accounting standard for the agriculture sector, regular meetings, training, and workshops must also be conducted. Furthermore, a system for monitoring these activities must be implemented by gathering feedback from stakeholders and making updates and adjustments to enhance the standard's effectiveness. Through regular evaluations and assessments, we can ensure the continuous improvement of the application of accounting standards across the agriculture sector.

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Research article

Assessing Locals' Perceptions on the Environmental, Economic, and Socio-Cultural Impacts of Agritourism Versus Conventional Farming in Tanzania

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Abstract Agriculture and tourism are two critical sectors with a considerable influence on the socio-cultural, economic, and environmental aspects of Tanzanian society. These two sectors not only offer substantial employment opportunities but also contribute significantly to income generation and foreign exchange earnings. Nevertheless, the success of these sectors depends upon the participation and support of local communities, whose engagement is closely linked to their perceptions. In recent years, agritourism has emerged as a unique form of diversification in the agricultural sector, offering Tanzanian farmers a potential avenue to introduce a blend of agriculture and tourism-related activities and open a new income stream. Furthermore, since the impact of the COVID-19 pandemic on conventional farming and agritourism was different, post-pandemic opinions in the local community are likely to differ. Therefore, this study aimed to provide insights into the locals' perceptions and the factors that influence their perceptions to support a sustainable post-pandemic recovery. The study was conducted in the Arusha and Mwanza regions of Tanzania, and a total sample of 191 respondents was selected randomly for interviewing and filling out the questionnaires. To analyze the data, descriptive analysis, and principal component analysis were used. The findings indicate that locals' perceptions of conventional and agritourism farming are, on average, positive. Despite both sectors being perceived positively, the underlying reasons for the perception and support were different. For agritourism, the positive perception was primarily associated with the economic benefits, including income generation and the creation of employment opportunities. Whereas, for conventional farming, positive perception was associated with environmental conservation, economic benefits, food security, and community cohesion.

Keywords locals' perceptions, agritourism, sustainability, principal component analysis, Tanzania

INTRODUCTION

Tanzania's socio-cultural, economic, and environmental aspects are significantly influenced by the agriculture and tourism sectors (Sanches-Pereira, 2017). These sectors provide a significant amount of revenue and foreign exchange earnings in addition to employment creation. Agriculture is the cornerstone of Tanzania's socioeconomic growth. It contributes to employment, a sizeable portion of GDP, and export revenues (Mayala, 2021). Tanzanian agriculture has historically been dominated by conventional farmers who practice subsistence farming, raising animals, and the production of staple crops. Conventional farming, although significant, has several challenges such as financial and technological limitations, and climatic change (Kinyondo and Magashi, 2017). In recent years, the emergence of agritourism offers a distinctive avenue for farmers to diversify their farms to introduce an exciting blend of agriculture and tourism-related activities, creating new income streams and elevating living standards (UNDP, 2018). Tourism-oriented diversification is a feasible and efficient

approach to accelerate socioeconomic development (Ohe and Kurihara, 2013). Agrotourism in Tanzania involves integrating local agricultural communities into tourism value chains, aiming for inclusive development by linking farmers to tourism food supply chains (Anderson, 2018). The expansion of tourism activities from initially traditional tourist destinations like safari parks, beaches, and mountains to farming communities and rural areas brought about some transformational changes. These changes could lead to different reactions based on how they are perceived locally. The locals' perceptions may have an impact on their support for tourism expansion. Understanding this becomes essential for promoting sustainable growth. This study explores locals' perceptions of conventional agriculture and agritourism, as well as the relationship between these perceptions and support for the growth of agritourism. Since community engagement is crucial, this research is guided by a community-based strategy that acknowledges locals as significant stakeholders. The outbreak of the COVID-19 pandemic added another layer of complexity, with distinct effects on conventional farming and agritourism. In Tanzania, due to restrictions on people's freedom of movement and engagement, agritourism farmers experienced greater hardships than conventional farmers (Kachenje and Ohe, 2024). The effects of COVID-19 might change how the locals view these two subsectors. Therefore, it is essential to understand local perceptions to build a more effective recovery strategy. Despite its significance, as far as the author knows, there has been no research into the locals' perceptions about the conventional and agritourism sub-sectors following the COVID-19 epidemic. Therefore, this study aims to remedy the above deficiencies by comparing the perceptions of environmental, economic, and socio-cultural impacts among locals and farmers in agritourism areas and conventional farming areas.

Moreover, the study looks at how different variables affect the perceptions of the locals about conventional farming and agritourism. These variables included social issues like land tenure and perceived exclusion within the tourism industry, as well as demographic factors like gender, age, and education. Other factors were economic constraints like limited funding and working in the tourism sector. First, because of societal norms, there's a gender disparity in Tanzanian agriculture. Women face discrimination, which lowers their productivity relative to men (Nchanji et al., 2020). Second, educational background and farmer's age greatly influence how they respond to obstacles and how they decide to adapt to Tanzanian agriculture (Pauline, 2023). Also, research indicates that the age of farmers is positively correlated with their understanding of climate variability (Mamiro, 2014). The education level of farmers in Tanzania exhibits significant variation. Bundala et al. (2020) found that approximately 90% of small-scale farmers have limited or no formal education, highlighting disparities in educational backgrounds within the farming community. It is suggested that improving secondary agricultural education positively contributes to developing agricultural human capital and fosters positive attitudes (Mwaikambo, 2013). When it comes to land tenure, Tanzanian farmers primarily acquire their land through purchases or inheritance (Lyatuu and Urassa, 2014). The country exhibits diverse land tenure systems (Msangi et al., 2020). Land ownership is concentrated; according to Lyatuu and Urassa (2016), 55.5% of households possess less than the average amount of land per capita, which is 0.2 hectares. Also, land tenure is often controlled by husbands and fathers, putting women in a disadvantaged position (Agunga et al., 2018). Youth involvement in agriculture is restricted by limited access to land and capital, which presents difficulties for aspiring farmers and sustainable rural livelihoods (Lindsjö, 2019). Land tenure in Tanzania is impacting creditworthiness and crop diversification (Hepelwa, 2021).

Limited funds for farmers in Tanzania pose a significant barrier to improving agricultural productivity and livelihoods (Kinyondo and Magashi, 2017). It hinders productivity due to inadequate access to quality inputs, machinery, and transport, impacting overall profitability (Mdemu et al., 2017). Few farmers with appropriate resources benefit, while the poorest are often excluded, impacting food security and sustainability efforts (Tumusiime and Matotay, 2014). According to Mwonge and Naho (2021), several issues, including interest rates, gender, and collateral, can impede smallholder farmers' access to funds, which in turn hinders agricultural development. Perceived exclusion among locals in Tanzania's tourism sector stems from various factors. Factors influencing this perception include limited business opportunities leading to feelings of exclusion (Jani, 2023). Moreover, the insufficient absorption of youth in the tourism sector despite its employment potential exacerbates feelings of exclusion, with factors like limited access to capital and inadequate

employment practices playing a role (Lesseri, 2022). Other factors include language barriers, inadequate experience, poor education, cultural differences, and commitment issues (Magigi and Ramadhani, 2013). Additionally, social alienation, lack of trust in local governments, information gaps, and organizational and legal barriers to community involvement could be the reasons (Frolova et al., 2023). Finally, the level of familiarity among locals in Tanzania's agrotourism sector significantly impacts the attitude, development, and growth of the industry (Anderson, 2018). Locals' familiarity with rural tourism resources, such as agricultural products and clay soil for creating souvenirs, is crucial for fully utilizing these assets to attract tourists (Mkwizu et al., 2020).

OBJECTIVE

First, the study sought to examine locals' perceptions of the environmental, economic, and sociocultural effects of agritourism and conventional farming. Secondly, it aimed to explore the factors affecting their perceptions. Lastly, the study sought to investigate the correlation between the locals' perceptions and their degree of support for agritourism.

METHODOLOGY

The study was carried out in the Arusha and Mwanza regions from September to October 2023, using a cross-sectional survey research approach. These areas were chosen because of the significant concentrations of traditional and agritourism farming operations in them. The study focused on household heads as the statistical population. A random sample of 131 locals from agritourism areas, along with 60 locals from conventional farming areas, was selected. To guarantee equal representation and a fair probability of selection for every member of the population, a random sample was applied (Noor et al., 2022). The primary data collection was conducted using questionnaires. The questionnaire used a five-point Likert scale to rank responses and probed locals' perceptions and levels of support. Respondents were assigned scores of 5 for strongly agree, 4 for agree, 3 for neutral, 2 for disagree, and 1 for strongly disagree. Furthermore, demographic information was gathered through the questionnaire, including age, gender, education level, familiarity with agritourism, land tenure, perceived exclusion, and place of residence.

Descriptive analysis, correlation analysis, regression analysis, and principal component analysis were used to analyze the data. Principal component analysis is used to reduce data complexity by grouping variables, facilitating better interpretation and measurement of perceptions (Durham and King, 2010). This study employed principal component analysis due to its capability to describe multiple datasets effectively. Regression analysis was used to determine the factors influencing variation in locals' perceptions. The explained variable's restricted range (1 to 5) and the explanatory variables' ordinal nature supported the use of ordinal logistic regression. When there is an ordinal explained variable (i.e., a meaningful order with uneven intervals between categories), as in the cases of Jajang et al. (2022), and Dewi and Kusumawati (2022), this regression approach works effectively. Furthermore, correlation analysis was conducted to evaluate the relationship between the perception of agritourism's impact and the level of support for present and future agritourism development. The preferred method was Spearman's correlation since the data were ordinal and non-normally distributed. Often denoted as Spearman's ρ, Spearman's rank-difference coefficient of correlation is a statistical measure used to evaluate the relationships between two nonparametric variables (MacFarland et al., 2016).

RESULTS AND DISCUSSION

Respondents' Descriptions

In agritourism areas, 138 questionnaires were distributed, and 131 valid responses were collected. The respondents were dominated by women, with 60.3%. The average age was 38.5 years. The

education level is medium education, with most respondents having reached the ordinary level (secondary education). In conventional farming areas, out of the 67 questionnaires distributed, there were 61 valid responses. The majority of sexes were dominated by women (55%), With an average age of around 38.6 years and a level of education that was medium to slightly high.

Common Factors in Locals' Perception

In the research areas, conventional and agritourism farming are generally perceived positively. 93.3% of respondents gave conventional farming a score higher than 3, while 87.1% of respondents gave agritourism a score higher than 3. Principal Component Analysis (PCA) was employed to identify the variables that underlie the perceptions of the locals about conventional and agritourism. The results are explained in the section that follows.

Locals' perception of the impact of conventional farming: Based on Eigenvalues of more than 1.0, we selected 4 factors for the perception of the impact of conventional farming. Eigenvalues above 1.0 indicate that collectively, the items can be represented as a unified factor. To measure factorability, Bartlett's Test of Sphericity was conducted, with the results presented in Table 2 showcasing the significance of our variables. According to Hair et al. (2010), Bartlett's test of sphericity less than 0.05 is considered suitable to assume the factorability of the correlation matrix. The overall Kaiser-Meyer-Olkin (KMO) value of 0.611 was adequate. In alignment with Hair et al.'s (2010) recommendation, a KMO value of 0.6 or above is considered acceptable for analysis, and any factor loadings below 0.5 were eliminated. The principal factoring extraction method and varimax rotation were used to obtain factor loadings. The cumulative contribution of these four factors was 63.5%, indicating their substantial explanatory power (see Table 1). Further, Table 1 also shows the uniqueness, which represents the variance that is not shared with other variables. The larger the 'uniqueness', the lower the relevance of the variable in the factor model. In our results, all the variables have a low uniqueness value, suggesting that they are strongly correlated with each other in their respective factors. The only exception is that the variable " difficulties in accessing markets" has a higher uniqueness value, implying that it contains unique variance not explained by other variables, hence being less relevant in the model.

Table 1 The results of principle component analysis (PCA) (n=61)

	Component				
	1	2	3	4	Uniqueness
Environmental conservation efforts	0.853				0.279
Management of water resources	0.847				0.219
Negative impact on biodiversity	0.714				0.476
Management of water resources	0.523				0.463
Creation of employment opportunities		0.769			0.374
Source of income for the locals		0.745			0.315
Diversification of economic activities		0.700			0.221
Difficulties in accessing markets					0.747
Conventional farming is a primary source of food			0.892		0.192
Improvement of nutrition and self-sufficiency			0.866		0.279
Enhancement of the local culture and traditions				0.747	0.355
Influence our lifestyle and maintain our ethnic identity				0.663	0.455
Cohesion and community engagement				0.594	0.375

Summary			
Component	SS Loadings	% of Variance	Cumulative %
1	2.70	20.8	20.8
2	2.31	17.7	38.5
3	1.68	12.9	51.4
4	1.56	12.0	63.5

Source: Authors' calculation based on primary data.

Table 2 Bartlett's test of sphericity

χ^2	df	p
251	78	< .001

Source: Authors' calculation based on primary data.

The analysis revealed different factors reflecting the different interplays between environmental conservation, economic impacts, and cultural considerations. The factors are explained as follows:

Factor 1: Environmental conservation and resource management

This factor accounted for 20.8% of the variance, showing the relationship between conventional farming and environmental conservation efforts. Positive loadings for variables such as "environmental conservation efforts" and "management of water resources" underscore the community's recognition of conventional farming's potential to foster sustainable environmental practices. The emphasis on conservation aligns with contemporary discourse promoting responsible agricultural practices.

Factor 2: Economic impacts and livelihood enhancement

This factor contributed 17.7% of the variance and reflects the economic dimensions of conventional farming. Variables like "creation of employment opportunities," "source of income for the locals," and "diversification of economic activities" exhibit substantial loadings, emphasizing the pivotal role of conventional farming in the local economy. This factor highlights the importance of conventional farming to serve as a catalyst for economic growth in rural communities.

Factor 3: Food security and nutritional resilience

This factor accounted for 12.9% of the variance. Variables like "conventional farming is a primary source of food" and "improvement of nutrition and self-sufficiency" reflect the community's reliance on conventional farming practices not only for sustenance but also for the enhancement of nutritional well-being and self-sufficiency.

Factor 4: Cultural enrichment and social cohesion

This factor accounted for 12% of the variance. It includes variables such as "enhancement of the local culture and traditions," "influencing our lifestyle and maintaining the ethnic identity," and "cohesion and community engagement". It indicates that the locals perceive conventional farming as a dynamic force that enhances local cultural practices, influences lifestyle choices, and plays a pivotal role in maintaining and celebrating ethnic identity.

Locals' perception of the impact of agritourism: In principle component analysis, three factors emerged, with Eigenvalues surpassing the 1.0 threshold. The overall Kaiser-Meyer-Olkin (KMO) was appropriate at the value of 0.858. This value, as recommended by Hair et al. (2010), exceeds the threshold of 0.6, supporting the suitability of the data for further analysis. Bartlett's Test of Sphericity was used to confirm the factorability of the correlation matrix, and the findings were significant (see Table 4). According to Hair et al. (2010), factor loadings below 0.5 were eliminated for improved accuracy. The principal factoring extraction method and varimax rotation were used to obtain the factor patterns, where the factor pattern describes the factor loading value. The total contribution of the four factors is 81.7% (Table 3). Variables in each factor have a strong correlation, as indicated by the low uniqueness value (see Table 3). The only variable that has high uniqueness and is distinct is the variable "negative impact on the natural landscape," hence the lower relevance of the variable in the model.

Factor 1: Economic impacts and livelihood enhancement

It accounts for 34.0% of the variance and reflects various economic dimensions. Variables such as "income generation," "market for local crafts and arts," "employment creation for the locals," and "A source of economic diversification" were included. This indicates that the locals perceive agritourism as a catalyst for economic growth and improved livelihoods.

Factor 2: Environmental conservation and sustainability

It accounts for 27.3% of the variance, this component emphasizes the dual role of agritourism in environmental preservation. Factors such as "improved local scenery," "protection and preservation of local flora and fauna," and "facilitate environmentally sustainable practices". These variables

showcase a community appreciation for agritourism's positive impact on local ecosystems and cultural heritage.

Table 3 Principal component analysis (PCA) (n=131)

	Component			
	1	2	3	Uniqueness
Income generation	0.875			0.231
Market for local crafts and arts	0.844			0.174
Employment creation for the locals	0.833			0.146
A source of economic diversification	0.822			0.105
Opportunity to economically benefit from culture	0.789			0.121
Economic growth and improved livelihood	0.694			0.167
Improved local scenery		0.897		0.108
Protection and preservation of local flora and fauna		0.893		0.106
Facilitate environmentally sustainable practices		0.759		0.324
Negative impact on the natural landscape				0.624
Enhancement of local cultural heritage			0.955	0.080
Over-dependence on tourism			-0.908	0.067
Interaction with tourists			0.902	0.130

Summary

Component	SS Loadings	% of Variance	Cumulative %
1	4.42	34.0	34.0
2	3.54	27.3	61.2
3	2.66	20.4	81.7

Source: Authors' Calculation based on primary data.

Table 4 Bartlett's test of sphericity

χ^2	df	p
1909	78	<.001

Source: Authors' Calculation based on primary data.

Factor 3: Cultural engagement and concerns

Accounting for 20.4% of the variance, this component explains the social aspects of agritourism and its potential negative influence. Key variables include "enhancement of local cultural heritage," "interaction with tourists" and "overdependence on tourism". While the variable cultural heritage and interaction with tourists underscore the positive impact, this factor also reflects concerns about potential overdependence on tourism.

The relationship between locals' perceptions and their level of support for agritourism: Using Spearman's rank correlation coefficient as a measure of monotonic association, a Test of Independence was carried out to investigate the connection between locals' perceptions and their support for agritourism. This approach was used since it can be applied to nonparametric variables. The null hypothesis (H0) posited no correlation between the variables "Level of Support" and "General Perception," while the alternative hypothesis (H1) proposed the existence of a correlation. The two variables, "the locals' general perception of agritourism" and "level of support for agritourism," showed a strong positive monotonic association, according to Spearman's rank correlation coefficient (rho) of 0.744. This significant correlation, supported by a p-value of 0.0000, led to the rejection of the null hypothesis, underscoring the statistical significance of the observed association.

These results are consistent with previous studies showing a close relationship between locals' perceptions of the impact and their level of support. Studies by Anuar et al. (2022), Cui et al. (2022), and Wang et al. (2021) consistently underscore the positive relationship between locals' perceptions of tourism impacts and their support for sustainable tourism development. Notably, the positive

perception of economic, social, and environmental impacts has been shown to improve locals' attitudes towards tourism development.

In interpreting these overwhelmingly positive perceptions and support among the locals, it is important to keep in mind Tanzania's very early stages of agritourism development. According to studies like Vargas-Sánchez et al. (2014), communities generally view low-to-moderate tourism development as beneficial, but as the industry grows, locals' attitudes may change to the negative.

Regression Analysis: This section presents the output of ordered logistic regression, which examines the relationship between explanatory variables and the explained variable (general perception) for both conventional farming and agritourism.

Regression for perception of the impact of conventional farming

The logistic regression results show the perception of conventional farming and its association with various factors. The regression model is specified as following Eq. (1):

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \epsilon \quad (1)$$

where Y is the explained variable and $X1$, $X2$, $X3$, $X4$, $X5$, $X6$ as the explanatory variables and $\beta 0$, $\beta 1 \ldots$, βk are the coefficients, and ϵ represents the error term.

Table 5 The results of ordered logistic regression (n=61)

General perception	Coefficient	Std. err.	Z	P>|z|	95% conf. interval	
Gender	-3.4918	1.6318	-2.14	0.032*	-6.6900	-0.2936
Age	-0.2742	0.0857	-3.20	0.001**	-0.4421	-0.1063
Education	0.8020	0.6537	1.23	0.220	-0.4793	2.0833
Farmer	2.7571	1.0576	2.61	0.009**	0.6843	4.8299
Land tenure	6.5275	2.1515	3.03	0.002**	2.3106	10.744
Limited Fund	0.5173	0.7831	0.66	0.509	-1.0175	2.0522

Source: Authors' Calculation based on primary data.

*Note: The author coded the variables as follows: gender (male = 1, female = 0); land tenure (tenure = 1, no tenure = 0); Involvement in farming (farmer = 1, non-farmer = 0); Education (1 = primary, 2 = secondary, 3 = high school, 4 = college education); Limited fund (1=strongly agree, 5 = strongly disagree). *p<0.05, **p<0.01, ***p<0.001 denote statistical significance.*

The likelihood ratio chi-square statistic was used to indicate the goodness-of-fit of the model. A p-value of 0.0000 suggests the model is statistically significant. The pseudo-R^2 value of 0.592 indicates that the model explains approximately 59.2% of the variation in the explained variable.

The negative coefficient for gender suggests a gender-based disparity in the perception of conventional farming, with men associated with a lower probability of having a positive perception compared to women. This could be because traditionally, in the agriculture sector in Africa, women work mainly as food producers (Amusan et al., 2017). Hence, agriculture is very important for feeding their families. The negative coefficient for age highlights a generational aspect of the perception of conventional farming. The younger the farmers, the greater the likelihood of having a positive perception. Widiyanti et al. (2018) conducted research to identify the young generation's perception of the agricultural sector. The results showed that most youths had fairly good perceptions in terms of income, social status, and work convenience in the agricultural sector. However, it also pointed out that many rural parents in developing countries do not want their children to farm.

The positive coefficient for the "farmer" variable indicates that the locals involved in conventional farming are more likely to have positive perceptions. This could be because the locals involved in farming are direct beneficiaries of conventional farming. At the same time, the strong positive coefficient for land tenure highlights the connection between land tenure and positive perceptions toward conventional farming. In other words, this indicates that individuals who own their land are more likely to have positive perceptions of conventional farming. This could be because ownership of land comes with great benefits, such as lowering the cost of production and maximizing the profit gained. Furthermore, it has been shown that land ownership and the stability of land rights increased the income of farmers significantly (Zhang et al., 2023). Finally, the lack of statistical significance for limited funds and education suggests that, in this context, financial constraints and

level of education may not be significant factors influencing general perceptions of conventional farming.

Regression for perception of the impact of agritourism farming

The logistic regression results show the perception of agritourism and its association with various factors. The regression model is specified as follows:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \epsilon \quad (2)$$

where Y is the explained variable and $X1$, $X2$, $X3$, $X4$, $X5$, $X6$ as the explanatory variables and $\beta 0$, $\beta 1 \ldots, \beta k$ are the coefficients, and ϵ represents the error term.

The likelihood ratio chi-square statistic was used to indicate the goodness-of-fit of the model. A p-value of 0.0000 suggests the model is statistically significant. The pseudo-R^2 value of 0.8471 indicates that the model explains approximately 84.7% of the variation in the explained variable.

Table 6 The results of ordered logistic regression (n=131)

General perception	Coefficient	Std. err.	Z	P>|z|	95% conf. interval	
Gender	-7.420	2.5114	-2.95	0.003**	-12.3422	-2.498
Age	-0.204	0.0660	-3.09	0.002**	-0.3329	-0.0744
Education	2.106	0.8303	2.54	0.011*	0.4781	3.7326
Level of familiarity	2.037	0.7991	2.55	0.011*	0.4703	3.6028
Working in agritourism	26.658	3033.73	0.01	0.993	-5919.34	5972.7
Perceived exclusion	-3.660	1.6090	-2.27	0.023*	-6.8133	-0.5063

Source: Authors' Calculation based on primary data.

*Note: The author coded the variables as follows: gender (male = 1, female = 0); working in agritourism (agritourist = 1, non-agritourist = 0) education: (1 = primary, 2 ¬= secondary, 3 = high school, 4 = college education); level of familiarity: (1=very unfamiliar, 5 = very familiar); perceived exclusion: (1= highly excluded, 5 = not at all excluded). *p<0.05, **p<0.01, ***p<0.001 denote statistical significance*

The coefficient associated with gender exhibited statistical significance. The negative coefficient suggests that holding other variables constant, men are associated with a lower probability of having a positive perception compared to women. In the African context, women have traditionally played a crucial role as food producers, often unpaid (Amusan et al., 2017). The emergence of tourism-oriented diversification presents a significant opportunity for women to transform this role into a source of substantial income. Women now have the opportunity to access previously unattainable economic prospects by offering a variety of culinary services to tourists, this could explain their overwhelmingly positive perception. This can also be supported by Gil Arroyo et al. (2019), who stated that agritourism is an important instrument to improve the social status of women.

The coefficient associated with age exhibited statistical significance. The negative coefficient means that an increase in age corresponds to a reduction in positive perception. This suggests that youth have a favorable view of agritourism activities compared to the older generation. Previous studies have mentioned that age is a factor that affects farmer participation in agritourism (Bagi and Reeder, 2012; Tew and Barbieri, 2012).

The coefficient of education was statistically significant. The positive coefficient signifies that all other factors held constant, an increase in education leads to a rise in the favorable perception of agritourism. This substantiates the pivotal role of education as a driving force shaping perceptions surrounding agritourism among the locals in Tanzania. Lewis-Cameron. (2022) disclosed that there is a positive association between education and the success of tourism-related activities in the destination.

The coefficient for the level of familiarity was statistically significant. The positive coefficient signifies that, with other variables held constant, an increase in the level of familiarity with agritourism activities corresponds to an increase in the likelihood of having a positive perception. This indicates a substantial role for familiarity as a catalyst in shaping perceptions regarding agritourism among the locals. Abdillah et al. (2020) found that rising awareness among the locals improved their support for tourism. The paper stated that lack of awareness initially caused negative perception, however, the perception changed as locals became more familiar.

The coefficient for perceived exclusion exhibits statistical significance. The negative coefficient signifies that an increase in perceived exclusion corresponds to a decrease in the probability of having a positive perception. A study by Stone and Nyaupane (2020) indicates that the exclusion of locals from tourism-related activities can lead to resentment and negative impacts on tourism areas. Finally, the lack of statistical significance for working in the agritourism industry suggests that, in this context, the variable may not be a significant factor influencing general perceptions of the impact of agritourism.

CONCLUSION AND RECOMMENDATION

In conclusion, the purpose of this study was to compare the locals' perceptions of the environmental, economic, and sociocultural effects of agritourism versus conventional farming, identify the factors influencing these perceptions, and investigate the relationship between the level of support and the perceptions of agritourism's impact. It was shown that both agritourism and conventional farming were generally perceived positively by the locals. Being a historically dominant practice, conventional farming reveals unique and complex perceptions. Locals view conventional farming not just as an economic activity but also as a dynamic force that enhances local cultural practices, influences lifestyle choices, and is essential to celebrating and maintaining ethnic identity. They also view conventional farming as a source of food sufficiency. As a new economic activity, the locals' perceptions of agritourism and their level of support for agritourism-related activities were also found to be significantly positively correlated. However, the positive attitudes observed can be contextualized within the infant stage of agritourism development in Tanzania, where locals potentially see the sector as a promising avenue for economic, social, and environmental benefits. Given the trends observed in more established agritourism destinations, it is crucial to recognize the possibility of a shift in perception as agritourism grows. As Tanzania navigates the post-COVID-19 recovery phase, understanding and addressing these perceptions, along with potential challenges, is pivotal for formulating sustainable and community-based strategies for agritourism (Ohe, 2020) and conventional farming development.

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Research article

Determination of Factors Affecting the Performance of Sediment Microbial Fuel Cells by Long-Term Electricity Generation Using Lactic Acid Bacteria–Attached Electrodes

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Abstract Sediment microbial fuel cell (SMFC) performance can be improved using electrodes fermented with and without aeration as cathodes and anodes, respectively. However, this improved performance does not exceed 60 days. In this study, the cathode water-based factors affecting SMFC performance were identified using long-term electricity generation. Meanwhile, SMFC performance (polarization) was measured in experimental conditions. In addition to the polarization measurement, the pH, electrical conductivity (EC) of the cathode water, and adenosine triphosphate (ATP) on the cathode surface were measured. Experiments were conducted with and without the overflow of cathode water. Thereafter, the scanning electron microscopy–energy dispersive X-ray (SEM–EDX) analysis of the cathodes was performed. In line with existing literature, SMFC performance began to decrease on Day 60 from the commencement of the experiments. Furthermore, the pH difference before and after Day 60 was within 0.2, indicating that the pH of the cathode water did not directly affect SMFC performance. Moreover, EC was kept low with cathode water overflow, significantly decreasing SMFC performance. Further, the SMFC performance increased with an increase in ATP, indicating that the bacterial activities on the electrode affected SMFC performance. The SEM–EDX results revealed that metal ions that were obtained from the dissolution of steelmaking slag attached to the cathode surface, indicating the crystallization of these metal ions during the experiments. These findings indicate that the crystallization on the cathode driven by long-term electricity generation inhibited bacterial activities and cathode reactions, thereby decreasing SMFC performance.

Keywords performance, pH, electrical conductivity, adenosine triphosphate, crystallization

INTRODUCTION

Microbial fuel cell technology (MFCT) is expected to offer numerous benefits for addressing social issues, such as organic waste disposal and energy scarcity, particularly in developing countries. However, its performance remains low and must be improved before being deployed, and increasing electrode performance represents one strategy for improving MFCT performance.

Regarding the improvement of electrode performance, the adsorption of bacteria or metal ions on an electrode surface is a notable strategy. Wang et al. (2009) enhanced electrode performance by activating bacteria on the electrode, thus decreasing potential losses. Meanwhile, Nishimura et al. (2018) reported that the ferric ions obtained from the dissolution of steelmaking slag (SS) improved sediment microbial fuel cell (SMFC) performance. Thus, SMFC performance can be improved using SS and lactic acid bacteria (LAB) as the anode of SMFC (Touch et al., 2020).

Thus, numerous studies are exploring the changes in the performances of carbon fiber electrodes caused by the adsorption of iron ions (Fe) obtained from the dissolutions of SS and LAB on electrode

surfaces (Touch and Hibino, 2022). Touch et al. (2023) reported the possibility of improving SMFC performance using electrodes fermented with and without aeration as the cathode and anode, respectively. However, the improved performance only lasted for approximately 60 days owing to changes in the quality of the cathode water caused by long-term electricity generation. The factors accounting for the decreased SMFC performance after 60 days are still unknown.

Hong et al. (2009) experimentally examined the effects of controllable (e.g., electrode surface area ratio, external load, spacing between electrodes) and uncontrollable factors (e.g., dissolved oxygen concentration at the cathode, electrical conductivity [EC], and temperature) on electricity generation. Furthermore, the pH of the cathode water must be considered when bacteria are attached to the cathode, and crystallization on the cathode surface must be also examined.

OBJECTIVE

This study, which was based on long-term electricity generation, was conducted to identify the effects of the cathode water factors that decrease SMFC performance. Next, the cell polarization (current-voltage relation) was measured to detect changes in SMFC performance when fermented electrodes with and without aeration were used as the cathode and anode, respectively. Subsequently, the relationship between SMFC performance with the changes in the bacterial activities on the cathode was examined. The study further investigated the effects of the cathode water quality on SMFC performance.

METHODOLOGY

Experimental Materials and Procedures

The carbon fiber electrodes were pretreated following the method of Touch et al. (2023). Briefly, tap water (3 L), SS (layer height = 20 mm), a commercially available lactic-fermenting beverage (10 mL), and bamboo powder (3 g) were added in cylindrical bottles. For the case with aeration, an air stone was placed on the SS layer and the carbon fiber electrodes were positioned 90 mm from the bottom of the bottle. Further, carbon cloth (News Company, PL200-E) was employed as the electrode material; it was preheated for 1 h at 500°C to improve its performance (Nagatsu et al., 2014). The heated carbon cloth (width and length = 100 mm) was separated into fibers to form a brush-type electrode.

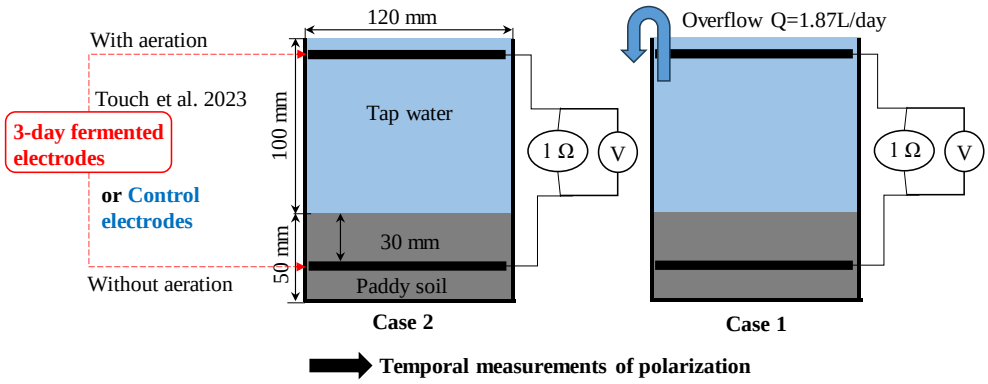


Fig. 1 Experimental procedures

The fermented electrodes with and without aeration, which were extracted from the bottles on Day 3, were utilized as the cathode and anode of SMFC, respectively, to examine the long-term performance of the cell in electricity generation (Fig. 1). Two cases were established: one with cathode water overflow (Case 1) and the other without it (Case 2). Henceforth we used Cases 2-1 and 2-2 to denote cases where the control and fermented electrodes were utilized in Case 2,

respectively. Similarly, Cases 1-1 and 1-2 denote when the control and fermented electrodes were utilized in Case 1, respectively.

By comparing Cases 2-1 and 2-2, we examined the changes in SMFC performance with the changes in the cathode water quality and determined the effects of the fermented electrodes on SMFC performance. By comparing Cases 1 and 2, we elucidated the effects of an overflow (lowering changes in the cathode water quality) on SMFC performance.

Operations and Measurements

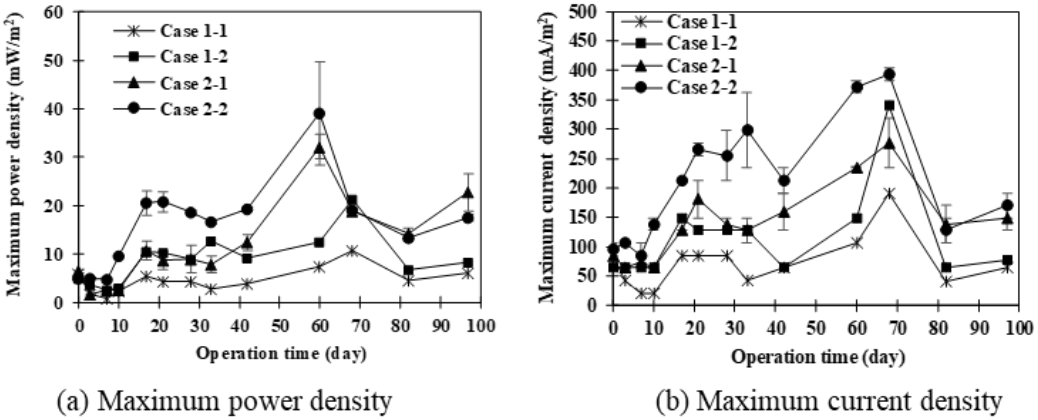
The experiments were conducted for 97 days, as schematically shown in Fig. 1. To generate the electrical current, we loaded an external resistance of 1 Ω between the anode and cathode. The polarizations were measured several times during the electricity-generation experiments to examine the changes in SMFC performance. During the measurement, an external resistance of 1–9.1 kΩ was loaded between the anode and cathode. The cell voltage was recorded after 1 min of loading each external resistance and used to calculate the current by Ohm's law: $I = U/Rex$, where U [V] is the voltage, I [A] is the current, and Rex [Ω] is the external resistance. The power, P [W], was calculated using $P = IU$. Next, the current and power densities were obtained by dividing these values by the surface area of the electrode, i.e., 0.01 m^2. The maximum current density was also determined from the polarization.

The pH, EC of the cathode water, and the adenosine triphosphate (ATP) on the cathode surface were measured on the day of polarization measurement. The pH and EC were measured using a pH/EC meter (Horiba, D-74) while ATP was measured using a lumitester (Kikkoman, Lumitester-Smart). After the experiments, we performed scanning electron microscopy–energy dispersive X-ray (SEM–EDX) to analyze the adsorbed crystalline compounds on the cathode.

RESULTS AND DISCUSSION

Temporal Changes in Sediment Microbial Fuel Cell Performance

Figures 2a and 2b show the comparison of the SMFC performances (power and current density) in both Cases 1 and 2. The maximum power density (P_{max}) and current density (I_{max}) of SMFCs with the fermented electrodes (Cases 1-2 and 2-2) were higher than those with the control electrodes (Cases 1-1 and 2-1). Average 1.7- and 1.5-fold increases were observed in P_{max} (Fig. 2a) and I_{max} (Fig. 2b), respectively, when the fermented electrodes were used. However, it started decreasing from Day 60. These findings agree with those of Touch et al. (2023). Interestingly, inducing cathode water overflow (Case 1) produced lower P_{max} and I_{max} than the absence of overflow (Case 2), and the reasons for this will be discussed in the next section.



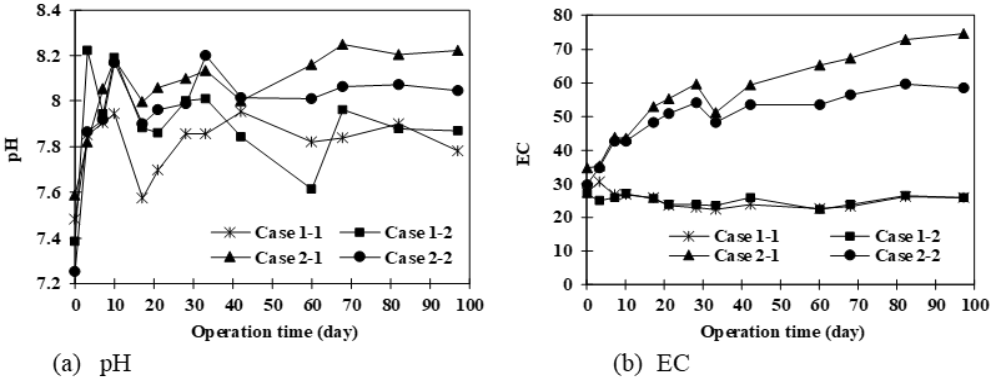
(a) Maximum power density (b) Maximum current density

Fig. 2 Temporal variations of P_{max} and I_{max}

Temporal Changes in the pH and Electrical Conductivity

Figures 3a and 3b show that the pH and EC of the cathode water increased temporally. The diffusion of ions from paddy soils into the cathode water contributed to these increments. Additionally, the reduction of oxygen at the cathode contributed to the increase in pH. Hong et al. (2009) reported that changes in cathode water quality caused variations in SMFC performance. Likewise, in this study, we observed a relationship between SMFC performance and EC. Compared with the EC of Case 2 (without overflow), that of Case 1 (with overflow) was lower, contributing to lower power generations in Cases 1-1 and 1-2 (Fig. 2a) than in 2-1 and 2-2. Generally, a higher EC corresponds to a higher electron flow.

Considering the pH variation, we observed that the pH difference before and after Day 60 was within 0.2, indicating that pH did not directly affect the significant decrease in SMFC performance after Day 60 (Fig. 2).

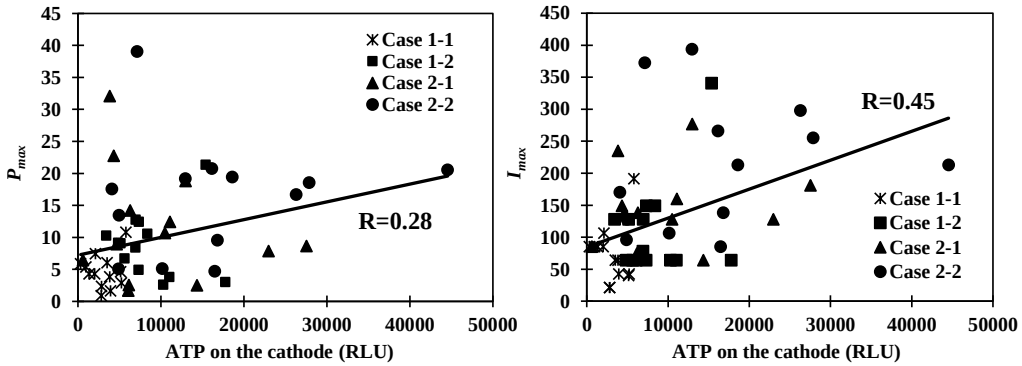


(a) pH (b) EC

Fig. 3 Temporal changes in the cathode water pH and EC

Effects of Bacterial Activities on Sediment Microbial Fuel Cell Performance

Generally, SMFC performance depends on the cathode water quality and bacterial activities on the cathode. Figures 4a and 4b show the relationship between ATP on the cathode surface and SMFC performance. Notably, P_{max} increased with the increasing ATP within the correlation coefficient of 0.28, whereas I_{max} increased with the increasing ATP within the correlation coefficient of 0.45. Our results also confirmed that SMFC performance depends on the bacterial activities on the electrode surface, which agreed with Kang et al. (2012). This in turn confirmed that the decrease in the bacterial activities on the cathode might contribute to the decrease in SMFC performance after Day 60.



(a) ATP with Pmax **(b) ATP with Imax**

Fig. 4 Relationship between ATP on the cathode and the SMFC performance

Crystallization on the Cathode Surface

During the experiments, the appearance of white substances attached to the cathode surface was confirmed (Fig. 5). It is possible that they might affect the bacterial activities on the cathode. In Case 1-1, the formation of the substances (crystallization) was not confirmed from the SEM image, as most of the ions flowed out (Fig. 3b, EC was kept low as well as the tap water level) of the cathode chamber, causing a lack of ions for crystallization. Therefore, these substances were formed from the reaction of the cathode with ions present in the cathode water.

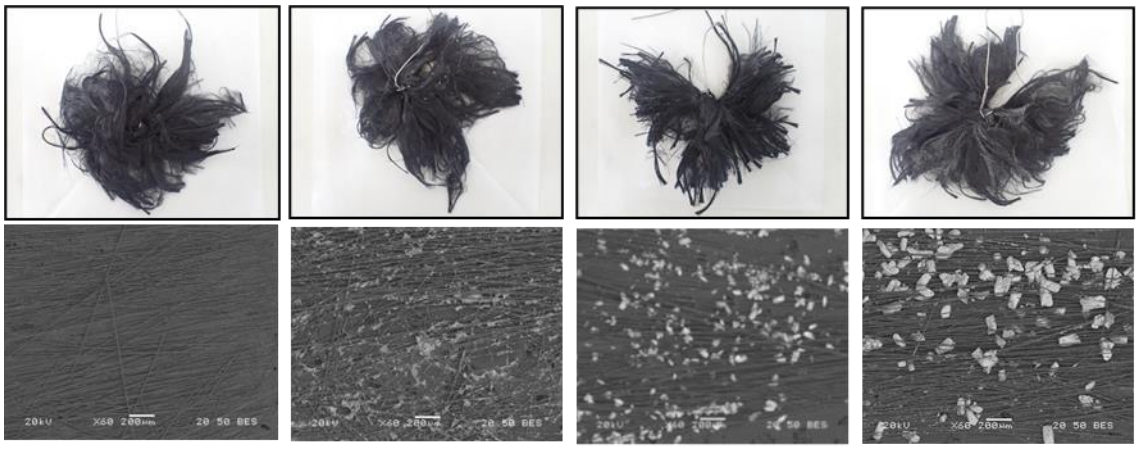
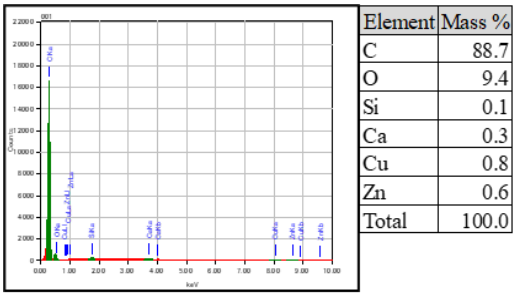


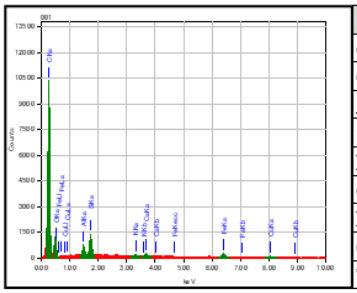
Fig. 5 SEM images of the cathodes

We also characterized the attached substances in Cases 1-2; however, they exhibited different characteristics from those of Cases 2-1 and 2-2. These substances might have been attached to the electrode during fermentation. As the amount of electricity that was generated (Fig. 2b, Case 2-2) was positively correlated to the number of these crystalline substances formed, these substances might have been obtained from the crystallization of the metal ions during cathode reactions.



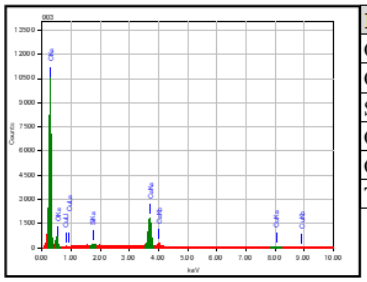
Case 1-1

Element	Mass %
C	88.7
O	9.4
Si	0.1
Ca	0.3
Cu	0.8
Zn	0.6
Total	100.0



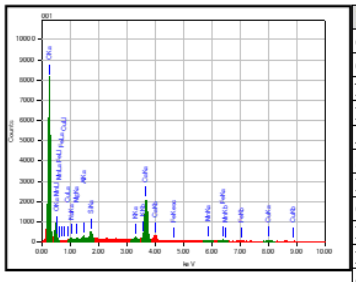
Case 1-2

Element	Mass %
C	69.8
O	23.0
Al	1.2
Si	2.3
K	0.2
Ca	0.5
Fe	1.9
Cu	1.2
Total	100.0



Case 2-1

Element	Mass %
C	76.3
O	16.0
Si	0.1
Ca	7.0
Cu	0.7
Total	100.0



Case 2-2

Element	Mass %
C	66.6
O	21.1
Na	0.5
Mg	0.2
Al	0.4
Si	0.8
K	0.3
Ca	8.1
Mn	0.3
Fe	0.6
Cu	1.1
Total	100.0

Fig. 6 Results of EDX analysis of the cathodes

The EDX results (Fig. 6) revealed that more metal ions, that is, Al, Si, Fe, Mn, and Mg ions, were attached to the fermented cathode (Cases 1-2 and 2-2) than to the control cathode (Cases 1-1 and 2-1). These metal ions are obtained from the dissolution of the steelmaking slag. The dissolution could attach metal ions to the carbon fiber electrode through fermentation. The crystallization of these metal ions on the cathode surface might restrain the bacterial activities and chemical reactions on the cathode, thereby decreasing SMFC performance.

CONCLUSIONS

In line with existing literature, SMFC performance started decreasing on Day 60 after the commencement of the experiments. As the difference in the pH values before and after Day 60 was minimal, we concluded that the pH of the cathode water did not directly affect SMFC performance. SMFC performance decreased even though the cathode water overflowed. Notably, inducing cathode water overflow further decreased the SMFC performance. We observed a positive correlation between ATP on the cathode surface with SMFC performance. Therefore, the changes in the bacterial activities on the cathode surface might cause a decrease in SMFC performance during long-term electricity generation. The SEM–EDX results indicated that the metal ions obtained during the dissolution of steelmaking slag were adsorbed on the cathode surface, indicating the crystallization of these metal ions at the end of the experiments. Thus, during long-term electricity generation, crystallization on the cathode inhibits bacterial activities and cathode reactions, resulting in a decrease in SMFC performance.

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