Sustainability assessment of paddy farming system in Kaduwela wetland ecosystem in Sri Lanka

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ABSTRACT

As a result of intensive agriculture, the number of worldwide natural wetlands are losing their biodiversity and unique characteristics. Kaduwela wetland ecosystem is such a natural wetland in Colombo district of Sri Lanka which has a long history of paddy farming. This study was carried out to assess the sustainability of this wetland paddy ecosystem while determining factors affecting paddy farmers' adaptability for sustainable agricultural practices in the locality. A household questionnaire survey was conducted in 2019 for 100 randomly selected paddy farmers in the Dedigamuwa Grama Niladhari Division to collect data. Both qualitative and quantitative methods were used for data analysis. Thirteen different indicators were developed to assess economic, social, and environmental sustainability, and then economic efficiency index (EEI), social security index (SSI), and environmental security index (ESI) were derived which were used to calculate the total sustainability index (TSI). Multiple linear regression was used to identify the factors affecting paddy farmers' adaptability for sustainable agricultural practices. Results revealed that only 3% of the farmers are sustainable (TSI ≥ 0.5) while 97% (TSI < 0.5) are vulnerable. Furthermore, profitability from paddy farming (0.0001 ± 0.0000; $p = 0.007$), education level of the farmers (0.6552 ± 0.2063; $p = 0.002$), frequency of extension services (1.6809 ± 0.7713; $p = 0.031$), women participation in farming (5.6694 ± 2.7946; $p = 0.045$) and paddy farming experience (0.4746 ± 0.1061; $p = 0.0026$) positively influenced while hired labours per acre per season (–0.2905 ± 0.0937; $p < 0.0001$) negatively influenced on the adaptability of sustainable agricultural practices by the paddy farmers. The results of this study reported decreasing the cost of production, using resource–conserving practices, and improving technologies, increasing information availability and accessibility as the major factors that are vital to promoting sustainability in this wetland–paddy ecosystem. The study also suggests the need for government support and intervention in agricultural advisory services as an engine to promote sustainable agricultural practices while conserving unique characteristics of Kaduwela wetland paddy ecosystems in Sri Lanka.

Keywords: Ecosystem, paddy farming system, sustainability index, wetland

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INTRODUCTION

Wetland agriculture has been identified as one of the important strategies for poverty reduction and enhancing the food security of associated communities in many developing countries (Frenken and Mharapara, 2002) including Sri Lanka. Highly fertile lands by the side of rivers have been used for different crop cultivations from ancient times as a result of regular sediment deposition, especially during the flooding season. Riverine wetlands are not only ideal areas for food production but also contribute to different ecosystem services. However, many wetlands across the world significantly degrade due to negative impacts on biodiversity and peoples' livelihoods. The losses are larger and faster on inland wetlands than on coastal natural areas (IUCN, 2018). Until the early 20th century, wetland rice fields were very rich in diversity, including macro-invertebrates, fish, and waterfowls (Kawano, 2000; Shimoda, 2007). However, with intensive agricultural practices, especially followed by the green revolution in the late 1960s, overuse of fertilizer and improper application of pesticides have led to a dramatic decrease in rice–field biodiversity (Bambaradeniya, 2003). With increasing the global population, the need for expansion of food production led to the conversion of the majority of the wetlands into conventional farmlands. In such wetland ecosystems, biodiversity has been impacted severely and some agriculture–based wetlands may no longer even be able to qualify as wetlands.

The Ramsar Convention on wetland recognizes that the importance of sustainable and wise use of worldwide wetlands toward achieving sustainable development. Hence sustainability assessments and identification of determinants for the adoption of sustainable agricultural practices are essential for innovative policy formulations not only in agriculture based natural wetlands but also other unique ecosystems (Seifollahi–Aghmiuni *et al*., 2019). Researchers observed that the concept of sustainability is normative and cannot be defined singularly (Bond *et al*., 2012). But the assessment of the sustainability of any system is to pursue the plans and activities that make an optimal contribution to sustainable development (Verheem, 2002). Many studies have been carried out in both developed and developing countries to measure sustainability practices.

A study by Roy *et al.* (2013) was conducted in Bangladesh to assess rice farming sustainability by developing a composite indicator (CI) considering all four pillars of sustainability. They observed that only less than 50% of rice growers were sustainable in terms of economic viability, ecological benefits, and quality of life. Another study, conducted to analyse the sustainability of ecological and conventional agricultural systems in Bangladesh, used five indicators as, land–use patterns, cropping patterns, soil fertility management, pest and disease management, and soil fertility status to assess the environmental sustainability; land productivity, yield stability and profitability from staple crops to assess the economical sustainability and input self–sufficiency, equity, food security and the risks and uncertainties involved in crop cultivation to assess the social sustainability (Rasul and Thapa, 2003). In a Malaysian case study done for creating a farmer sustainability index, scientists have developed a composite farmer sustainability index (FSI) involving 33 production practices used by 85 cabbage farmers (Taylor *et al*., 1993). Three case studies were undertaken to assess the sustainability of land management systems in farmers on sloping lands of Vietnam, Indonesia, and Thailand. They have focused on issues related to sustainable land management, especially in slopy lands in South–East Asia, and explored with the evidence that land management involves issues that go beyond the subject of social quality (Lefroy *et al*., 1999). A study conducted in Zimbabwe, to assess the sustainability of peasant farming systems, identified three key indicators that are needed to consider in any attempt at sustainability assessment, issues related to the selected indicators or performance criteria, special scales or boundaries, and temporal scales of measurement (Campbell *et al*., 1997).

Dedigamuwa, Kaduwela wetland paddy ecosystem is one of the freshwater ecosystems in the western province of Sri Lanka and is situated in the western part of the Kelani river basin. The area is highly vulnerable to flooding and agriculture is one major way that the urban community is linking to the wetland. Paddy farming is practiced as major cultivation within this ecosystem for a longer period only in the Maha season. Additionally, local people use wetlands for the cultivation of vegetables, edible herbs, yams, and other crops especially during the water deficit period, Yala. Surrounding households are the major beneficiaries of this wetland. For decades, it was a paradise for different flora and fauna species, but long-term conventional farming practices made many disturbances to the ecological value of the area and a question is now arising on the sustainability of the agro–ecosystem in the area. Assessment of the sustainability of this wetland paddy farming system is also important to recognize the sustainability level of the system and to plan for future expansions, omissions, or additions of the components to the system.

Therefore, the first objective of this study was to assess the sustainability status of paddy farming in the wetland–paddy ecosystem in Kaduwela which will help to make rational decisions in future sustainable development plans of the system. Similarly, identification of different sustainable agricultural practices that the farmers in the Kaduwela area are using in their farming and their adaptability and factors affecting the adaptability of such practices are needed to be explored to assess the sustainability level and to suggest a sustainability enhancement plan for the Kaduwela wetland agro-ecosystem which is also less touched by other researchers. Hence the second objective of this study was to identify factors affecting the adaptability of sustainable agricultural practices by Kaduwela wetland paddy farmers.

MATERIALS AND METHODS

Dedigamuwa Grama Niladhari (GN) Division of Kaduwela Divisional Secretariat, Colombo district in the western province in Sri Lanka was the study area for this research. The current total population of the Dedigamuwa GN Division is 2,190 people consisting of 1,188 females and 1,002 males. Among them, there are around 120 paddy farmers including both females and males. The total extent of the cultivable paddy lands under the Dedigamuwa GN Division is approximately 110 acres.

Hundred (100) paddy farmers from Dedigamuwa GN Division were randomly selected for the study. Data were collected in 2019 and key informant interviews, farmer group discussions, and household surveys were conducted to collect the primary data using pre–tested questionnaires. The questions were specially aimed at identifying the environmental, social, and economic sustainability, identifying the sustainable agricultural practices used by farmers and their adaptability level in the paddy farming system. Required secondary data were extracted from the Department of Agriculture of Sri Lanka, Department of Census and Statistics of Sri Lanka, Agrarian Service Center of Kaduwela, and published and unpublished data from various sources and the internet. Both qualitative and quantitative methods were used in analysing data to ensure data are effectively interpreted using the numbers, tables, figures as well as narratives. Descriptive analysis was used to analyse the socio–economic characteristics of paddy farmers in the area.

Sustainability Assessment of the Farming System

To measure the overall sustainability, all three dimensions of sustainability of farming systems were measured using identical indices. Economic sustainability was measured using economic efficiency index (EEI) while social security index (SSI) for measuring social sustainability. The environmental security index (ESI) was used to measure environmental sustainability.

Different indicators were developed to analyse economic, social, and environmental sustainability respectively and then total sustainability was calculated (Vanloon *et al.,* 2005; Hayati *et al.,* 2010; Nazir *et al*., 2017). Data were collected from two paddy growing seasons and average values were calculated respectively. Average seasonal crop productivity, average seasonal income from paddy farming, and seasonal returns on investment of paddy farming were used to measure economic sustainability. Indicators developed to measure social sustainability were average seasonal farmer income, frequency of receiving extension services within the cropping season, seasonal woman's participation in the agricultural activities, and education level of the respondents. Six indicators were developed to measure environmental sustainability namely the amount of organic manure usage, amount of inorganic fertilizer usage, amount of agrochemical usage, and levels of adoption of integrated pest management (IPM) practices, good agricultural practices (GAP), and traditional agricultural practices (TAP) by farmers within the cropping season. The calculations of all indicators for economic, social, and environmental sustainability are presented in Table 1. The selected IPM, GAP, and TAP practices used to calculate environmental sustainability are shown in Table 2.

The EEI. SSI and ESI were calculated as the simple mean of their respective individual variables.

$$\text{EEI/SSI/ESI} = \frac{\sum_{j=1}^{n} I_j}{N}$$

where I_j is the normalized value of j^{th} variable of EEI/SSI/ESI and N is the number of indicators that are used to measure EEI/SSI/ESI

To measure EEI, SSI, and ESI, the following equation was used to normalize the values of each indicator.

$$I_j = 1 - [(X_j - \text{Minimum } X_j) / (\text{Maximum } X_j - \text{Minimum } X_j)]$$

where X_j is the value of each indicator variable for individual observations and I_j is the normalized value of j^{th} variable of EEI/SSI/ESI

To measure the total sustainability index (TSI), a simple mean of respective sustainability indices (EEI/SSI/ESI) of the individual variables was used.

$$TSI_{(EEI/SSI/ESI)} = (EEI + SSI + ESI) / 3$$

The total sustainability index of the farming system was used to categorize whether the system is sustainable or vulnerable. If the total sustainability index value was equal or greater than 0.5 ($TSI \geq 0.5$) the system was considered as sustainable while lesser than 0.5 ($TSI < 0.5$) the system was considered as vulnerable.

Table 1 Indicators used to calculate the economic, social and environmental sustainability

Indicators		Calculation
Economic sustainability	1) Seasonal productivity	Total yield per season (kg) divided by land area used per season (acre)
	2) Seasonal income from paddy	Net seasonal income from paddy (LKR) divided by land area used per person (acre)
	3) Seasonal return on investment	Profit from paddy farming per season (LKR per acre) divided by total cost for paddy farming per season (LKR per acre)
Social sustainability	1) Proportion of income of paddy	Income earned from paddy farming (LKR) divided by total household income (LKR)
	2) Frequency of receiving extension services	Number of contacts made by the farmers with the extension agent of the area per cropping season
	3) Woman's participation in farming	Work hours of women in farming per season divided by total work hours per season
	4) Education level of respondents	Number of years spent by the respondents for the education
Environmental sustainability	1) Amount of organic manure used	Amount of organic manure used per season (kg) divided by total cultivated area per season (acre)
	2) Amount of inorganic manure used	Amount of inorganic manure used per season (kg) divided by total cultivated area per season (acre)
	3) Amount of agrochemicals used	Amount of agrochemicals used per season (mL) divided by total cultivated area per season (acre)
	4) Level of adoption of IPM	Number of IPM practices used by individual farmer per season divided by 10
	5) Level of adoption of GAP	Number of GAP practices used by individual farmer per season divided by 10
	6) Level of adoption of TAP	Number of TAP practices used by individual farmer per season divided by 10

Note: IPM = integrated pest management practices, GAP = good agricultural practices, TAP = traditional agricultural practices

Table 2 Selected integrated pest management practices, good agricultural practices and traditional agricultural practices

Strategies	Selected practices
Integrated pest management practices	1) Use of natural enemies, predators and biological agents in the season to prevent diseases and pest attacks 2) Changes in frequency of irrigation 3) Seasonal application of adequate nutrients for paddy cultivation 4) Continuous maintenance of field sanitation throughout the season 5) Use of mixed cropping practices in the season 6) Usage of trap crops/ traps in the season 7) Usage of pheromones seasonally 8) Use of bio–pesticides seasonally (e.g., neem leaves or seeds, hot pepper, tobacco, wood ash, and soap) 9) Usage of barriers to protect the crop in the season 10) Selection of the most effective sowing date avoiding drought, pests and diseases occurrences
Good agricultural practices	1) Performing minimum tillage 2) Availability of biodegradables and non–biodegradables in the paddy fields 3) Use of improved and resistant seeds to the most frequent diseases 4) Use of correct crop protection chemicals, fertilizer and compost according to the directions in the labels 5) Use of good quality water for irrigation 6) Sowing at an adequate distance 7) Using clean garden tools 8) Practicing monthly weeding 9) Consulting agricultural instructor when needed during the cropping season 10) Use of proper amount of organic and inorganic fertilizers
Traditional agricultural practices	1) Using Kem practices and rituals in the season 2) Use of traditional manual land preparation methods in the season 3) Use of traditional weed control methods 4) Seasonal practicing of the Pangu method 5) Practicing traditional manure application techniques in the season 6) Using traditional methods in the season to safeguard the paddy field 7) Use of traditional bio pesticides in the season 8) Use of traditional water management techniques 9) Use of traditional seed treatment methods 10) Selection of paddy varieties in the season based on the traditional weather forecasting

Measuring of Paddy Farmers' Adaptability and Factors Affecting Adaptability of Sustainable Agricultural Practices (SAPs)

To calculate the seasonal adaptability for sustainable agricultural practices, 15 recommended sustainable agricultural practices were selected. Seasonal adaptability (%) was calculated by number of recommended SAPs followed by individual farmer per season divided by total number of recommended SAPs (15) then multiplied by 100.

The selected recommendation for SAPs consisted of 1) performing minimum tillage, 2) applying adequate nutrients for paddy farming, 3) practicing manual weeding, 4) status of field sanitation, 5) using natural enemies, predators, and biological agents to prevent pest and diseases, 6) adopting mixed cropping practices, 7) use of proper irrigation practices, 8) use of biopesticides, 9) use of clean tools, 10) use the proper amount of organic fertilizer, 11) cultivating traditional rice varieties, 12) practicing crop rotation, 13) use of certified seeds, 14) selection of suitable sowing date avoiding drought, pests, and diseases and 15) combined with agroforestry practices.

Multiple linear regression was used to analyse the factors affecting the paddy farmers' seasonal adaptability for SAPs using nine variables as described in Table 3.

$$Y_i = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 X_{i1} + \boldsymbol{\beta}_2 X_{i2} + \boldsymbol{\beta}_3 X_{i3} + \ldots.. + \boldsymbol{\beta}_n X_{in} + \varepsilon$$

where Y_i is seasonal adaptability for sustainable agricultural practices, β_0 is the intercept of the model, $\beta_1, \beta_2, \beta_3 \ldots..\beta_n$ are regression coefficients of the independent variables, $X_{i1}, X_{i2}, X_{i3} \ldots..X_{in}$ are the independent variable and ε is error

Table 3 Variables used to analyse the factors that are affecting for the paddy farmers' seasonal adaptability for sustainable agricultural practices

Independent variables	Description (unit of measurement)
Profitability from paddy farming	Net seasonal profit from paddy farming (LKR/season/acre)
Education level of the farmer	Years of formal education (number of years)
Frequency of extension services	Number of contacts with extension officer per season
Age of the farmer	Age of the farmer (years)
Women participation in farming	Number of seasonal women working hours over total seasonal working hours
Extent of paddy farming	Acres of seasonal paddy farming (acres cultivated/season)
Hired labours per acre per season	Number of hired labours per season (number of labours/acre)
Paddy farming experience	Number of years in paddy farming (number of years)
Off–farm income of paddy farmers	Seasonal off–farm income (LKR/season)

RESULTS AND DISCUSSION

Primary data collected from the questionnaire survey were utilized for the discussion of the socio-economic background of the respondents. Gender, age, marital status of the farmer, education level of the farmer, average seasonal land extent under paddy farming, primary and secondary occupations of the farmer, and seasonal ownership of the paddy land were described as the socio–economic characteristics of the paddy farmers in Dedigamuwa wetland ecosystem (Table 4).

Considering the gender composition of the farmers, the majority (93%) of respondents were males in this sample while 7% were females. Among them, most of the farmers belonged to the age category of 50–59 years. The mean age of the respondents was 56 years while minimum and maximum ages were 30 and 80 years, respectively. Results showed that the younger generation is not much preferring to engage in paddy farming in the Dedigamuwa wetland area and they prefer to engage in the private sector or government sector jobs as per personal communication with the households. Out of the total respondents, 92% were married, and 6% were widowed. Most of the female-headed households were widowed.

Table 4 Socio-economic characteristics of paddy farmers

Variables (n = 100)	Percentage	Mode
Gender		Male
Male	93%	
Female	7%	
Age		50–59 years
30–39 years	4%	
40–49 years	19%	
50–59 years	43%	
60–69 years	23%	
≥70 years	11%	
Level of education		6–10 years
0 years	1%	
1–5 years	2%	
6–10 years	70%	
11–13 years	25%	
>13 years	2%	
Marital status		Married
Married	92%	
Widowed	6%	
Single	2%	
Land extent		Less than 1 acres
Less than 1 acres	67%	
1–2 acres	32%	
More than 2 acres	1%	
Primary occupation		Private employee
Farming	14%	
Government employee	14%	
Private employee	32%	
Self–employee	26%	

Table 4 Continued.

Variables (n = 100)	Percentage	Mode
Secondary occupation		Farming
Farming	85%	
Agricultural labour	1%	
Self–employee	9%	
Non–agricultural labour	2%	
Unemployed	3%	
Land ownership		Own
Own	66%	
Tenant	24%	
More than one owner	10%	

Since educated farmers are expected to follow and understand the agricultural instructions, manage and adopt advance and novel technologies than the less educated farmers, farmer education level can be identified as one of the most important socio–economic characteristics of the farming community which affects the adaptability of sustainable agricultural practices. According to the results, the majority of the farmers (70%) of the total sample did schooling up to grade 10 (secondary education) while only 2% had their education up to degree level. Many farmers who had accomplished secondary education or above engaged in farming as their secondary income source since most of them are engaged in any other profession. Similar to these results certain empirical studies also revealed that education has a fundamental association with rice farming sustainability (Roy *et al*., 2013).

Primary occupation is the main income source of the farmers. Only 14% of the farmers were engaged in paddy farming as their primary income source and the rest of the farmers cultivate paddy while engaging in some other income generation activity. Alam *et al*. (2013) also reported that since agriculture is less profitable, the majority of the farmers are trying to engage in agriculture as a part–time activity. Secondary occupation is another income generation source in addition to the main occupation and very much important to identify the economic status of the farmers. According to the majority of the results of the respondents (85%) had engaged in paddy farming as their secondary occupation. Another 9% were self-employees while 2% were non-agricultural labourers and only 1% was agricultural labour.

The average seasonal paddy land extent ranged from 0.25–5 acres in the total sample, while the mean land extent of the respondents was 0.622 acres. The majority (66%) of respondents had their land and 24% had utilized tenant land while 10% of the land had more than one owner. For tenant lands, farmers should give part of their yield to the landowners.

Sustainability Assessment of Kaduwela Wetland Paddy Farming

The results indicated that only 13, 8, and 4% of paddy farmers respectively were economically, socially, and environmentally sustainable concerning their paddy farming (Figure 1). Based on TSI, only 3% of respondents were sustainable (TSI ≥ 0.5) while the rest of the 97% were vulnerable with respect to their paddy farming practices.

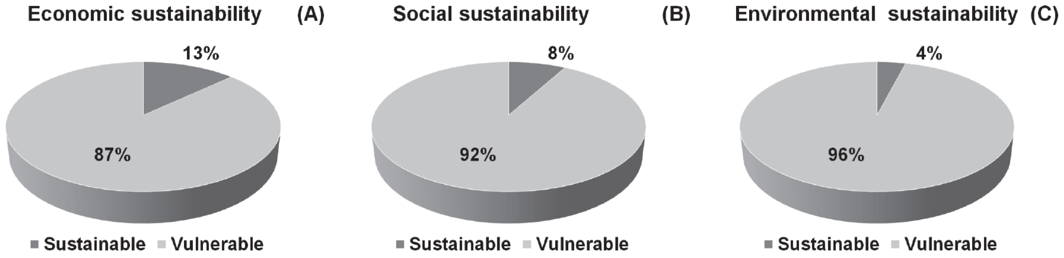

Figure 1 Economic (A), social (B) and environmental sustainability (C) of farmers in wetland paddy ecosystem

Though seasonal paddy land extent of studied area varied between 0.25 and 5 acres, the majority were cultivating 0.50 acres or less as most of the respondents were engaged in government and private sector employment and farming is their secondary income source. The majority of them used seasonal hired labourers for almost all the paddy farming activities from land preparation to harvesting and hence, higher labour cost reduced their seasonal profit. Also, none of the respondents practiced crop rotation or intercropping seasonally and as a result of that, continuous paddy farming leads to decrease unit land productivity and the ultimate result of that is 87% of respondents were not economically sustainable.

Most farmers are willing to apply organic manure to their fields, but due to the lack of availability of an adequate amount of organic matter, they had to get used to applying inorganic fertilizer in each season to their paddy farming. A considerable number of farmers have continuously applying synthetic fertilizer, hence their production depends on external fertilizer application as per them. Furthermore, over the use of inorganic fertilizer is another major problem, since farmers are not having a clear idea about the fertilizer recommendations.

Based on the communication with the farmers, their busy daily working schedules disturb them to practice manual weeding and land preparation in their cultivations. Even the middle-aged and younger farmers stated that they don't have enough knowledge of IPM and TAPs. As a result, they applied different weedicides and pesticides frequently to their fields to control weeds, pests, and diseases. However, they were aware of the fact that agrochemicals get mixed with natural water streams and it is affecting negatively to their health as well as the species diversity of wetland plants. As per the observations made by the research team and the information gathered during the study, heavy tillage causes a reduction of the quality of cultivation soils, soil erosion, and disrupts biodiversity in the cultivated localities. As a result of these consequences, 96% of the respondents in the Kaduwela wetland paddy ecosystem were not environmentally sustainable.

Lack of proper and continuous extension services within the growing seasons, poor engage of women in farming practices and especially continuous paddy yield reduction mainly lead towards the social vulnerability among 92% of the paddy farmers in the wetland-paddy ecosystem.

Farmers' Adaptability of Sustainable Agriculture Practices in the Season

The descriptive statistics of the independent variables for measuring the farmers' seasonal adaptability for SAPs are presented in Table 5. All nine variables were continuous hence the discussion of the results is based on the parameter estimates and probability (p) values from the regression model (Table 6).

Table 5 Descriptive statistics of the independent variables used in the regression model

Factors	Mean	Standard deviation	Minimum	Maximum
Profitability from paddy farming	33,251.42	19,592.29	2,000	80,320
Education level of the farmer	10.29	2.26	4	17
Frequency of extension services	1.33	0.91	0	3
Age of the farmer	55.94	10.28	30	80
Women participation in farming	0.17	0.18	0	0.86
Extent of paddy farming	0.78	0.62	0.25	5
Hired labours per acre per season	9.26	6.65	0	36
Paddy farming experience	22.78	6.67	1	40
Off–farm income of paddy farmers	256,050	61,925.73	90,000	420,000

The R–square value was 79% which indicated that 79% of the variance in the model was explained by the independent variables. The analysis revealed that six variables significantly contributed to the sustainability of this wetland paddy ecosystem ($p < 0.05$). These significant variables were seasonal profitability from paddy farming, farmer education level, frequency of receiving extension services per season, seasonal women participation in farming, number of hired labour per acre per season, and paddy farming experience of the household. Age of the farmer, seasonal extent of cultivation, and off–farm income of paddy farmers were not significant in explaining the adaptability of sustainable agricultural practices by the farmers. Among these six significant variables, five variables showed a positive relationship on adaptability while the number of hired labour per acre showed a negative effect on adaptability (Table 6). There was no significant correlation among the independent variables used in the model.

Table 6 Regression coefficient for measure the farmers' seasonal adaptability of SAPs

Factors	Regression coefficient	Standard error
Profitability from paddy farming	0.0001*	0.0000
Education level of the farmer	0.6552*	0.2063
Frequency of extension services	1.6809*	0.7713
Age of the farmer	–0.0349	0.0569
Women participation in farming	5.6694*	2.7946
Extent of paddy farming	–0.9080	0.7908
Hired labours per acre per season	–0.2905*	0.0937
Paddy farming experience	0.4746*	0.1061
Off–farm income of paddy farmers	–0.0000	0.0000

Note: * Significant at 5% level

The results indicated that seasonal profitability from paddy farming had a positive relationship with the sustainability of the system. With increasing profitability, farmers may have a better economic condition that makes them can spend more on family needs such as education of their children, health, and having a better nutritious diet. Besides, they can invest more in their paddy farming in the next season to buy good quality planting materials which increase the chance to adapt to technologies. It showed that, with increasing the profitability, the sustainability of the system may also increase using having higher adaptability on sustainable agricultural practices. A study conducted in Malaysia to assess the sustainability of paddy farmers also revealed that, when the profitability of agricultural production is declined, educated people are less interested in agriculture because of low profitability compared to the other income generation activities (Alam *et al*., 2013).

Farmer education level also revealed a positive relationship with the sustainability of the system. Educated farmers are expected to understand agricultural instructions much clearly and adapt to new advanced technologies faster. Farmer education directly affects their decision–making procedures in farming. Moreover, with proper education, farmers also tend to apply recommended amounts of fertilizers which optimize both farming output and environmental sustainability. Thus, it can be expressed that increasing the farmer education level causes increasing the sustainability of the system. Similar results were obtained by several studies conducted in different countries. A study conducted to assess the sustainability of the dairy production system in the Uttarakhand hills of India showed that the education level of households had a positive relationship with dairy farming sustainability (Nazir *et al*., 2017). The findings of South Korean research also revealed that the education level of the farmers had a positive significant relationship with farmers' adoption of environmentally friendly farming practices (Lee *et al.,* 2016). Further, Mishra *et al.* (2018) also confirmed that more educated farmers are highly willing to adopt more sustainable agricultural practices.

Extension services received by farmers during the season also showed a significant positive relationship with sustainability. It implied that, when extension services increase, farmers become more aware of new technologies, new varieties, and proper agronomic practices. Hence, better seasonal extension services could enhance the seasonal productivity of paddy farming in this area. Since most of the paddy farmers have a lack of awareness of SAP and the need for SAPs, proper extension services are essential to motivate farmers towards sustainability. A study conducted in the USA reported that lack of adequate knowledge about sustainable farming and unfamiliarity with new technologies negatively affect the less adoption of sustainable agricultural practices and hence extension services are essential to promote sustainability (Mishra *et al*., 2018).

Seasonal women's participation in agricultural activities also had a positive significant relationship with adaptability for sustainable agricultural practices. Usually, the majority of women are engaged in household activities and caring for their children while some are engaged in income generation activities. But, if women can engage in their paddy farming practices, during their free time as family labour, it helps to reduce their seasonal hired labour cost especially for activities like weeding and harvesting. Reduction of seasonal labour cost directly affects the reduction of seasonal production cost and then the reduction of production cost, farmers can gain better profits. Further, with manual weeding, frequent application of weedicides is not needed and it helps to enhance environmental health. Similarly, a study in South-East Nigeria confirmed that the amount of family labour used including women's participation was directly proportional to the practice level of SAPs (Mgbada *et al*., 2016).

A significant positive relationship was shown between paddy farming experience and adaptability for sustainable agricultural practices. Farmers who have been involved in paddy farming practices for the long term may have better personal knowledge on proper land preparation techniques, fertilizer requirements and application frequency, traditional weed and pest control techniques, and proper water management techniques than the farmers who have less farming experience. The results agree with the findings of the study that was conducted in Iran which found that farmer experience on agricultural activities had a positive significant relationship with farmers' knowledge about sustainable agricultural practices (Daryaei, 2014).

According to the results, the number of hired labour per acre per season had a negative significant relationship with adaptability for sustainable agricultural practices. With increasing the number of hired labour per season to cultivate the unit land area (one acre), the seasonal labour cost per unit land area also increased. In the studied area, the daily wage for one labourer is around LKR 2,000–2,500, and most of the farmers revealed that a larger portion of their paddy income goes to the payments of hired labour. Therefore, with increasing the labour cost, the profitability of the paddy farmers is decreased, and it negatively affects the adaptability for sustainable agricultural practices of the wetland paddy ecosystem.

CONCLUSIONS

The majority of farmers in the Kaduwela wetland paddy ecosystem were not sustainable concerning their paddy farming practices. Profitability from paddy farming, education level of the farmers, frequency of extension services, women participation in agricultural activities, higher labour per acres, and paddy farming experience were the major factors affecting the adaptability of sustainable agricultural practices by paddy farmers in the Kaduwela wetland paddy ecosystem in Sri Lanka.

Since most of the farmers are lacking in awareness about sustainable agricultural practices, it is essential to establish strong advisory services to bring knowledge and technology to them. In the Sri Lankan context, this is vital to apply all the farming communities without restricting to the wetland ecosystems and for that, steady government intervention and regular monitoring are essential. Even though there are efforts to promote community involvement to conserve the natural ecosystems in Sri Lanka, most of them have not become significant success stories and limited capacity for the enforcement of relevant laws is the major challenge for the sustainable management of natural ecosystems in Sri Lanka. Making facilities available for the farmers to regularly check their soil fertility status and availing due recommendations, overuse of chemical fertilizers for paddy farming could be controlled. Further, innovative policies and new farming approaches are needed to enable and prepare paddy farmers to overcome the economic, ecological, and social challenges of sustainable rice farming while conserving the natural environment. Hence it is the responsibility of respective local or regional authorities to design such policies that are at implementable levels.

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