Sustainability of Peri-Urban Rice Farming Practices in Ilorin, Nigeria

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ABSTRACT

This study assesses the sustainability level of environmental management practices among peri-urban rice farmers in Ilorin, Nigeria. Given the increasing demand for food in cities and the simultaneous reduction of agricultural land, peri-urban farming emerged as a crucial strategy for food security. Rice, a staple food in Nigeria, is increasingly cultivated in peri-urban areas, characterized by proximity to urban markets and intensive production methods. However, this farming system faces significant sustainability challenges that have received limited attention.

The research adopted a three-staged sampling technique, delineating the peri-urban zone of Ilorin based on distance thresholds and urban morphology. Questionnaires were administered to rice farmers in purposively selected communities. The sustainability index (SI) was adopted to evaluate the environmental management practices, categorizing farmers into unsustainable (0-0.39), moderately sustainable (0.40-0.60), and sustainable (0.61-1.0) groups.

Findings reveal that many of the environmental management practices employed by farmers are less sustainable. A significant majority (69.51%) rely on chemical sprays for crop protection, and 69.85% use chemical fertilizers, indicating an over-reliance on synthetic inputs. Practices like using resilient varieties (30.58%), natural products (51.63% never used), biofertilizers (16.99% often used), and lime (75.16% never applied) are less common. For soil erosion control, 59.28% construct bunds, but nearly half (49.85%) never use zero-tillage, contributing to soil degradation. The overall Environmental Management Practices Sustainability Index (EMPSI) for all farmers was 0.492, falling into the moderately sustainable category. Irrigated lowland rice producers showed the best performance in erosion control (0.572), while soil health maintenance practices had the lowest average index (0.432).

The study concludes by highlighting the need for improved sustainable environmental management practices among peri-urban rice farmers in Ilorin. It recommends an intensive education on the adverse effects of excessive chemical use and promotion of more sustainable alternatives to ensure long-term environmental health and agricultural productivity.

Keywords: Peri-urban, Sustainability index, rice farming

INTRODUCTION

Globally, feeding over 4.8 billion urban dwellers is a significant challenge in ensuring food security (FAO, 2021; Ahn et al., 2022). Over the years, unprecedented urbanisation has led to an increased demand for food in cities, while simultaneously reducing the availability of agricultural land. In response, urban and peri-urban agriculture (UPA) emerged as a strategy to address food shortages and job creation. Among various crops grown around cities, rice (Oryza sativa L. spp.) holds particular significance as the third most consumed cereal worldwide after maize and wheat (Vinci et al., 2023). With over 490 million tons (MT) global consumption (Arouna et al., 2021a), rice accounts for approximately 19% of the world's dietary energy supply (Rahman & Zhang, 2022).

In Sub-Saharan Africa (SSA), rice consumption exceeds production from the traditional farming system (USDA, 2024). Over the past two decades, the mean annual per capita consumption in SSA countries has risen from 17.5 kg to 48 kg (Rizal et al., 2024). In Nigeria, rice is the fastest-growing staple food. The Food and Agriculture Organization (2019) reported that it is the second most important staple in the country, accounting for 10.5% of the average caloric intake. With recent developments in Nigeria's rice value chain, rice has become a lucrative cash crop. Besides providing food for farmers, rice cultivation creates enormous income for many small-scale farmers. It generates jobs for more than 12 million Nigerians in its value chain (Adesiji et al., 2022).

Although rice cultivation thrives in all ecological zones in Nigeria, and its production is predominantly rural and rain-fed, peri-urban rice farming is fast gaining recognition in the country. Urban dwellers, particularly the poor, often engage in peri-urban rice farming to satisfy their dietary needs. According to Petrikova et al. (2024), peri-urban areas are defined as spaces where elements of urban construction have already spread to but remain interspersed with rural landscapes. Scholars view urban and peri-urban agriculture (UPA) as an industry that grows, rears, processes, markets, and distributes food within urban and peri-urban regions (Mougeot, 2005; Gravel, 2024; Petrikova et al., 2024; Rizal et al., 2024). Rice farming at urban fringes is characterized by its proximity to urban markets, intensive production, and direct access to consumers. It often involves more intensive farming methods compared to traditional rural agriculture due to land constraints and market demands. This farming system has enormous sustainability challenges, which have received little attention.

Sustainable peri-urban farming practices are the methods by which farmers manage soil, water, and other basic resources at the fringes of cities to increase productivity, while maintaining them to meet farm and family needs without adversely affecting the production environment and future resource utilization (Frimawaty et al., 2013; Ahn et al., 2022). The sustainability of rice farming methods has become a growing concern because of the increasing demand for natural resources (Stuart et al., 2017). The majority of peri-rice producers in Ilorin are small-scale farmers, practising four main types of cultivation systems: rainfed, irrigated, upland rice, and deep-water farming systems. The traditional environmental management practices of farmers pose significant environmental challenges and threaten efforts toward achieving Sustainable Development Goals 12 (responsible consumption and production) and 13 (climate action).

According to Xu et al. (2021), the urban and peri-urban agricultural sector contributes approximately 35% of anthropogenic greenhouse gas (GHG) emissions in cities each year. Rice fields are known to contain a substantial amount of greenhouse gases (methane and nitrous oxide) (Lesk, Rowhani & Ramankutty, 2016). To date, few empirical studies have systematically examined the sustainability level of environmental management practices among rice farmers with emphasis on traditional rural farming (Roy et al., 2013; Arouna et al., 2021b; Adesiji et al, 2022; Chang et al, 2024). Hence, this study aims to assess the sustainability level of environmental management practices among peri-urban rice farmers in Ilorin, Nigeria. The specific objectives are to (i) identify environmental management practices among peri-urban rice farmers and (ii) assess the level of sustainability of these practices.

MATERIALS AND METHODS

Description of study area

Ilorin, the capital of Kwara State, Nigeria, is located between latitudes 8°24'N and 8°36'N, and longitudes 4°30'E and 4°50'E. The city is made up of three (3) local government areas, namely: Ilorin West (105 km²), Ilorin East (486 km²), and Ilorin South (174 km²). It, however, cuts across some parts of the Asa and Moro LGAs. The core Ilorin and its surrounding peri-urban zone cover an area of approximately 490 km², with the

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built-up area extends over about 145 km². It is located in the Guinea Savanna grassland of Nigeria. Ilorin metropolis, situated along the Lagos-Kaduna Expressway, is approximately 306 km from Lagos, 600 km from Kaduna, and about 500 km from Abuja, the Federal Capital Territory of Nigeria.

River Asa is the most important river in Ilorin. It flows in the north-south direction and occupies a reasonably wide valley. The river practically divides Ilorin into two parts- the eastern and western parts. The eastern part covers the planned neighbourhoods where the government reservation areas (GRAs) are located, while the indigenous and core Ilorin grew organically, and are found in the western part (Orire et al., 2025). The drainage pattern, is dendrite with river Asa as the main water body and its tributaries which include rivers Agba, Alalubosa, Okun, Osere and river Aluko. The banks of these rivers provide fertile soils for all-season farming.

Population census of 2006 shows a figure of 777,667 people within the metropolis (Nigeria Population Commission, NPC, 2006). Using a growth rate of 2.8, a projected population of 1.31 million in 2025 reveals that Ilorin is the sixth-largest city in Nigeria by population (Abdulfatai et al, 2021). Majority of the farmers in Ilorin grow maize, rice, sorghum, millet, groundnut, cowpea, soybean, yam, cassava, and vegetables.

Delineating the peri-urban area of Ilorin

The authors are aware of the debate surrounding what constitutes a peri-urban area of a city. The term urban in itself has various definitions and operationalizations across countries. For example, what is considered ‘urban’ in a country like Lesotho may be considered a small town in another country, such as Nigeria (Chagomoka et al., 2018). Consequently, there is no one-size-fits-all definition. However, according to Salem et al. (2025), a peri-urban area (PUA) represents a dynamic interface between urban and rural areas, where urban expansion, rural livelihoods, and environmental sustainability intersect, posing complex challenges for land use management. Peri-urban environments serve as the hub for a variety of human activities, power dynamics, and social-ecological processes (Babalola et al., 2022; Rastandeh et al., 2025). While effective land use management in these transition zones is crucial for promoting sustainable urban growth, it remains one of the most challenging tasks for planners and policymakers.

While scholars such as Schlesinger (2013) and Badami and Ramankutty (2014) critique the use of the distance threshold to estimate peri-urban zones, many others accept it as the primary criterion to distinguish between the core city and the surrounding rural setting (Moustier, 2001; Mbuligwe, 2011; Chagomoka et al., 2018; Gravel, 2024; Cattivelli & Pinna, 2025). According to Moustier (2001), the peri-urban interfaces of most large Western and Central African cities begin around 50 km from the city centres. Additionally, similar studies conducted by the Africa Rice Centre, the National Resource Institute, and the International Water Management Institute in Côte d’Ivoire, Ghana, and Mali estimated the peri-urban area to be approximately 30–40 km from the city centre.

In our approach, we adopted a distance threshold and urban morphology to delineate the peri-urban zone of Ilorin. A radius of 10 km from the Emir of Ilorin’s palace (approximately the city centre) shows a dynamic interface in the urban-rural continuum. Hence, the first zone within 10 km is regarded as urbanized Ilorin, the second zone, 10–20 km, is the peri-urban Ilorin, while beyond 20 km is the rural area.

Table 1: Urbanized zones and peri-urban areas in Ilorin metropolis

Ilorin metropolis	Urbanization zone	Some main neighbourhood
Urbanized areas (core city)	Baboko	Taiwo road and Stadium axis
	Balogun Fulani	Maraba, Post office axis, Pakata axis
	Magaji Ngeri	Ilorin central mosque, Emir’s Palace, Idi Ape axis
	Oloje	Oloje central mosque axis, Idi Ose axis
	Okaka	Opo-Malu, Ipata market axis
	Oko-Erin	Irewolede, Asa Dam axis

Peri-urban zones	Malete axis	Shao area, Oloru, Malete, Sobi axis
	Warrah Osin	Gerewu area, Atere community, Idiya axis
	Madala axis	Okolowo axis, Madala area, Gbako
	Eyenkorin	Ballah axis, Pampo road, Eyenkorin central market
	Oke-Oyi	Badi area, Idi Igba axis
	Ajasse-Ipo axis	Jimba-oja area, Dogari, Idafian axis

Source: Adopted from Aduloju et al. (2025) and modified by the authors (2025)

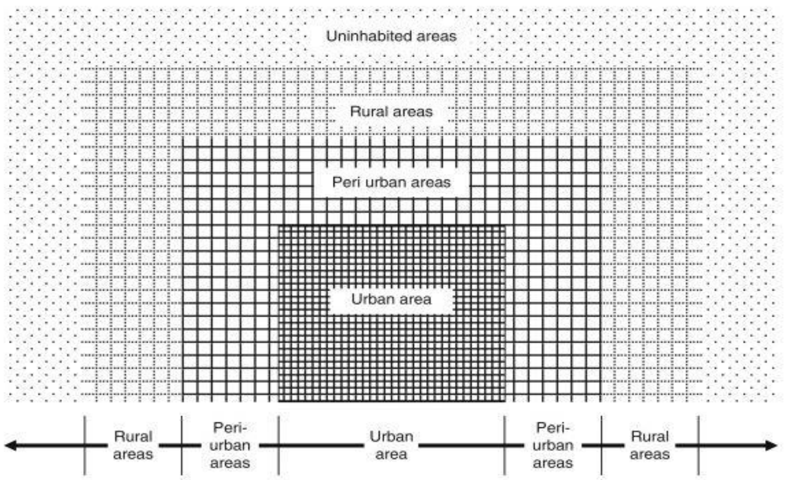

Figure 1: Illustration of Urban–Rural Continuum   Source: Mbuligwe (2011)

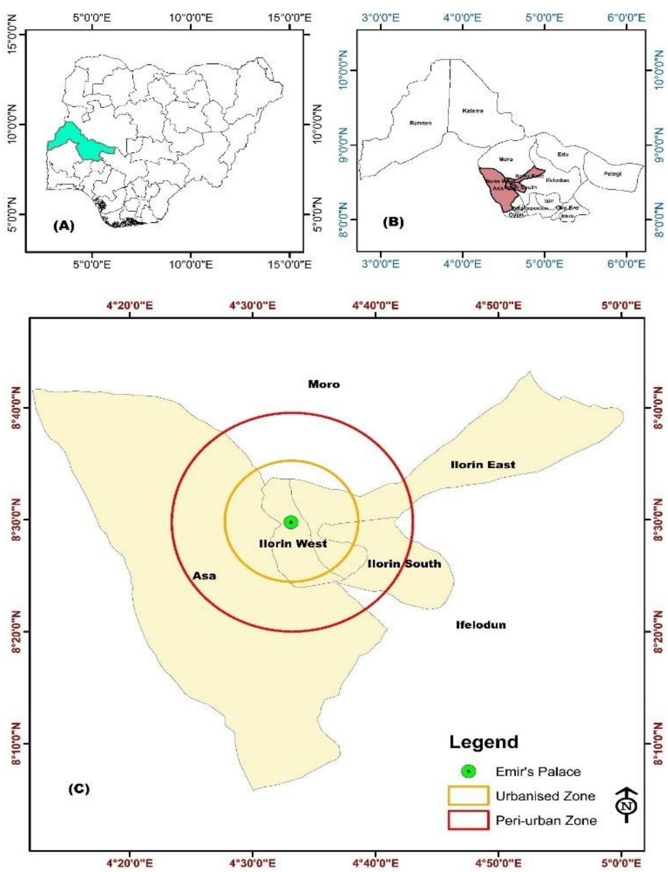

Figure 2: (A) Map of Nigeria showing Kwara State; (B) Map of Kwara State showing LGAs in Ilorin metropolis; (C) Map of the study area showing urbanised and peri-urban zones

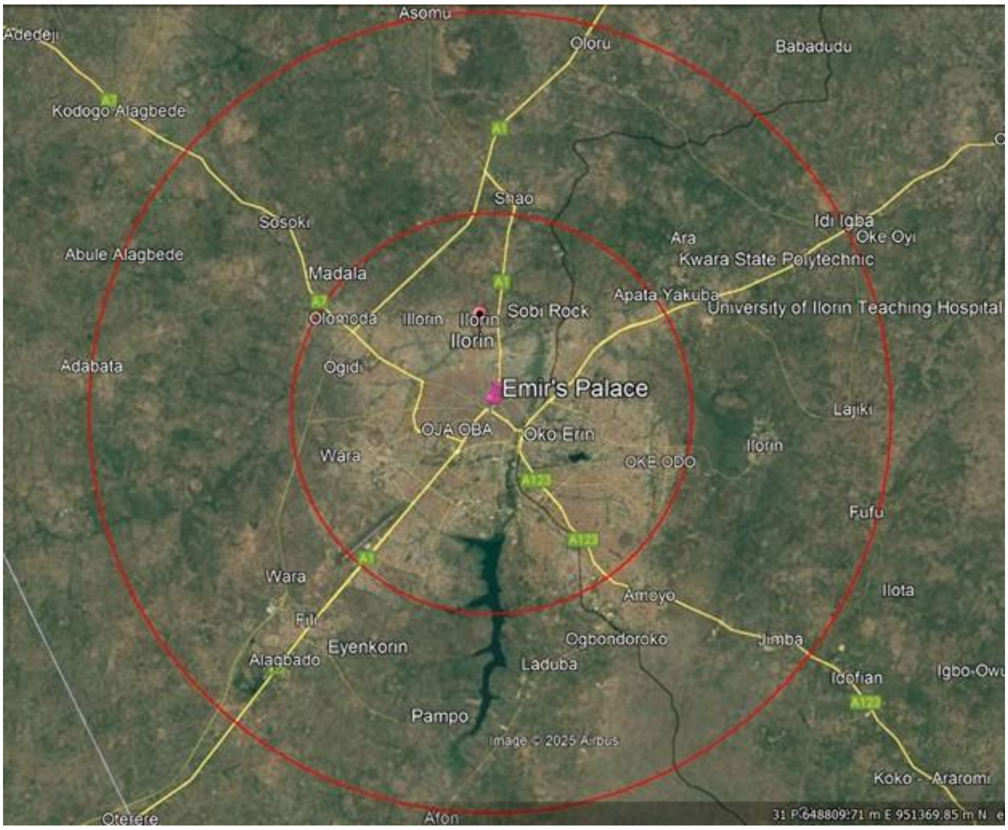

Plate 1: Imagery of Ilorin urban and peri-urban zone. Source: Google Earth Pro (2025)

Sampling technique, sample size, and method of analysis

A three-stage sampling technique was adopted to select the respondents. First, the Ilorin metropolis was divided into urbanized (0–10 km) and peri-urban (10–20 km) zones. Second, a distance gradient of the peri-urban interface was conducted, resulting in 10 - 13km, 13 - 17km, and 17 -20km as near, mid, and far peri-urban, respectively. Finally, six rice farming communities were purposively selected, and questionnaires were administered to the farmers.

Descriptive statistics were used to present the socioeconomic characteristics of the rice farmers. The sustainability index (SI) was used to evaluate the varying sustainability levels of the environmental management practices employed by rice farmers in the area. The sustainability index value ranges from 0 to 1 and is used to categorize farmers into three groups: the unsustainable group (0–0.39), the moderately sustainable group (0.40–0.60), and the sustainable rice farmer group (0.61–1.0).

Table 2: Sampled location and size in the peri-urban Ilorin

Peri-urban Zone	Communities surveyed	Sub-division of peri-urban	Coordinates	Sample size	Number of questionnaires returned
Malete axis	Shao	Near(10-13km)	$8^{o}35^{I}20^{II}$N, $4^{o}33^{I}37^{II}$E	60	58
Warrah Osin	Warrah	Mid (13-17km)	$8^{o}25^{I}13^{II}$N, $4^{o}27^{I}20^{II}$E	60	60
Madala axis	Madala	Near(10-13km)	$8^{o}33^{I}14^{II}$N, $4^{o}27^{I}58^{II}$E	60	59
Eyenkorin	Pampo	Mid (13-17km)	$8^{o}21^{I}16^{II}$N, $4^{o}30^{I}47^{II}$E	60	58
Oke-Oyi	Idi Igba axis	Far (17-20km)	$8^{o}21^{I}16^{II}$N, $4^{o}30^{I}47^{II}$E	60	60
Ajasse-Ipo	Jimba-oja	Far (17-20km)	$8^{o}34^{I}35^{II}$N, $4^{o}42^{I}00^{II}$E	60	57
					N = 352

Source: Field survey (2024)

RESULTS AND DISCUSSION

Environmental management practices

This section examines the existing environmental management practices adopted by rice farmers in the study area. Twenty environmental management practices were identified and grouped into three thematic areas: environmental management practices for rice crop protection, practices for maintaining soil fertility, and management practices for erosion control (see Table 3, columns a, b, and c, respectively).

Peri-urban rice protection practices

Table 3, column a, presents the environmental management practices adopted by peri-urban rice farmers to protect rice crops. It involves all the processes from seed selection to harvesting. The results revealed that 69.51% of the rice farmers used chemicals to combat weeds and protect rice. The use of chemicals such as herbicides, pesticides, and insecticides to protect rice from weeds, insects and disease is a common practice among peri-urban rice farmers in Ilorin. A focused group discussion with the farmers indicated that the Federal Government of Nigeria annually supports small-scale rice farmers with agrochemicals and knapsack sprayers. However, there is insufficient knowledge about the dangers of excessive usage of chemicals on the sustainability farming in this transition zone (Obaniyi et al., 2019). With respect to the use of tolerant varieties, only 30.58% adopted climate-resilient crops. More than half (51.63%) of the rice farmers had never used natural products (such as organic fertilizer) or biological means of weed and pest control. These findings corroborate the works of Roy et al. (2013) and Dumrongrojwatthana et al. (2020), who opined that rice farmers at urban fridges use excessive chemicals to improve yields.

Table 3: Environmental management practices used by rice farmers for rice crop protection Maintenance of soil fertility and control of soil erosion

(A) Environmental management practices used by rice farmers for crop protection			**(B) Environmental management practices by rice farmers for maintenance of soil fertility**			**(C) Environmental management practices used by rice farmers to control for soil erosion**		
Characteristics	**Category**	**Freq. (%)**	**Characteristics**	**Category**	**Freq. (%)**	**Characteristics**	**Category**	**Freq. (%)**
Spraying of chemical	Never used	14 (3.96%)	Use of chemical fertilizer	Never used	26 (7.38%)	Construction of bunds	Never used	42 (11.98%)
	Rarely used	40 (11.28%)		Rarely used	25 (7.08%)		Rarely used	45 (12.87%)
	Often used	54 (15.24%)		Often used	55 (15.69%)		Often used	56 (15.87%)
	Always used	244 (69.51%)		Always used	246 (69.85%)		Always used	209 (59.28%)
	Total	352 (100%)		Total	352 (100%)		Total	352 (100%)
Use of tolerant variety	Never used	34 (9.79%)	Use of biofertilizer	Never used	179 (50.96%)	Smoothening and levelling	Never used	33 (9.49%)
	Rarely used	60 (17.13%)		Rarely used	53 (15.06%)		Rarely used	50 (14.24%)
	Often used	150 (42.51%)		Often used	60 (16.99%)		Often used	92 (26.27%)
	Always used	108 (30.58%)		Always used	60 (16.99%)		Always used	177 (50.00%)
	Total	352 (100%)		Total	352 (100%)		Total	352(100%)
Use of biological/natural products	Never used	182 (51.68%)	Use of organic manure	Never used	147 (41.88%)	Integrated cropping	Never used	171 (48.71%)
	Rarely used	81 (22.94%)		Rarely used	97 (27.50%)		Rarely used	100 (28.39%)

	Often used	51 (14.37%)		Often used	61 (17.19%)		Often used	40 (11.29%)
	Always used	38 (11.01%)		Always used	47 (13.44%)		Always used	41 (11.61%)
	Total	352 (100%)		Total	352 (100%)		Total	352(100%)
Adjusting sowing dates	Never used	101 (28.80%)	Use of lime	Never used	265 (75.16%)	Zero tillage	Never used	175 (49.85%)
	Rarely used	116 (33.33%)		Rarely used	46 (13.21%)		Rarely used	54 (15.48%)
	Often used	55 (15.53%)		Often used	19 (5.35%)		Often used	75 (21.36%)
	Always used	80 (22.69%)		Always used	22 (6.28%)		Always used	48 (13.31%)
	Total	352 (100%)		Total	352 (100%)		Total	352(100%)
Use of light traps and other mechanical means	Never used	194 (55.08%)	Use of crop rotation	Never used	208 (59.27%)	Use of mulching	Never used	164 (46.54%)
	Rarely used	97 (27.69%)		Rarely used	59 (16.72%)		Rarely used	79 (22.33%)
	Often used	37 (10.64%)		Often used	57 (16.11%)		Often used	22 (6.29%)
	Always used	24 (6.77%)		Always used	28 (8.00%)		Always used	87 (24.84%)
	Total	352 (100%)		Total	352 (100%)		Total	352(100%)
Crop rotation	Never used	187 (53.09%)	Use of fallow	Never used	224 (63.58%)	Planting of cover crops	Never used	205 (58.31%)
	Rarely used	95 (80.25%)		Rarely used	67 (19.14%)		Rarely used	84 (23.82%)
	Often used	35 (9.88%)		Often used	25 (7.10%)		Often used	23 (6.58%)
	Always used	35 (9.88%)		Always used	36 (10.18%)		Always used	40 (11.29%)
	Total	352 (100%)		Total	352 (100%)		Total	352(100%)
						Construction of canal	Never used	97 (27.63%)
							Rarely used	59 (16.82%)
							Often used	45 (12.91%)
							Always used	151 (42.64%)
							Total	352(100%)
						Use of sandbags	Never used	86 (24.44%)
							Rarely used	76 (21.59%)
							Often used	75 (21.27%)
							Always used	115 (32.70%)
							Total	352(100%)

Source: Field survey (2024)

Soil fertility maintenance practices by peri-urban rice farmers in Ilorin

The results of the environmental methods adopted by farmers to maintain soil fertility are presented in Table 3, Column B. The findings indicate that the majority (69.85%) of the rice farmers used chemical fertilizer to increase soil fertility. The effect of using chemical fertilizer over a long period leads to a further degradation of soils. It also increases production costs and reduces the profit of peri-urban rice farmers (Mali et al., 2023). In the study area, it is erroneously believed that the only way for rice production to thrive is to apply a large amount of inorganic or chemical fertilizer, especially urea. The findings show that only 16.99% of the rice farmers often used biofertilizers. This finding is similar to the result obtained by Naher et al. (2015) in India. They reported that rice farmers' overdependence on synthetic fertilizers is a major cause of greenhouse gases and a pollutant of underground water.

Also, the result revealed that three-quarters (75.16%) of the rice farmers did not apply lime to their rice farms. Liming is commonly used to improve the productivity of acidic soil by increasing the soil pH, thereby reducing the acidity of the soil. Only 6.29% of the rice farmers used lime to control soil acidity. Moreover, 63.58% of the rice farmers interviewed never abandoned their farmland, so their fertility could be restored. This might be associated to high competition for land in this area. Bush fallowing is not a common practice among the peri-urban farmers sampled. This could explain why rice farmers continue to rely on chemical fertilizers to increase production and improve soil fertility at the expense of maintaining a healthy environment.

Soil erosion control practices by peri-urban rice farmers

Peri-urban rice farmers in Ilorin employ eight primary strategies to control soil erosion. Table 3 column C shows that 59.28% of the rice farmers constructed bunds to prevent soil erosion. The results suggest that many of the farmers practice intensive tillage, as almost half (49.85%) of them never use the zero-tillage method in their rice production. This predisposes the soil to erosion and negatively affects the soil fertility and biodiversity balance of the environment. This result aligns with the findings of Kumar et al. (2021), who reported that the health and nutritional balance of soils were negatively impacted by the excessive cultivation and puddling operations of rice farmlands in India. Zero tillage, which involves the direct sowing of seeds into compacted farmlands, ensures the ecological balance of the farms (Mukhlis et al., 2024). Additionally, by maintaining the physical characteristics of the soil layer, the no-tillage method increases the wilting point, bulk density, infiltration, and field capacity through microbial and biotic activity (Ahmad et al., 2020). However, high soil compaction was observed in some farmlands in the study area, which might account for the low patronage of zero tillage among the peri-urban rice farmers.

The study revealed that only 24.84% of the rice farmers mulched their rice. Mulching is useful for improving crop yield, grain quality, and rice water productivity through soil moisture retention, erosion and pest control and suppressing weed growth. Another 11.29% of the rice farmers planted cover crops on their rice plots as a means of controlling soil erosion. The results further revealed that 42.64% of the peri-urban rice farmers invested in canals and drainage construction to manage soil erosion. Another method of controlling erosion in the study area is the use of sandbags, with approximately 32.70% of the rice farmers constantly using it to control floods and erosion on farmlands.

Sustainability of peri-urban rice farming practices in Ilorin, Nigeria

The environmental management practices sustainability index (EMPSI) is a measure of the sustainability of rice farmers and indicates the degree of environmental challenges faced by the farmers (Jiao et al.; 2023). A higher EMPSI value indicates that growers faced fewer challenges related to the dimensions of environmental sustainability. This, however, does not indicate long-term performance. The sustainability indices of the three rice farming systems in the study area are presented in Table 4.

Table 4: Table of Sustainability Indices According to Rice Production Systems

Environmental Dimension	Rainfed Upland	Rainfed Lowland	Irrigated lowland	Total
Crop Protection Practices	0.517	0.467	0.509	0.498
Soil Health Maintenance Practices	0.442	0.385	0.468	0.432
Erosion Control Practices	0.526	0.544	0.572	0.547
Mean (x)	**0.495**	**0.465**	**0.516**	**0.492**

Source: Field Survey (2024)

The overall index score for all the farmers was 0.492 on a scale of zero to one. The EMPSI value of 0.492 means that the rice farmers in the study area were practising less sustainable rice farming systems. The irrigated lowland rice producers had the best performance in terms of the use of practices that enhanced the control of erosion. The results show that farmers' erosion management practices support a healthy environment, with an index of 0.547. Additionally, a score of 0.572 indicates that the irrigated peri-urban rice producers used more of the practices recommended for the control of erosion. This might be explained by the fact that irrigated rice systems use technologies that help reduce the negative impacts of erosion on the environment.

The rainfed lowland rice growers also performed well in the practices they used to control erosion. The results revealed a score of 0.544, which was within the moderately sustainable threshold. The lowest performance was recorded for the rainfed upland rice systems, with an average index score of 0.526. Similarly, the results show that irrigated lowland and rainfed lowland rice systems are moderately sustainable in terms of the use of practices that could protect rice crops from pests. Nevertheless, the irrigated lowland rice system outperformed the rainfed lowland rice system. Rice producers in both production systems use synthetic chemicals to protect their crops.

The practices used by peri-urban rice producers to improve soil fertility. The average index for all the rice producers on the maintenance of soil health fertility was the lowest at 0.432, which is moderately sustainable. These results indicate that producers may experience soil nutrient depletion and leeching. Peri-urban rice producer would have to replace chemical fertilizer with biofertilizers. Naher et al. (2015) reported that in Malaysia, biofertilizers reduce the use chemical fertilizer by 30%, increase the yield of grain by 69%, and increase the straw yield by 35%.

Determinants of sustainability level of peri-urban rice farming practices in Ilorin

Table 5 presents the results of multinomial logistic regression, which examines factors that determine the sustainability of the environmental management practices among peri-urban rice farming in Ilorin.

Table 5: Determinants of sustainability level of peri-urban rice farming practices in Ilorin

Variable	Unsustainable	Moderately Sustainable
Household size	0.0527008 (0.80)	0.0423349 (0.85)
Farming experience	0.0342879 (1.30)	0.0154367 (0.74)
Group membership	1.548549** (2.32)	-0.5974488 (0.31)
Years of successful schooling	2.187755 (0.99)	0.0691141 (0.71)
Nonfarm income (N)	-4.89e-06 (-0.28)	3.24e-06 (0.28)
Rice farm size (Ha)	-0.2369935 (0.53)	0.17515961(0.47)
Qty of fertilizer (kg)	-0.0128161 (-0.33)	0.0392491 (-1.25)
Qty of chemical (l)	-0.0289821 (-0.68)	-0.0358984 (-1.11)
Labour (MD)	0.0844725** (2.07)	0.0734824** (2.12)

Upland rice system	0.599676 (0.85)	0.2072479 (0.37)
Lowland rice system	0.9518488** (1.81)	0.9731452** (2.38)
Constant	0.6928743 (0.52)	2.187755 (2.07)
Log likelihood ratio (λ)	-247.075	

** $p < 0.05$;

Number of observations = 352

LR chi square (39) = 47.99

Prob > 0.1806

Pseudo $R^2 = 0.088$ Log likelihood = - 247.075

Source: Field Survey (2024)

The results in Table 5 show the logistic coefficient for each independent variable and each alternative category of the dependent variable. From the LR (39) = 47.99, the P-value is greater than the 0.05 (0.18806) and the model is not statistically significant different, so we fail to reject the null hypothesis. This means that, collectively, the predictors do not explain the sustainability level of environmental management practices in a statistically significant way, though individual variables might still show significant associations. The positive and significant coefficients of variables such as farming group membership, labour required for planting and rainfed lowland rice production systems imply that the probability of grouping peri-urban rice producers into different environmental management practices sustainability categories relative to the reference group increases as these variables increase.

The mean likelihood estimates revealed that the variables that significantly influenced the sustainability level of environmental management practices in peri-urban rice farming were group membership, labour requirements, and rainfed lowland rice production systems ($p < 0.05$). The implication is that a unit increase in these inputs has the probability of increasing the sustainability level by 2.32%, 2.07%, and 1.81%, respectively. A positive value indicates that inputs were not used at an optimal level. Therefore, an additional unit of these inputs used by rice farmers will lead to increased crop yield.

The mean likelihood estimate for membership of the rice producers' group implies that a unit increase would be expected to increase the relative probability of the rice farmers belonging to the comparison category moving to the reference category. The results indicate that farmer participation in the rice producer group positively affects the sustainability of rice farmers' environmental management practices and was significant at the 5% level. This implies that farmers who are members of the rice farmer association stand the chance of building capacity, receiving training on sustainable rice production, transferring knowledge, making collective purchases of inputs at better rates, and ensuring market accessibility.

The amount of labour required for planting rice was found to be positively and significantly correlated with the level of sustainability of environmental management practices. A unit increase in labour (man-day) required for planting may, in turn, increase the probability of peri-urban rice producers in the unsustainable and moderately sustainable groups by factors of 2.07 and 2.12, respectively, to move into the sustainable group. This result implies that the number of man-day for planting on nursery beds and transplanting was high. Peri-urban rice farmers tend not to follow the standard procedure in terms of spacing and the quantity of seeds to plant per row. If too much labour is required for sowing, it will deter the farmers from following through on prescribed guidelines. The rigorous and intensive nature of the task of planting/transplanting also has implications for farmer health. The posture assumed during the performance of this task has implications for the sustainability of environmental management practices since it affects farmer health in the long run, and farmers eventually suffer from backache and other health-related issues.

The rainfed lowland rice production system employed by rice farmers was found to be positively and significantly correlated with the level of sustainability of environmental management practices. This implies that a one-unit increase would be expected to increase the relative probability of rice farmers belonging to the comparison category (i.e., unsustainable and moderately sustainable) to move to the reference category. This result further shows that rainfed lowland rice production systems are still grossly underutilized and that farmers can maximize benefits from rainfed lowland rice production systems by using environmental management practices that can lead to increased yields, healthy environments, and improved wellbeing. Importantly, rainfed lowland rice systems constitute the most common rice ecosystem and are the most common among rice farmers. Concerted efforts should be made to ensure that rice farmers are motivated to achieve optimal outcomes from this system.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study investigated the sustainability level of environmental management practices among peri-urban rice farmers in Ilorin, Nigeria. The findings reveal that while peri-urban agriculture plays a crucial role in food security and job creation in the region, the current environmental management practices employed by rice farmers are largely unsustainable or only moderately sustainable. Specifically, the widespread reliance on chemical inputs for crop protection and soil fertility maintenance poses significant environmental risks, including soil degradation, greenhouse gas emissions, and water pollution. The study highlighted that a high percentage of farmers use chemical fertilizers (69.85%) and chemical pesticides (69.51%), with insufficient knowledge about their long-term dangers. Practices such as liming and the use of biofertilizers are underutilized (6.29% and 16.99% respectively). Furthermore, traditional practices like bush fallowing are not common due to land competition, leading to continuous reliance on chemical inputs to maintain productivity.

Regarding soil erosion control, while bund construction is common (59.28%), intensive tillage is still prevalent (49.85% never use zero-tillage), contributing to soil erosion and negatively impacting soil health. Practices like mulching (24.84%) and planting cover crops (11.29%) are not widely adopted.

The Environmental Management Practices Sustainability Index (EMPSI) of 0.492 indicates that the overall sustainability of rice farming systems in the study area is less than optimal, falling into the moderately sustainable category. While irrigated lowland rice systems show better performance in erosion control, the general trend points towards practices that do not support long-term environmental health.

Factors influencing sustainability include group membership, labour requirements, and rainfed lowland rice production systems. Membership in farmer groups positively impacts sustainability by facilitating knowledge transfer, training, and access to resources. However, the intensive labour required for planting, particularly due to non-standard procedures, can deter farmers from adopting more sustainable practices. The underutilization of rainfed lowland rice systems, despite their prevalence, also presents an opportunity for improving sustainability through better management practices.

Recommendations

Based on the findings of this study, the following recommendations are put forth to enhance the sustainability of peri-urban rice farming practices in Ilorin, Nigeria:

1. Promote sustainable agricultural practices: There is an urgent need to educate peri-urban rice farmers on the adverse effects of excessive chemical use and promote the adoption of more sustainable alternatives. This includes encouraging the use of organic fertilizers, biofertilizers, and biological pest control methods. Demonstrations and field schools can be effective in showcasing the benefits and practical application of these methods.

2. Knowledge enhancement and Awareness: Government agencies and agricultural extension services should intensify efforts to provide comprehensive training programs for farmers on sustainable farming practices. This training should cover proper chemical application, the benefits of tolerant crop varieties, and the importance of soil health management techniques such as liming and crop rotation.
3. Encourage zero or low-tillage and mulching: To combat soil erosion and improve soil health, farmers should be encouraged and incentivized to adopt zero-tillage practices and mulching. This can be achieved through awareness campaigns, provision of appropriate tools, and financial support for initial adoption.
4. Strengthen farmer cooperatives and associations: Supporting and strengthening farmer groups can significantly improve the adoption of sustainable practices. These groups can serve as platforms for knowledge sharing, collective purchasing of sustainable inputs, and accessing credit and markets. Policy interventions should aim to facilitate the formation and growth of such associations.
5. Optimize labour practices: Research and extension efforts should focus on developing and disseminating labour-efficient planting techniques that align with sustainable practices. This could involve introducing improved tools or methods that reduce the physical burden on farmers while adhering to recommended spacing and planting densities.
6. Invest in rainfed lowland rice systems: Given that rainfed lowland rice systems are common, there is a significant opportunity to improve their sustainability. Investment in research and development for improved varieties and management practices tailored to these systems can lead to increased yields and environmental benefits.
7. Policy support and incentives: The government should formulate and implement policies that incentivize sustainable farming practices, such as subsidies for organic inputs, tax breaks for adopting eco-friendly technologies, and penalties for environmentally damaging practices. This will create a conducive environment for farmers to transition towards more sustainable methods.

By implementing these recommendations, it is possible to significantly improve the environmental sustainability of peri-urban rice farming in Ilorin, contributing to both food security and environmental protection in the region.

AUTHORS' CONTRIBUTIONS

Abubakar Alhaji Ahmed conceptualized and designed the study. Rasheed Abiodun Kuranga championed data collection and analysis. Abubakar Alhaji Ahmed and Oluwadara Latifat Isola-Muyideen wrote the first draft of the manuscript, and all authors commented on previous versions of the manuscript. The authors have read and approved the final manuscript.

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DECLARATION OF CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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DATA AVAILABILITY STATEMENT

Data generated and analysed during this study are not publicly available. However, it can be made available by the corresponding author on reasonable request.

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