ADOPTION DECISION AND INTENSITY OF INORGANIC FERTILIZER USAGE AMONG PADDY FARMERS IN KALUTARA: A CRAGG'S DOUBLE HURDLE MODEL APPROACH

Ishara I.D.C.[1], Thayaparan A.[1] and Gunathilaka G.Y.N.[1]

Abstract

Fertilizer, whether inorganic or organic is one of the most essential inputs for increasing productivity which leads to increase the agricultural production and the income of the farming community. Therefore, understanding the factors that affect farmers' use of fertilizers is crucial to develop strategies to improve its efficient use and to minimize its negative impacts on rural community. In this background, this study aimed to identify the determinants of adoption decision and intensity of inorganic fertilizer usage among paddy farmers in Kalutara district. The data related to 150 paddy farmers were collected from Mathugama, Dodangoda and Horana Divisions in Kalutara district using multistage random sampling method. Among the respondents, 56% were farmers adopting inorganic farming and 44% of them adopting organic fertilizers. Results of independent samples t-test suggested that on average farmer's age, distance to the nearest market and land size significantly differed between inorganic and organic farmers. Cragg's double hurdle model was used to investigate the determinants of adoption decision and intensity of inorganic fertilizer usage among paddy farmers. The results of the study revealed that the likelihood of fertilizer adoption decision was influenced by land size, distance to the nearest market and credit accessibility while, the factors such as age, income and, off – farm income significantly influenced the intensity of fertilizer adoption. Therefore, a concerted effort is needed to encourage fertilizer adoption and intensity of inorganic fertilizer usage by increasing the size of land, facilitating to access credit, motivating the young farmers towards paddy farming and, stimulating the farmers to engage in off – farm income activities, which could be useful for fertilizer adoption decision and its extension of application in the study.

Keywords: Adoption Decision, Cragg's Double Hurdle Model, Inorganic Fertilizer, Land Ownership, Off – Farm Income.

[1] Department of Business Economics, University of Vavuniya, Vavuniya, Sri Lanka.
*Corresponding author. Email: aruppillaithayaparan@yahoo.com

1. Introduction

Sri Lanka is an emerging economy as well as it is classified as a developing economy that relies heavily on agriculture, services, and industry. In particular, the cultivation of rice serves as the primary food crop and is vital for over 70 percent of the country's rural population. In 2021, Sri Lanka's economy exhibited a real growth rate of 3.7 percent, indicating a significant improvement compared to the 3.6 percent contraction experienced in the previous year. The agricultural sector contributes approximately 7 percent to the Gross Domestic product (GDP) and employs 27 percent of the workforce, the industrial sector contributes around 26 percent to the GDP and employs a similar proportion of the workforce (Institute of Policy Studies of Sri Lanka, 2022). Over time, Sri Lanka has undergone a conventional process of structural change, leading to a decrease in the agricultural sector's share of the GDP, while witnessing an increase in the shares of both industry and services. Consequently, the agricultural sector's contribution to the overall GDP has exhibited a decline in comparison to the contributions of other sectors. To mitigate price fluctuations and ensure a consistent supply of rice, the government periodically intervenes in the paddy and rice markets. Since 1962, Sri Lanka has implemented a fertilizer subsidy program aimed at encouraging farmers to adopt high-yielding rice varieties, thus achieving rice self-sufficiency, and alleviating the financial burden on farmers (Institute of Policy Studies of Sri Lanka, 2022).

Sri Lanka is facing one of its worst economic crises, on the heels of the havoc created by the coronavirus (COVID 19) pandemic and policy responses. The adverse impacts of food shortages and high prices are causing public unrest, especially among the poor people with limited access to food. As the economic crisis unfolded, the government announced a ban on the importation of chemical fertilizers, pesticides, and herbicides as of May 2021. Since 1962, fertilizer subsidies were provided in various forms, with the main objective of making fertilizer available as cheaply as possible to encourage its wider use and thereby expanding agriculture production. However, the government suddenly moved to ban chemical fertilizers and agrochemicals with the aim of transitioning to 100% organic farming as well as to introduce an organic fertilizer policy. The agricultural sector has since suffered from the loss of production, sparking unrest among farmers due to the significant drop in farm incomes, food shortages and rising food prices. The loss of farm- related livelihoods in turn resulted in a further deterioration of food security in the country. (Institute of Policy Studies of Sri Lanka, 2022).

The fertilizer ban has had a sizeable adverse impact on Sri Lanka’s paddy production. Over the last few decades, paddy production had expanded considerably due to the expansion of irrigation coverage, cultivation of high – yielding varieties and the increased use of fertilizers. As a result, since 1960s, paddy productivity has improved overtime in both Yala and Maha seasons but, with the chemical fertilizer ban, it was predicted that the average yield of paddy can drop by 30% approximately if chemical fertilizers are fully replaced by organic fertilizers and paddy farming productivity was assumed to be reduced by 33% due to this productivity loss (Institute of Policy Studies of Sri Lanka, 2022).

Although the ban on the importation of inorganic fertilizers and other agro-chemicals was cancelled towards the latter part of 2021, the fertilizer importation continued to remain low with the lack of domestic foreign exchange liquidity raising concerns about overall agricultural production. Many farmers use agro-chemicals for their crops, and they believe that it will increase the paddy yield (Perera**,** 2020). Majority of paddy farmers in Sri Lanka are engaged in inorganic paddy cultivation practices due to high productivity and high profit margins. However, since of late, some farmers tend to practice organic paddy cultivation due to higher market prices and higher demand for the traditional varieties (Dayarathne & Gunawardena, 2014).

Kalutara district is one of the major districts which practice both organic and inorganic paddy cultivation systems successfully and it contributes 55% of the total production of the Low Country Wet Zone. Out of the total paddy cultivated land 81.1% is practicing chemical intensive cultivation and 10.7% is practicing organic based paddy cultivation (Kalutara District Secretariat, 2014). In such background, this study examined the factors influencing the adoption decision on fertilizer and the intensity of its usage in Kalutara district, Sri Lanka. The farmers have the options to adopt to fertilizer if it is inorganic or inorganic is determined by many factors, and among them, this study tries to answer the two main research questions which are the demographic and farming characteristics influencing the decision on fertilizer usage and its intensity, as well as, how these characteristics affect their decision, and the amount of fertilizer usage, in the study. Further, if they adopt inorganic fertilizer how much they would purchase fertilizer depends on demographics like age, gender, education and farming characteristics like land size, experience, etc. Based on these reasons the following two objectives were considered in the study.

Objectives of the study

1. To identify the key demographic and farming characteristics which influence the probability of fertilizer adoption decision among paddy farmers in Kalutara District.
2. To determine how the demographic and farming characteristics influence the intensity of inorganic fertilizer usage among the paddy farmers in the above study area.

2. Literature Review

There are many researchers who had analyzed the factors influencing the adoption decision and intensity of fertilizer usage among different crops cultivated by farmers in different countries. Some of them had focused on the adoption decision towards organic fertilizer and others had focused on inorganic fertilizers in their studies. In Sri Lanka, the research on the adoption decision and intensity of inorganic fertilizer usage among paddy farmers is limited. A study was conducted by Dayarathne & Gunawardena (2014) focused on the economic analysis of organic and inorganic paddy cultivation systems in the Kalutara district. Another study was done by Perera (2020) which examined the impact of agrochemical usage on paddy yield in the same district, utilizing a regression approach. Further, there is a dearth of studies conducted by researchers specifically focusing on the intensity of inorganic fertilizer usage utilizing the double hurdle regression model. Thus, this study aimed to fill the

research gap by considering these issues and explain how demographic and farming characteristics determined the adoption decision and intensity of inorganic fertilizer usage among paddy farmers in Kalutara district. From the findings of the study, specific contributions to society are assessed and it also fits within the existing literature. However, by applying different analytical tool such as double hurdle model, the study was able find the factors to determine the both adoption decision and intensity of inorganic fertilizer usage together which were not explained by the previous scholars and researchers.

Dalango & Tadesse (2019) found that in the first stage, the decision to adopt chemical fertilizer usage was influenced by factors such as farm size, family size, availability of family labor, education level, access to credit and information, and distance to the nearest market. In the second stage, the intensity of chemical fertilizer application was influenced by membership in a cooperative, availability of extension services, access to credit, farm size, family size, availability of family labor, educational level, and the gender of the household head. Similarly, Muluneh et al., (2022) conducted a study and found that the utilization of organic fertilizer was positively associated with factors such as age, marital status, literacy level of the household head, number of laborers, farming experience, and farm size. On the other hand, factors such as marital status, labour costs, household income, and distance between the home and farm were found to have a negative association with the utilization of organic fertilizer.

Olatunji & Akanbi (2022) investigated the drivers and pattern of fertilizer usage among cereal-based farmers in Kwara State, Nigeria and they concluded that household size, access to credit, cost of fertilizer, distance to point of purchase and marital status statistically influenced the usage of fertilizer.

In another study done by Dabessa Iticha et al., (2021), the focus was on understanding the factors that determine the use of inorganic fertilizer and its profitability in smallholder maize production in Ethiopia. Their findings indicated that factors such as education level, livestock ownership, and regular interactions with extension agents had a positive impact on both the probability and intensity of fertilizer use. On the other hand, the perception of production costs had a negative effect on both the adoption and intensity of fertilizer use. Interestingly, the study also revealed that off-farm income had a positive influence on the intensity of fertilizer use among the participants. Aligned with the same idea, Tadesse & Molla (2021) analyzed the factors influencing the utilization of inorganic fertilizers among small-scale farmers in South Wollo, Ethiopia and they found that, farm size, total income, use of credit service, and frequency of extension contact were found significantly promoting the amount of fertilizer used by smallholder farmers.

Researchers examined the factors that affect the acceptance and the use intensity of organic fertilizer. The findings demonstrated that various factors, namely gender, household size, availability of credit and extension services, knowledge of organic fertilizer usage, land ownership, size of livestock, and access to social grants, significantly influence the adoption of organic fertilizer. Similarly, the age of the farmer, knowledge regarding organic fertilizer usage, farm size, and livestock holding

size were found to significantly impact the intensity of organic fertilizer usage (Zondo, 2020).

Beshir et al., (2012) and Dassa et al., (2022) examined the determinants of the intensity of inorganic fertilizer usage and they found that age, land size, non – farm, and sex are the main factors in determining the use of fertilizer intensity in the study. Aryal et al., (2021) examined the factors affecting farmers' use of organic and inorganic fertilizers in South Asia using Heckman models and the findings demonstrated that the utilization of organic and inorganic fertilizers in rice and wheat is affected by a range of socio-economic and geographical factors.

In a study conducted by Anago et al., (2020) in Benin it was discovered that the adoption of inorganic fertilizer technology is influenced by factors such as age, educational background, household size, the importance of rice in household income, and the use of organic fertilizers. Similarly, the intensity of inorganic fertilizer usage is significantly affected by the farmer's age, the quality of training in soil fertility management, the size of the rice cultivation area, the contribution of rice to household income, farming experience, the availability of inorganic fertilizers, and the utilization of organic fertilizers.

Tefera et al., (2020) did a research on the determinants of smallholder farmers' decisions on fertilizer usage for cereal crops in the Ethiopian highlands and their results showed that the probability of fertilizer adoption increased due to the household education status, the number of active family members, access to credit, cooperative membership, and an increase in farm size. Conversely, the intensity of use of fertilizers was influenced by the status of education of the household head, family size, access to credit, membership to cooperatives, the use of crop rotation, annual income, number of farm plots owned, the use of soil and water conservation, and agroecology.

Belete (2022) analyzed the factors that determine the Organic fertilizer adoption in Moretna Jeru District, Northern Ethiopia and they found that, farmers' characteristics such as extension contact, amounts of livestock, landownership via title deed, and household size have a favorable and they significantly impact on organic fertilizer usage.

3. Materials and Methods

The data utilized in this research was gathered through a survey carried out on a group of paddy farmers located in the Kalutara District, specifically during the Maha season, which spans from September to March, in the year 2020-2021. To select the divisions and paddy farmers, a multistage random sampling approach was employed. In the first stage, Kalutara district was selected purposely which has 14 Divisional Secretariats (DS) and inorganic and organic based paddy cultivating divisions were selected according to the 2020 Yala/Maha statistics and the information from agrarian officers. According to that Horana, Mathugama and Dodangoda divisions were selected by adopting systematic sampling in the second stage. Farmers who were implementing inorganic and organic based paddy farming during the 2020 Maha season were considered for the sample selection and based on that, in the third stage, self-administered questionnaires were used to collect information from a total of 150 both inorganic and organic farmers who were cultivating paddy in the selected study

area. The farmers were asked whether they adopted inorganic or organic fertilizer in their paddy farming using binary scale and if they adopt inorganic, how much of inorganic fertilizer they used to gauge the inorganic fertilizer intensity as the next question. Based on these, after collecting the data the farmers could be grouped into two as inorganic farmers and organic farmers in the study. Data analyses were carried out using various analytical tools such as descriptive statistics, frequency, chi – square test, independent samples t – test. Cragg's double hurdle model was applied to identify the factors that determine the fertilizer adoption decision and the intensity of inorganic fertilizer usage of paddy farmers in the study.

Cragg's double hurdle model

The provided information describes the use of Cragg's double hurdle model in analyzing the determinants of adoption decisions and intensity of fertilizer use at the farm level. The study employed a two-stage approach, where the first stage utilizes a probit regression to determine the probability of adopting inorganic or organic fertilizer. The second stage employed Ordinary Least Squares (OLS) regression to analyze the factors influencing the intensity of fertilizer adoption.

In Cragg's double hurdle model, the first stage focuses on the adoption decision, represented by a binary variable (D_i), indicating whether the farmer uses inorganic fertilizer or organic fertilizer. The probit model estimates the probability of this adoption decision based on explanatory variables such as land ownership, land size, distance to the nearest market, and credit accessibility. The second stage of the model examined the intensity of inorganic fertilizer usage (Y_i) using OLS regression. The explanatory variables in this stage included the farmer's age, farm income, off-farm income, credit accessibility, among others.

It is worth noting that the model assumed that the determinants of inorganic fertilizer use and its intensity were independently determined. The double hurdle model allows for the separation of the initial adoption decision and the intensity or extent of fertilizer application, which is particularly relevant when studying smallholder farmers cultivating paddy and their fertilizer usage patterns. Unfortunately, the research did not yield any specific references or sources for Cragg's double hurdle model in the context of fertilizer adoption. However, the information provided outlines the structure and methodology of the model and its application in analyzing adoption decisions and intensity of fertilizer use.

Researchers had employed various models to analyze the factors influencing the adoption of fertilizer and the intensity of inorganic fertilizer usage at the farm level. Some studies had utilized the Tobit model to estimate the adoption patterns associated with limited dependent variables, while others had employed the Heckman selection model through a two-step procedure. However, this study used Cragg's double hurdle model using two stages where the first stage analyzed the determinants of adoption decision towards fertilizer using probit model and the determinants of fertilizer intensity was identified using ordinary least square regression in second stage.

Smallholder farmers who cultivate paddy may apply inorganic or organic fertilizer and if they apply the inorganic fertilizer, the researcher needed to clarify the amounts of inorganic fertilizer which the farmers were applying in their farming.

Thus, the Cragg's double hurdle model has two stages which allows for separation between the initial decision to adopt inorganic or organic fertilizers ($Y > 0\ versus\ Y \leq 0$) and the intensity or extent of the fertilizer application. Therefore, the model used probit regression in the first step to assess the probability of decision to adopt inorganic or organic and in the second step the model used ordinary least squares to determine the intensity of adoption (Greene, 2007) and the method correct sample selection bias. The Cragg model, introduced in 1971, was employed for the analysis, assuming that the factors influencing the use and intensity of inorganic fertilizer were determined independently.

Probit model predicts the probability of determinants of whether an individual household uses inorganic fertilizer or not. The probit model in the first stage is specified as:

$D_i = \beta_1 X_i + \varepsilon_i \sim N(0,1)$

Where, i = 1, 2…n

$D_i = 1\ if\ Z_i\ \delta + U_i > 0$

$D_i = 0\ if\ Z_i\ \delta + U_i <= 0$

Where, D_i is a binary variable which represent the farmer's adoption decision on fertilizer usage that takes the value 1 if the farmer adopts inorganic fertilizer and zero for the adoption of organic fertilizer in the study.

The factors which determine the adoption decision towards fertilizer choices and the intensity of fertilizer usage were selected based on the previous literature for both models (Beshir et al., 2012) and according to that, the following empirical model employed to determine the fertilizer adoption decision in the study.

$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon_i$

Where,

Y_i = Adoption decision coded as 1 for the farmer adopts inorganic and 0 for organic fertilizers.

β_0 = Constant term.

$\beta_1\ to\ \beta_4$ = the parameters of the respective explanatory variables in the model.

X_1 = Land ownership

X_2 = Land size

X_3 = Distance to the nearest market

X_4 = Credit accessibility

ε_i = Error term

The second stage of the analysis involved the ordinary least square regression model to identify the factors that determine the intensity of inorganic fertilizer usage. Observations on positive and greater than the zero amount of inorganic fertilizer usage are only used in the analysis. The ordinary least square regression model in the second stage is specified as:

$Y_i = X_i \beta + \varepsilon_i \sim N(0, \sigma^2)$

$Y_i = Y_i^*\ if\ D_i = 1$ and $Y_i^* > 0$

$Y_i = 0\ if\ Y_0 \leq 0$ and $D_i \leq 1$

Where,

Y_i is the intensity of inorganic fertilizer usage which depends on the latent variable Yi^* being greater than zero and conditional to the decision to use D_i fertilizer, xi is the vector of explanatory variables hypothesized to determine the intensity of inorganic fertilizer usage, Y_o is the threshold of intensity of inorganic fertilizer usage in the study area.

The empirical model employed to determine the intensity of fertilizer usage is given as:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 LnX_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon_i$$

Where,

Y_i = Intensity of inorganic fertilizer usage

β_0 = Constant term.

β_1 *to* β_4 = the parameters of the respective explanatory variables in the model.

X_1 = Age of the farmer

LnX_2 = Farm income in logarithmic

X_3 = Off - farm income

X_4 = Credit accessibility

ε_i = Error term

Table 1: Definitions and measurements of the variables

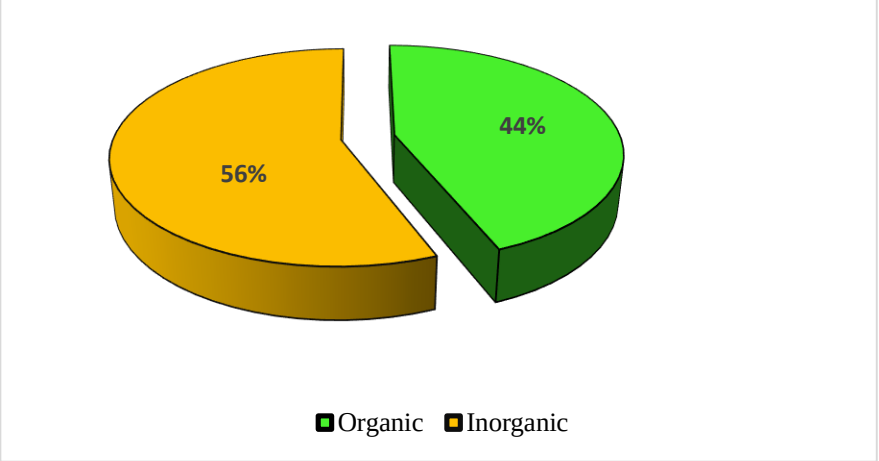
Definition of the variables	Measurement of variables
Dependent variables	
Adoption decision on fertilizer AND	Dummy variable coded as 1 for inorganic and 0 for organic
Amount of inorganic fertilizer	Continuous variable measured in Kilogram
Independent variables	
Land ownership	Dummy variable coded as 1 for tenant land and 0 for own
Land size	Cultivated area in Ha
Distance to the nearest market	In Kilometer
Credit accessibility	Dummy variable coded as 1 for yes and 0 for no.
Age of the farmer	Years
Log of farm income	Continuous variable measured in Rs
Off - farm income	Binary variable coded as 1 for yes and 0 for no

Source: Compiled by authors

4. Results and Discussion

In the beginning of this section, descriptive statistics, frequency of the selected variables between inorganic and organic farmers were analyzed and thereafter chi-square test and independent samples - t test also were applied to illustrate the association between selected variables and test the mean differences in the selected variables across inorganic and organic farmers in the study.

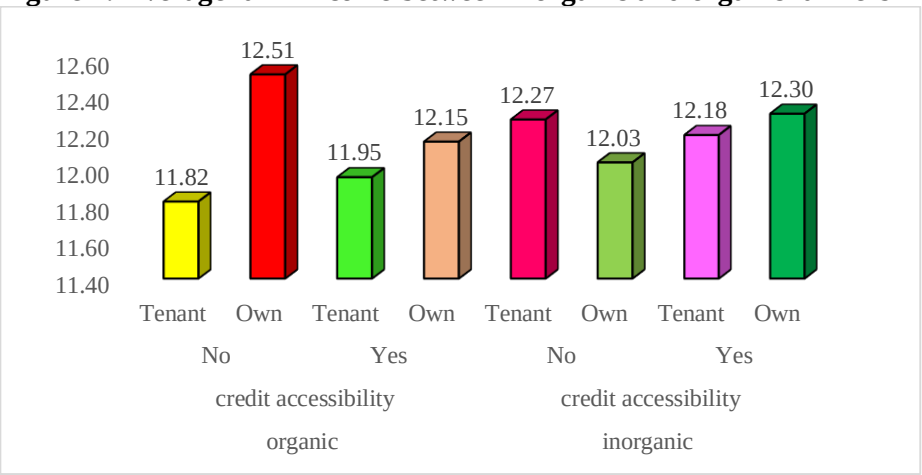
Figure 1: Frequency of inorganic and organic fertilizer users



Source: Compiled by authors, 2022

The result of the frequency indicates that out of 150 sample respondents, 56% of the farmers are inorganic fertilizer users and the remaining 44% of them were using organic fertilizer in their paddy cultivation during the study period.
The figure 2 graphically depicts the log of average farm income earned by the farmers who were adopting inorganic and organic farming, under different farming practices.

Figure 2: Average farm income between inorganic and organic farmers

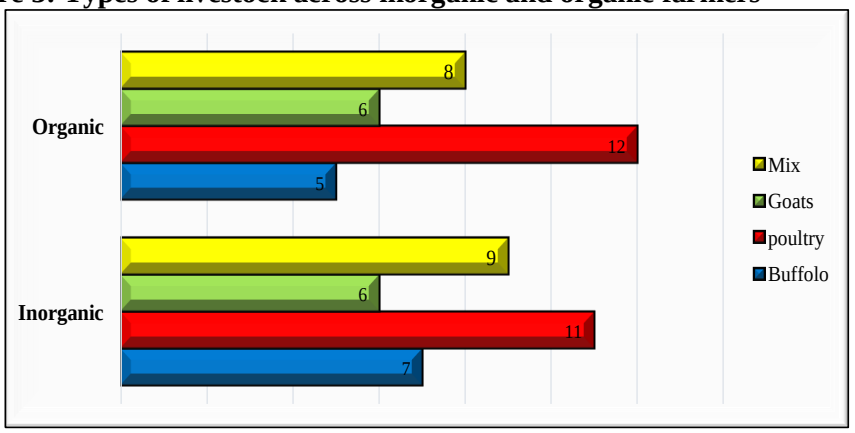


Source: Compiled by authors, 2022

It shows that log of average farm income is Rs 12.51/= and it is the highest number of organic farmers who cultivates in their own land without credit facilities than their other counterparts. According to the study, the inorganic farmers who have credit facilities cultivate in their own land earn on log of average income Rs 12.30/=.

Further, the data related to types of livestock reared by the organic and inorganic farmers were also collected in the study.

Figure 3: Types of livestock across inorganic and organic farmers



Source: Compiled by authors, 2022

The results show that, 12 farmers adopt organic fertilizer and they have poultry farms and among the inorganic farmers there are 11 of them who have poultry farms in the study but, there are only 5 organic and 7 inorganic farmers who reared buffalos as their source of organic fertilizer. These findings summarize that, whether one is an inorganic or organic farmer, one prefers to adopt certain level of natural fertilizers also for their paddy farming.

Results of descriptive statistics

Results of descriptive statistics, mainly mean and standard deviation of selected variables were compared between the farmers who adopt inorganic and organic fertilizers in the paddy farming and the results are illustrated in Table 2. The descriptive analysis aims to provide a fundamental overview of the demographic and farming characteristics of farmers who utilize both inorganic and organic fertilizers in the study area.

Findings of the study showed that average amount of inorganic fertilizer used by the farmers, is lower than organic farmers and the cost of organic fertilizer is also higher than the inorganic according to the study. Compared to organic farmers, age and family size of the inorganic farmers is higher, but log income received from farming by the organic farmers is higher than the inorganic farmers.

Table 2: Descriptive statistics of the variables

Variables	Inorganic fertilizer users		Organic fertilizer users	
	Mean	**SD**	**Mean**	**SD**
Amount of fertilizer use	189.63	105.40	1677.92	1016.74
Cost of fertilizer	4577.24	2521.96	6582.76	10398.59
Age	48.06	12.484	42.48	13.04
Family size	2.63	.902	2.545	0.963
Log of farm income	230000.00	126066	224363.60	131058.84
Market distance	7.76	3.258	3.57	2.80
Farm experience	15.95	11.39	14.25	11.80
Land size	2.00	1.11	3.01	1.55

Source: Compiled by authors, 2022

Further, the survey results indicate that the farm experience of the inorganic farmers is slightly higher than the organic, however, the size of land for organic farmers is 3.01 which is significantly higher than the inorganic farmers.

Table 3 compares the results of selected demographic and farming characteristics of the respondents across inorganic and organic fertilizer users. The results revealed that compared to male farmers, involvement of females in paddy farming either inorganic or organic, is of very low percentage in the samples. 96.4% of the farmers who have off – farm income applying inorganic fertilizer while 25.8% of the farmers who don't have off – farm income uses organic fertilizer in the paddy cultivation. Moreover, majority of the land owning farmers apply organic farming and only 33.3% of the tenant farmers use inorganic fertilizers.

Table 3: Frequency of demographic and farming characteristics

Variables	Inorganic farmers		Organic farmers	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Gender				
Male	60	71.4	50	75.8
Female	24	28.6	16	24.2
Marital status				
Single	4	4.8	7	10.6
Married	80	95.2	59	89.4
Education level				
Primary	79	94	62	93.9
Secondary	5	6	4	6.2
Off – farm income				
Yes	81	96.4	49	74.2
No	3	3.6	17	25.8
Land ownership				
Own land	56	66.7	53	80.3
Tenant land	28	33.3	13	19.7
Availability of livestock				
Yes	50	59.5	31	47
No	34	40.5	55	53
Types of labour				
Hired labour	4	4.8	10	15.2

Family labour	80	95.2	56	84.8
Union membership				
Yes	81	96.4	55	83.3
No	3	3.6	11	16.7
Seed variety				
Modern	78	92.9	56	84.8
Traditional	6	7.1	10	15.2

Source: Compiled by authors, 2022

Majority of the sampled farmers' own livestock and relatively inorganic farmers have a better livestock holding than the organic farmers. In case of seed variety, nearly 93% of the farmers who cultivates paddy with modern seed variety, they applied inorganic and only 7% of the farmers who cultivate using traditional seeds and organic fertilizer.

Apart from the major objectives, this study intends to identify the association between of demographic and farming characteristics across the farmers who are using inorganic and organic fertilizers during the study. Even the chi – square test belongs to the non – parametric approach, to identify the association between any set of categorical variables, chi – square test is more applicable. Because of these reasons chi – square test was applied and the results were shown in Table 4.

Table 4: Results of chi-square test

	Types of fertilizers		**χ^2 -value**	**Significant value**
Variables	**Inorganic**	**Organic**		
Off – farm income	-	-	15.74	0.000
Yes	62.3%	37.7%		
No	15%	85%		
Credit accessibility	-	-	46.8	0.031
Yes	50%	49.1%		
No	71.7%	28.9%		
Land ownership	-	-	3.46	0.063
Own land	31.7%	68.3%		
Tenant land	48.6%	51.4%		
Types of labour	-	-	4.71	0.030
Hired labour	41.2%	58.8%		
Family labour	71.4%	28.6%		

Source: Compiled by authors, 2022

Accordingly, there was statistically significant association between inorganic fertilizer adopter and organic fertilizer adopter in off – farm income, accessibility of credit and types of labour while land ownership has associates with types of fertilizer users, at 10% significant level. The results derived from group comparison of inorganic and organic farmers was computed by using independent samples t – test indicated in Table 5 below.

Table 5: Results of independent samples t – test

Characteristics	Inorganic		Organic		Significant value
	Mean	SD	Mean	SD	
Age	48.06	12.484	42.48	13.046	0.009
Log of farm income	230000	126066.24	224362	131058.84	0.790
Distance to the market	7.76	3.258	3.58	2.801	0.000
Farm experience	15.958	11.398	14.258	11.806	0.375
Land size	2.000	1.115	3.018	1.554	0.000
Family size	2.63	0.902	2.55	0.964	0.577

Source: Estimated by authors using SPSS

The results of independent samples – t test reveal that there was no statistically significant difference between inorganic fertilizer adopter and organic fertilizer adopter concerning log of farm income, farm experience and family size while there was a significant difference in age, distance to the market and size of land. This demonstrates the importance of age of the farmers, distance to the market and size of land whether the farmer to adopt inorganic or organic fertilizers.

Results of an econometric estimation

In this sub section, Cragg's double hurdle analysis was employed to identify the demographic and farming characteristics that influence smallholder farmers' choices regarding the adoption of inorganic or organic fertilizers. The first stage involved applying probit regression to determine the factors that determine the initial decision of farmers to adopt either inorganic or organic fertilizers. In the second stage, the conditional estimation or ordinary least square method was utilized to examine the factors that influence the intensity of fertilizer adoption among farmers.

Factors determining the farmers' fertility adoption decision in paddy

The result from the first stage of double hurdle model has been estimated by probit model and the overall model is significant at 1% level (Probability > chi^2 = 0.0000) as indicated by Log pseudo likelihood value of -552.44. This implies that the significance of explanatory variables was included in the model.

Table 6 shows the estimated coefficients for probit regression and its significant values of explanatory variables that influence the likelihood of paddy farmers' adoption decision on fertilizer. The models constructed with four independent variables and the results indicated that the statistically significant factors which determine the adoption decision of fertilizers on paddy cultivation were land size, distance to the market and credit accessibility and ownership of land insignificant in the model.

The coefficient of land size has negative sign, and it is significant at 1% level, which indicates that with the farmers who have bigger size of land, the probability to adopt inorganic fertilizer decision will be lower than the farmers who have smaller size of land. In other words, an increase in size of the farm increases the probability of intensity towards organic fertilizer. This suggests that as smallholder farmers expand the size of their farms, they demonstrate a tendency to increase the usage of organic fertilizer in their paddy farming practices. These findings align with previous

studies conducted by Gelgo et al., (2016) & Obuobisa-Darko (2015), but inconsistent with the findings of Dalango & Tadesse (2019).

The study found that the coefficient of distance to the market had a negative impact on the likelihood of farmers adopting inorganic fertilizers at 1% level of significance. This means that as the distance between the farm and the market increases, the probability of adopting inorganic fertilizers decreases. Conversely, when the household residence is closer to the market, there is a higher probability of using inorganic fertilizers. This is because shorter travel time and lower transportation costs are associated with closer proximity to the market. This finding aligns with similar studies conducted by Teshome (2017), Beshir (2012), and Duressa (2015).

Table 6: Results of first stage Cragg's Double - Hurdle probit model

Variables	Coefficient	Standard error	Z	P> z
Land ownership	-0.203	0.265	-0.770	0.444
Land size	-0.235	0.079	-2.980	0.003
Distance to the market	-0.260	0.037	-7.020	0.000
Credit accessibility	-0.762	0.285	-2.680	0.007

Numbers of observations =150
LR chi^2 (4) = 112.15
Probability > chi^2 = 0.000
Pseudo R^2 = 0.0921
Log likelihood = - 552.44

Source: Estimated by authors using Stata 17

Access to credit negatively influenced the adoption of fertilizer decision which indicates that the famers who have credit accessibilities, are less likely to adopt inorganic fertilizer than their counterparts. Same findings were reported by Akpan et al., (2012), but it is insignificant in their study.

Factors determining the intensity of inorganic fertilizer usage in paddy

The second stage of the double hurdle model was estimated by OLS to examine the factors that determine the intensity of inorganic fertilizer on paddy cultivation among the farmers and its results illustrated in Table 7.

Table 7: Results of second stage Double - Hurdle OLS model

Variables	Coefficient	Standard error	Z	P> z
Age	-2.934	0.816	-3.590	0.000
Farm income	45.887	5.438	8.440	0.000
Off – farm income	-225.091	48.807	-4.610	0.000
Credit accessibility	-24.456	22.186	-1.100	0.270

Source: Estimated by authors using Stata 17

According to that age, farm income and off-farm income were the statistically significant factors that determine the intensity of inorganic fertilizer used by the farmers. In the above results, age of the farmer negatively and significantly impacts on the intensity of inorganic fertilizer usage at 1% level. It represents that with an increase in age of the farmer by one year, it decreases the intensity of inorganic

fertilizer usage by 2.9 Kg/ Ha. Commonly, the farmers who are older do not consistently follow the advice of the agricultural experts and do not accept new techniques and the changes to practice quickly than the young farmers. The findings are consistent with the research conducted by Dassa et al., (2022) and Anago et al., (2020), which revealed that older farmers tend to be more risk-averse and assess the intensity of inorganic fertilizer usage compared to younger farmers.

The results further indicate that the farmers who earn more income from their paddy farming had a positive effect on intensity of inorganic fertilizer usage. A unit increase in farm income led to a 45.88 Kg/ha increase in usage of inorganic fertilizer intensity. These results contradicted the findings of Martey et al., (2014) and line with Ade Freeman & Omiti (2003). Availability of off – farm income is shown a negative sign and statistically significant at 1% level, which suggests that the farmers, who had off – farm income, led to reduce the uses of inorganic fertilizer by 225.09 Kg/ Ha in their paddy cultivation but, Beshir et al., (2012) found that it positively influenced the intensity of use of chemical fertilizer. In addition to the estimated coefficients of the variables, marginal effects were also employed to examine the impact of each explanatory variable on the intensity of inorganic fertilizer usage.

Table 8: Results of marginal effect for Cragg's Double – Hurdle model

Variables	Marginal effects	Standard error	Z	P> z
Age	-1.405	0.383	-3.660	0.000
Farm income	21.975	2.786	7.890	0.000
Off- farm income	-107.795	23.553	-4.580	0.000
Credit accessibility	-52.875	17.804	-2.970	0.003
Land ownership	-10.964	14.252	-0.770	0.442
Size of land	-12.728	3.857	-3.300	0.001
Distance to the market	-14.041	1.098	-12.787	0.000

Source: Estimated by authors using Stata, 17

The results reveal that there is a significant negative marginal effect of age at a 1% level. This implies that for every additional year of age, the farm households' intensity of inorganic fertilizer uses decreases by 1.405 Kg. Further, as farm income increases by one more rupee, the intensity of usage in inorganic fertilizer will increase by 21.975 Kg, but increase in off – farm income, which reduces the intensity of inorganic fertilizer usage by 107.79 Kg. Access to credit negatively influenced the intensity of inorganic fertilizer by 52.87Kg while ownership of land did not influence the intensity of inorganic fertilizer usage. The negative coefficient of marginal effect associated with land size indicates that for each additional hectare of farm size, there is a decrease of 12.72 kilograms in the usage of organic fertilizer.

5. Conclusion

The objective of this study was to analyze the determinants of adoption decision towards fertilizer and intensity of inorganic fertilizer usage on paddy cultivation by smallholder farmers in Kalutara district, Sri Lanka. To achieve this, the researchers employed a two-step approach using Cragg's double hurdle model. In the first stage, a probit model was utilized to identify the determinants of the adoption decision.

Subsequently, an ordinary least squares analysis was conducted in the second stage to identify the factors influencing the intensity of inorganic fertilizer usage.

Result from probit model in the first stage indicated that, out of four explanatory variables, the size of land, distance to the market and credit accessibility were the major factors that determined the adoption decision on fertilizer while land ownership is insignificant in the first stage. In the second stage, OLS model was employed, and its results revealed that out of four explanatory variables, age, farm income and off – farm income were the significant factors that influence the intensity of inorganic fertilizer usage in paddy farming. The findings of the study contribute to the farmers as well as policy makers to identify how demographic and farming characteristics influence the adoption preferences on inorganic and organic fertilizer in the current scenario and based on what factors they can decide the amount of inorganic fertilizer usage in their farming. According to the analysis, the Kalutara district exhibits significant potential for paddy production. However, the utilization of inorganic fertilizers among farmers remains relatively low. Based on the study's findings, several policy recommendations were proposed. It was suggested that the government and volunteer groups should prioritize the support and involvement of agricultural experts. Furthermore, the research discovered that some farmers in the study area have already embraced the use of organic fertilizers derived from their livestock. Encouraging these farmers to continue utilizing organic fertilizers can lead to increased farm revenue, improved living conditions, and environmental sustainability. To promote this shift, the government and non-governmental organizations should offer incentives and support these organic farmers, thereby encouraging more smallholder farmers to adopt organic fertilizers for the benefits.

Simultaneously, the study revealed that 56% of farmers currently utilize inorganic fertilizers in their paddy farming. Thus, it is recommended that the government pays special attention to increasing the adoption and usage of inorganic fertilizers in paddy production to enhance productivity and yield in the future. Furthermore, the study findings indicate that factors such as land size, distance to markets, credit accessibility, age of farmers, and farm and non-farm income play a significant role in farmers' decisions to adopt fertilizers and determine the extent of inorganic fertilizer usage. Therefore, it is suggested that improving these factors, such as providing education, facilitating farm household asset formation, and offering extension services and credit, can positively influence farmers' adoption decisions and enhance their productivity. These actions have the potential to mitigate food shortage issues and promote economic growth by improving agricultural productivity in the future.

References

Ade Freeman, H., & Omiti, J. M. (2003). Fertilizer use in semi-arid areas of Kenya: Analysis of smallholder farmers' adoption behavior under liberalized markets. *Nutrient Cycling in Agroecosystems*, *66*(1), 23–31.

Akpan, S.B., S. Nkanta, V., & Essien, UA. (2012). A Double-Hurdle Model of Fertilizer Adoption and Optimum Use among Farmers in Southern Nigeria. *Tropicultura*, *30*(4).

Anago, F. N., Dieudonné, D. G., Emile, A. C., Brice, O. C. T., & Guillaume, A. L. (2020). Inorganic Fertilizer Adoption, Use Intensity and Rainfed Rice Yield in Benin. *Open Journal of Soil Science*, *10*(01). https:// doi.org/ 10.4236/ ojss. 2020.101001

Aryal, J. P., Sapkota, T. B., Krupnik, T. J., Rahut, D. B., Jat, M. L., & Stirling, C. M. (2021). Factors affecting farmers' use of organic and inorganic fertilizers in South Asia. *Environmental Science and Pollution Research*, *28*(37), 51480–51496.

Belete, A. A. (2022). Determinants of Organic Fertilizer Adoption in Moretna Jeru District, Northern Ethiopia. *Advances in Agriculture*, *2022*. https:// doi. org/ 10.1155/2022/9983782

Beshir, H., Emana, B., Kassa, B., & Haji, J. (2012). Determinants of chemical fertilizer technology adoption in Northeastern highlands of Ethiopia: the double hurdle approach. *Journal of Research in Economics and International Finance*, *1*(2), 39–49.

Cragg, J. G. (1971). Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica: Journal of the Econometric Society*, 829–844.

Dabessa Iticha, M., Jaleta, M., & Mitiku, F. (2021). Determinants and profitability of inorganic fertilizer use in smallholder maize production in Ethiopia. *Cogent Food and Agriculture*, *7*(1). https://doi.org/10.1080/23311932.2021.1911046

Dalango, D., & Tadesse, T. (2019). Determinants of smallholder teff farmer's chemical fertilizer technology adoption in Southern Ethiopia, in case of Gena District in Dawro Zone (Heckman Two-Stage Model). *Journal Perspektif Pembiayaan Dan Pembangunan Daerah*, *7*(2), 111–126.

Dassa, A., Ifa, A., & Gobena, E. (2022). Determinants of Inorganic Fertilizer Use Intensity on Cereal Crop among Smallholder Farmers: The Case of Toke Kutaye District, West Shewa Zone, *Oromia National Regional State, Ethiopia*.

Dayarathnne, H.K.S.P., & Gunawardene, U.A.D.P. (2014). Economic Analysis of Organic and Inorganic Paddy Cultivation Systems with Special Reference to Kalutara District. Academia. Retrieved from https:// www. academia. edu/ 28041320/Economic_Analysis_of_Organic_and_Inorganic_Paddy_Cultivation_Systems_with_Special_Reference_to_Kalutara_District.

Duressa, D. (2015). Analysis of factors influencing adoption of quncho Tef: The case of Wayu Tuqa District. *International Journal of African and Asian Studies*, *12*, 20–28.

Gelgo, B., Mshenga, P., & Zemedu, L. (2016). Analyzing the determinants of adoption of organic fertilizer by smallholder farmers in Shashemene District, Ethiopia. *J Nat Sci Res*, *6*, 35–44.

Greene W. H. (2007). Econometric Analysis, sixth edition. Macmillan, New York, USA.

Institute of Policy Studies of Sri Lanka. (2022). Status of the Economy 2022: Institute of Policy Studies of Sri Lanka. 100/20, Independence Avenue, Colombo 07, Sri Lanka.

Kalutara District Secretariat. (2014). Performance Report: District Secretariat. Retrieved from http://parliament.lk /uploads/ documents/paperspresented/ performance-report-district-secretariat-kalutara-2014.pdf

Martey, E., Wiredu, A. N., Etwire, P. M., Fosu, M., Buah, S. S. J., Bidzakin, J., Ahiabor, B. D. K., & Kusi, F. (2014). Fertilizer adoption and use intensity among smallholder farmers in Northern Ghana: A case study of the AGRA soil health project. *Sustainable Agriculture Research*, *3*(526-2016–37782).

Muluneh, M. W., Talema, G. A., Abebe, K. B., Dejen Tsegaw, B., Kassaw, M. A., & Teka Mebrat, A. (2022). Determinants of Organic Fertilizers Utilization Among Smallholder Farmers in South Gondar Zone, Ethiopia. *Environmental Health Insights*, *16*. https://doi.org/10.1177/11786302221075448

Obuobisa-Darko, E. (2015). Socio-economic determinants of intensity of adoption of cocoa research innovations in Ghana. *International Journal of African and Asian Studies*, *12*(1), 29–40.

Olatunji, O. S., & Akanbi, S.-U. O. (2022). Drivers and Pattern of Fertilizer Usage Among Cereal-Based Farmers in Kwara State, Nigeria. *Acta Scientific Nutritional Health*, *6*(6), 54-61.

Perera, B. L. N. (2020). Effect of agrochemical for paddy yield in Kalutara district: a regression approach (Doctoral dissertation).

Tadesse, A. S., & Molla, D. A. (2021). Determinants of Inorganic Fertilizer Use by Smallholder Farmers in South Wollo and Oromia Special Administrative Zones, Ethiopia. *Journal of Agricultural Extension*, *25*(4). https:// doi. org/ 10. 4314/jae. v25i4.11

Tefera, T., Elias, E., & Van Beek, C. (2020). Determinants of smallholder farmers' decisions on fertilizer use for cereal crops in the Ethiopian highlands. In *Experimental Agriculture* (Vol. 56, Issue 5). https:// doi.org/ 10.1017/ S0014 47972000023X

Teshome, S. (2017). Determinants of adoption of improved teff varieties by smallholder farmers: the case of Kobo District, North Wollo Zone, Amhara Region, Ethiopia (Doctoral dissertation, Haramaya university).

Zondo, B. S. (2020). Determinants of adoption and use intensity of organic fertilizer. *SA-TIED Working Paper No 135*.