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Research Article

Determinants of Crop Diversification Decision and Crop Intensity among Vegetable Farmers

Aruppillai Thayaparan
Department of Business Economics, Faculty of Business Studies
University of Vavuniya, Sri Lanka
thaya69@vau.ac.lk

Abstract

This study aims to recognize the factors influencing the decision to diversify the crops and attempts to identify the determinants influencing the decision to diversify the crops and the determinants of crop intensity in diversification among vegetable farmers in Kotagala during 2020. The study adopts Heckman's two-stage selection model to identify the determinants of crop diversification decisions and the number of crops grown by the vegetable farmers separately. Further, Cragg's double hurdle model was also applied to distinguish the factors influencing the crop diversification decision and the determinants of crop intensity among the farmers in the study. Results of the Heckman selection two-stage model found that education, land size and market distance were found to have more probability of engaging in crop diversification. In contrast, gender, farm experience, land size and market distance were the significant factors in determining the number of crops grown by the diversifiers. outcomes from Cragg's double hurdle model showed that education and land size are the primary determinants in crop diversification. In contrast, age, land size and market distance are the crucial factors influencing the intensity of crop diversification in the study. Therefore, the government and policymakers should consider the policies focusing on education, land and market facilities as their major strategies to increase the engagement in crop diversification and crop diversity, which in turn will increase the earnings in the economy.

Keywords: Crop diversification and crop intensity, Cragg's double hurdle model, farm experience, Heckman's two stage model, vegetable farmers, market distance.

Introduction

The agricultural sector plays a significant role in the economy in terms of contribution to the GDP, employment opportunities and income generation. Even though its contribution to the gross domestic product declined substantially during the past three decades, from 30 % in 1970 to 7.3 % in 2020, it is the most important source of employment for most of the Sri Lankan workforce. Nationally, 25.5 % of the total employed population are engaged in the agricultural sector, including forestry and fishery (Thanigaseelan, 2021). Although Sri Lanka is a fertile tropical land with the potential for the cultivation and processing of a variety of crops, some issues such as productivity and profitability hamper the growth of the sector in the country (Thanigaseelan, 2021). Nevertheless, the contribution of agriculture to Gross Domestic Product was registered as 6.9 % in 2021, and it contributed 27.3 % to employment opportunities directly and indirectly in Sri Lanka (Central bank annual report, 2021).

Diverse agroecological regions of Sri Lanka are well suited for cultivating different kinds of vegetable crops, and there are two main groups of vegetables grown in Sri Lanka based on the agroecological adaptability. The upcountry (Hilly areas) vegetables constitute crops such as carrot, cabbage, beetroot, cauliflower, knol-khol, potato, bean, tomato, leeks, parsley, lettuce and capsicum, which are grown on a commercial scale with high input use. The other group constitutes the low-country (plains) vegetables, which include brinjal, bitter gourd, pumpkin, luffa, cucumber and snake gourd cultivated less intensively under low input systems. In addition, vegetables such as bell peppers, tomato, and salad cucumbers are also grown under intensive culture under protected agricultural systems, mostly for the hotel industry and exports. Although the country is virtually self-sufficient in vegetables, there is a very high potential for expansion of their cultivation for domestic consumption and export (Gunasena, 2007).

Efforts to identify the factors influencing crop diversification among smallholder farmers have been made by researchers worldwide, including Sri Lanka. However, they used different data analysis methods and the variables used in their study also differ. The current study aims to identify the factors that determine the preferences on adoption decision towards crop diversification as well as identify the factors which influence the intensity of crop diversification using Heckman selection model and Cragg's double hurdle model. Besides, the fact that none of these empirical studies is conducted in Sri Lanka using these types of models creates the need to undertake this study to attain the above objectives. In this background, this paper aims to recognize the factors influencing the decision to diversify the crops and attempts to identify the determinants of crop intensity in diversification among vegetable farmers in Kotagala during 2020. To attain these objectives, the study employed two econometric models: the Heckman selection model and Cragg's double hurdle model.

The remainder of this paper is structured as follows. The second section reviews the theoretical and empirical literature on crop diversification and its determinants. The third section presents the methodology, including the method of data collection and the analytical framework used in the study. Finally, while the

fourth section discusses the empirical results derived from different econometric models, the conclusion and policy implications are described in the last section.

Literature review

Theoretical Literature

Crop diversification means the shift from the regional dominance of one crop to the regional production of several crops, to meet -increasing demand for cereals, pulses, vegetables, fruits, oil seeds, fodder etc. Crop diversification in agriculture means increasing the total crop production in terms of quality, quantity and monetary value under specific, diverse agro-climatic situations (Jeyawardane and Weerasena, 2000). There are many opportunities for crop diversification that may lead a farm household to cultivate more than one crop depending on risks, government policies, Water shortages and the feasibility of proposed changes within a socioeconomic and agro-economic context. Crop diversification provides several advantages, such as high net return from crops, higher net returns per unit of labour, optimization of resource use and increased job opportunities (Dharmasena, 2015).

Several indices are used to measure crop diversification, and out of them, the Herfindahl Index, Simpson Diversity Index, Ogive Index, Margalef Index, Shannon Index, Berger-Parker Index and Entropy Index are important. Further, counting the number of crops grown by farmers is another standard method for measuring crop diversification. Among the above indices, Herfindahl Index is a concentration index which is often used to determine crop diversification. When the index has zero value indicates the specialization in a particular crop only, and a movement toward one shows an increase in the extent of crop diversification (Adjimoti, 2018).

This study applied two indices to measure: the count crop diversification count of the number of crops grown by the farmer and the Herfindahl Index. In the study area, the farmers produce diversified vegetable crops such as carrot, cabbage, beetroot, knol-khol, potato, bean, leeks, parsley and lettuce at a time. Thus, to compute the Herfindahl index, the authors used the total cropped land (ha) of diversifiers and the proportion of land allocated for growing above each crop (ha) in the 2018/2019 harvested season.

The extent of crops diversification is measured by the Herfindahl index, which can be written as:

$$P_i = \frac{A}{\sum_{i=1}^{n} A_i}$$

Pi = Proportion of i^{th} crop
Ai = Area under i^{th} crop
$\sum_{i=1}^{n} A_i$ = Total cropped area
ι = 1, 2, 3……..n (Number of crops)
From the above formula, the Herfindahl index (H_i) can be calculated by:

Where,
N is the total number of crops, and P_i represents the area proportion of the i^{th} crop in the total cropped area.

Now, the crop diversification index (CDI) is obtained by subtracting the Herfindahl Index (HI) from one which is given by,

$$CDI = 1 - \sum_{i=1}^{n} P_i^2 = 1 - HI$$

When the crop diversification index has zero value, only one crop is cultivated with specialization, and a movement toward one shows an increase in the extent of crop diversification (Malik and Singh, 2002). Generally, the value of crop diversification index increases with the increase in diversification and assumes 0 value when farmers cultivate only one crop.

Based on the index value, which ranges between 0 and 1, the probability of engaging in crop diversification is classified as 1 for diversifier and 0 for non-diversifier. Thus, the decision to engage in crop diversification is taken as the binary dependent variable in the Heckman selection equation or Probit model. Extent of crop diversification is measured by the number of crops grown by the farmers taken as the dependent variable in the Heckman quantity equation (OLS) while the Herfindahl index is taken as dependent variable in the quantity equation in Cragg's double hurdle model or Tobit model.

Empirical Literature

Numerous studies have been done by many researchers on the determination of crop diversification among smallholder farmers and they found several factors influencing crop diversification.

Factors influencing crop diversification in Sri Lanka were identified by Mohamed et al. (2006) based on the data collected from the Sri Lanka Integrated survey carried out across all provinces of the country from October 1999 to September 2000. They analyzed the data using the binomial logistic model, and the results implied that availability of family labour, area of land cultivated, credit constraint, lack of water, poor land quality, and lack of extension services and inputs are the significant factor in determining crop diversification.

Kiru et al. (2008) examined the determinants and extent of crop diversification among smallholder farmers in Zambia. They used secondary data, which were analyzed using the double-hurdle model and indicates that landholding size, fertilizer quantity, distance to market, and the type of tillage mechanism adopted have significantly influence whether farmer practices crop diversification or not in the study.

Another study was carried out by Raju et al. (2013) to determine the diversification of cropping pattern and its role in flood-affected agriculture of Assam plains in India. They used 342 randomly selected farms in the study, and results of censored regression suggest that crop diversification has been adopted as a mechanism to cope with limits imposed by floods while results of a linear regression concluded that crop diversification has a vital role in enhancing farm income in the country.

A study on determinants of crop diversification in Ethiopia and its evidence from Oromia Region was performed by Rehima et al. (2015). The data was analyzed using Hackman's two-step method, and the estimated results suggest that asset ownership, soil quality, agricultural extension, and level of infrastructural development are the significant drivers of crop diversification in Oromia.

Another study was done by Lighton et al. (2015) to assess the degree of crop diversification and the factors influencing crop diversification among the farm households at the Dundwa agricultural camp of Zambia. The degree of crop diversification was measured using the Entropy index, and the censored Tobit model was used to examine the impact of farmers' socio-economic characteristics influencing crop diversification. The Tobit regression model results positively influence crop diversification showed that crop diversification is positively influenced by gender, the production of cash and household investment in essential farming equipment. On the contrary, age, total farm size, access to agricultural markets and total area cultivated negatively influenced crop diversification in the study.

Kumara et al. (2016) revealed that factor affecting to participation and cultivation extent of other field crops was determined by education, social capital and field location during both Yala and Maha in Sri Lanka. The value of crop diversification was taken as the dependent variable in the Heckman two-stage model, and in addition to the above variables, principal occupation, water source, and market distance were significant in Yala for crop diversification participation, while sex and land area significantly involved to the extent of crop diversification in both seasons.

Determinants and extent of crop diversification at the household Level in Manipur were identified by Monika et al. (2017). The factors influencing the household decision on crop diversification were examined by Heckman's two-stage model, and its results implied that education of the household head, exposure to farming information by the households and distance to the nearest market from the homestead were found to have a positive impact on the level of crop diversification. Access to fertilizer, availability of irrigation and the farmers who attend training regularly are more likely to diversify crop. Only access to plough has positively affected both the household's decision to diversify crop and crop diversification.

Crop diversification on red pepper dominated smallholder farming system analyzed in Ethiopia by Dessie et al. (2019). They used the Tobit model to analyze the data, and the results revealed that crop diversification status and intensity were significantly influenced by farmland, sex, age, land fragmentation, distance to development centre, market distance, and off-farm income participation. Nasim et al. (2019) conducted a study on crop diversification and its determinants in India, and they measured crop diversification by using the Herfindahl index. The regression model was applied to access the determinants of crop diversification, and its results revealed that population density, rainfall, percentage of gross irrigated area to gross cropped area and percentage of high yield variety area to gross cropped area were the significant factors in crop diversification in the study. Socio-economic determinants of crop diversity and Its effect on farmer income in Guangxi, Southern China, done by Cheng et al. (2021), and they found that crop diversity increased with land size and closeness to the city in the study.

Derso et al. (2022) applied a double hurdle estimation of crop diversification decisions by smallholder wheat farmers in Sinana District, Bale Zone, Ethiopia, and their results revealed

that crop diversification decision was positively associated with household size, access to fertile farm plots, and access to extension services and negatively associated with age, and participation in non-farm activities. In addition, the extent of crop diversification is positively associated with access to extension services, labour availability, membership in farmers' cooperatives, and distance to market.

Based on previous literature, some studies by researchers focus on the determinants of crop diversification in other countries. However, very few studies have been done by researchers in Sri Lanka using binomial logistic regression (Mohamed et al., 2006). Nevertheless, this study focused on a particular area concerning the determinants and extent of crop diversification among vegetable farmers. The determinants of crop diversification and the intensity of crop diversification were analyzed using different econometric techniques such as the Heckman selection two-stage model and Cragg's double hurdle model in the current study.

Thus, these approaches are different from other studies done by previous researchers, and to fill the research gap; both models are applied which, considered that the number of crops cultivated by the farmers and the Herfindahl index were taken as two different dependent variables in the Heckman selection two-stage model and Cragg's double hurdle model respectively.

Methodology

To identify the factors influencing the probability of adopting crop diversification and the number of crops grown by the farmers as well as the determinants of intensity of crop diversification among vegetable farmers, Kotagala area was selected in the study. Therefore, the study was conducted in Kotagala division during 2020, when the farmers cultivated nine diversified vegetable crops. The primary data was collected from vegetable farmers through a structured questionnaire related to the information on socio-economic and farming characteristics as well as the total area devoted to each crop in the study area. Nuwara-Eliya district has 05 Divisional Secretariat divisions, among them Nuwara-Eliya is one of the divisions. Therefore, Kotagala was selected as the study area from Nuwara-Eliya Divisional Secretariat division. From the Kotagala area, 100 farmers were selected using a simple random sampling technique and out of them, only 86 smallholder farmers were selected who are cultivating nine vegetable crops such as carrot, knol-khol, cabbage, beetroot, potato, leeks, beans, parsley and lettuce. The collected data were analyzed using various analytical tools that coincide with the study's objectives.

Methods of data analysis

To estimate crop diversification, index measurement was used in the study and followed by the Heckman selection model, and Cragg's double hurdle model was also applied.

Heckman selection model

The decision of smallholder vegetable farmers to diversify their crops is based on the theory of random utility maximization (Rahm and Huffman, 1984). Farmers will diversify their crops if the utility of existing farm operations (U_0) is less than that of introducing additional crops (U_1). Therefore, the i^{th} farmer will

diversify (D_i) if the utility derived from diversification is greater than not diversifying and if $U_{1i} > U_{0i}$ or if the non-observable (latent) random variable $Di^* = U_{1i} - U_{0i} > 0$.

$$D_i = \begin{cases} U_{1i} > U_{0i}, & if\ frmer\ diversifiers, or \\ U_{1i} \leq U_{0i}, & if\ farmer\ not\ diversify \end{cases}$$

Where,

U_{1i}= Utility that the ith farmer engages in crop diversification.

U_{0i}= Utility that the ith farmer does not engage in crop diversification.

Thus, the first stage of the Heckman Two-Stage model (Heckman, 1979), is the selection equation that considers a Probit model which estimates the probability of the farmer diversifying the crop (1) or not (0) in their cultivation. Thus, in the first stage participation decision can be used as,

$D_i^* = \delta_1 + \delta_2 X_{1i} + \varepsilon_{1i}$ and it can be expanded as,

$$D_i = \delta_0 + \delta_1 X_1 + \delta_2 X_2 + \delta_3 X_3 + \delta_4 X_4 + \delta_5 X_5 + \delta_6 X_6 + \delta_7 X_7 + \varepsilon_i$$

Where,

D_i = latent variable, which denotes the decision of vegetable farmers to engage in crop diversification or not.

δ_0 = Intercept

δ_1 to δ_7 are the parameters to be estimated

X_1 = Level of education

X_2 = Gender coded as 1 for male, 0 for female

X_3 = Farm experience

X_4 = Land size in acre

X_5 = Types of land coded as 1 for own, 0 for tenant

X_6 = Types of labour coded as 1 for family, 0 for hired

X_7 = Market distance in Km

ε_i = Error term

In the second stage, the outcome equation is the extent of crop diversification measured by the number of crops grown by the farmers taken as the dependent variable. It can be shown as:

$$Y_i = \psi_i + \psi_2 X_{2i} + \varepsilon_{2i}$$

Where,

Y_i = Number of crops grown by the farmers

ψ_i = Intercept

ψ_2 = Regression parameters to be estimated

X_{2i} = Vector of independent variables that explain the number of crops chosen by the farmers as defined earlier except education level

ε_{2i} = Error term

In addition to the Heckman selection model, Cragg's double hurdle model also applied to answer research questions such as why some vegetable farmers adopt crop diversification, and some do not engage in it? And why does the intensity of crop diversification vary among the crop diversifiers?

In order to answer these questions, Cragg's double hurdle model is better than the Heckman selection model. According to Jones (1989), the significant difference between these two models is the source of zero. In the Heckman model, the non-diversifiers will never cultivate more than one crop in any case. Alternately, in the double hurdle model, non-diversifiers stay as a corner solution in a utility-maximizing model. The most underlying assumption of the model is that adoption and adoption level is supposed to be independent,

which means two decisions are made in two different stages.

The first stage of Cragg's double hurdle model is a Probit model to determine the participation in crop diversification while, the second stage is an outcome equation expressed by the Tobit model, which is used to identify the determinants of adoption intensity (Cragg, 1971). Thus, the Probit model is taken as the dependent variable in the first model, while the Herfindahl index (Hi) is taken as the dependent variable in the Tobit model.

Based on the specification by Cragg (1971), the two hurdles can be written as,

$$d_i^* = \alpha z_i + \gamma_i$$
$$y_i^* = \beta x_i + \varepsilon_i$$

Where,

$$d_i = 1, \text{ if } d_i^* > 0$$
$$0, \text{ if } d_i^* \leq 0$$

and

$$y_i = \begin{cases} y_i^* \ if\ y_i>0\ and\ d_i>0 \\ o\ if\ otherwise \end{cases}$$

Where, z_i is the vector of variables explaining whether a vegetable farmer participates in crop diversification or not and x_i is the vector of variables explaining the intensity of crop diversification such as age, gender, education, land size, land types, labour and market distance.

The first hurdle is to decide whether or not to participate in crop diversification defined in probability using Probit model and the second hurdle is to decide on the extent of participation or intensity of crop diversification participation which was measured by the number of crops cultivated by the farmers. It is important to note that at least one of the explanatory variables in the first equation is not included in the second step for identification (Maddala, 1983). Hence, gender variable was excluded from the second equation, and it was included in the first model in this study.

Results and discussions

The number of farmers who cultivate different vegetable crops is shown by the Figure 1, and it shows that out of 86 respondents, 35 of them cultivate carrots followed by 33 of them cultivate cabbage. Only 7 of them cultivate parsley and lettuce in the study.

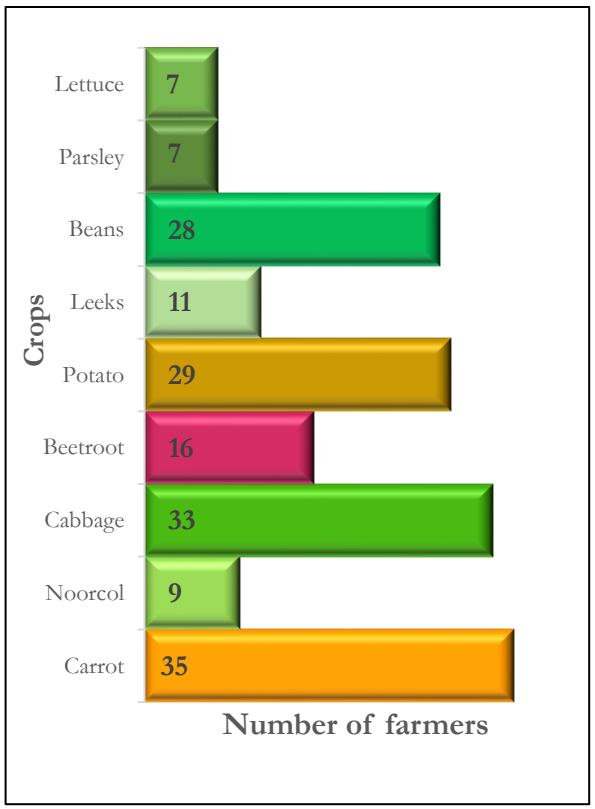

Figure1: Number of crops selected by the farmers in their vegetable cultivation

Further, the allocated land size for each crop given by the Figure 2 reveals that 2.55 acre of

land were allocated for carrot and only 0.6 acre of land allocated for lettuce by the study area.

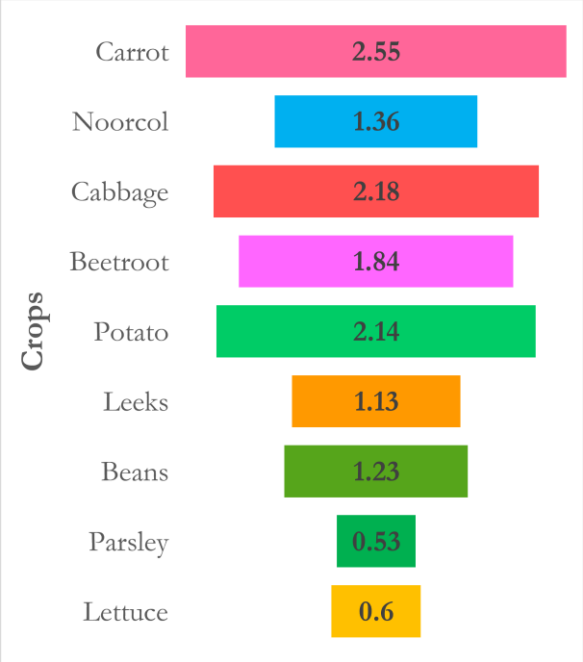

Figure 2: Allocated land size for each crop in acre

Mean values for some selected variables ere measured across diversifier and non- diversifier, representing that the average age of the diversifier is higher than non-diversifier.

At the same time, the farmers who cultivate more than one crop cultivated land area is higher than non- diversifier.

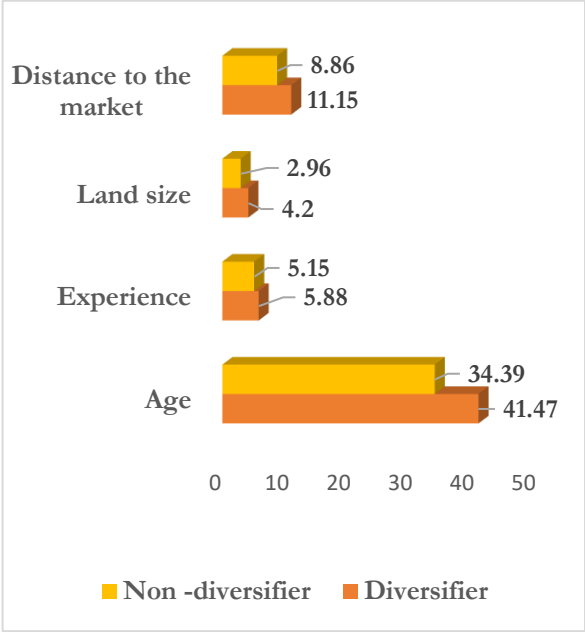

Figure 3: Means of selected variables across diversifier and non- diversifier.

The correlation between the Herfindahl index and the number of crops chosen by the farmers was estimated, and its results suggest that a highly positive correlation exists between them at a 1% significant level.

Table 1: Correlation Between Herfindahl Index and Number of Crops

		Herfindahl index	Number of crops
Herfindahl index	Pearson correlation	1	0.965***
	Significant (2 -tailed)		0.000
Number of crops	Pearson correlation	0.965***	1
	Significant (2 -tailed)	0.000	

Note: **represents the significant at the 0.01 level (2-tailed).
Source: Author's calculations based on survey data, 2020.

Results of Heckman selection model

Heckman selection model is employed to identify the farmers' decision towards whether they engage in crop diversification or not, and if they engage in it; in the next step, the decision on the number of crops to cultivate is also measured in the study. The estimated results of the Heckman selection model are presented in the following table.

Table 2: Determinants and Extent of Crop Diversification in Heckman Selection Model

Variables	Probability of engaging crop diversification			Total crops grown, if engage in crop diversification		
	Coefficients	Standard error	t-value	Coefficients	Standard error	t-value
Education	1.112***	0.296	3.750	……	…….	……..
Gender	0.045	0.315	0.150	0.239**	0.108	2.210
Farm experience	0.005	0.028	0.200	0.0278***	0.008	3.090
Land size	0.208***	0.069	3.010	0.191***	0.041	4.580
Types of land	0.219	0.451	0.490	-0.242	0.155	-1.560
Types of labour	0.065	0.401	0.170	-0.065	0.128	-0.510
Market distance	0.029*	0.017	1.680	0.016***	0.006	2.640
Mills						
λ	-0.019	0.179	-0.110			
ρ	-0.068					
σ	0.286					

Number of observations	86
Censored observations	52
Uncensored observations	34
Wald chi- square (6)	48.860
Probability > chi- square	0.000

Note: ***, **and **represent the significant levels at 1%, 5% and 10% respectively.
Source: Author's calculations based on survey data, 2020.

First, Probit regression was used as a selection model to identify whether a farmer diversifies his or her crop production, which depends on the level of education, gender, experience in farming, size of land holding, types of cultivated land, types of labour and distance from the farm to market. In the next step, if they engage in crop diversification, the number of crops chosen by the farmers to cultivate is taken as the dependent variable with the same explanatory variables except education in the ordinary least square model. The model is a well-fitted one with a value of Wald chi-square 48.86 at a 1% significant level, indicating that engaging in crop diversification was jointly explained by all independent variables used in the study.

In the above table, the first part of the results represents the probability of engaging in crop diversification derived from the Probit model. According to that, education level, land holding size and market distance significantly impact crop diversification decision. The ordinary least

square model was used as an outcome equation to analyze the extent of crop diversification among smallholder crop farmers in the study.

Selection bias was tested by the inclusion of the inverse mill's ratio (Mills lambda) in the model, which is insignificant, confirmed that selection probability terms do not work in an unconditional expectation. Hence the selection is essentially random. Thus, the inverse Mills ratio coefficient is reported as λ, which is insignificant with a t-value of -0.11, further explaining that selection bias is not a significant issue in the above model. Gender, farm experience, land size and distance from the farm to market significantly impact the intensity of crop diversification.

As expected, education of the vegetable farmers is found to have a positive impact on the engagement of crop diversification and it is significant at 1%, which implies that farmers with more educational qualifications are more likely to adopt crop diversification.

Gender is insignificant in the participation equation, while the analogous coefficient in the quantity equation was significant at 5%, implying that when the female farmers engage in crop diversification, they tend to cultivate more than one crop compared to male farmers. Similarly, farm experience is insignificant in the participation equation. However, it was significant at a 5% level in the intensity equation, suggesting that farmers with more experience in farming would like to cultivate more than one crop in the study. The coefficient of land size in the participation equation as well as in the intensity equation is positive, indicating that, as the size of land increases, the probability that a farmer will engage in crop diversification will be more and thus, he or she can choose multiple crops to cultivate in the farming.

Distance to the market significantly determines the probability of a farmer engaging in crop diversification and the number of crops grown by the farmer. This reveals that, as the distance to the market increases, the farmers have more probability of engaging in crop diversification, and thus they like to diversify their crops with more than one in their cultivation. This implies that farmers located far away from markets are found to diversify crops to meet their subsistence and nutritional needs.

In the above discussions, the Heckman two – steps selection model's parameter estimates provide the direction and not the probability or magnitude of change in the variable. Thus, based on the signs of the estimated coefficients the results were interpreted in the model.

However, coefficients of the Heckman selection model are difficult and meaningless to interpret only by using the direction of the sign. Hence, compared to the interpretation of the coefficients and their direction, marginal effects are more practical to explain the impact of each independent variable on the dependent variable in the analysis.

Table 3: Marginal Effects of the Heckman Two-Steps Selection Model

Variables	dy/dx	Standard error	Z	P > Z
Gender	0.239	0.108	2.210	0.027
Farm experience	0.027	0.008	3.090	0.002
Size of land	0.191	0.041	4.580	0.000
Types of land	-0.242	0.155	-1.560	0.119
Types of labour	-0.065	0.128	-0.510	0.611
Market distance	0.016	0.006	2.640	0.008

Note: dy/dx for factor levels is the discrete change from the base level.
Source: Author's calculations based on survey data, 2020.

From the above marginal effects results, gender has a positive sign implying that female farmer has 23.9% more probability to engage in more than one crop compared to male farmers. The coefficient of farm experience was a positive sign that an additional year of farm experience encourages the farmers to cultivate more than one crop by 2.7%. The more significant factor is the farm size which was a positive sign implying that an additional hectare under cultivation increases the number of cultivated crops by 19.1%, assuming other factors held constant. This means that a 1% increase in the size of the land will increase the probability of producing more than one crop by 19.1%. Thus, an extra size of the land will motivate the farmers to diversify their crops, and they can decide the number of crops grow in their farming.

Finally, the marginal effect of distance to the market is 0.016 shows that a one% increase in the distance to the market significantly increases the probability of cultivating multiple crops by 1.6%. The farmers located nearer to the market are found to be easier to diversify their crops and to take the products to the market than the farmers who live farther away from the market.

The following Table 4 shows the maximum likelihood estimates of the double-hurdle model, which are taken as Probit and Tobit models to illustrate the participation in crop diversification and intensity of crop diversification, respectively. According to that, loglikelihood value is -28.95, and the probability value for Chi-square is significant at a 1% level, implying that factors that influence the two-stage decision relating to the adoption of crop diversification and the intensity of crop diversification in the study area can well be expressed in the independent double hurdle model.

Coefficients in the first hurdle indicate how a given decision variable affects the probability of participating in crop diversification using the Probit model. The coefficients in the second hurdle indicate how decision variables influence the intensity of crop diversification which are preferred to cultivate multiple crops.

Results of Cragg's double hurdle model

The Cragg's double hurdle model identified the probability for adoption decision and the intensity of adoption level in crop diversification. The adoption probabilities are ascertained through the first stage of Cragg's double-hurdle model, which is the Probit model, whereas the Tobit regression model identifies the factors that affect the extent or intensity of crop cultivation.

The intensity or extent of crop diversification is measured by the Herfindahl index, which is the dependent variable in the Tobit model. The value of the index closer to zero indicates perfect specialization, and a movement towards one shows an increase in the extent of crop diversification (Malik and Singh, 2002). The estimated results derived from Cragg's double hurdle model are illustrated in Table 4.

Table 4: Determinants and Intensity of Crop Diversification in Cragg's Double-Hurdle Model

Variables	Participation in crop diversification			Intensity of crop diversification		
	Coefficients	Standard error	t - value	Coefficients	Standard error	t - value
Age	0.007	0.009	0.840	0.008***	0.001	5.060
Gender	-0.016	0.312	-0.050	……..	……..	…….
Education	1.165***	0.303	3.840	0.060	0.050	1.180
Land size	0.163**	0.076	2.130	0.033***	0.011	2.880
Types of land	-0.258	0.447	-0.580	-0.062	0.083	-0.740
Types of labour	-0.137	0.404	-0.340	0.001	0.074	0.010
Market distance	0.020	0.020	1.010	0.008**	0.003	2.280
Ln σ						
Constant***	-1.729	0.101	-17.110			
σ	0.177	0.017				

Note: ***, **and **represent the significant levels at 1%, 5% and 10% respectively.
Source: Computed from survey data, 2020.

The results of the first hurdle in Probit model indicate that only education level and size of cultivated land are statistically significant decision variables that influenced the probability of crop diversification among the vegetable farmers in the study area. The results of the Tobit model reveal that age, land size and market distance are statistically significant decision variables that influence the intensity of diversified crops in cultivation. The age coefficient in the Tobit model has a significantly positive effect on the intensity of crop diversification at a 1% significance level. This indicates that older farmers have more likely to cultivate multiple crops than young farmers. The marginal effects of the Tobit model show the changes in the probability of intensity in crop diversification for an additional unit

increase in the independent or decision variables depicted in Table 5. According to Table 5, the marginal effect of age in the Tobit model suggests that, as the age increases by one year, the intensity of cultivating more than one crop increases by 0.6%. However, this may diminish as the farmers get older.

The relationship between crop diversification and the educational of the farmers is an empirical question. However, it is believed that if they attended a secondary education level, the more likely a farmer is able to make constructive decisions to accept new ideas, which enhances their willingness to diversify the crops in their farming.

In the above results, the farmer's education level does not affect the intensity of crop cultivation, but it positively influences the decision of crop cultivation in the selection model. The most of the previous studies proved that there is a positive impact of farmers' education on the intensity of crop diversification (Sharna, 2020). Education makes farmers more compatible with accumulating information and knowledge about the cultivation of multiple crops and its agricultural practices. Therefore, educated farmers quickly understand specific techniques and skills that simultaneously push them to cultivate more crops.

Table 5: Marginal Effects of the Cragg's Double-Hurdle Model

Variables	dy/dx	Standard error	Z	P > Z
Age	0.006	0.002	3.020	0.003
Gender [a]	-0.003	0.063	-0.050	0.957
Education level [a]	0.181	0.060	2.990	0.003
Land size	0.054	0.017	3.170	0.001
Types of land [a]	-0.090	0.101	-0.890	0.372
Types of labour [a]	-0.027	0.096	-0.290	0.774
Market distance	0.009	0.004	2.020	0.043

Note: [a] represents dy/dx is for discrete change of dummy variable from 0 to 1
Source: Author's calculations based on survey data, 2020.

The marginal effect of education is 0.181, which is significant at 1%, which means that more educated farmers have 18.1% more likely to extend their vegetable crops in their farming than less educated farmers. Size of land holding is significant in both participation and intensity of crop diversification equations imply that as the size of landholding increases, the probability of participating in crop diversification will be higher. Thus, the number of crops grown by a farmer also will be higher. The marginal effects of land size in the double hurdle model indicate that as the size of land holding increases by 1 acre, the probability of engaging more than one crop increases by 5.4% and is significant at 1% level.

This suggests that large farm landholding may allow the farmers to allot their land to grow various crops than smaller farm landholders. This finding, in line with the previous studies, revealed that land size positively and significantly affected crop diversification (Benin et al. 2004; Ashfaq et al. 2008; Abay, Bjørnstad, and Smale 2009; Bonham et al. 2012). This result is also consistent with recent findings (Kanyua et al. 2013; Sichoongwe 2014; Huang et al. 2014; Mussema et al. 2015; Makate et al. 2016) ;) reporting that an increase in the availability of farmland leads the farmers to practice crop diversification and thus motivates them to cultivate several crops.

The study indicated that the distance to the market is insignificant in the selection model while it is significant in the intensity equation, which shows that the market distance is influenced only in determining the extent or intensity of diversification. Further, the marginal effect of market distance has a positive and significant effect on crop extension at a 5% level, that as the distance increases from farm to market by one more Km, the number of crops a farmer will grow will also grow increase by 0.9%. Thus, farmers far from the market incurred higher transaction costs for getting information, technology, and industrial consumable goods and services. As a result, the farmer's decision and intensity of crop diversification increase to meet and improve their family consumption and nutritional needs. The finding is in consistent with the findings of Benin et al. (2004) and Rehima et al. (2013). The effect of other variables such as gender, land types and labour are found to be insignificant in determining the intensity of crop diversification in the study.

Conclusion and policy implications

This study was conducted to determine the factors influencing the probability of engaging in crop diversification as well as the determinants number of crops grown and intensity of crop diversification among vegetable farmers in the Kotagala area in 2020. 86 farmers who cultivate nine vegetable crops were selected from a survey, and the collected data was analyzed using the Heckman selection model and Cragg's double–hurdle model. Results of Heckman selection model reveal that education, size of land and market distance were the significant factors that determine the probability of adopting crop diversification, and the second equation of this model reveals that gender, farm experience, land size and market distance were the significant determinants in the number crops grown by the farmers in the study. In addition to the Heckman selection model, to identify the factors that influence the crop diversification decision and the determinants of intensity of crop diversification among the farmers Cragg's double–hurdle model was also estimated in the study. The results of the model represent that education and size of land determine the probability of engaging in crop diversification, while the intensity of crop diversification determines by age, land size and market distance in the study.

From the study results, the fact that the size of landholding positively determines crop diversification; there is a need for the government and relevant stakeholders to undertake policies that will improve the access of the farmers, which will help them to invest in various crop production activities and diversify the crops in their farming. In addition, education of the farmers encourages them to

cultivate more than one crop; thus, government and policy makers should consider facilitating the farmers through education also.

Given the distance to the market, which is an indicator of access to the market, the policy implication is that there is a need for the government to promote and support policies oriented toward bringing trading markets closer to the farmers. This can be done by investing in reliable and adequate market infrastructure, thus fostering agricultural trade for farmers. Thus, market infrastructure will improve farmers' access to markets, thereby increasing their earnings and livelihoods. Furthermore, the government can promote market infrastructure development by encouraging the private sector participate in developing the agricultural market in future.

Mr. Aruppillai Thayaparan is a senior lecturer in the Department of Business Economics, University of Vavuniya, Sri Lanka. His research interests include agricultural economics, labour economics, efficiency and productivity analysis. His publications have appeared in journals such as Journal of Management Matters, Sri Lankan Journal of Business Economics, Wayamba Journal of Management, The Journal of Business Studies, Sri Lanka Journal of Social Sciences and Humanities, Journal of Management and Tourism Research, Journal of Business Management, Sabaragamuwa University Journal.

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