Journal of Agriculture and Value Addition
June 2024, Vol. 7(1): 20-35
DOI: https://doi.org/10.4038/java.v7i1.132

RESEARCH ARTICLE

Adaptation to Climate Change in Tea Plantations: A Heckman's Two-stage Model

R.M.P.S. Rathnayaka[a,b*], A.M. Poornima[a]

[a]*Faculty of Animal Science and Export Agriculture, Uva Wellassa University, Badulla 90000, Sri Lanka*

[b]*Sri Lanka Export Development Board, Nawam Mawatha, Colombo 02, 00200, Sri Lanka*

Submitted: June 12, 2023; Revised: July 12, 2023; Accepted: September 15, 2023
*Correspondence:prabodha.rathnayaka965@gmail.com, https://orcid.org/0000-0002-2336-1242

ABSTRACT

Tea is an important sector of Sri Lanka's economy, serving as the main source of foreign exchange and employment. However, climate change and low profitability have adversely affected the sector, affecting its sustainability and economic viability. Therefore, the tea industry requires appropriate adaptation strategies to cope with ongoing climate change and low profitability. Although crop diversification has long been proposed as an adaptive strategy for combatting climate change and low profitability, the literature indicates that achieving complete transformative change against climate change and price volatility is extremely challenging for tea plantations due to conspicuous differences between annual and perennial crops. To the best of authors' knowledge and as far as literature is concerned, no study has been conducted on the effects of climate change and price on crop diversification in tea plantations. Therefore, this paper, was aimed to contribute to the literature by analyzing the effects of climate change and price on crop diversification based on the secondary data-monthly panel data from 49 tea estates representing all the tea growing regions in Sri Lanka from 2004 to 2018. For this purpose, the Crop Diversification Index and Heckman's two-stage model were employed for empirical analysis. The mean Crop Diversification Index value shows a notable deficiency in diversity among Sri Lanka's tea estates. Results from Heckman's two-stage model show that climate variables have a statistically significant association with crop diversification in tea plantations, indicating the influence of climate variability on crop diversification at 5% and 10% confidence interval levels. Results further show that the price of tea has a positive influence on the decision to diversify. Moreover, the analysis revealed that the real price of rubber, tea yield, elevation, field labor, and cropping area significantly influence the decision for crop diversification, whereas the only the latter three variables affect the extent of diversification.

***Keywords**: Price, Tea industry, Crop diversification, Crop diversification index, Heckman's two-stage model*

INTRODUCTION

The plantation sector in Sri Lanka plays an important role in the economy. Tea, the prominent crop of the plantation sector, is considered one of the key contributors to foreign exchange and employment (Gunathilaka *et al.*, 2017). Tea sector contributes to 1.34 billion export earnings of the country and employs around 10% of the country's workforce (Central Bank of Sri Lanka, 2022).

Despite the economic significance of tea in Sri Lanka, the industry is struggling to maintain its profitability and sustainability due to downward production trends, high international competition, global fluctuations in commodity prices, the rising cost of production, labor issues, and climate change (Jayasinghe and Kumar, 2019). These challenges have both direct and indirect effects on tea production, highlighting the need for adaptation strategies against low profitability and climate change as a priority due to their unavoidable consequences (Gunathilaka *et al.,* 2018 b, Jayasinghe and Kumar, 2019)

Tea is primarily grown as a rain-fed plantation crop, and tea yield is greatly influenced by weather (Gunathilaka *et al*., 2017). Drought affects both the quantity and quality of tea harvests, causing considerable loss in export earnings and an increase in the cost of production (Wijeratne, 1996, Upadhyaya and Panda, 2004, Gunathilaka *et al.,* 2017). According to Gunathilaka *et al*. (2017), tea production in Sri Lanka will be negatively affected by rise in temperature and rainfall. They find that a 1 °C increase in average temperature will cause a 4.6% reduction in tea production, and an additional 100 mm of annual rainfall decreases tea production by around 1%, across all elevations of tea growing areas. Further, Jayasinghe and Kumar (2019) explain that, increased rainfall and temperature during the quality season will negatively affect the aroma, taste and color of the made tea. Compared to the annual crops, perennial crops such as tea are less adaptable and more vulnerable to the impacts of climate change due to the longer life span and higher establishment costs (Gunathilaka *et al.,* 2017). Therefore, climate change is expected to have an adverse effect on both the quality and quantity of tea; thus, the adaptation is crucial.

In general, use of new crop varieties and livestock species that are better suited to drier conditions, irrigation, crop diversification, adoption of mixed crop and livestock farming systems and adjusting planting dates are the common adaptation methods used in agriculture (Fadina and Barjolle, 2018, Gunathilaka *et al*., 2018 a, Karuri, 2020). Among these options, diversification (increasing the variety of production locations, crops, enterprises, or income sources) has been commonly identified as a potential response and a most common adoption measure to climatic variability and change (Verchot *et al*., 2007, Altieri and Koohafkan, 2008, Kissinger *et al*., 2013). A sizeable body of literature has emphasized the potential for adaptation in agriculture to reduce costs or increase gains associated with climate change (Burton and Lim 2005). So far, however, there has been little discussion on adopting crop diversification in perennial cropping systems and the factors affecting on the adaptation decision (Gunathilaka *et al*., 2017).

Previous researchers have used various econometric models to determine factors' effect on diversification decision and extent of diversification. These models include Ordinary Least Square (OLS) (Huang *et al*., 2014, Ojo *et al*., 2014, McCord *et al*., 2015), multinomial logit analysis (Esham *et al*., 2018), multiple regression (Singh *et al*., 2018), Tobit model, Poisson model, Probit model, double-hurdle model (Sichoongwe *et al*., 2014) and Heckman's two-stage model (Rehima *et al*., 2013, Mussema *et al*., 2015, Aheibam *et al*., 2017). The Heckman two-stage model is widely used in the study of climate change adaptation because it adheres to the characteristics of evaluating two stages of perceiving and adapting to climate change. For instance, it was used by Deressa *et al*. (2011) to examine the two-step process farmers in the Ethiopian Nile River Basin use to adjust to climate change. In addition, Batool *et al*. (2018) used the Heckman two-stage model to pinpoint the variables influencing how women perceive climate change and how they cope. Thus, we used the Heckman's two-stage model to study the factors affecting on perception and adoption to crop diversification in Sri Lankan tea estates.

Moreover, in Sri Lankan context, the majority of the research has been focused on crop diversification in annual crops. However, the adaption of crop diversification as a farm-level response to climate change and price remains unclear. Given the economic and social significance of the tea industry in Sri Lanka, crop diversification could offer a sustainable solution benefiting all stakeholders against climate change and low profitability. Therefore, it is important to have a solid understanding of their influence on crop diversification to develop suitable and applicable policies. Thus, aiming to address the above research gaps, this study employs Heckman's two-stage model to identify the factors influencing the decision for crop diversification in tea estates, in order to contribute designing the climate change adaptation policies with respect to tea plantations in Sri Lanka.

MATERIALS AND METHODS

Conceptual Framework

The two stages of Heckman's model are illustrated in Figure. 1. Accordingly, in the first stage, the factors affecting on the diversification decision are estimated. The dependent variable (categorical) is diversification decision (adoption or non-adoption/ propensity to diversify). Independent variables are consisted with climate characteristics, market characteristics and estate specific characteristics. In the second stage, only the adopters are considered for the analysis. Accordingly, the factors affecting on the crop diversification extent of the adopters are estimated in the second model. The extent of crop diversification is measured in terms of Crop Diversification Index (CDI). The same set of independent variables are used in the second stage as well.

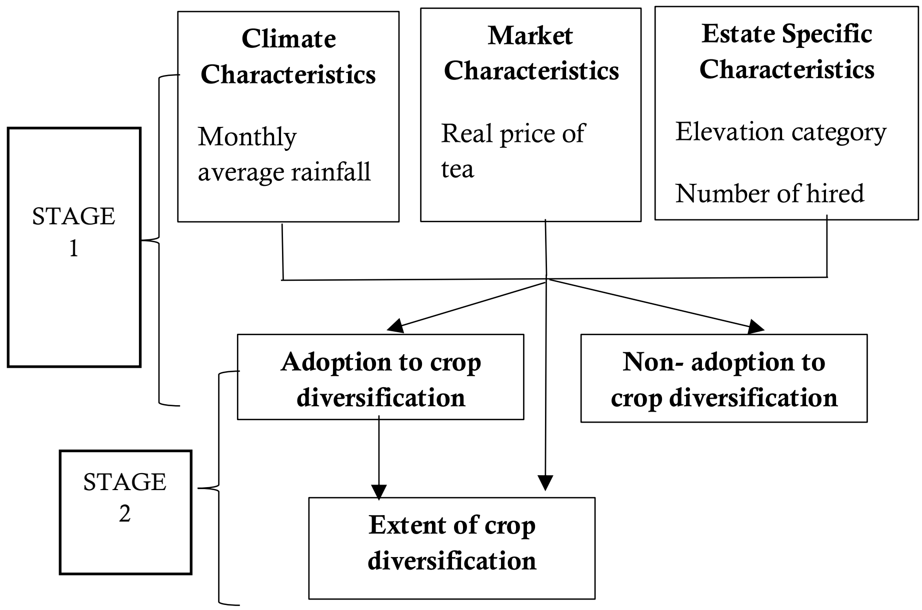

Figure1: Conceptual framework - Heckman's Two-stage Model

Study Area and Sampling

Tea growing regions in Sri Lanka are categorized according to differences in elevation: Up Country (>1200 m above sea level), Uva (1000 m-1600 m above sea level), Mid Country (600 m-1200 m above sea level) and Low Country (<600 m above sea level) (Department of Meteorology Sri Lanka, 2019). A stratified random sampling technique was employed to obtain a representative sample from 307 tea estates in Sri Lanka. The sample consisted of 49 tea estates, including 18 from the Up Country, 10 from the Mid Country, 12 from the Low Country, and 9 from the Uva region.

Data and Variables

Depending on the availability of data, the study used a monthly panel dataset collected from the 49 tea estates over the period 2004-2018. Data on the number of wet days (>2 mm) per month, monthly average rainfall, green leaves quantity per hectare, cropping area under tea, field labor, the market price for tea and other crops, and the elevation were directly obtained from the estate records for 15 years of period. Data on monthly mean temperature was collected from the Meteorology Department of Sri Lanka as tea estates in Sri Lanka do not record daily temperature. The independent variables used in this study were based on the literature and availability of data. Selected independent variables were broadly categorized into climate, market, and estate characteristics (Table 1). Data were analyzed using STATA statistical software.

Table 1: Independent variables used in the Heckman's two stage model

	Variable Name	Type	Measuring Scale	Units/Symbols
Climate Characteristics	Monthly average rainfall	Continuous	Millimeters	mm
	Monthly average temperature	Continuous	Celsius	°C
	Wet days	Continuous	No. of days	Number
Market Characteristics	The real price of tea	Continuous	Rupees per kilogram	Rs
	The real price of rubber[1]	Continuous	Rupees per kilogram	Rs
Estate/ Physical Characteristics	Total area, Cropping area	Continuous	Hectares	Ha
	Number of field labor	Continuous	Person days	Number
	Elevation category Uva Up Country Mid Country Low Country	Dummy		
	Tea yield	Continuous	Green leaves kilograms per hectare	Kg

[1] >2 mm rainfall considers as a wet day
[1] Rubber price was selected for the analysis as rubber was the most commonly adopted crop in diversified tea lands.

Model Specification

Estimating Crop Diversification Index (CDI)

The study employed the CDI to measure the extent of diversification. The CDI was calculated using the Herfindahl Index (HI) based on the concept of relative abundance (Ojo *et al.*, 2014). Thus, CDI is calculated based on proportions instead of absolute counts (Bradshaw *et al.*, 2004).

The CDI was calculated as shown below;

$$p_i = \frac{A_i}{\sum_{i=1}^{n} A_i} \tag{1}$$

$$\textit{Herfindahl index (HI)} = \sum_{i=1}^{n} p_i^2 \tag{2}$$

Where, p_i is the proportion of area under the ith crop, A_i is the actual area under ith crop, $\sum_{i=1}^{n} A_i$ is the total cropped area/summation of the area under all '*i*' crops and i is the number of crops (1, 2, 3……., n).

$$\textit{Crop Diversification Index (CDI)}=1-\sum_{i=1}^{n} p_i^2 = 1\text{-}HI \quad (3)$$

Thus, the value of CDI ranges between zero and one and values approaching one indicates a high extent of diversification while values approaching zero indicates a low extent of crop diversification (Ojo *et al.*, 2014).

Heckman's Two-stage Model

Stage 1
A probit model was employed to estimate the factors affecting the decision to adopt crop diversification (propensity to diversify).

Thus, the equation for first stage as follows;

$$P(Di = 1|X_i) = \beta + w_i\alpha + v_i \quad (4)$$

Where Di is a dummy for propensity to diversify and w_i are the vectors of explanatory variables assumed to affect the propensity to diversify and α is the vector of the coefficient associated with w_i, v_i is the error term.

To correct the selection bias in the first stage equation, the Inverse Mills Ratio (IMR) was added as an explanatory variable. IMR can be computed as:

$$\lambda = \frac{\varphi\big(h(w_i, \tilde{a})\big)}{\varphi(w_i, \tilde{a})} \quad (5)$$

Where λ denotes IMR, φ is the normal probability density function, $\varphi(.)$ is the standard normal cumulative density function, w_i are the vectors of explanatory variables assumed to affect the diversification decision.
The Wald test statistics were used to measure the model fit.

Stage 2

In the second stage, the OLS model was used to estimate the factors affecting on the extent of crop diversification of the tea estates which adopted crop diversification.

The second equation is given by:

$$Y_i = \alpha + x_i\beta + \gamma\lambda_i + \mu_i \quad (6)$$

Where, Y_i is the crop diversification index (CDI), x_i are the vectors of explanatory variables assumed to affect the extent of crop diversification which is conditional on observing diversification, β is the vector of the coefficient associated with x_i, λ_i is the Inverse Mills Ratio, γ is the corresponding parameter of λ and μ_i is the error term.

The two equations for the two steps of Heckman's two-stage model were specified as follows:

Stage 1-

$$P(Di = 1|X_i) = \alpha_0 + \alpha_1 w_1 + \alpha_2 w_2 + \alpha_3 w_3 + \alpha_4 w_4 + \alpha_5 w_5 + \alpha_6 w_6 + \alpha_7 w_7 + \alpha_8 w_8 + \alpha_9 w_9 + \alpha_{10} w_{10} + v_i \quad (7)$$

Where Di is the dummy for propensity to diversify and w_i are the vectors of explanatory variables assumed to affect the propensity to diversify and α is the vector of the coefficient associated with w_i, v_i is the error term.

Stage 2-

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{3+} x_3 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8 + \beta_9 x_9 + \beta_{10} x_{10} + IMR + \mu_i \quad (8)$$

Where, Y_i is the CDI, x_i are the vectors of explanatory variables assumed to affect the extent of crop diversification which is conditional on observing diversification, β is the vector of the coefficient associated with x_i, IMR is the Inverse Mills Ratio, γ is the corresponding parameter of λ and μ_i is the error term.

RESULTS AND DISCUSSION

Summary Statistics

According to the summary statistics, more than 80% of tea growers were non-diversifiers. Thus, only 20% of sampled tea estates have diversified tea lands into alternative crops whereas the majority (80%) focused on tea as the main crop. The majority of diversifiers had mainly shifted from tea to rubber, while others had planted commercial crops such as coffee, mandarin, cinnamon, pepper, and cocoa. Results indicated that diversified tea estates had a mean computed CDI value of 0.204 with a standard deviation of 0.185, while non-diversifiers had CDI equal to zero. However, all the corporate sector tea plantations were found to have CDI values lesser than 0.5 (Figure 2).

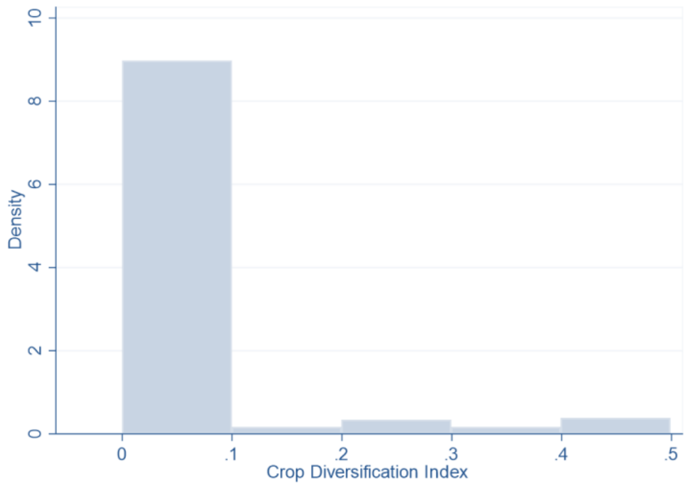

Figure 2: Distribution of the Crop Diversification Index within the sample (Note: Density is the number of tea estates)

Overall CDI showed that there is a significant spatial and temporal discrepancy exists in crop diversification in tea plantations. The extent of diversification was noticed to be higher in recent years compared with the initial years.

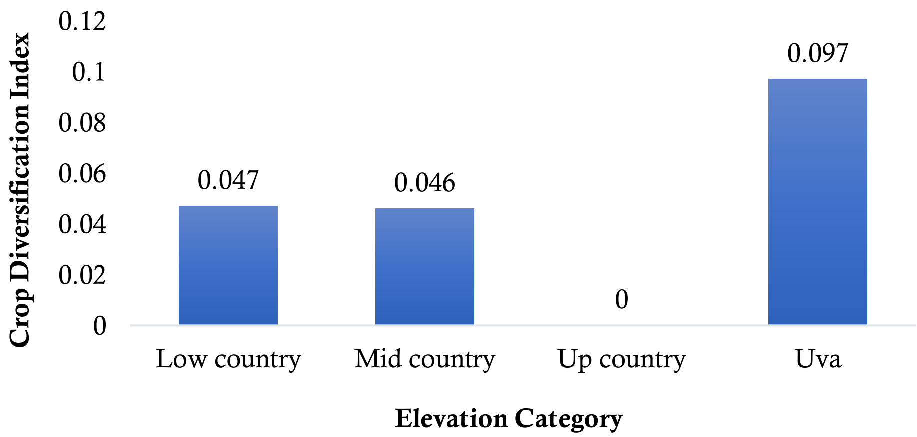

Figure 3: Distribution of Crop Diversification Index among different tea growing regions

Regional comparison of crop diversification indicated that CDI is zero for all the sampled tea estates in the Up Country as none of the tea estates had diversified.

In contrast, the Uva region had the highest mean CDI value of 0.097 followed by the Low Country with 0.047 and the Mid Country with 0.046 (Figure 3). Thus, the results showed that the extent of crop diversification was highest in Uva region tea plantations, followed in declining order by Low Country and Mid Country, respectively. This spatial difference of crop diversification may result from longitudinal and latitudinal variations and thus physical, geographical, and climatic features that suitable only for the particular crops.

Summary statistics of the variables used in the Heckman two-stage analysis are presented in Table 2. The study indicated that 70% of the diversifiers were in the Uva region whereas 46% of the non-diversifiers were in the Up Country. Moreover, the results revealed that on average, diversifiers had a lower average rainfall, wet days, cropping area, the real price of tea, tea yield, and field labor compared to non-diversifiers. On contrary, the monthly average temperature and real price of rubber were greater for diversified tea estates, unlike their non-diversifying counterparts.

Table 2: Summary statistics of continuous independent variables in Heckman's two stage model

Variables	Diversifiers (n=1440)		Non-diversifiers (n=7380)		Overall
	Mean	Standard Deviation	Mean	Standard Deviation	Mean
Monthly average temperature	24.7	2.2	19.3	4.6	20.2
Monthly average rainfall	206.5	191.4	226.0	201.9	222.8
Wet days	10.6	6.5	12.0	6.9	11.8
Cropping area	321.7	141.9	358.7	129.2	352.7
Real price of tea	413.0	330.5	417.1	353.0	416.4
Real price of rubber	377.7	314.8	276.3	104.6	292.9
Field labour	668.3	456.7	696.4	505.1	691.8
Tea yield	126.0	98.7	261.8	196.7	239.61

Table 3: Summary statistics of categorical independent variables in Heckman's two stage model

Variable	Diversifiers (n=1440)		Non-diversifiers (n=7380)		Overall	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Low County	360	25.00	1800	24.39	2160	24.49
Mid Country	180	12.50	1620	21.95	1800	20.41
Up Country	0	0	3240	43.90	3240	36.73
Uva	900	62.50	720	9.76	1620	18.37

Heckman's Two-stage Model

The value of Wald test statistics, that is, 7672.6 confirmed that the coefficients of the diversification decision and extent of diversification equations are significantly different from zero, indicating that the model fulfilled the conditions of good fit. As shown in Table 4, the variables; wet days, temperature, rainfall, the cropping area, elevation (Up Country, Mid Country, Uva), tea yield, field labor, the real price of tea, and real price of rubber were statistically significant at 95% confidence level.

Accordingly, tea estates which receive higher number of wet days were more propensity to adopt crop diversification while opposite was true for tea estates which receive higher rainfall. It explains that, more distributed rainfall throughout the month favors the growth of tea and the other crops compared to intense rainfall. However, tea estates which record higher temperature favor crop diversification. In the sample many of the adopted tea estates are in Uva region where it has higher temperature compared to Up Country and Mid Country. That may be the reason to have a positive relationship between temperature and propensity to diversify. Surprisingly, the tea estates with larger land extents reluctant to diversify. However, as expected, the higher tea yield and higher price for tea favors the tea estates to remain monocrop. Tea estates with higher labor availability are more propensity to diversify and it is true when the estates could receive higher price for the alternative crops. Similar to the dis distribution of the diversified tea estates among the tea growing regions, compared to the lower elevations, tea estates in higher elevations prefer crop diversification except the Up Country. Up Country has the largest tea estates with higher yield. That may be the reason to not to prefer crop diversification in the tea estates.

Table 4: Probit regression for the determinants of crop diversification decision

Variable	Coef.	Std. Err.	*P*>(z)	Marginal effect
Monthly average Rainfall	-0.0006605	0.0002237	0.003**	-0.0000242
Wet days	0.0313711	0.0065066	0.000***	0.003397
Monthly average temperature	0.3034638	0.0163926	0.000***	0.0321235
Cropping area	-0.0045125	0.0003147	0.000***	-0.000478
Tea yield	-0.0035881	0.0002236	0.000***	-0.00003801
Field labor	0.0011864	0.0000742	0.000***	0.0001275
Real price of tea	-0.0003323	0.0000698	0.000**	-0.0000352
Real price of rubber	0.002548	0.0001454	0.000***	0.0002699
Mid Country	0.6904331	0.0766995	0.000***	0.0731401
Up Country	-5.105242	0.2011546	0.000***	-0.5408172
Uva	1.559005	0.0917821	0.000***	0.1651512
Constant	-8.051119	0.4546784	0.000***	

Note: ***, ** and * indicate the extent of statistical significance at 1% and 5% and 10% probability levels, respectively

Table 5: OLS regression for the determinants of the extent of crop diversification (Dependent Variable: CDI)

Variable	Coefficient	Std. Error	*P*>(z)	Z stat
Monthly average rainfall	0.0000923	0.0000267	0.001***	3.46
Wet days	-0.0029459	0.0008099	0.000***	-3.64
Monthly average temperature	0.0115313	0.0033802	0.001***	3.45
Cropping area	0.0006145	0.0000765	0.000***	8.04
Tea yield	-0.0000726	0.0000544	0.182	-1.33
Field labour	-0.0002354	0.0000174	0.000***	-13.54
Real price of rubber	- 0.0000144	0.0000206	0.485	- 0.70
Mid country	-0.0676315	0.0148696	0.000***	18.00
Uva	0.2696309	0.0179609	0.000**	-3.88
Constant	-0.1246948	0.1005736	0.215	-1.24
lambda	0.0622797	0.0201229	0.002	3.09
Rho	0.48884			
sigma	0.127404			

Note: ***, ** and * indicate the extent of statistical significance at 1% and 5% and 10% probability levels, respectively

The results of the OLS in Heckman's two-stage model (Table 5) show that extent of crop diversification is dependent on the temperature, rainfall, wet days, cropping area, elevation category (Mid Country, Uva), and the number of field laborers. All these variables were statistically significant at a 95% confidence level. Selection bias was tested by including the Inverse Mills Ratio (IMR).

Results reveal that seven independent variables significantly effect on the extent of crop diversification in the crop diversification adopted tea estates. Only the diversified tea estates in Uva, Mid Country and Low Country tea growing regions are considered in the OLS analysis. Accordingly high rainfall positively impacts on the crop diversification even though the degree of impact is negligible (coefficient – 0.0000). Thus, when the tea estates receive more rainfall, they adopt to crop diversification more. Increased rainfall during the quality seasons reduces the tea production in terms of both quantity and quality (Damayanthi *et al.*, 2010, Gunathilaka *et al.*, 2017, Jayasinghe and Kumar, 2019). According to Gunathilaka *et al.* (2017), an additional 100 mm of annual rainfall decreases tea production by around 1%, across all elevations of tea growing areas. Hence, tea estates diversify the tea lands in to other crops to counteract the income losses. In contrast, increased number of wet days has a negative impact on extent of crop diversification. Distributed rainfall has an incremental effect on tea production as tea prefers even and distributed rainfall throughout the month to produce quality teas with better aroma, taste and color. Thus, when the tea estates receive expected distributed rainfall, the estates may remain growing tea rather than diversifying the tea lands into other crops.

Similar to the rainfall, temperature rise during the quality season in each tea growing region has a detrimental effect on the quality of tea resulting lower quality tea production and lower revenue generations (Gunathilaka *et al.*, 2017, Jayasinghe and Kumar, 2019). Gunathilaka *et al*. (2017) have explained that, 1°C increase in average temperature will cause a 4.6% reduction in tea production in all tea growing regions in Sri Lanka. Hence as indicated in the results, when the temperature increases by one unit the extent of crop diversification in diversified tea lands increase by 0.01. Increased cropping area also favors the crop diversification in tea estates. According to the results, when the land extent is increased it slightly (0.0006) increases the extent of crop diversification. As expected, tea estates which have higher land extent may more diversify the marginal tea lands into other crops to earn more income. Surprisingly, when one more labor is added to the workforce, the extent of crop diversification is decreased by 0.0002. Thus, may be characterized by the nature of the diversified tea estates in the sample. Majority of the diversified tea estates belong to the Uva region where it records lower labor availability. That may be the reason for the resulted relationship. Finally, compared to the Low Country tea growing region, extent of crop diversification is higher in Uva region and opposite is true for Mid Country. As per our sample, many of the tea estates in Uva region adopted to crop diversification. Uva region is known to be adversely impacted by climate change compared to other tea growing regions. Hence, the tea estates in Uva region adopt more to crop diversification to counteract the revenue losses.

CONCLUSIONS

Present study aimed to study the impact of climate, market and estate specific factors on the decision and extent of crop diversification in tea estates, the main economic crop in Sri Lanka. Accordingly, A Heckman's two stage model was employed to a panel of 15 years data collected form 49 tea estates covering all tea growing regions in the country. Only 20% of the sample diversified the tea estates with other crops while majority of the tea estates remained monocrop. Overall, the level of adoption is fairly lower which recorded 0.20 mean value. The results reveal that distributed rainfall, higher temperature, more availability of labor and higher rubber price favor the decision to adopt crop diversification mostly in tea estates in Uva and Mid Country tea growing regions. However, high rainfall and temperature along with larger tea land extents increase the extent of crop diversification in tea estates. However, the price of tea and alternative crop does not impact on the extent of crop diversification. The tea estates in Uva region are more likely to adopt to crop diversification compared to other tea growing regions. Thus, the study proposes to consider the spatial discrepancy observed in adopting to crop diversification when the related policies are formulated and implemented. Introduction of plant varieties which are more resistant to higher temperature and rainfall would more encourage the tea estates to adapt crop diversification. Uva region can be more focused in popularizing crop diversification in order to adapt to the changes in climate and offset the lower revenue due to quantity and quality losses of tea.

There are several limitations experienced in the present study. We used a monthly panel data set to investigate crop diversification at the country level. However, due to the perennial nature of the crop, future research should investigate crop diversification using annual data for a long period as it may yield better results. Moreover, further studies are encouraged on crop diversification at regional levels for the better understanding of the regional heterogeneity of climate change and adopting to crop diversification.

ACKNOWLEDGEMENT

The authors would like to thank estate managers and chief executive officers of plantation companies in Sri Lanka for assisting with the data collection and participating in the interviews. Authors thank Dr. Dayani Gunathilaka for her advices and support in successfully completing this study. The authors thank Ms. Leena Fernando in data collection and data entering. Further the authors thank

Uva Wellassa University for funding this research study (grant no. UWU/RG/2020/020).

REFERENCES

Aheibam, M., Singh, R., Feroze, S.M., Singh, N.U., Singh, R.J. and Singh, A.K. (2017). Identifying the Determinants and Extent of Crop Diversification at Household Level: Evidence from Ukhrul District, Manipur. Economic Affairs, 62(1), p.89. doi:https://doi.org/10.5958/0976-4666.2017.00031.6.

Altieri, M.A. and Koohafkan, P., 2008. Enduring Farms: Climate Change, Smallholders and Traditional Farming Communities. Penang: Third World Network (TWN).

Batool, H., Ali, W., Manzoor, R. and Mahmood, N. (2018). Women's Perception of Climate Change and Coping Strategies in Pakistan: An Empirical Evidence. Earth Systems and Environment, 2(3), pp.609–619. doi:https://doi.org/10.1007/s41748-018-0073-7.

Bradshaw, B., Dolan, H. & Smit, B. (2004) Farm-Level Adaptation to Climatic Variability and Change: Crop Diversification in the Canadian prairies, Climatic Change. 67, pp. 119-141.

Burton, I. and Lim, B. (2005). Achieving Adequate Adaptation in Agriculture. Climatic Change, 70(1-2), pp.191–200. doi:https://doi.org/10.1007/s10584-005-5942-z.

Central Bank of Sri Lanka. (2022) Annual Report, Central Bank of Sri Lanka, Colombo.

Damayanthi, M., Mohotti, A. and Nissanka, S. (2011). Comparison of Tolerant Ability of Mature Field Grown Tea (Camellia sinensis L.) Cultivars Exposed to Drought Stress in Passara Area. Tropical Agricultural Research, 22(1), p.66. doi:https://doi.org/10.4038/tar.v22i1.2671.

Department of Meteorology Sri Lanka. (2019) Climate of Sri Lanka [Online]. Department of Meterology, Sri Lanka. Available: http://www.meteo.gov.lk [Accessed 30.04.2023].

Deressa, T.T., Hassan, R.M. and Ringler, C. (2010). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. The Journal of Agricultural Science, 149(1), pp.23–31. doi:https://doi.org/10.1017/s0021859610000687.

Esham, M., Jacobs, B., Rosairo, H.S.R. and Siddighi, B.B. (2017). Climate Change and Food Security: A Sri Lankan Perspective. Environment, Development and Sustainability, [online] 20(3), pp.1017–1036. doi:https://doi.org/10.1007/s10668-017-9945-5.

Fadina, A. & Barjolle, D. (2018). Farmers' Adaptation Strategies to Climate Change and their Implications in the Zou Department of South Benin. Environments, 5(1), p.15. doi:https://doi.org/10.3390/environments5010015.

Gunathilaka, R.P.D., Smart, J.C.R. and Fleming, C.M. (2017). The Impact of Changing Climate on Perennial Crops: The Case of Tea Production in Sri Lanka. Climatic Change, 140(3-4), pp.577–592. doi:https://doi.org/10.1007/s10584-016-1882-z.

Gunathilaka, R.P.D., Smart, J.C.R. and Fleming, C.M. (2018 a). Adaptation To Climate Change in Perennial Cropping Systems: Options, Barriers and Policy

Implications. Environmental Science & Policy, 82, pp.108–116. doi:https://doi.org/10.1016/j.envsci.2018.01.011.

Gunathilaka, R.P.D., Smart, J.C.R., Fleming, C.M. and Hasan, S. (2018 b). The Impact of Climate Change on Labour Demand in The Plantation Sector: The Case of Tea Production in Sri Lanka. Australian Journal of Agricultural and Resource Economics, 62(3), pp.480–500. doi:https://doi.org/10.1111/1467-8489.12262.

Huang, J., Jiang, J., Wang, J. and Hou, L. (2014). Crop Diversification in Coping with Extreme Weather Events in China. Journal of Integrative Agriculture, 13(4), pp.677–686. doi:https://doi.org/10.1016/s2095-3119(13)60700-5.

Jayasinghe, S.L. and Kumar, L. (2019). Modeling the Climate Suitability Of Tea [Camellia sinensis(L.) O. Kuntze] in Sri Lanka in response to Current and Future Climate Change Scenarios. Agricultural and Forest Meteorology, 272-273, pp.102–117. doi:https://doi.org/10.1016/j.agrformet.2019.03.025.

Karuri, A.N. (2020). Adaptation of Small-Scale Tea and Coffee Farmers in Kenya to Climate Change. African Handbook of Climate Change Adaptation, pp.1–19. doi:https://doi.org/10.1007/978-3-030-42091-8_70-1.

Kissinger, G.,Lee, D.,Narasimhan, P.,King'uyu, S.,Sova, C. & Orindi, V. (2013). Planning Climate Adaptation in Agriculture. Meta-Synthesis of National Adaptation Plans in West and East Africa and South Asia. CCAFS Report No. 10. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

McCord, P.F., Cox, M., Schmitt-Harsh, M. and Evans, T. (2015). Crop Diversification as a Smallholder Livelihood Strategy within Semi-Arid Agricultural Systems near Mount Kenya. Land Use Policy, 42, pp.738–750. doi:https://doi.org/10.1016/j.landusepol.2014.10.012.

M Rehima Mussema, Kassa, B., Alemu, D. and Rashid Shahidur (2015). Determinants of Crop Diversification in Ethiopia: Evidence from Oromia Region. Ethiopian journal of agricultural sciences, 25(2), pp.65–76.

Ojo, M.,Ojo, A.,Odine, A. & Ogaji, A. (2014). Determinants of Crop Diversification among Small–Scale Food Crop Farmers in North Central, Nigeria. Journal of Production Agriculture and Technology, 10, pp.1-11.

Rehima, M.,Belay, K.,Dawit, A. & Rashid, S. (2013). Factors Affecting Farmers' Crops Diversification: Evidence from SNNPR, Ethiopia. International Journal of Agricultural Science, 3, pp.558-565.

Sichoongwe, K.,Mapemba, L.,Tembo, G. & Ng'ong'ola, D. 2014. The Determinants and Extent of Crop Diversification among Smallholder Farmers: A Case Study of Southern Province Zambia. Journal of Agricultural Science, 6, pp.150-159.

Singh, K.M., Ahmad, N., Sinha, D.K., Singh, R.K.P. and Mishra, R.R. (2018). Diversification and its Determinants: A Search for an Alternative Income and Agricultural Development in Eastern India. International Journal of Current Microbiology and Applied Sciences, 7(2), pp.695–702. doi:https://doi.org/10.20546/ijcmas.2018.702.087.

Upadhyaya, H. and Panda, S.K. (2004). Responses of Camellia sinensis to Drought and Rehydration. Biologia plantarum, 48(4), pp.597–600. doi:https://doi.org/10.1023/b:biop.0000047158.53482.37.

Verchot, L.V., Van Noordwijk, M., Kandji, S., Tomich, T., Ong, C., Albrecht, A., Mackensen, J., Bantilan, C., Anupama, K.V. and Palm, C. (2007). Climate

Change: Linking Adaptation and Mitigation Through Agroforestry. Mitigation and Adaptation Strategies for Global Change, 12(5), pp.901–918. doi:https://doi.org/10.1007/s11027-007-9105-6.

Wijeratne, M.A. (1996). Vulnerability of Sri Lanka Tea Production to Global Climate Change. Water, Air, and Soil Pollution, 92(1-2), pp.87–94. doi:https://doi.org/10.1007/bf00175555.