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Distributional Impacts of Climate Change on Smallholder Agriculture in Sri Lanka

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Abstract

This research develops a methodology based on the popular agricultural household model that take the nature of agricultural producers and the full income of households into consideration in predicting changes of welfare due to climate change. The effect of climate change on the choice of livelihood, as well as income from a given livelihood is analysed using a cross sectional data set from Sri Lanka. First, a multinomial logistic regression was estimated to model livelihood choice to assess whether it is climate dependent. Second, to assess the variations in the impact of future climate on the chosen livelihood strategies separate regression equations were estimated for each livelihood strategy. Predictions for a future climate were made using the model with household characteristics as it fits data better than the other two models. The recent IPCC predictions of temperature and rainfall were used in the predictions. Results reveal that there is a clear case of climate playing a significant role in livelihood choice by farmers. Of the livelihood choices considered, three strategies were found to be resilient to changes in climate: Tea and rubber, Coffee/pepper/betel and the wage labour strategy. They show a positive change in welfare with the changes in climate. The spatial distribution of the welfare impacts show that resilience/vulnerability of livelihood strategies vary spatially. This study highlights the importance of developing opportunities for farmers for off farm strategies and also to give due consideration of the spatial distribution of impacts when designing climate policies

Keywords

Climate change, agriculture, livelihood, Sri Lanka

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1. Introduction

Impacts of climate change are likely to be felt more by developing nations than by developed countries (Munasinghe, 2001). One characteristic of these developing nations is their high dependence on agriculture and majority of agricultural production comes from smallholders in rural areas (World Bank, 2015). Therefore, traditionally, rural areas were equated to farming. Because the climate is expected to affect agriculture in varying degrees, measurement of welfare impacts of such climatic changes on rural households has been studied with a keen interest (Kurukulasuriya and Mendelsohn, 2006; Kurukulasuriya and Mendelsohn, 2007). Ricardian analysis is the most common tool for measuring the welfare effects of climate change in agriculture because it takes into account the long run adaptation of farmers to changes in the climate (Mendelsohn, *et al.*, 1994). Due to this advantage in analysis, studies using the Ricardian technique have proliferated over the years (Mendelsohn, *et al.*, 2010; Mendelsohn, and Seo, 2008; Kurukulasuriya, P. and R. Mendelsohn, 2006; Seo, *et al.*, 2005; Reinsborough, 2003; Mendelsohn, *et al.*, 1994).

In the Ricardian analysis, the long term impact of climate on agriculture is measured by relating climate normals to agricultural profits and thereby, predicting the agricultural profits for a future climate (Mendelsohn, *et al.*, 1994). Thus, welfare effects of smallholders are solely measured on the impact of climate change on agriculture. However, it is now clear that this is erroneous. Rural households in Africa, developing Asia and Latin America derive 40-45%, 30%, and 40% of their income respectively from non-agricultural sources (Barrett *et al.*, 2001; Deininger and Olinto, 2001). Therefore, welfare impacts calculated maybe misleading because the diverse livelihood strategies those rural farmers employ have not been taken into consideration.

Thus, several questions are addressed in this research. Firstly, do smallholder farmers change their livelihood strategies as adaptations to climate change? In other words, is their choice of the livelihood strategy dependent on climate normals? What are the welfare impacts of these strategies for a future changes in the climate? Are there livelihoods that are more resilient to climate than others? To address these issues, first, livelihood choices are modelled in a multinomial framework to enable prediction of choices made by farmers to changes in climate. Second, a Ricardian model is estimated for each strategy to enable prediction of welfare changes on farmers who choose each strategy.

Sri Lanka looks at diversification as a strategy for rural development. One of the priority areas identified by the World Bank support in Sri Lanka includes fostering agricultural and rural non-farm growth and competitiveness. This seems plausible because, farming on its own is increasingly unable to provide a sufficient means of survival in rural areas (Ellis, 2000). Changes in climate normals are expected to lead to adjustments in land and water regimes that will affect agricultural productivity. Further, experts predict that a reduction in agricultural yields in tropical countries (Mendelsohn and Dinar, 1999) will affect food production. One major goal in combating climate change by the government of Sri Lanka is to establish food security in the face of climate change threats (National Council for Sustainable Development, 2009). In Sri Lanka and in many parts of the developing world, differing livelihood groups exist among rural households. These livelihood strategies have evolved over time in adjusting to shocks (economic as well as natural/climate) faced by rural households. These are “coping” mechanisms by households in order to withstand such shocks and reduce food insecurity. With the expected changes in the climate, will these livelihood strategies be sustainable? However, while diversification of rural income is seen as means to alleviate income inequality and poverty (Lanjouw and Lanjouw, 1995), it may also limit economic growth due to the reduction of specialization and efficiency gain (Wuyts, 2001). Empirical evidence is mixed with studies that support livelihood diversity (Piesse *et al.*, 1999) and otherwise (Deininger and Olinto, 2001). Nevertheless, as stated earlier, literature on impacts of climate change on smallholders has been seldom considered this rural-non farm economy. Therefore, livelihood diversity as a survival strategy of the rural household in developing nations needs to be understood in a changing climate. This is a step in that direction.

Although, a small nation, Sri Lanka has been the subject of many studies looking at welfare impacts of climate change. Seo *et al.* (2005) used the Ricardian technique using data from Sri Lanka. They looked at net revenues from four of the most important crops in the country and used secondary district aggregate data in estimating the Ricardian model. Then they used predictions of five AOGEM models to assess climate impacts. Kurukulasuriya and Ajwad, (2007) took it further by incorporating individual household data in to the model. They state that it enabled them to control for a host of factors such as human and physical capital available in the farm and to adaptation mechanisms at farm level. Welfare analyses of climate change impacts on Sri Lanka have focused on coconut production (Fernando *et al.*, 2007), tea cultivation (Wijeratne *et al.*, 2007), farm profitability (Kurukulasuriya and Ajwad, 2007), soil moisture deficits which have a serious impact on water resources (De Silva, 2006), adaptation to climate change in the agricultural sector (Esham and Garforth, 2013), and impact on the agricultural sector as a whole (Seo *et al.*, 2005). However, distributional impacts have not been studied in depth. This study contributes to the existing literature in several ways. First, examination of livelihoods' dependence on climate has not been assessed to the knowledge of the author. Second, the examination of the variation of welfare effects due to changes in climate on various livelihoods is also assessed. Third, from purely a methodological point of view, clustered standard errors are used in estimation to avoid the 'Moulton effect' due to availability of climate data on an aggregate rather than at household level which is the unit of analysis (Moulton, 1986).

2. Methods

2.1 Theoretical ideas underlying the study

PL

Rural households are agricultural based. As in consumer theory, their objective is to maximize welfare. However, because rural households are producers cum consumers, their utility maximisation is different to that of a pure consumer. Taking this aspect into consideration, the popular Agricultural Household Model (Singh *et al.*, 1986) postulates that an agricultural household is facing a problem of utility maximisation subject to three constraints,

Maximise	$\max U (X_F, X_{NF}, X_L, H)$	[1]
Household Utility		
Subject to	$P_{NF} X_{NF} \leq P_F (Q_F - X_F) - P_L (L - F) - P_I I$	[2]
Cash income constraint:		
HH time constraint:	$X_L + F \leq T$	[3]
Production-feasibility constraint:	$Q_F \leq (L, I, C, H)$	[4]

Equations [1] – [4] state that agricultural households attempt to maximise utility by consuming food (X_F), non-food (X_{NF}) and leisure (X_L) while features of the household that affect its utility is denoted by H. In doing so, face a cash income constraint that states expenditure ($P_{NF} X_{NF}$) should be less than total income ($P_F (Q_F - X_F) - P_L (L - F)$), a time constraint that states household leisure time and labour (F) should be less than or equal to total time availability (T) and a production feasibility constraint which states that food production (Q_F) is constrained by a production feasibility (f (L, A, C)) where C denotes climate. P_F is the price of food produced by the household, P_{NF} is the price of non-food products, P_L is price of labour bought or sold, and L is total labor used in production, both household labor and hired labor. $P_I I$ denotes the cost of agricultural inputs.

If this maximisation problem is solved, one could end up obtaining a food demand function,

$$X_F = (P_F, P_{NF}, P_L, Y, H) \quad [5]$$

$$Y = P_F Q_F - P_I I - P_L L + P_L T \quad [6]$$

where Y is full income, P_I is the input price, I is the input quantity used, P_L is the wage rate for the household and T is time. Equation [6] tells us that the food consumption is affected through full income. Thus, any change in income through climate effects would impact food consumption (X_F) and hence, it is imperative that climate sensitivity of household income be studied in-depth. The term, $P_F.Q_F - P_X X - P_L L$ in [6] measures the profit (π) from agriculture (i.e. total revenue ($P_F.Q_F$) less total costs ($P_X X + P_L L$). Because farmer adaptations are reflected in profits, the Ricardian analysis examines how profits shift with climate variables (Mendelsohn, *et al.*, 1994). Thus, Ricardian analysis relates this profit from agriculture to climate variables (C) as

$$\pi = f(C, P_I, P_F, H) \qquad [7]$$

However, the traditional Ricardian model uses land value as the dependent variable while income (profit) is used here. While profit is a short run concept, land value is believed to be affected in the long run. Thus, traditional Ricardian model estimates structural relations between historical climate and agricultural land values under the presumption that such relations reflect a steady-state level of adaptation of regional farming systems to local climate characteristics. In this research, a relationship between a one period profit/income and historical climate is obtained mixing both these short run and long run variables together in an econometric model.

Thus, the full income constraint can now be stated as

$$Y = \pi (C, P_I, P_F, H) + WT \qquad [8]$$

Assuming that income would differ according to livelihood strategy selected, the full income of a household *i* employing the livelihood strategy *j* would be

$$Y_{ij} = f(\pi_{ij}) = f(C_{ij}, P_{Iij}, P_{Fij}, H_i) + P_L T, \qquad [9]$$

Where livelihood strategy refers to the choice of crops and the allocation of labor across crops and between on-farm and off-farm activities. Therefore, in this specification, the household income is stated in terms of climate. This specification differs from the traditional Ricardian analysis by relating climate variables to income, rather than just profits from agriculture. So that true welfare effect could be measured. Further, allowing income from each livelihood strategy to be related to climate variables enables calculation of welfare effect of climate change on each livelihood strategy.

In light of the above, two important research questions arise. First, do smallholder farmers choose various livelihood strategies as a result of climate change? In other words is livelihood a coping mechanism or an adaptation strategy to climate change? To answer this question, a smallholders' livelihood choice is modelled with climate variables. Households may choose the livelihood strategy *j* if

$$Y_{ji} > Y_{ki} \text{ for } \forall k \neq j \qquad [10]$$

That is, households will choose livelihood strategies that return highest income. Thus, probability that household *i* will choose livelihood strategy, *j* among *J* alternative strategies could be obtained by;

$$P_{ji} = \frac{\exp(z_{ji}\,\gamma_j)}{\sum_{k=1}^{j} \exp(z_{ji}\,\gamma_j)} \qquad [11]$$

where, P_{ji} is now the probability of selecting livelihood strategy *j*, not price; Z_{ij} represents the climate variables and socio-economic variables affecting profit from agriculture; and γ are the coefficients to be estimated. By incorporating climate variables in Z_{ij} in addition to socioeconomic factors influencing choice of livelihood strategy, it is also made climate dependent. This is prudent, in the sense that households may have adopted their chosen strategy as an 'adaptation' measure to withstand long term climate effects on their income. The outcome variable in equation [11] is multinomial in nature and therefore, it can be estimated using a 'Multinomial Logit' model.

The second important issue is to study how effective is this adaptation in terms of livelihood strategies? In other words, is there a differing effect of climate change of these strategies that farmers choose? To answer this, equation [9] is estimated for each livelihood group and welfare is predicted.

In the estimations carried out, two problems might occur. First is the problem of endogeneity because of inclusion of socio economic variables in the model. For example, education might be influenced by level of income and income may intern affect education. However, because dependent variable is the current year profit and education is a predetermined variable endogeneity may not be an issue. Because all socio-economic variables that are incorporated are largely predetermined in a similar manner, the concern for endogeneity is minimum in the present model.

A second issue might be the correlation of errors across equations in the system of income equations estimated. Although, such correlation will not affect the unbiasedness or consistency of OLS estimators, it biases the standard errors and reduces the efficiency of the estimates. For example, with positive serial correlation, the OLS estimates of the standard errors will be smaller than the true standard errors. This will lead to the conclusion that the parameter estimates are more precise than they really are. There will be a tendency to reject the null hypothesis when it should not be rejected. To address this issue, equation system in [9] was estimated using the Seemingly Unrelated Regression (SUR) technique proposed by Zellner (1962).

2.2 Obtaining livelihood strategies

In order to estimate equation [11], livelihood strategies must be clearly defined. Livelihood strategies are the combination of activities that people choose to undertake in order to achieve their livelihood goals. Following Alinovi *et al.*, (2008) a cluster analysis was performed to identify livelihood strategies. Each household was classified according to their own livelihood strategies by using cluster analysis. The information on shares of income sources, productive assets and occupational activities was used to allow the data to identify the most meaningful and homogeneous groupings of livelihood strategies. Employing these grouping variables, clusters of rural households using similar livelihood strategies were found and were used in the subsequent estimation of equation [9] and [11].

2.3 Welfare analysis

An important outcome that needs to be estimated is the welfare effect due to a change in climate. A non-marginal change in welfare (ΔYj) was obtained by predicting income for each livelihood strategy for a future climate and deducting from this the prediction for the present climate. The predictions were obtained by using the estimated equations from the econometric analysis.

$$\Delta Y_{ij} = Y_{ij}\,(C\text{- after}) - Y_{ij}\,(C\text{- before}) \qquad [12]$$

Here, the $Y_{ij(C\text{-after})}$ means the welfare after climate change has occurred (i.e. future) and $Y_{ij(C\text{-before})}$ means the welfare before the change in climate (i.e. present) The levels of climate variables in future to predict welfare for a future climate was obtained from the fifth IPCC Assessment Report (IPCC, 2013)

2.3 Data and variables

Data from the Income and Expenditure Survey (2006/07) from the Department of Census and Statistics of Sri Lanka is used in the analysis. This survey was conducted using a two stage stratified random sampling technique during July 2006 to June 2007. Urban, rural and estate sectors of the district are the domains for stratification. The total sample size of 22,000 housing units was selected and distributed among districts in Sri Lanka. The survey covered information on demographic characteristics, household expenditure and income, school education, information related to health, inventory of durable goods, access to facilities in the area, debts of the household, information about housing, and agriculture holdings and livestock. These cover relevant socio-economic variables required for the present study. Variables necessary to depict the climate in the model was obtained from the department of Meteorology in Sri Lanka.

Two variables relating to the climate were incorporated: temperature and rainfall. Temperature was included at two levels: minimum and maximum which are averages for the year. Rainfall was included in two ways. Because total as well as duration of rainfall matter in crop production, both were included in the analysis. Total rainfall is the average total rainfall in Millimetres and duration is number of rainy days during the year. In all cases, 30 year averages were used. However, climate data are not available for each household but are available at weather stations situated in each of the 19 districts in the sample that cover all 4,861 households, which is the subset of the agricultural households from the total sample. This is because the interest in this study is to evaluate the impact on smallholder agriculture. In addition to variables related to the climate, several other variables relating to human capital (gender and education of head of the household), assets of farmers (land) and soil types have been included to control their effect on the choice of the livelihood strategy. These variables were selected because prior studies have included them (see for example Kurukulasuriya and Mendelsohn, 2006 and Benhin, 2006). Gender was included as a dummy variable (1=male). Education was measured as the number of years of formal schooling. The land area was measured in acres of agricultural land owned by farmers. Soil types are obtained as a percentage of area covered by each soil type in each district. There were 6 major soil groups out of which five were used in the regression, the inceptisol_histosol soil group was excluded as the base case.

3. Results and Discussion

3.1 Livelihood groups: The results of the cluster analysis

As indicated under the methodology section, the first exercise that was carried out was identifying the underlying livelihood groups in the data. For this purpose, a *k-means* cluster analysis was carried out. In *k-means* clustering, the number of clusters need to be specified in advance and therefore, cluster analysis was carried out until a set of meaningful clusters are obtained. The analysis yielded 6 such clusters (Table 1). The six clusters are named based on the highest mean values of income shares used in the analysis (Table 2). Therefore, according to results, there are 6 different livelihood strategies in the sample.

In order to verify the reliability of the clusters identified, the spatial distribution of the clusters was observed (Figure 1). Certain regions of the country are known for production of certain agricultural products. Therefore, the objective of studying the spatial distribution is to assess whether the livelihood identified corresponds to this a priori knowledge of production distribution in the country. For instance, the tobacco and paddy cluster correctly corresponds to major paddy growing districts in the country such as Anuradhapura, Polonnaruwa, Batticaloa and Ampara. It is also evident that farmers whose main income is derived from coconut cultivations are situated in coastal districts (except Kurunegala) which are suitable for cultivation of coconuts. In fact, in Sri Lanka, coconuts are cultivated in three main districts (Puttalam, Kurunegala and Colombo) which are termed as the coconut triangle. Coconut cultivators and traders are mostly found in these three districts. Similarly, farmers involved in the two major plantation crops, tea and rubber, are located in Kalutara and Ratnapura districts.

Highest mean incomes are observed in the tea/rubber livelihood group. This is as expected given the favourable prices in the plantation sector, especially in the case of rubber. It is also evident that lowest incomes are obtained by wage labourers.

3.2 Choosing the livelihood strategy: The results of the multinomial logit

A multinomial logit (MNL) regression was carried out to examine the impact of the climate on the livelihood choice by farmers. As is usual in Ricardian analysis, to verify the non-linear effect of climate variables, quadratic terms of the climate variables were introduced in the MNL selection equations as well. Because climate variables are recorded not at individual farm levels but at district level, the standard errors were clustered to the district to reduce any within-group dependence (Moulton, 1986; Cameron et al, 2008). However, the standard errors of estimates could still be biased downwards as there are small number of clusters (19 districts) but this bias would be probably less than that if unclustered robust standard errors were used.

The results of MNL regression are reported in Table 4. The 'wage labor' is treated as the reference category partly because the impact of climate on labor may be indirect. The regressions in Table 4 ignores the $P_L T$ term of the model derived in equations [9] through [11], mainly because the unavailability of wage rates (P_L). This exclusion probably affects the standard errors of the coefficients more than the coefficients themselves. Therefore, it means that the estimation is less likely to falsely conclude that a particular variable is significant. Because prices are exogenous variables for farmers, it is possible that they are correlated with the climate variables. Therefore, by excluding them, the full effect of the climate variables on livelihood decisions can be obtained. Table 4 show that most of the livelihood strategies are sensitive to climate. In some cases, both the linear term and the quadratic terms are significant while in others, only one of them is significant. Due to this reason, the joint significance tests of these climate variables were conducted. The results of these joint significance tests are reported in Table 5.

It is clear that the null hypothesis of either linear or quadratic terms are non-significant can be rejected in many cases. Although, the linear and the quadratic term of minimum temperature are insignificant in tobacco and paddy cluster, they show joint significance in Table 5. Therefore, their importance in selecting this livelihood strategy is clear. But in the case of coconut cultivators and traders, individual as well as joint significant tests fail to reject null hypothesises and therefore, minimum temperature does not influence this strategy. The number of rainy days shows joint significance in all strategies. However, when individual coefficients in Table 4 are examined, they are not significant in tobacco and paddy cluster, fruit cultivators, coconut cultivators and traders and tea and rubber producers. Because of the joint significance of the linear and quadratic term with respect to number of rainy days, it is an important factor in selecting these livelihood strategies although individual coefficients are non-significant. However, maximum temperature show joint significance only in the case of fruit cultivators and tea and rubber producers while rainfall total show joint significance in tobacco and paddy producers and tea and rubber producers. Therefore, it is evident from this multinomial choice estimation that farmers' selection of livelihood strategies is influenced by climatic factors. Therefore, this may be a coping or adaptation mechanism to climate change by smallholder farmers in Sri Lanka

Results also highlight that socio-economic variables show significance in self-selection in to livelihood strategies. Gender of the farmer play a significant role in selecting livelihood strategies. This variable returned a negative sign for all strategies. Thus, the relative probabilities of males being in any of these livelihood strategies are smaller compared to the wage labour strategy which is the base strategy. Farmers' age is also significant in all livelihood strategies and shows a positive impact. This implies that odds of selecting any of these strategies are greater than selecting wage labour strategy with older farmers. This is as expected because, when farmers become older, prospective employers may be less willing to hire them as labourers. Education significantly affects the livelihood choice only in the case of 'tobacco and paddy', 'fruit cultivators' and 'tea-rubber producers'. Their negative sign indicate it is less likely for educated smallholder farmers to select these strategies. Land is included in the regression as a control for physical capital available to farmers. It generally shows significant effect. Having a physical asset such as land improves probability of being selected into all livelihood strategies as expected. As intuition suggests, probability of a respondents' main income source being wage labour declines when land extents increase. Soil groups show varying levels of impacts on selection of livelihood strategies.

3.3 Impact of climate normals on income: Results of the ricardian regression

Table 6 reports the results of the Ricardian model with climate variables as well as the household characteristics. The dependent variable is the income in Rupees per household per month. The model with the socio-economic characteristics of the household is preferred over others because they proxy the adaptive abilities of farmers in the face of climate change (Kurukulasuriya and Ajwad, 2007). Therefore, they are used in the predictions for a future climate. From the results of the estimation in Table 6 it is clear that variables related to demographic features (gender) and human capital (age and education) are significant only in the wage labour strategy. Availability of physical capital (land) increases incomes in all strategies. As was the case with the previous multinomial selection model, climate variables show varying levels of significance in the regressions. Therefore, joint hypothesis tests were performed to verify their true importance and the results are reported in Table 7.

Minimum temperature has influence on incomes of tobacco and paddy farmers, coffee, pepper, betel producers, tea and rubber producers and wage labourers. It is also marginally (at 10% error) significant for fruit cultivators.

Maximum temperature influences incomes of tobacco and paddy cluster, fruit cultivators, coffee, pepper, betel, producers, tea and rubber producers and wage labourers. The number of rainy days and total rainfall received are important climatic aspects for all clusters except the wage labour strategy. It is clear from Table 7 that wage labour strategy is not influenced by rainfall but by temperature changes. It is also clear from the results in Table 7 that both the rainfall and the temperature play an important role in influencing incomes of almost all livelihood strategies.

Table A2 (in annex) reports the results of the Seemingly Unrelated (SUR) estimation of the Ricardian model where share of income from each strategy was used as the dependent variable. The purpose of the SUR estimation in Table A2 is to overcome the possible correlations among errors in the equations estimates and thereby increase the efficiency of estimates. By comparing the results of Table 6 and the Table A2, it is clear that most coefficients that were non-significant in Table 6 have become significant in the SUR estimation (Table A2) indicating that the estimation efficiency has increased due to the use of SUR.

3.4 Welfare measurements: Impacts of future climate

In this section, climate simulations are made using the parameter estimates from the preceding Ricardian model. A set of climate change scenarios predicted by IPCC is used to do this. According to AR5 report of the IPCC, the temperature in South Asia is to rise by 1.5 ^{0}C and the rainfall is to increase by 10% by 2035 (Van Oldenborgh, *et al.*, 2013).

The projections of conditional income are given in Table **8Error! Reference source not found**. These are given for each livelihood strategy. It is clear that there are negative impacts of climate change in the tobacco and paddy, fruit cultivation and coconut cultivation/traders strategies. Thus, Coffee,/pepper/betel, tea/rubber and the wage labour strategy are resilient to climate change. Tea/rubber producers show the highest positive change in welfare. The worst affected strategy seems to be the fruit cultivation strategy where the predicted change in income is over 100% of the present income of this group[1].

In Table 9, distributional impact of welfare across districts and livelihood strategies are depicted. These are found by averaging the predicted welfare changes of households in each district. According to Table 8, Coffee,/pepper/betel, Tea/rubber and wage labour strategy are most resilient to climate. This is true in most districts in Table 9, but even these strategies show a negative impact in Badulla and Moneragala districts. These are the most poverty stricken districts in the Country. The Tobacco and Paddy strategy shows resilience in ten districts where as Fruit Cultivation strategy show resilience in five districts. 'Coconut cultivators and traders' show resilience only in three districts. Therefore, vulnerability/resilience differs spatially. Thus, it is difficult to make a blanket recommendation to support these livelihood strategies. Any policy targeted to assist any of these strategies will have to take into consideration of the location of farmers such farmers.

The changes of selection probabilities for each livelihood strategy is predicted using the estimated multinomial logit model (Table 10). The overall changes in predicted selection probabilities are small. However, there is a reduction in selection probabilities of Tobacco and Paddy, Fruit cultivator and the Coconut cultivators and traders strategy while for all other strategies a positive change is predicted although, there is a negative impact predicted for incomes from some of these strategies. Table 8 indicates that there is general finding that the fruit cultivators are expected to make the highest losses while tea and rubber producers to receive the highest positive change in the predicted income. Examining Table 10, it is clear that this is true in prediction of selection probabilities of these strategies. The values in Table 10 was obtained as the difference between the predicted choice probabilities with future climate variables and the predicted probabilities using the climate variables from the regression model. For a given district, the probabilities sum to zero (may not sum to zero in Table 10 because of rounding up). There is a negative change in the probability in fruit cultivation indicating that farms may move out of this strategy in future. Similarly, there is a positive change in the Tea/Rubber strategy indicating that farmers may move into this strategy.

[1] Calculated as the percentage change in income over the present average income of this group

4. Conclusions and Policy Recommendations

This study builds upon other studies of Ricardian analysis of climate change impacts in two ways. First, following Kurukulasuriya and Ajwad, (2007), a farm household level data set is used to control for individual effects. This goes beyond their paper by using the Ricardian model in the agricultural household modelling framework. It had enabled the analysis of climate change impacts on livelihood strategies. The second is the dis-aggregation of climate impacts on livelihood strategies, by districts and by sectors in the economy.

The study finds that livelihood strategies depend heavily on the climate. Farmers choose between strategies to minimise risks of loss of income. Number of rainy days seems to be the variable that affects largest number of livelihoods because it is significant across all livelihood strategies. Minimum temperature is also important in selection and shows a non-linear impact on choice of most of the livelihood strategies.

All climate variables are found to be significantly affecting conditional incomes of most livelihood strategies. Tea and Rubber strategy, Coffee,/pepper/betel and wage labour strategy predict positive changes in income for a future climate. These imply the importance of the development of the rural non-farm sector. Fruit cultivation is the most affected strategy by future climates. It is also evident that some strategies show resilience in some of the districts while the same are not resilient in others. This shows that impact on livelihood strategies differ spatially.

Based on the foregoing, it can be said that future climate has mixed impacts on the various sectors/areas in the country. As livelihood choice is found to be sensitive to climate, and farmers may wish to choose between livelihoods, an economic environment conducive for farmers to find alternative employments should be promoted. Rural non-farm growth should be enhanced. Those districts that are mostly vulnerable should be identified and work has to be initiated to develop non-farm sectors in such areas along with the agricultural sector. Results indicate that on the average across livelihood strategies, all districts except Matale, Moneragala and Nuwara Eliya record negative welfare effect. Based on these numbers, it is difficult to identify the districts that are most vulnerable because there is no set guideline to say one district is 'more' vulnerable than another because the negative changes in incomes are not contrastingly different from each other. However, if one orders the districts from the highest negative values to the lowest, Anuradhapura, Ampara, Kurunegala and Polonnaruwa districts becomes the first four. These are the country's main paddy producing areas and rice is the national staple.

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Tables

Table 1: Results of cluster analysis

Cluster Number	Cluster Name	No of Households
1	Tobacco and paddy producers	1395
2	Fruit cultivators	142
3	Coffee/pepper/betel cultivators	146
4	Coconut cultivators and traders	1483
5	Tea/rubber producers	578
6	Wage laborers	1117
Total		4861

Table 2: Income shares in main livelihood groups

Livelihood Strategy	Income Share					
	Fruit	Coffee/ pepper/betel	Coconut/ trading	Tea/ Rubber	Wage labour	Tobacco/ Paddy
Tobacco and paddy producers	0.005	0.003	0.023	0.003	0.032	0.693
Fruit cultivators	0.734	0.000	0.018	0.000	0.018	0.087
Coffee/pepper/betel cultivators	0.002	0.773	0.005	0.004	0.036	0.069
Coconut cultivators and traders	0.004	0.004	0.405	0.015	0.017	0.070
Tea/rubber producers	<0.001	0.001	0.014	0.829	0.045	0.039
Wage laborers	0.007	0.009	0.046	0.038	0.706	0.111

Note: Shares do not add to one because only the main strategies are listed here

Table 3: Average incomes of livelihood clusters

Cluster	Mean Per Capita Income (LKR/Month)
L1: Tobacco and paddy	3159.278
L2: Fruit cultivators	9568.4
L3: Coffee/pepper/betel producers	4849.365
L4: Coconut cultivators	10125.15
L5: Tea/rubber producers	7258.259
L6: Wage labourers	2949.119

Table 4: Results of the Multinomial Logistic Regression (MNL), showing selection into livelihood strategies

	Tobacco and paddy cluster	Fruit cultivators	Coffee, pepper, betel producers	Coconut cultivators and traders	Tea and rubber producers
Min Temperature	0.478	-7.986	5.896	-0.473	-7.053
	(0.49)	(4.65)***	(2.50)**	(0.82)	(2.95)***
Min Temperature^2	-0.016	0.175	-0.136	0.011	0.165
	(0.71)	(4.51)***	(2.57)**	(0.86)	(2.99)***
Max Temperature	-1.523	9.992	-1.721	0.273	9.148
	(1.30)	(5.45)***	(0.78)	(0.38)	(3.66)***
Max Temperature^2	0.028	-0.152	0.007	-0.003	-0.151
	(1.44)	(5.17)***	(0.18)	(0.23)	(3.78)***
Rainy Days	0.043	-0.071	0.194	0.025	-0.09
	(1.88)	(1.86)	(2.68)***	(1.44)	(1.01)
Rainy Days^2	<0.00	<0.00	<0.00	<0.00	<0.00
	(2.28)**	(2.22)**	(2.69)***	-1.13	-1.5
Total Rainfall	-0.004	-0.001	-0.002	0	-0.002
	(5.05)***	(1.39)	(0.89)	(0.59)	(1.09)
Total Rainfall^2	0.00	0.00	0.00	0.00	0.00
	(5.19)***	(1.30)	(1.84)	(0.51)	(0.57)
Gender	-1.04	-1.962	-1.345	-1.542	-1.117
	(4.74)***	(10.33)***	(4.35)***	(9.62)***	(6.26)***
Age	0.052	0.055	0.074	0.074	0.053
	(9.61)***	(7.31)***	(7.83)***	(16.80)***	(8.49)***
Education	-0.112	-0.087	-0.048	0.024	-0.111
	(5.33)***	(3.58)***	-1.77	-1.4	(4.25)***
Land	1.723	1.738	1.326	1.36	1.888
	(6.63)***	(6.44)***	(2.98)***	(6.50)***	(7.24)***
Soil Types					
Alfisol	-0.004	0.008	-0.008	-0.001	-0.009
	(1.58)	(2.55)**	(0.85)	(0.42)	(1.10)
Ultisol	0.005	-0.052	0.028	-0.007	0.008
	(0.50)	(5.65)***	(1.80)	(1.61)	(0.67)
Oxisol	-0.083	0.174	-0.057	0.039	-0.015
	(8.90)***	(4.71)***	(1.84)	(2.05)**	(0.20)
Aridisol	0.756	-2.039	1.222	-0.239	0.047
	(5.41)***	(4.86)***	(4.34)***	(1.13)	(0.08)
Entisol	0.005	-0.06	0.095	-0.001	-0.188
	(0.45)	(3.33)***	(1.56)	(0.08)	(2.32)**
Constant	17.478	-70.039	-33.612	-5.579	-59.165
	(2.23)**	(4.86)***	(2.23)**	(1.19)	(4.09)***

Note: * p<0.1 ** p<0.05; *** p<0.01, Wage labour is the base outcome, t statistic within parenthesis, ,standard errors shown are clustered by districts, N=4861, 19 clusters

Table 5: Results of joint significance tests of the climate variables

	Tobacco and paddy cluster	Fruit cultivators	Coffee, pepper, betel producers	Coconut cultivators&traders	Tea &rubber producers
t_min	11.76***	29.26***	7.40**	1.60	13.04***
	(0.002)	(0.000)	(0.025)	(0.450)	(0.002)
t_max	3.11	32.84***	4.13	2.64	21.40***
	(0.211)	(0.000)	(0.127)	(0.267)	(0.000)
rf_days	13.01***	9.12***	7.36**	6.19**	27.00***
	(0.002)	(0.010)	(0.025)	(0.045)	(0.000)
rf_tot	27.41***	1.93	4.44	0.37	8.51**
	(0.000)	(0.382)	(0.109)	(0.831)	(0.014)

Note: * p<0.05, ** p<0.05; *** p<0.01, Chi-square values are reported, *p* values within parenthesis

Table 6: Estimates of the Ricardian model with socio-economic variables of income for each livelihood strategy

	Tobacco and paddy cluster	Fruit cultivators	Coffee, pepper, betel producers	Coconut cultivators & traders	Tea & rubber producers	Wage labourers
Gender	-317.0	-4033.9	-1791.0	3877.8	5166.4	374.7
	(-0.89)	(-0.99)	(-0.62)	(1.83)	(0.68)	(1.72)
Age	16.70	228.3	82.28	-61.54	69.71	24.21**
	(1.38)	(1.30)	(1.02)	(-1.12)	(0.23)	(3.28)
Education	142.8*	450.0	-28.03	604.1*	1077.3	231.0***
	(2.38)	(0.64)	(-0.16)	(2.39)	(1.70)	(10.60)
Land	2257.2***	4068.3*	11634.4*	9452.7*	14763.3	1223.6***
	(9.93)	(2.74)	(2.25)	(2.48)	(2.03)	(5.71)
Min Temperature	-5638.0***	62035.8**	-17803.4	-8671.1	99.1*104***	-1315.5
	(-9.97)	(3.12)	(-1.42)	(-0.49)	(11.88)	(-0.95)
Min Temperature^2	129.6***	-1416.8**	445.0	207.8	-22801.6***	28.97
	(10.22)	(-3.12)	(1.48)	(0.50)	(-11.96)	(0.90)
Max Temperature	5342.8***	88851.7*	24774.3	14147.7	-1081059.6***	2297.3
	(7.67)	(2.21)	(1.24)	(0.73)	(-10.47)	(1.38)
Max Temperature^2	-90.96***	-1501.3*	-446.9	-268.0	17419.6***	-38.15
	(-7.19)	(-2.27)	(-1.28)	(-0.85)	(10.22)	(-1.36)
Rainfall days	-45.72	726.6*	-424.6	-1279.7***	-588.1	-63.22
	(-1.99)	(2.20)	(-0.91)	(-4.20)	(-0.23)	(-1.63)
Rainfall days^2	0.0416	-2.965*	1.270	4.122***	-6.766	0.209
	(0.56)	(-2.77)	(0.84)	(4.10)	(-0.70)	(1.63)
Total Rainfall	-5.513***	-36.25***	21.42*	39.22**	511.9***	2.776*
	(-8.85)	(-4.16)	(2.78)	(3.76)	(19.22)	(2.57)
Total Rainfall^2	0.0012***	0.0101***	-0.00410*	-0.00859**	-0.091***	<-0.000*
	(8.89)	(5.31)	(-2.22)	(-3.74)	(-13.16)	(-2.11)
Soil Types						
Alfisol	-0.0433	70.06**	90.81	-0.397	-1758.8*	0.477
	(-0.02)	(3.49)	(1.32)	(-0.01)	(-2.42)	(0.14)
Ultisol	33.89**	319.3**	-16.52	65.15	1569.0	-26.29**
	(3.53)	(3.54)	(-0.71)	(1.08)	(1.80)	(-3.80)

Oxisol	-5.862	353.5	190.9	-258.6	-43826.9***	39.52
	(-0.42)	(1.41)	(0.59)	(-1.00)	(-4.48)	(1.18)
Aridisol	475.0*	-5711.2	-448.3	378.6	380517.0***	-217.0
	(2.41)	(-1.92)	(-0.40)	(0.14)	(4.45)	(-0.65)
Entisol	-47.33**	1223.8***	-428.6	290.2	23880.6**	-23.72
	(-3.72)	(5.23)	(-0.83)	(0.88)	(3.19)	(-1.04)
Constant	-7173.7	-201.7*104*	-159.1*103	-38.1*102	571.6*104***	-18*103
	(-1.30)	(-2.82)	(-1.19)	(-0.33)	(11.55)	(-1.70)
R^2	0.276	0.302	0.361	0.0894	0.159	0.205
N	1395	142	146	1482	578	1116

t statistics in parentheses **p*< 0.05, ***p*< 0.01, ****p*< 0.001

Table 7: Results of joint hypothesis tests for the Ricardian model with household characteristics

	Tobacco and paddy cluster	Fruit cultivators	Coffee, pepper, betel producers	Coconut cultivators & traders	Tea & rubber producers	Wage labourers
t_min	10.46***	2.68	46.39***	0.73	35.76***	4.66**
	(0.001)	(0.099)	(0.000)	(0.493)	(0.000)	(0.023)
t_max	7.84***	7.94***	15.47***	2.39	50.78***	4.27**
	(0.003)	(0.004)	(0.000)	(0.120)	(0.000)	(0.030)
rf_days	16.42***	3.60**	32.81***	9.08***	36.57***	2.14
	(0.000)	(0.051)	(0.000)	(0.002)	(0.000)	(0.147)
rf_tot	9.25***	15.81***	5.52**	6.56***	77.66***	3.03
	(0.002)	(0.000)	(0.018)	(0.007)	(0.000)	(0.074)

*p< 0.1, **p< 0.05, ***p< 0.01 Chi-square values are reported, *p* values within parenthesis

Table 8: Welfare effect of climate change across livelihood strategies by 2035

Variable	Mean Change in Per Capita Income	Percentage Change over present income
Tobacco and paddy cluster	-43.20	-1.37
Fruit cultivators	-10831.45	-113.20
Coffee/pepper/betel producers	429.26	8.85
Coconut cultivators/traders	-3130.03	-30.91
Tea/rubber producers	2532.53	34.89
Wage labourers	49.86	1.69

Note: values are in LKR/month/household

Table 9: Distribution of welfare effects across districts for each livelihood strategy

	Tobacco and paddy cluster	Fruit cultivators	Coffee, pepper, betel producers	Coconut cultivators & traders	Tea & rubber producers	Wage labourers
Colombo	803.62	-21575.05	2184.94	-5809.24	7681.38	134.35
Gampaha	319.48	-23194.25	1202.06	-4453.39	4348.74	75.66
Kalutara	191.64	-17749.41	2188.57	-3169.12	5453.64	185.03
Kandy	-560.62	1399.78	-364.60	-1290.94	-285.00	44.39
Matale	-724.78	5013.32	22.32	-228.02	-72.14	92.89
NuwaraEliya	-1354.54	80093.01	519.79	4108.61	789.06	346.74
Galle	1086.14	-16484.75	3683.68	-5943.46	11008.17	263.57
Matara	880.66	-13370.25	5281.99	-3994.34	12542.85	430.15
Hambantota	416.24	-24774.97	3006.12	-3639.07	7447.18	221.14
Batticaloa	422.23	-27474.52	2424.31	-4180.12	6280.20	171.07
Ampara	-213.22	-27453.10	-99.94	-3123.59	369.16	-17.04
Kurunegala	-284.16	-21484.00	-818.42	-3178.91	-693.76	-64.59
Puttalam	116.44	-28714.29	1632.05	-3366.17	4155.91	110.58
Anuradhapura	-430.30	-30495.66	-670.46	-2591.24	-1227.32	-65.41
Polonnaruwa	435.58	-32342.79	2663.30	-4073.15	6803.45	171.25
Badulla	-1335.69	7310.22	-2875.98	476.36	-6485.67	-120.92
Moneragala	-1214.53	14571.15	-1419.82	1103.00	-3541.43	12.98
Ratnapura	1271.66	-6740.74	-5368.11	-11906.20	964.84	-600.30
Kegalle	-424.56	-21111.22	-346.67	-2258.39	-503.32	-13.25

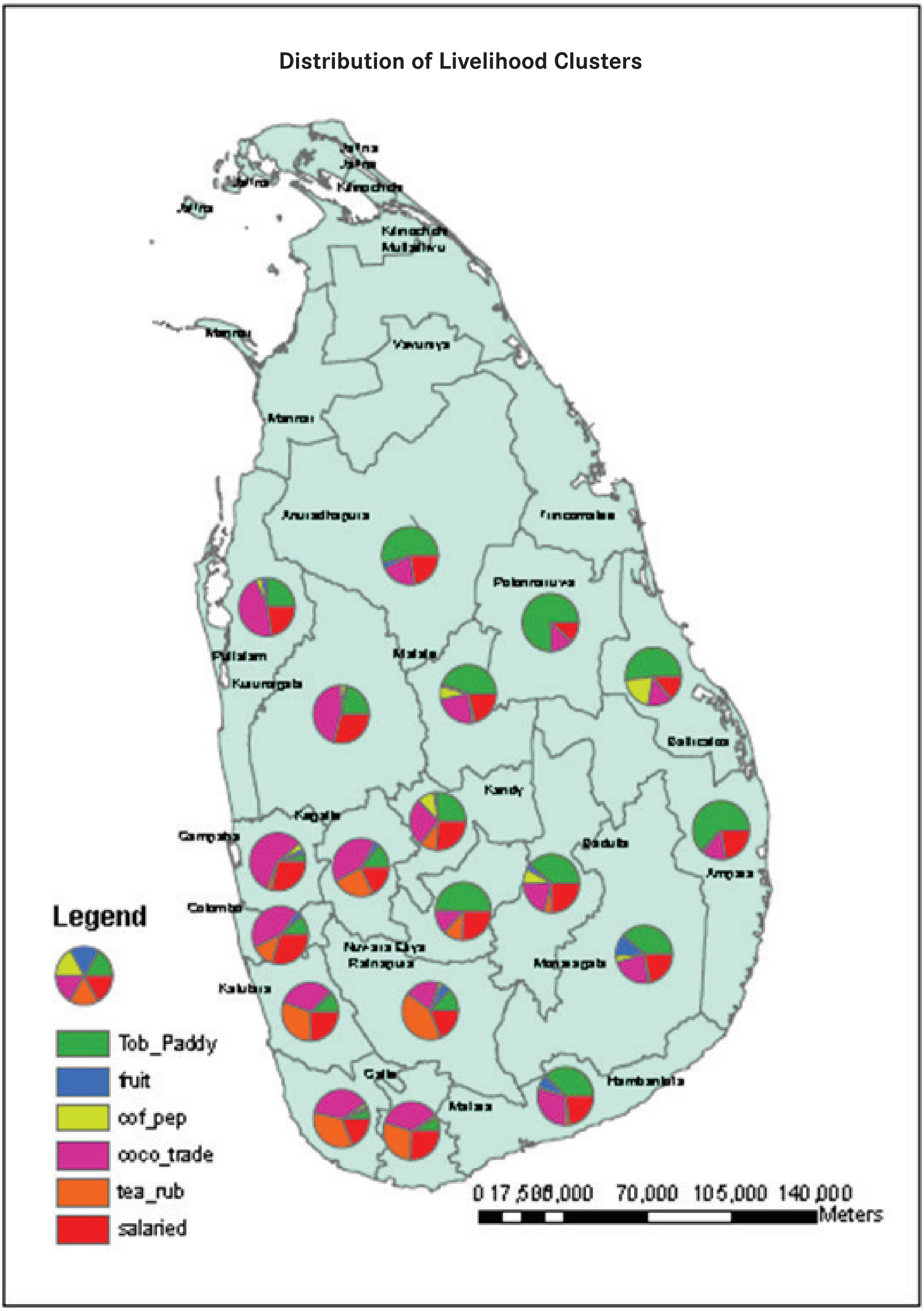
Table 10: Changes of choice probabilities across livelihood strategies for a future climate

	Tobacco and paddy cluster	Fruit cultivators	Coffee, pepper, betel producers	Coconut cultivators & traders	Tea & rubber producers	Wage labourers
Colombo	0.206	-0.002	0.011	-0.169	0.005	-0.050
Gampaha	0.167	0.009	0.002	-0.228	0.079	-0.029
Kalutara	0.197	0.007	0.028	-0.023	-0.229	0.020
Kandy	0.072	0.020	-0.076	0.017	0.041	-0.075
Matale	-0.121	0.004	-0.028	0.074	0.067	0.004
NuwaraEliya	-0.189	0.027	0.017	0.176	0.005	-0.035
Galle	0.264	0.017	0.012	-0.070	-0.241	0.017
Matara	0.194	0.024	0.001	-0.044	-0.153	-0.022
Hambantota	-0.097	-0.041	0.021	0.031	0.101	-0.014
Batticaloa	-0.235	0.027	-0.144	0.208	0.078	0.066
Ampara	-0.352	0.017	0.023	0.167	0.101	0.044
Kurunegala	0.083	0.016	0.003	-0.166	0.113	-0.049
Puttalam	0.022	0.006	-0.010	-0.173	0.102	0.054
Anuradhapura	-0.285	-0.001	0.026	0.105	0.137	0.019
Polonnaruwa	-0.379	0.022	0.021	0.119	0.110	0.107
Badulla	-0.117	-0.004	-0.058	0.111	0.067	0.001
Moneragala	-0.135	-0.085	-0.006	0.107	0.109	0.010
Ratnapura	0.138	-0.022	0.012	0.108	-0.279	0.043
Kegalle	0.116	0.013	0.032	-0.086	-0.095	0.020
Overall	$-.2.1/10^{5}$	$-2.03/10^{5}$	$4.67/10^{6}$	$-3.68/10^{5}$	$6.0/10^{3}$	$7.0/10^{3}$

Note: the overall prediction in the last line is obtained as the difference between the predicted choice probabilities with future climate variables and the predicted probabilities using the climate variables from the regression model for each household and averaging over all districts.

Figures

Figure 1: Spatial distribution of livelihood clusters



Annex

Table A1: Marginal effects after MNL regression

	Tobacco and paddy	Fruit cultivators	Coffee, pepper, betel	Coconut & traders	Tea & rubber producers	Wage labour
Gender*	0.032	-0.026***	-0.004	-0.171***	0.001	0.167***
	(0.027)	(0.006)	(0.006)	(0.021)	(0.004)	(0.015)
Age	0.0005	0.0001	0.0005***	0.009***	0.0001	-0.010***
	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
Education	-0.025***	-0.001**	0.000	0.023***	-0.003***	0.007**
	(0.003)	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)
Land	0.157***	0.012***	0.002	0.049**	0.029***	-0.249***
	(0.027)	(0.003)	(0.006)	(0.024)	(0.007)	(0.028)
t_min	0.285	-0.185***	0.129***	-0.023	-0.290***	0.084
	(0.179)	(0.038)	(0.024)	(0.153)	(0.100)	(0.109)
t_min^2	-0.008	0.004***	-0.003***	0.001	0.007***	-0.002
	(0.004)	(0.001)	(0.001)	(0.004)	(0.002)	(0.003)
t_max	-0.560***	0.238***	-0.040	0.018	0.390***	-0.046
	(0.213)	(0.038)	(0.032)	(0.174)	(0.105)	(0.134)
t_max^2	0.010***	-0.004***	0.000	0.000	-0.007***	0.000
	(0.004)	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)
rf_days	0.007	-0.002***	0.004***	0.001	-0.005	-0.004
	(0.006)	(0.001)	(0.001)	(0.005)	(0.003)	(0.003)
rf_days^2	-0.3*10^{-4}	0.1*10^{-4}***	-0.1*10^{-4}***	0. 04*10^{-4}	0.2*10^{-4}**	0.02*10^{-3}
	(0.2*10^{-4})	(0.00)	(0.00)	(0.02*10^{-3})	(0.1*10^{-4})	(0.1*10^{-4})
rf_tot	-0.001***	0.03*10^{-5}	-0.7*10^{-5}	0.44*10^{-3}***	-0.13*10^{-4}	0.3*10^{-3}***
	(0.2*10^{-3})	(0.2*10^{-4})	(0.03*10^{-3})	(0.01*10^{-2})	(0.6*10^{-3})	(0.7*10^{-4})
rf_tot^2	0.2*10^{-6}***	0.000	0.02*10^{-6}	-0.1*10^{-6}***	-0.1*10^{-7}	-0.6*10^{-7}***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
alfiso~p	-0.001	0.2*10^{-3}***	-0.013*10^{-2}	0.045*10^{-2}	-0.3*10^{-3}	0.04*10^{-2}
	(0.001)	(0.7*10^{-4})	(0.19*10^{-3})	(0.48*10^{-3})	(0.3*10^{-3})	(0.3*10^{-3})
ultiso~p	0.002	-0.001***	0.001***	-0.002	0.41*10^{-3}	0.3*10^{-3}
	(0.002)	(0.2*10^{-3})	(0.02*10^{-2})	(0.002)	(0.4*10^{-3})	(0.001)
oxisol~p	-0.024***	0.004***	-0.001	0.019***	0.000	0.002
	(0.004)	(0.001)	(0.001)	(0.004)	(0.003)	(0.002)
aridis~p	0.201***	-0.053***	0.022***	-0.142***	-0.003	-0.026
	(0.047)	(0.009)	(0.007)	(0.049)	(0.022)	(0.023)
entiso~p	0.004	-0.001***	0.002**	0.002	-0.008***	0.001
	(0.003)	(0.4*10^{-3})	(0.001)	(0.003)	(0.003)	(0.002)

Note: *p<0.1, **p<0.05; ***p<0.01, standard error within parenthesis

Table A2: Estimates of the seemingly unrelated estimation of Ricardian model

	share_fruit _grp	share_coff_pep _bet_grp	share_coc_ trade_grp	share_tea_ rub_grp	share_tobacco_ paddy_grp
t_min	-0.187**	0.166**	0.345**	-0.451***	0.388**
	(-3.22)	(2.97)	(2.95)	(-4.99)	(3.00)
t_min_square	0.00413**	-0.00405**	-0.00732**	0.0109***	-0.00937**
	(3.10)	(-3.17)	(-2.73)	(5.28)	(-3.16)
t_max	0.190**	-0.0238	-0.544***	0.654***	-0.512**
	(2.68)	(-0.35)	(-3.82)	(5.95)	(-3.25)
t_max_square	-0.00293*	0.0000108	0.00902***	-0.0111***	0.00895***
	(-2.53)	(0.01)	(3.86)	(-6.19)	(3.47)
rf_days	-0.00148	0.00117	0.0108***	-0.0171***	0.0104***
	(-1.31)	(1.08)	(4.76)	(-9.73)	(4.15)
rf_days_square	0.00000612	-0.00000843*	-0.0000331***	0.0000647***	-0.0000389***
	(1.68)	(-2.41)	(-4.51)	(11.45)	(-4.79)
rf_tot	-0.0000401	-0.000000497	0.000144*	0.0000779	-0.000264***
	(-1.36)	(-0.02)	(2.42)	(1.70)	(-4.02)
rf_tot_square	9.24e-09	9.09e-09	-1.70e-08	-3.25e-08**	4.78e-08**
	(1.41)	(1.44)	(-1.29)	(-3.19)	(3.26)
alfisol_grp	0.000125	-0.000385***	-0.000637**	0.000698***	0.0000454
	(1.05)	(-3.38)	(-2.66)	(3.79)	(0.17)
ultisol_grp	-0.00110***	0.000658*	-0.00318***	0.00180***	0.00153*
	(-3.41)	(2.14)	(-4.93)	(3.60)	(2.14)
oxisol_grp	0.00367***	-0.00460***	0.0177***	-0.000281	-0.0224***
	(4.30)	(-5.62)	(10.31)	(-0.21)	(-11.76)
aridisol_grp	-0.0505***	0.0607***	-0.142***	0.0285*	0.159***
	(-5.42)	(6.80)	(-7.59)	(1.97)	(7.67)
entisol_grp	-0.000260	-0.00193	0.00324	-0.0109***	0.0162***
	(-0.25)	(-1.95)	(1.56)	(-6.82)	(7.06)
Constant	-0.762	-0.884*	3.427***	-3.912***	3.245**
	(-1.68)	(-2.03)	(3.74)	(-5.54)	(3.20)
r2	0.019	0.05	0.09	0.23	0.19
Chi2	89.11	230.93	412.18	1303.68	1048.94
P>Chi2	0.000	0.000	0.000	0.000	0.000
N			4451		

t statistics in parentheses *p< 0.05, **p< 0.01, ***p< 0.001

Table A3: Summary statistics of variables used in the Ricardian regressions

Variable	Description	Mean	Standard Deviation
Income	Per capita income in Rupees per month	5957.81	18822.01
Gender	Gender of farmer	0.81	0.39
Age	Age of household farmer		
	Male	81.28%	
	Female	18.72%	
Education	Education level of farmer measured in number of years of formal schooling	7.22	3.85
Land	Total land available measured in acres of agricultural land owned by farmers	0.51	1.34
Min Temperature	Minimum temperature in Celsius	22.35	2.88
Max Temperature	Maximum temperature in Celsius	30.28	2.46
Rainfall Days	Number of rainy days	158.50	38.16
Total Rainfall	Total rainfall received in mm	1750.39	659.19
Alfisol	Percentage of area covered by Alfisol soil	48.78	53.09
Ultisol	Percentage of area covered by Ultisol soil	32.26	24.93
Oxisol	Percentage of area covered by Oxisol soil	2.68	6.42
Aridisol	Percentage of area covered by Aridisol soil	0.31	0.73
Entisol	Percentage of area covered by Entisol soil	6.59	6.03

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