ECONOMICS OF CLIMATE CHANGE ADAPTATION

Understanding the Impact of Climate Change on the Agriculture Sector and Optimal Policy Response in Sri Lanka

Photo Credit: UNDP

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FOREWORD

Climate change, including climate variability, is having detrimental effects on human well-being and health across the developing world. Increasing temperatures, changing rainfall patterns, rising sea levels and increasing frequency and intensity of extreme weather events are adversely affecting ecosystem functioning, water resources, food security and infrastructure. Moreover, these climate change effects are predicted to become increasingly severe. Conscious of the need to counter climate change impacts which are already being felt in the region and to prepare for future, more severe impacts, countries are eager to understand how national budgets can be applied to address the challenges of climate change in the most cost effective manner.

The Capacity Building Programme on the Economics of Climate Change (ECCA) was a three-year programme, comprised of a series of technical trainings interspersed with mentor-assisted in-country applied work to enable trainees from 10 countries in Asia to master key economic concepts and tools for adaptation planning and decision-making. Launched in October 2012, ECCA addressed a consensus reached during a regional stakeholder consultation that a more comprehensive approach to mainstreaming climate change risks into planning processes was needed to ensure economically-efficient climate change strategies at the sectoral, sub-national and national levels. The innovative program aimed to identify gaps in capacity development needs in an area that is critical for helping countries formulate national adaptation plans and access climate finance.

The programme targeted mid- and senior-level public sector officials from planning, finance, environment and other key ministries responsible for formulating, implementing and monitoring climate change programmes. They were grouped into multi-disciplinary country teams. The country teams participated in four regional workshops, which provided training on theory and the practical application of cost-benefit analysis, and introduced participants to forecasting, modelling and sectoral analysis, looking into country-specific institutional development plans, within the context of ongoing and new initiatives. Each regional training was interspersed with fieldwork application, guided by economists who served as mentors to the country teams. Together, these two principal programme components provided building blocks to guide participants through the theory, principles and application techniques of economic analysis.

Country teams have now begun reporting the results of their training and in-country application. This report was prepared for the consideration of decision-makers in Sri Lanka by the Sri Lanka country team together with their economics mentor and ECCA expert staff. With this training and hands-on experience, it is expected that the members of the country teams will play pivotal roles in mainstreaming climate considerations into future development planning, ultimately seeking to institutionalize these important analytical skills.

The training activities, together with the country reports and the regional report, which compiles the individual country reports to take a view of regional considerations in the agriculture sector, has contributed to a key area of technical assistance required by countries, as per the United Nations Framework on the Convention of Climate Change's (UNFCCC) guidelines for countries on the National Adaptation Plan (NAP) process – a process established under the Cancun Adaptation Framework (CAF) to help countries identify their medium- and long-term adaptation needs.

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The core team in Sri Lanka was led by Babatunde Abidoye as the economist mentor and includes Dr. L.H.P. Gunaratne, Department of Agricultural Economics and Business Management in the Faculty of Agriculture, University of Peradeniya; Aruna Sooriyaarachchi from the Faculty of Agriculture, University of Peradeniya ; Chamila Perera from the Field Crops Research and Development Institute, Faculty of Agriculture, University of Peradeniya and Mrs. Nilmini Ranasingha from Ministry of Mahaweli Development and Environment.

Our thanks extend to the UNDP Country Team of Sri Lanka for their involvement, and for providing insight into their country portfolio.

Finally, the contribution by AECOM International Development implementing the USAID Adapt Asia-Pacific Programme is acknowledged.

EXECUTIVE SUMMARY

The Economics of Climate Change Adaptation initiative is supported by UNDP, in collaboration with USAID's Adapt Asia-Pacific programme. It is a capacity-building programme aimed at strengthening the skills and knowledge base of technical officers in Ministries of Planning and Finance as well as line ministries including Environment, Agriculture, Water, and Public Works, on the economics of adaptation as it relates to medium- and long-term national, sub-national and sectoral development plans. Support is provided to also strengthen skills in applying techniques in evaluating adaptation investment projects.

This report is one of the outputs of the programme after two years of working with technical officers in the Ministry of Agriculture in Sri Lanka. During this period, the United Nations Development Programme (UNDP) and the United States Agency for International Development (USAID) delivered a structured training programme targeting technical officers at the national and sub-national level to estimate the economic costs and benefits of climate change impacts, as well as adaptation options relevant for the agriculture sector in Sri Lanka. The report reflects the work undertaken in Sri Lanka and the results of the analysis of survey data that were explicitly collected for the purpose of better understanding the impacts of climate change on smallholder farmers in the country. The report also provides insight into the potential impact of climate change on poverty across the country.

Understanding the economic costs and benefits of climate change at the micro and sectoral level requires detailed information of the sector and the potential vulnerabilities. While there have been numerous ad hoc reports aimed at understanding the impact of climate change on different economies, detailed data required for rigorous evaluation and understanding of the impact and optimal adaptation strategy are typically lacking. The results of this report and the policy response proposed are based on detailed farm level information collected from this project. The data are representative of the agro-ecological zones and the farming occupation in Sri Lanka.

HOW SHOULD THESE STUDY FINDINGS BE USED?

This report sheds light on the vulnerabilities of the agriculture sector to climate change by examining the impact of climate change on net revenue (NR) of farmers in the country. The use of observed NRs per acre of farms, rather than concentrating on experimental data on yields of particular crops, takes into consideration a variety of adjustments that farmers make in response to a variety of actual determinants, including climate. Consequently, the results provide an indication of the likely impact of climate change with and without adaptation. This information, and information from any follow-up studies that may be undertaken, can be used by policymakers to strengthen the inclusion of fact-based climate change considerations into existing and new climate change adaptation policies and strategies. It can also serve as a guide to generating economic justification for domestic and international financial support to implement these policies and strategies.

ACRONYMS AND ABBREVIATIONS

AI	Agricultural Instructor
CCCMA	Canadian Centre for Climate Modelling and Analysis
CMCC	Centro Euro-Mediterraneo per I Cambiamenti Climatici
CMIP5	Coupled Model Intercomparison Project
DSD	Divisional Secretariat Division
FAO	Food and Agriculture Organization
FIM	First Inter-monsoon
GCM	general circulation model
GDP	gross domestic product
HadCM3	Hadley Centre Coupled Model Version 3
HIES	Household Income and Expenditure Survey
LKR	Sri Lankan rupee
NEM	northeast monsoon
NGO	non-governmental organization
NR	net revenue
OPL	official poverty line
PDA	Provincial Director of Agriculture
SDG	Sustainable Development Goal
SIM	Second Inter-monsoon
SWM	Southwest-monsoon
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

INTRODUCTION

Agriculture is a major sector in Sri Lanka. It is one of the largest employers of labour in the country (engaging about 28.5 per cent of the labour force), and it is the major land use practice in the country (Sri Lanka Labour Force Survey, 2014)[1]. Given the importance of this sector for the economy of Sri Lanka, the analysis concentrates on this sector for the purpose of understanding the impact of climate change on the economy.

The report proceeds in the following manner. The first section 'Country Overview' provides a brief description of Sri Lanka to help understand the geography of the country and the agro-ecological zones with a focus on potential vulnerabilities and gains as a result of climate change. The study summarizes the role of agriculture in the country and provides a brief situation analysis. Application – Description of the Data0 provides summary statistics and information on how the data were collected. 'Evaluating Climate Change Impact and Adaptation' presents the model used to evaluate the impact of climate change on agriculture and the factors that determine adaptation in the country.

The report concludes with recommendations to policymakers.

Photo Credit: UNDP

1 See www.statistics.gov.lk/samplesurvey/LFS_Annual%20Report_2014.pdf

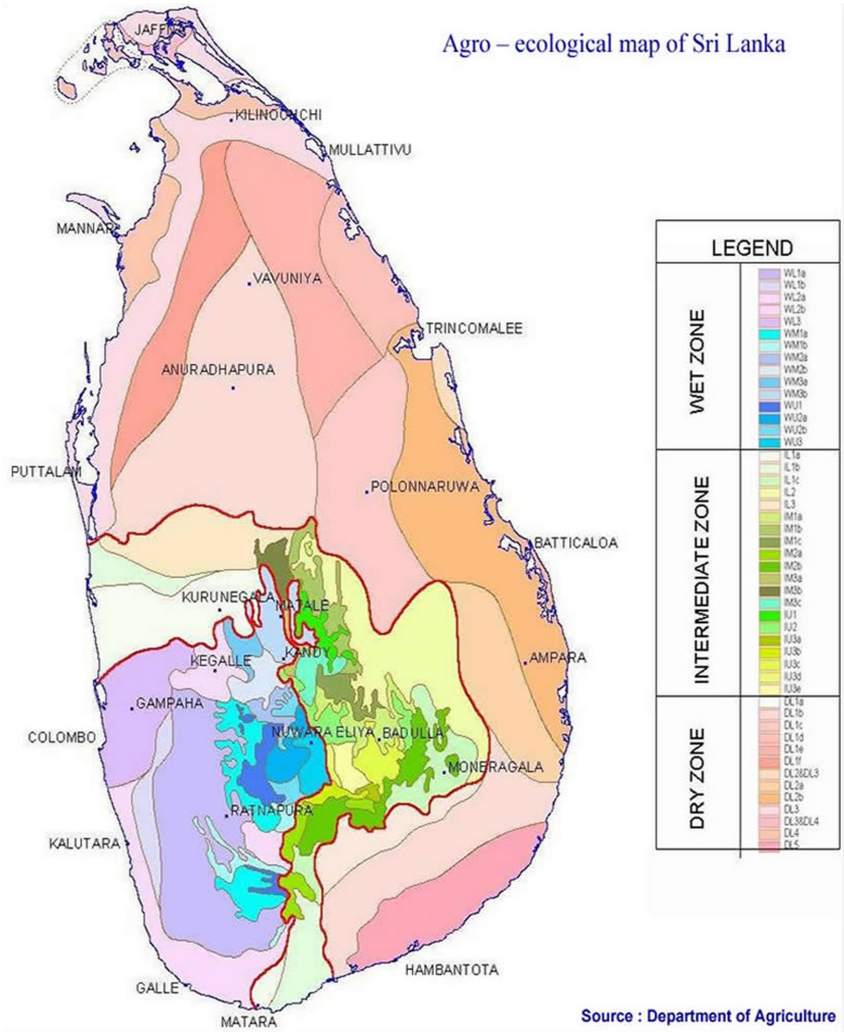
COUNTRY OVERVIEW

GEOGRAPHIC DESCRIPTION OF SRI LANKA

Sri Lanka is a mountainous island between 5° 55' to 9° 51' North latitude and between 79° 42' to 81° 53' East longitude. Except for the central part of the southern half of the country, the island is more or less flat. There are also several small hills that rise abruptly in the lowlands. The central part is mountainous with peaks rising above 2,500 metres (m). It contains complex topographical features such as ridges, peaks, plateaus, basins, valleys and escarpments. This topographical diversity has influenced the spatial patterns of winds, seasonal rainfall, temperature, and relative humidity within the monsoon season.

Photo Credit: UNDP

Figure 1: Tagro-ecological Maps of Sri Lanka



THE ROLE OF AGRICULTURE AND THE SITUATION ANALYSIS OF THE SECTOR

The economic development of Sri Lanka is a middle-income country, with consumption per capita in the bottom 40 per cent of the world but growing at 3.3 per cent per year. The economic growth averaged 6.3 per cent between 2002 and 2013, with the increase of gross domestic product (GDP) per capita from US$859 in 2000 to US$3,256 in 2013. Other human development indicators are remarkable for a lower middle-income country. Sri Lanka has satisfied most of the Millennium Development Goal (MDG) targets set for 2015 (World Bank, 2015).

The agricultural sector is considered the backbone of the Sri Lankan economy. It is the most important source of employment for the majority of the Sri Lankan workforce and the major land use practice. Economic development in other sectors has caused the contribution of agriculture to overall GDP to decline substantially during the past four decades (from 30 percent in 1970 to 10.8 percent in 2014). The GDP share of agriculture decreased from 10.8 per cent in 2013 to 10.1 per cent in 2014 mainly due to adverse weather conditions that prevailed during the year (Central Bank of Sri Lanka, 2014). The overall growth in the sector was a sluggish 0.3 per cent in 2014, compared to 4.7 per cent in 2013.

In 2014, the subsectors paddy, minor export crops and rubber contracted drastically, while the subsectors tea and coconut slowed marginally compared to the previous year. Conversely, the subsectors of livestock, plantation development and firewood and forestry recorded positive growth. The agricultural land use in Sri Lanka is comprised of plantations, food crops and minor export crops. This includes land under subsistence agriculture (rice paddy, horticultural crops, other field crops and spices), plantation crops (comprising mainly tea, rubber, coconut and sugarcane), minor export crops, and other beverage crops such as coffee. The other field crops (OFC) include over 100 species of cereals, grain legumes, condiments and oilseeds, onion and potato. At present, more than 2,000,000 ha under agricultural lands are located in the dry zone where any productivity enhancement is entirely dependent on water availability/rainfall.

Although the economic growth during the past five years was a peace dividend resulting from reconstruction efforts and increased consumption, sustained growth requires structural reforms to stimulate productivity growth and economic diversification across sectors, driven by technology and innovation, and new market development domestically and internationally (World Bank, 2015). The economy of Sri Lanka has made a transition from a rural-based agriculture economy towards a more urbanized economy focused on services. With the structural economic transformation, employment in primary agriculture will likely continue to decline. The sector needs to become more capital-intensive and technology-driven as labour shortages emerge (World Bank, 2015).

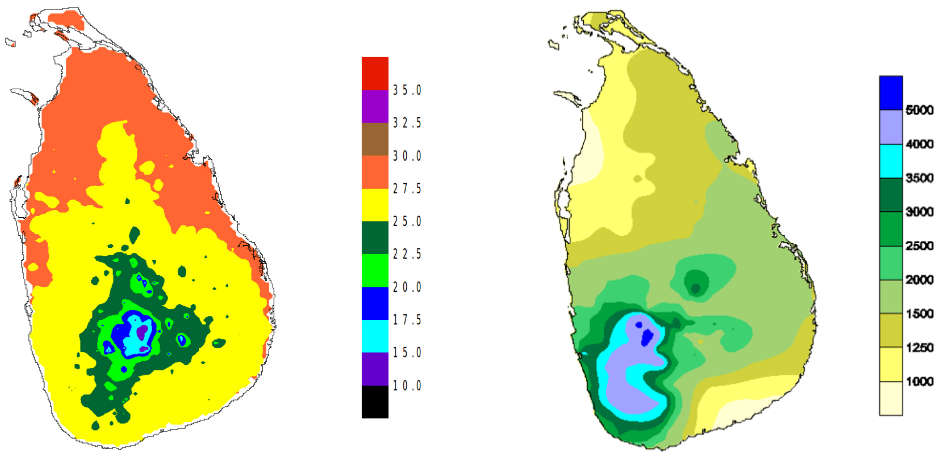
CLIMATE INFORMATION AND SOIL CHARACTERISTICS

CLIMATE OF SRI LANKA

The climate of Sri Lanka is tropical. The annual rainfall in Sri Lanka varies between 900 millimetres (mm) in the southeast and northwest to over 5,000 mm in the western slopes of the central highlands. Three distinct climatic zones based on rainfall are described as the 'wet zone', the 'intermediate zone' and the 'dry zone'. The mountains and the southwestern part of the country belong to the wet zone, which receives more than the annual average rainfall of 2,500 mm. The dry zone, covering most of the southeast, east, and northern parts of the island receives annual rainfall between 1,200 and 1,900 mm, and is the agricultural production hub of the country. The intermediate zone (1,750-2,500 mm) covers a relatively small area bordering the central hills except in the south and the west. The rainfall in Sri Lanka is influenced by the tropical monsoons of the Indian Ocean and Bay of Bengal that divide the climatic year into four seasons: first and second inter-monsoons, and southwest and northeast monsoons. Of these seasons, the northeast monsoons bring rain to the dry zone during December and January. The wet zone receives more rainfall from the southwest monsoons from May to July.343

Figure 2: Annual rainfall in Sri Lanka (Source Department of Meteorology)

Average Annual Temperature



Source: Department of Metrology

TOPOGRAPHY

Except the central part of the southern half of the country, the island is more or less flat. There are also several small hills that rise abruptly in the lowlands. The central part is mountainous with heights over 2,500 m, which contains complex topographical features such as ridges, peaks, plateaus, basins, valleys and escarpments. This topographical diversity has influenced the spatial patterns of winds, seasonal rainfall, temperature, and relative humidity within the monsoon season.

RAINFALL

Monsoonal, convectional and expressional rain accounts for the major share of rainfall in Sri Lanka. The mean annual rainfall ranges from under 900 mm in the driest parts (southeastern and northwestern) to over 5,000 mm in the wettest areas.

TEMPERATURE

Given the relative small size of the country, the ambient air temperature in Sri Lanka varies by altitude rather than by latitude. The mean annual temperature in Sri Lanka is relatively uniform in the lowlands but decreases with the altitude of the highlands. In the low country, the mean annual temperature ranges from 26.5 degrees Celsius (°C) to 28.5 °C, whereas in the highlands, the temperature falls rapidly with the elevation. Nuwara Eliya, the main city located in the central highland at 1,800 m above sea level, records a mean annual temperature of 15.9 °C.

CLIMATE SEASONS

This section is extracted from the report by the Department of Agriculture in Sri Lanka. [2] Sri Lanka has highly diverse climate conditions that depend on the geographical settings of respective locations in the country. As described earlier, Sri Lanka has traditionally been divided into three climatic zones. These zones help determine the agro-ecological zones in the country. Both the wet and intermediate zones spread across all three categories of elevation, whereas the dry zone is confined to the low country, resulting in seven agro-climatic zones covering the entire island. These seven agro-climatic zones are further subdivided into Agro-Ecological Regions (AERs) with a total of 46 AERs covering the entire island.

The weather pattern in Sri Lanka is determined by the topographical features and the southwest and northeast monsoons' regional scale wind regimes. Four major rainfall seasons have been identified for a 12-month climatic year in Sri Lanka that has been shown to start in March and not in January. These seasons are described as follows:

1. First Inter-monsoon (FIM) Season (March - April).
2. Southwest-monsoon (SWM) Season (May - September).
3. Second Inter-monsoon (SIM) Season (October - November).
4. Northeast-monsoon (NEM) Season (December - February).

These rainfall seasons do not bring homogeneous rainfall regimes over the whole island, but they are the main cause of the high agro-ecological diversity of the country despite its relatively small aerial extent. Out of these four rainfall seasons, two consecutive rainy seasons make up the major growing seasons of Sri Lanka, namely the Yala and Maha seasons. Generally, the Yala season is the combination of FIM and SWM rains. However, since SWM rains are not effective over the dry zone, it is only the FIM rains that fall during the Yala season in the dry zone from mid-March to early May. Being effective only for two months, the Yala season is considered the minor growing season of the dry zone.
The major growing season of the whole country, Maha begins with the arrival of SIM rains in mid-September/October and continues up to late January/February with the NEM rains.

SOILS IN SRI LANKA

Soil characteristics determine the type of crops that can be grown in a particular region and their yield. For Sri Lanka, there is a wide diversity of soil types mainly due to climatic and topographic factors. The physical properties of major soil groups include: reddish brown earths and immature brown loams; rolling, hilly and steep terrain (2.7 million ha); and red-yellow podzolic soils with a semi-prominent A1 horizon; and hilly and rolling terrain that covers about 1.5 million ha (FAO, 2005).

The three major soils, red-yellow podzolic, red and yellow latosols and reddish brown latasolic,[3] are favourable for wide-ranging agricultural purposes. The fertility of wet zone soils is poor due to these soils being extensively leached by high rainfall. The cation exchange capacity (CEC) values of most of the soils are low. Therefore, special fertilizer management practices on these soils are required. The base saturation of the dry zone soils remains at a higher range. Solodized solonetz, bog and half-bog soils are the major groups of soils that are not amenable to agriculture.

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2 See www.doa.gov.lk/index.php/en/crop-recommendations/903. Accessed on 29 November 2015.

3 Red-yellow podzolic soils are any of a group of acidic, zonal soils having a leached, light-colored surface layer and a sub-soil containing clay and oxides of aluminum and iron, varying in color from red to yellowish red to a bright yellowish brown. Latosol is a soil that is rich in iron, alumina, or silica and formed in tropical woodlands with great humidity and high temperatures.

Table 1: Soils of the dry and semi-dry intermediate zones

Previous name	New name (USDA)
Reddish Brown Earths	Rhodustalfs
Low Humic Gley soils	Tropaqualfs
Non-calcic Brown soils	Haplustalfs
Red Yellow Latosols	Haplustox
Alluvial soils	Tropaquents and Tropofluvents
Solodized Solenetz	Natraqualfs
Sandy Regosols	Quartzipsamments
Grumusols	Pellusterts
Immature Brown Loams	Ustropepts

Table 2: Soils of the wet zone and semi-wet intermediate zones of Sri Lanka

Previous name	Current name (USDA)
Red-Yellow Podzolic soils	Rhodudults/ Tropudults
The Modal group	
Sub group with strongly mottled subsoil	Tropudults
Sub group with soft or hard laterite	Plinthudults
Sub group with prominent A1 horizon	Tropohumults
Sub group with semi-prominent A1 horizon	Tropudults
Sub group with dark B horizon	Humudults
Reddish Brown Latosolic soils	Rhodudults/Tropudults
Immature Brown Loams	Eutropepts/Dystropepts
Bog soils/ Half Bog Soils	Tropohemists/Troposaprists
Latosols and Regosols.	Quartzipsamments
Red-Yellow Podzolic soils	Rhodudults/ Tropudults
The Modal group	The Modal group
Sub group with strongly mottled subsoil on old red and yellow sands	Tropudults

DESCRIPTION OF VULNERABILITIES TO CLIMATE CHANGE

PADDY SUB SECTOR

In the agriculture sector, a major concern with increasing variability of rainfall due to climate change is the likely adverse impact on paddy production in some agro-ecological regions. Rainfed paddy, which accounts for 30 per cent of the production, is perceived to be especially vulnerable to climate change. Paddy cultivation in the wet zone is mostly rainfed, while paddy fields in the dry and intermediate zones are either rainfed or irrigated. The coastal agricultural communities are vulnerable to saline intrusion due to sea level rise and storm surges, restricting freshwater availability for agriculture.

A recently compiled report by the Sri Lanka Ministry of Environment (2011) focused on the vulnerability of paddy to climate change, indicates that:

- Vulnerability to the increase in droughts expected due to climate change is widespread throughout the country, although it is particularly high in the dry and intermediate zones.
- 16 Divisional Secretariat Divisions (DSDs) are highly vulnerable to drought exposure. In these DSDs, there are 100,317 households with agriculture as the primary source of income; 400,973 acres of agricultural lands, of which 176,852 acres (44.1 per cent) are cultivated with paddy; and 3,153 tanks covering a total area of 88,395 acres.
- 23 DSDs are moderately vulnerable to drought exposure. There are 195,573 agricultural operators, 174,839 acres of paddy lands, and 3,901 tanks covering a total area of 80,675 acres in these DSDs.

PLANTATION CROPS

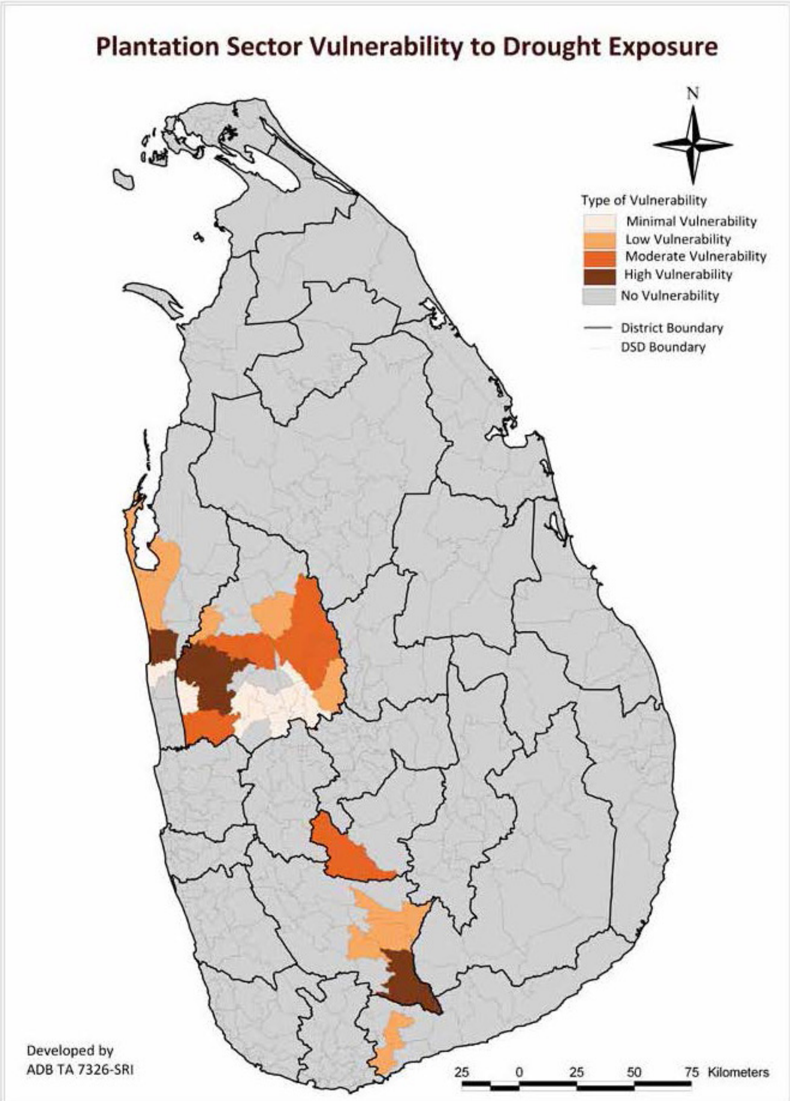
The main vulnerabilities related to the plantation sector, which comprises tea, rubber, coconut and sugar cane, are mainly floods, droughts and landslides, all of which are expected to increase in the future based on current and expected changes in rainfall patterns. High rainfall intensity will increase soil erosion in tea lands and reduce the number of days available for rubber tapping.

According to the Climate Change Vulnerability Data Book prepared by the Sri Lanka Ministry of Environment (2011):

- Five DSDs are highly vulnerable to drought exposure. There are 88,069 acres of coconut cultivations and negligible amounts of tea and rubber cultivations; a total population of 354,789 of whom 77,656 are below the poverty line; and 40,172 jobs in agriculture in these DSDs.
- Seven additional DSDs are moderately vulnerable. There are 108,340 acres of coconut, 54,230 acres of tea and very minimal rubber; a total of 10,522 jobs in agriculture, and an estate population of 143,272 in these DSDs.
- Of the 12 DSDs with high or moderate vulnerability to drought, nine are in the Kurunegala District. Plantations in these DSDs are primarily for coconut cultivation.

The report further identifies three DSDs, all in the Nuwara Eliya District, that emerge as highly vulnerable to landslide exposure, and three DSDs are exposed to floods (in the plantation sector).

Figure 3: Planatation sector vulnerability to drought exposure



LIVESTOCK SECTOR

The climate change-related impacts such as floods and landslides are also expected to have unfavourable effects on livestock production in some areas. This will have a negative impact on livelihoods of the dependent farming communities and on nutritional security. As per the Climate Change Vulnerability Data Book (Sri Lanka Ministry of Environment, 2011):

- Ten DSDs are highly vulnerable to drought exposure. There are 27,350 head of cattle and buffalo, and 47,085 head of goats and swine, and over 2.5 million head of poultry in these DSDs.
- 12 additional DSDs are moderately vulnerable. There are 146,811 head of cattle and buffalo, and 70,878 head of goats and swine in these DSDs.

Photo Credit: UNDP

APPLICATION – DESCRIPTION OF THE DATA

The data for this study were collected in 2014 by a national team. The survey instrument used for the data collection exercise can be downloaded on the webpage of the Capacity Building Programme on the Economics of Climate Change Adaptation (ECCA) in Asia.[4]

The sampling plan for this island-wide survey was prepared based on the agro-ecological map prepared by the Natural Resources Management Centre of the Department of Agriculture, Peradeniya, Sri Lanka. The area under each of the agro-ecological regions was identified together with the District, the DSD and the range of the Agricultural Instructor (AI), i.e. the extension officers. Within each of the agro-ecological regions, 1-3 AI ranges were selected for data collection based on the spread and the area of the agro-ecological region, resulting in approximately 92 AI ranges to represent 46 agro-ecological regions. The number of farmers contacted for data collection was decided based on probability proportional to the size.

The survey was carried out with the active collaboration of the Provincial Directors of the Department of Agriculture. The offices of the Provincial Director of Agriculture (PDA) are located in the provincial capitals, and the Director is responsible for all the field officers. The PDA offices of the Department of Agriculture manage the island-wide extension network where the AIs are the qualified (holding a diploma or degree) ground-level officers. By working with farming communities and attending different in-service training programmes, these officers usually possess technical knowledge as well as experience related to agriculture.

The questionnaire was first translated into the local language and tested twice with five farmers. All the PDA officers were met together with the necessary local government officials and stakeholders to facilitate the smooth collection of information. The names and the contact details of the AIs were obtained in advance and they were informed through the PDA to attend the training session. One-day training programmes were conducted for the selected AI officers at all the PDA offices except the North and East. They were then asked to undertake a rehearsal test prior to the commencement of the survey. The questionnaire was distributed according to the sampling plan and then enumerators were asked to return these within two weeks. The completed questionnaires were submitted to the Peradeniya office by the officers. The completed questionnaires were individually checked by the team and, in the case of inconsistencies, the enumerators were contacted over the phone for clarification.

Three hundred and twenty-one households throughout the agro-ecological zones of the country were interviewed. About 40 per cent of the sample were from the Central Province of the country, while the rest were distributed across the other provinces, including the North West and Uva Provinces (about 14 per cent). Figure 4 indicates the distribution of the sample area across Sri Lanka.[5]

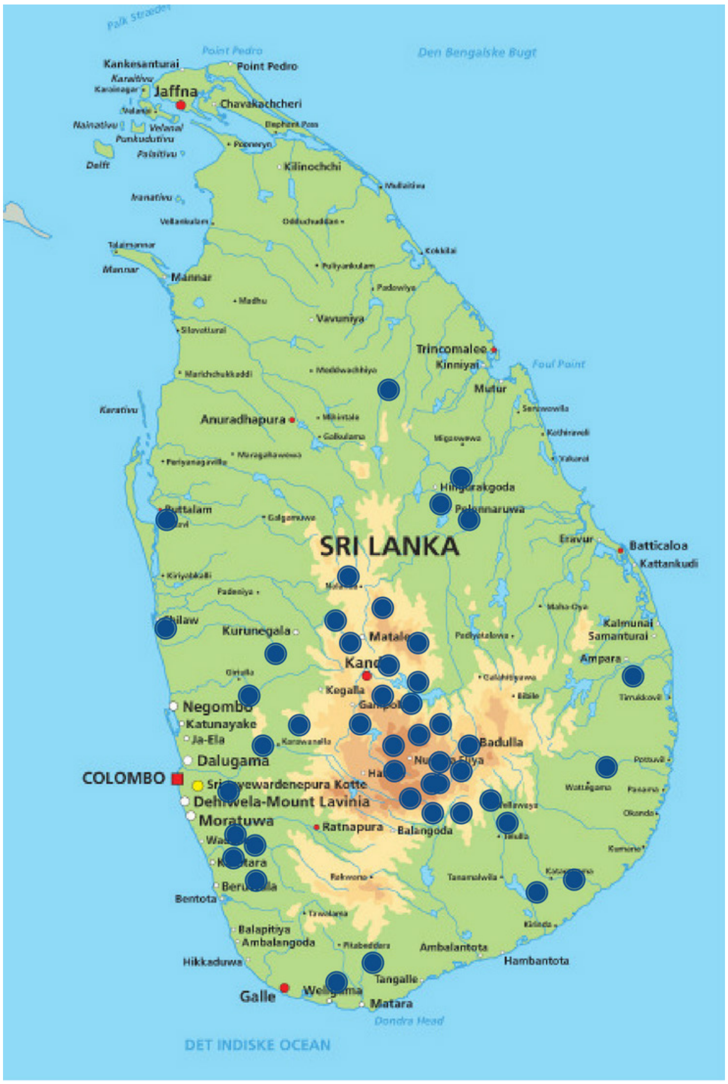
4 See www.adaptation-undp.org/projects/ecca-asia

5 Agro-ecological diversity is highest in the Central Highlands. Therefore, the sampling method chosen involved interviewing many more respondents from this area, where cropping patterns, water availability and seasons are different from the dry zone, which has the most extensive cultivation areas in the country. The survey is not representative at the province level but at the agro-ecological zones.

Table 3: Sample by Province in Sri Lanka

Province	Frequency	Percent
CENTRAL	126	39.25
EAST	6	1.87
NORTH CENTRAL	38	11.84
NORTH WEST	47	14.64
SABARAGAMUWA	7	2.18
SOUTHERN	17	5.3
UVA	44	13.71
WESTERN	36	11.21
TOTAL	321	100

Figure 4: Distribution of respondents in the survey



WHAT INFORMATION WAS COLLECTED IN THE QUESTIONNAIRE?

1. Past experience on climate change, communications and adaptation response. Interviewees were asked about their perception about climate change and current sources of weather information.

2. Detailed farming area information. The survey collected information on farm planting area, fallow land area, and the division of the plots by crops and other livelihood by the household.

3. Household information. Detailed information on household members, gender and basic infrastructure availability. Data were also collected on the primary and secondary occupation of the head of the households.

4. Data required to calculate the farmer's net revenue based on ongoing agriculture practices (crop and livestock). Data were collected on labour available to the household, type of crops grown including by growing season, prices as well as input costs including cost and quantity of fertilizer, irrigation, and machinery. Similar information was collected for livestock farmers.

5. Global Positioning System (GPS) locations. Location is important when analysing climate impacts so information on the latitude and longitude of farms was collected.

6. Detailed information on extension services provided by private extension groups, non-governmental organizations (NGOs), central government agencies, cooperatives and local government to be able to elicit potential policy tools available to support adaptation.

SUMMARY INFORMATION FROM THE DATA

With respect to household's farming experience, the survey reported a range from four years to 60 years, the majority of which reported 20 years. On average, each household consisted of five people (minimum four, maximum 16) with ten years of education. The majority (88 per cent) of the respondents owned a telephone and 33 per cent had a computer, 18 per cent of whom had access to the Internet.

On average, the respondents owned about 3.4 acres of planted land area (Figure 5) with about 1 acre left fallow, on average, in season one. A small percentage of the respondents owned more than 5 acres of land.[6] One statistic of interest is the change in the area planted by season. As shown in Table 4, farmers leave about 1.5 acre of their land to fallow in the Yala season relative to one acre in the Maha season (major raining season).[7] This indicated potential for farmers to increase production during the Yala season if they do not have to rely on rainfed agriculture. Other characteristics of the farm are presented in the appendix to this report. As shown in Table 5, 188 of farms were rainfed (out of 321 observations), while 133 were irrigated. The mean net revenue for irrigated farms was higher (US$498.25) than for rainfed (US$447.49) farms.

6 Note that the households sampled in this survey are not only small holder farmers or crop farmers. Small holder farmers in Sri Lanka are estimated to have between 2.5 and 3.7 acres of land. This is about 35% of the sample in this survey. The median land holding for the sample is 2.25 acres.

7 There can be different reasons for which households will have land fallow in the major growing seasons, such as limited labour to use all the land or changes in farming practice in the year of the survey. Further analysis is needed to study why this may be the case.

Figure 5: Distribution of land use planted area for season 1 plot 1

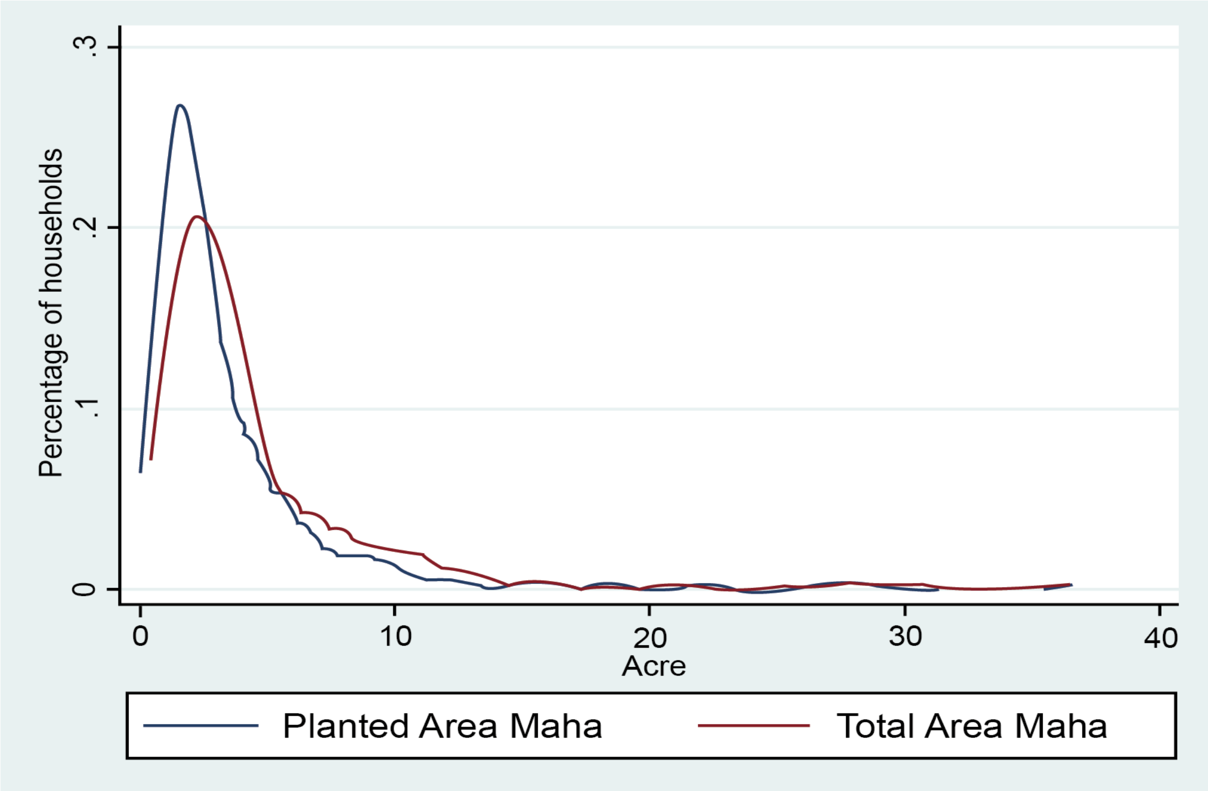


Table 4: Summary statistics of agricultural land area by season (acres)

Variable	Number Observations	Mean	Std. Dev.	Min	Max
Planted area season 1	321	3.4	3.9	0	36.5
Planted area season 2	321	2.9	3.6	0	30
Planted area season 3	321	1.0	3.2	0	35
Fallow area season 1	321	1.1	1.9	0	20
Fallow area season 2	321	1.5	2.3	0	23
Fallow area season 3	321	3.5	3.5	0	28
Total area	321	4.5	4.5	.5	36.5

Table 5: Net revenue for irrigated and rainfed farms

	Irrigated Farms		Not Irrigated Farms		Total	
Variables	NR	Farm area	NR	Farm area	NR	Farm area
Observations	133.00	133.00	188.00	188.00	321.00	321.00
Mean	498.25	6.87	447.49	7.75	468.52	7.39
Min	-1,305.37	0.50	-1,295.41	0.75	-1,305.37	0.50
25th Percentile	94.75	3.00	113.09	3.25	108.07	3.00
50th Percentile or Median	225.62	4.50	310.42	5.00	281.55	4.75
75th Percentile	584.33	7.00	547.27	9.00	568.56	8.20
Max	4,598.29	101.50	3,498.27	57.00	4,598.29	101.50

Climate change perception and indicated adaptation

One statistic of interest to policymakers on climate change is the level of awareness that climate is changing in the country. The data indicated that 92 per cent of the households surveyed have observed a long-term shift in temperature and 95 per cent observed a long-term shift in rainfall. The question on which factors determined their decision to adapt is addressed in the next section.

From Table 6, it appears that around half of the farmers surveyed have invested or provided access to irrigation using sprinkler systems or groundwater pumps. About 31 per cent of the sample selected to manage risks by only changing crop dates, and/or adjusting crop varieties, including hybrids. Interestingly, the data suggested that 17 per cent of the farmers were not doing anything additional to what they are currently practicing.

Table 6: Adaptation choices made by respondents for temperature shifts

Predominant Risk Management Practices	Households (%)
Irrigation Investment	52.34
Crops dates, crop types, crop varieties	31.15
Status Quo	16.51

EVALUATING CLIMATE CHANGE IMPACT AND ADAPTATION

Modelling the relationship between climate and agriculture is typically done using three approaches – crop-growth simulation models, agronomic economic models, and integrated assessment models, such as computable general equilibrium models and whole farm models. These models are based mainly on climate-crop physiology and development models. The first two models can handle some adaptation and crop management responses such as variety selection, change of planting dates and fertilizer use. However, the crop simulation models fail to account for the other key adaptation measures such as responses to key economic stimuli (input substitution and prices), and the switching of crops and multi cropping being crop specific. This is essential because without capturing these measures it leads to an overestimation of the climate damage.

In order to have an unbiased estimate of climate impact, a whole farm approach is needed that allows for adaptation responses. This model used here is the Ricardian method, named after David Ricardo's 1815 work.[8] This report is premised on the fact that land rents capture long-term farm productivity/value. The model assesses performance of farms across landscapes, capturing impacts of variations in climate attributes and other factors such as soils, prices, and socio-economic factors. As a proxy for the value of the land where data do not exist, the present value of the stream of future net farm revenue is used.

The model makes use of information that is implicit in the spatial variation of farm revenues to value the marginal contribution that climate attributes have, holding all else that affects revenues constant. The main advantage of the Ricardian model is that it accounts for adaptation to climate change. One other major advantage given the difficulty in getting time series data of many economic variables is that it does not rely on observing economic agents over time (which can be costly), but rather across geographic space. This ease of implementation (undertaking a survey) is an important advantage, especially for countries that do not have the resources for more complex data collection exercises. There are, however, a number of limitations of the model that can pose problems in adequately estimating the impact of climate change. A drawback of the Ricardian model is the possibility of the omission of variables, which is present in all cross-sectional analysis; another concerns the inefficiencies of the land and labour prices/markets that may distort prices. For additional information on the advantages and drawbacks of the approach, refer to Kurukulasuriya et al. (2006).

A simple representation of the Ricardian model can be represented as follows:

$$NR = \beta_0 + \beta_1 C + \beta_2 C^2 + \beta_3 Soil + \beta_4 Z + \varepsilon$$

Where net revenue (NR) is the net revenue per acre of the farmers, C are climate attributes such as temperature and rainfall; Soil includes soil characteristics; Z includes all other factors that may be an important determinant of NR of the farm. The quadratic term is included to capture non-linear relationships.

8 One of the first applications of this method to measure climate change impact is Mendelsohn et al. (1994).

If a positive number for the quadratic term is obtained, the function assumes a U-shaped form, whereas if the value is negative, the function assumes a hill shape form. Finally, ε is the error term.

The value of the net revenue of the farmer is obtained by calculating the total revenue (farm gate price and quantity sold by the farmer) and the total cost of production (labour input cost, fertilizer, pest and seed costs, irrigation cost, and machinery costs). Personal labour costs are not included which may overestimate net revenue of small farms.

The Ricardian analysis provides an understanding of the relationship between net revenue and climate variables. In order to be able to make appropriate inferences on this relationship, the model should capture the reality of the determinants of farm revenue and returns in the country. As a first step in understanding this, the study models net revenue of the farmers including different characteristics that can help explain differences in revenue apart from temperature and precipitation. These characteristics include differences in education of the farmer, differences in location, and soil characteristics. The model provides a good representation of the determinants of net revenue of farmers in the country based on the data collected.

Once the analysis has a model that adequately explains net revenue (applying different model diagnostics and robustness tests and ensuring adequate model specification by adequately controlling for potential nonlinearities in the relationship), then it can make inferences and different policy recommendations based on changes in temperature and precipitation. Using the model, the marginal impact of climate (temperature and precipitation) is estimated to give an indication of by how much net revenue changes when there is a unit change in climate. Finally, the impact of climate change is estimated by changing the values of the climate variables to levels predicted by climate change projections (holding other characteristics of the farmer constant) and comparing the projected net revenue to the current business as usual net revenue scenario. These steps are repeated for different climate scenarios.

EXPLAINING CLIMATE CHANGE IMPACT ON AGRICULTURE IN SRI LANKA

The equation on net revenue is estimated using an ordinary least square estimation procedure. The model diagnostics shows that the model performs well, and is stable. About 19 per cent of variations in net revenue are explained by the climate variables and soil characteristics; this increases to 27 per cent of the variation explained when it is controlled for household demographics and provinces (fixed effects).

Before explaining the relationship between the climate variables and net revenue, the study first explains the impact of non-climatic variables on net revenue in the country.[9] Start with the issue of land. The study asks, are larger farms more profitable than smaller farms? Looking at the result presented in Table 4, the data suggest that the larger the planted area for a farmer, the lower the net revenue – that is, smaller farms appear to be performing better per acre than larger farms. However, the apparent advantage of small farms most likely reflects measurement error because there is no observed cost for household labour. This inflates farm net revenues. Household labour is likely a higher fraction of the labour at small farms.

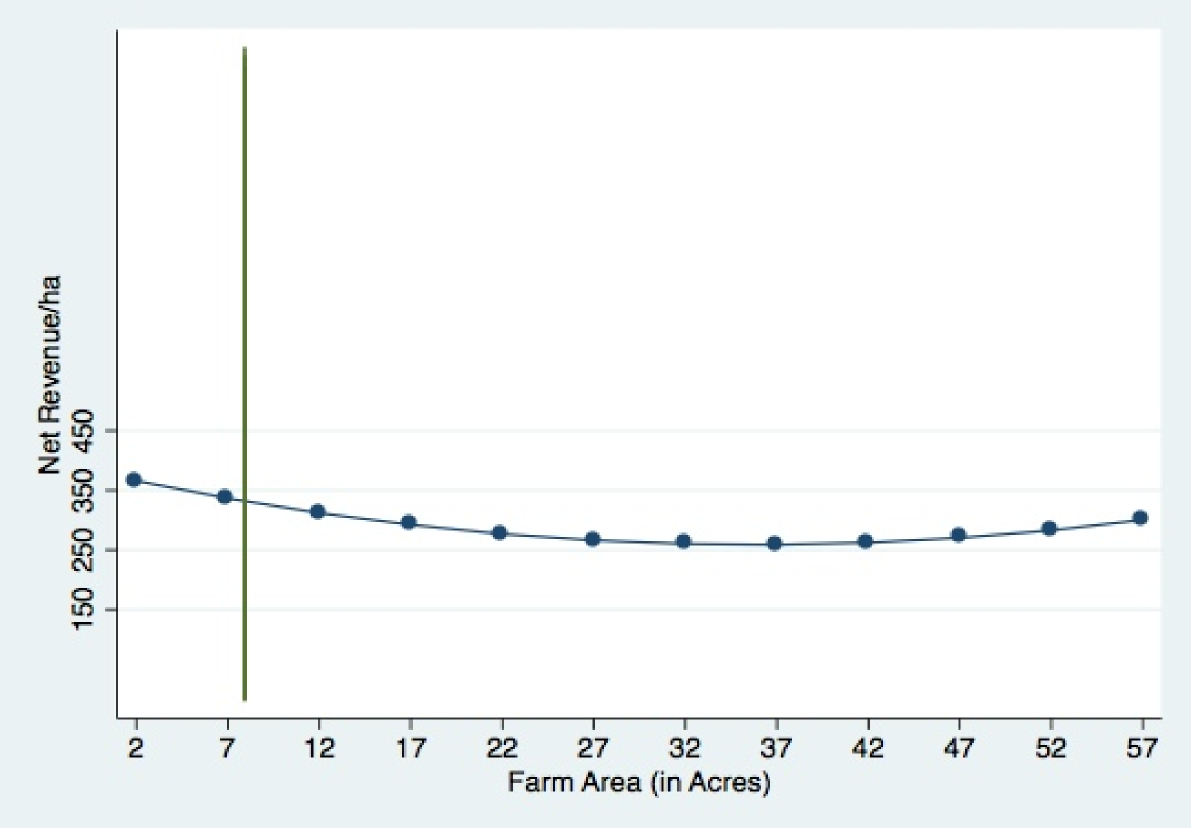
The analysis also considers the role that soil type and elevation play in determining net revenues per acre. The soil data that were used in the analysis reflects the primary soil type and topography the farmers faced in their particular locality (i.e. clay, sandy or medium texture or flat, steep and medium). The results show that farms in a flat area perform worse than those in medium flat areas while there is some evidence that farms in steep areas perform better than those in medium flat areas in terms of profitability. These differences are, however, very noisy especially once it is controlled for province heterogeneity as shown in the last column of Table 6. Also, soil characteristics do not matter much in explaining the differences in profitability in Sri Lanka. This is likely because there is not much variation in the quality of the soil across the sample. Lastly, there is some evidence that altitude marginally influences net revenue of farmers in Sri Lanka.

Other variables such as the role of electricity, phone, computer, internet, and household size do not have significant impact on net revenue of the farmers sampled conditional on all the other variables controlled for in this particular analysis.[10]

9 The full parameter estimates are presented in the Appendix showing the linear and nonlinear terms. We present the marginal effect at the mean in the report but interested readers can read the parameters estimates in the appendix.

10 Note that this might be because some of these variables are not truly exogenous to the farmers. They are choices that need to be made by the farmers and may be seen as an indicator of differences in farming practices, which, if homogenous, will have no significant impact on explaining NR differences.

Figure 6: Net Revenue (in US$/acre) predicted as a function of planted area



The analysis looks into the climate variables of interest, and what our model can reveal about the influence of temperature and rainfall on net revenue of the farmers in Sri Lanka. As a first step, it is measured using seasonal temperature and rainfall. The average temperature in each of the seasons is defined as follows: First inter-monsoon (FIM) season (March - April); Southwest monsoon (SWM) season (May-September); the Second inter-monsoon (SIM) season (October-November); and Northeast monsoon (NEM) season (December-February). The data in the analysis are from the current (1950-2000) climate dataset from WordClim's website at the "10 arc-minutes", which is the finest spatial data available.[11]

The analysis starts by observing the FIM season in Sri Lanka. It is the beginning of the Yala season with rainfall in the dry zone of the country from mid-March to early May. This season is considered a minor growing season of the dry zone, as discussed earlier. The results show that if it gets warmer during this period, net revenue (NR) of the farmers will initially decline before turning positive. Thus, the warmer it gets during the March to April rainfall season, the higher the fall in NR of the farmer. To put these results in perspective, the average temperature in this season is about 26.5°C. An additional 1°C warming in this period does not significantly increase NR; it will stay about the same (Figure 7). Precipitation has a positive impact. Figure 7 shows the relationship between NR and precipitation for the FIM season. During this season, rainfall above the average (currently 170mm) and beyond 200 mm will improve NR.

11 http://www.worldclim.org/current

Unlike the U-shaped relationship observed for the FIM season, a hill shaped relationship is observed for the SWM season. Recall that the SWM season is the second part of the Yala season but typically not effective over the Dry zone. Though the average temperature in this period is close to that of the FIM, a 1°C warming above the average will lead to an increase in net revenue, whereas any level of precipitation above the average has a positive effect in this season, or in other words, more rainfall of any level is beneficial for the growth of the crop once planting is completed.

Next, the analysis looks into the impact of temperature and rainfall in the major growing seasons – SIM Season and NEM Season. The result shows that rainfall above the average (at about 300mm), when Maha season begins, reduces net revenue of the farmers. However, the impact of precipitation during the NEM season increases up to about 230 mm before it starts to be harmful. An increase in temperature at the start of the Maha season is good, but continual increase towards the second part of the season (NEM) is not beneficial to the crops. On the other hand, the results for SIM season are U shaped and any increase above the average (currently 25 °C) would lead to an increase in net revenue.

In summary, warmer temperature in NEM of more than 2 °C is harmful, while less than 2 °C above average warming for SIM is also harmful. However, the annual effect (the sum of the seasonal marginal variables) is positive but not significant. This is presented in the lower section of Table 6. The next section explores different specifications to understand why the seasonal climate variables are not performing well.

Figure 7: Predicted relationship between mean seasonal temperature and net revenue (NR in US$/acre)

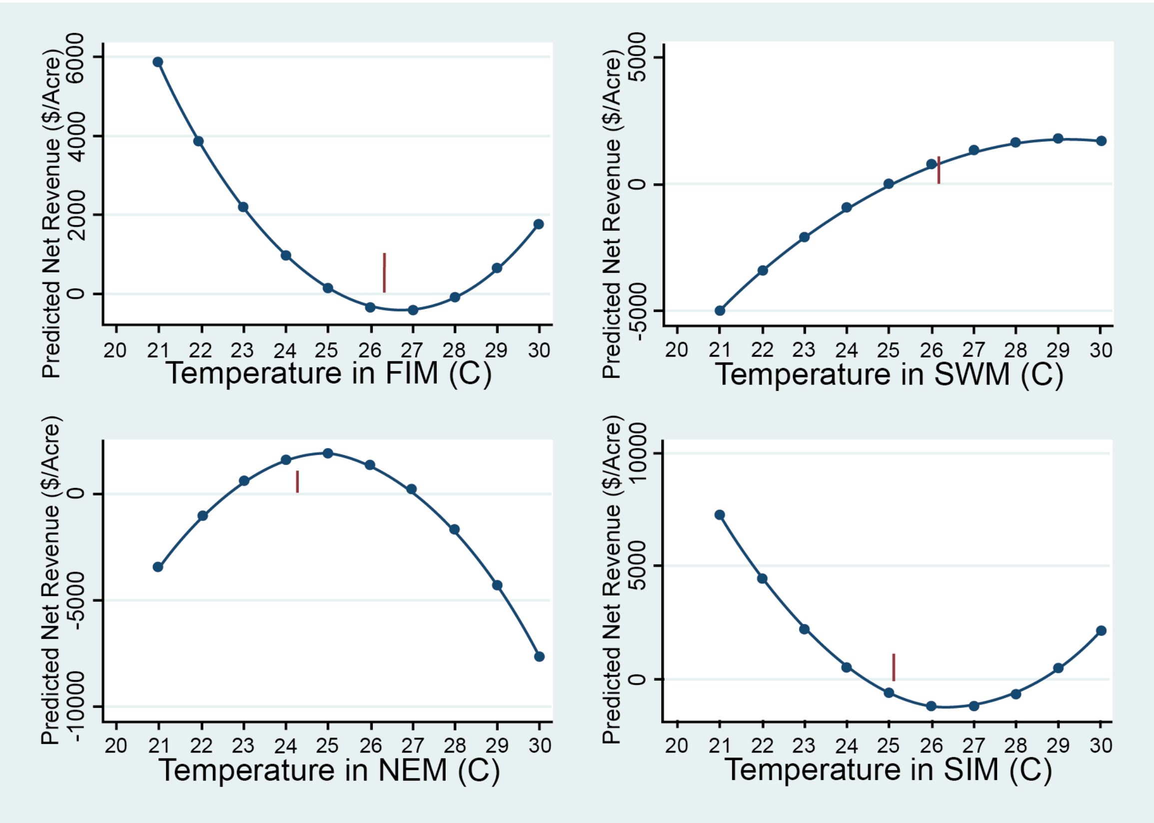
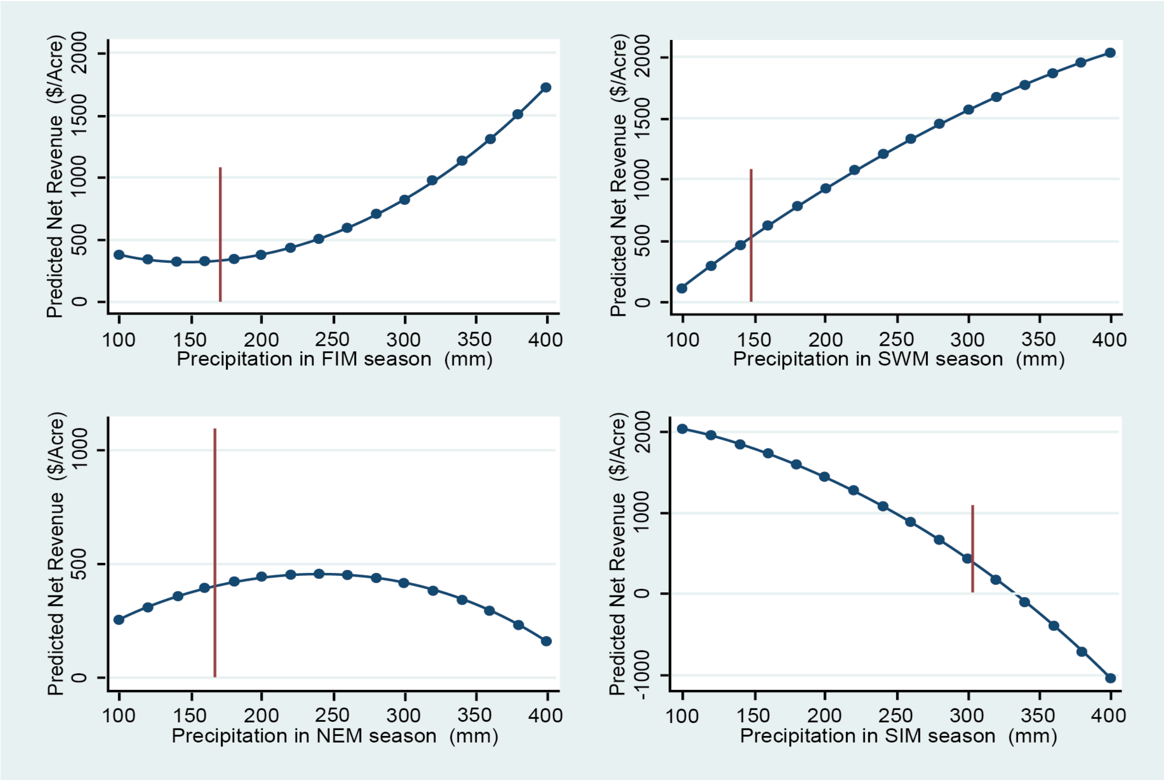


Figure 8: Predicted relationship between mean precipitation and net revenue (NR in US$/acre)



Note: The red line marks national mean.

Photo Credit: UNDP

Table 7: Marginal effect of each explanatory variable on net revenue per acre

Variable	Base	Base with control only	With temperature precipitation interaction	Base model with interactions and control
FIM Temperature	-268.402*	-239.710*	-163.352	-135.872
	(145.466)	(144.885)	(217.122)	(217.009)
SWM Temperature	-111.109	-62.586	518.843	600.972
	(287.576)	(294.501)	(353.555)	(370.451)
SIM Temperature	58.203	-59.424	-640.696	-801.742
	(550.152)	(561.921)	(600.150)	(627.589)
NEM Temperature	457.289*	492.735*	379.972	410.266
	(252.877)	(258.716)	(320.966)	(327.738)
FIM Precipitation	-3.579	-3.964	0.931	0.926
	(2.870)	(2.916)	(3.835)	(3.777)
SWM Precipitation	1.673	1.922	8.060***	8.252***
	(1.490)	(1.427)	(3.049)	(3.138)
SIM Precipitation	0.443	0.123	-12.124**	-12.600**
	(3.211)	(3.047)	(5.593)	(5.659)
NEM Precipitation	2.647***	2.728***	1.823	1.495
	(0.917)	(0.954)	(1.136)	(1.196)
Flat	-123.874	-103.804	-155.627	-145.504
	(90.552)	(97.841)	(97.894)	(108.506)
Steep	136.693	141.163*	268.076***	257.190***
	(82.882)	(82.838)	(91.972)	(93.784)
Clay	20.079	14.773	31.299	27.030
	(79.012)	(83.677)	(82.163)	(89.925)
Farm Area		-4.646*		-4.355
		(2.754)		(2.849)
Electricity		49.678		88.040
		(68.861)		(80.928)
Household size		2.440		-25.826
		(42.434)		(44.957)
Age		-1.265		-1.447
		(1.559)		(1.558)
Education		6.135		6.082
		(4.661)		(4.675)
Gender		-46.202		-42.253
		(121.870)		(117.442)
Cumulative Temperature	135.981**	131.015**	73.624	73.624
	(59.075)	(60.931)	(69.547)	(69.547)
Cumulative Precipitation	1.184	0.810	-1.927	-1.927
	(1.794)	(1.897)	(2.280)	(2.280)
Observations	257	257	257	257
R-squared	0.171	0.196	0.207	0.232

Notes: Standard errors in parentheses. (***), (**) and (*) significant at 1%, 5% and 10%, respectively..

TOTAL IMPACT OF TEMPERATURE AND PRECIPITATION

While considering the impact of climate variables, as typically classified, is helpful, ultimately the overall climate impact on productivity is of interest. In this section, the study explores a simpler specification that will help in understanding the impact of climate change that is not plagued by the high correlation between temperature and precipitation in the four seasons.[12] One main correlation that is typically ignored is what determines temperature especially in a country like Sri Lanka with various mountains and altitude. Temperature is not exactly an exogenous variable in the regression. It is determined by a combination of precipitation and altitude and becomes even more pronounced in countries with different altitudes. In the previous model, altitude has been excluded in order to reduce the correlation. However, the appropriate specification is to model the fact that precipitation and altitude are determinants of temperature in a two-stage least squares framework. [13] Specifically, the simple model specification models temperature impact using annual temperature, but leaves the precipitation terms as in the previous regression. The model, however, controls for distance to port, education, farm area and whether the farm has a clay soil or not.

The result shows that the impact of temperature on NR is negative and significant. Higher average annual temperature has an adverse impact on farmers in Sri Lanka.

Due to the importance of precipitation, the seasonal precipitation variables were included. The result shows that more rainfall in the FIM period hurts irrigated farmers (some fixed cost of irrigation cannot be recovered) but is good for non-irrigated farmers, although not significantly. More precipitation is good for non-irrigated farmers (FIM and NEM). It is also significantly good for irrigated farmers in the SIM season. The estimates in this study are similar to previous studies in Sri Lanka such as Kurukulasuriya and Ajwad (2007) and Seo et al. (2005). The model in this study is, however, different to that of previous studies by modelling irrigated and non-irrigated farmers separately and showing that the impact of temperature is higher for irrigated farms than non-irrigated farms and precipitation in the NEM period (towards the end of the Maha season), is significantly important for non-irrigated farms but not for irrigated farms.

The implication of the coefficient on annual temperature is that a 1°C increase in average temperature will lead to a US$85.95 (18 per cent of the total average NR) decrease in NR per acre. Also, one millimetre less rain in the NEM period will lead to a US$1.69 (0.3 per cent of the total average NR for non-irrigated farms) decrease in NR per acre for non-irrigated farmers. Summing the coefficients on precipitation implies that less precipitation has a significant negative impact. [14]

Lastly, the remaining variables presented in Table 8 are interpreted. Distance to port in general hurts farmers, and is more harmful to non-irrigated than irrigated farms (also synonymous to distance to water).

12 The square term in each season with correlation between the temperature and precipitation with limited variability in the data can potentially increase the noise surrounding the estimates as seen with large standard deviations in the previous models.

13 The two-stage least squares estimator models endogeneity in a regression equation by using the residuals from the regression (of annual temperature) that determines the endogenous variable (annual precipitation and altitude) in the equation instead of the endogenous variable itself. This removes the potential endogeneity bias.

14 Total net revenue for irrigated and rainfed farm is presented in Table 5.

Table 8: The Ricardian model showing the relationship between climate variables and net revenue instrumental variables approach

VARIABLES	All Data	Irrigated Farm	Non-Irrigated Farm
Annual temperature	-85.946***	-97.460***	-51.890
	(29.966)	(36.201)	(52.070)
FIM Precipitation	7.407	9.094	-8.195
	(4.923)	(6.493)	(11.321)
FIM Precipitation squared	-0.028*	-0.044*	0.024
	(0.017)	(0.024)	(0.029)
SWM Precipitation	-5.238**	-5.570	-6.394
	(2.581)	(3.416)	(4.670)
SWM Precipitation squared	0.008	0.009	0.010
	(0.005)	(0.007)	(0.009)
SIM Precipitation	-15.452**	-24.021***	16.591
	(6.336)	(9.100)	(18.163)
SIM Precipitation squared	0.031**	0.052***	-0.027
	(0.013)	(0.020)	(0.027)
NEM Precipitation	-9.166**	-13.283***	-1.173
	(3.589)	(5.036)	(5.249)
NEM Precipitation squared	0.028***	0.038***	0.009
	(0.010)	(0.014)	(0.015)
Farm area	-4.125	-3.933	-2.020
	(3.261)	(6.099)	(6.855)
Farm area squared	0.060*	0.044	0.041
	(0.035)	(0.101)	(0.066)
Education	8.696*	13.594*	1.751
	(5.132)	(7.370)	(5.724)
Distance to Port	-5.432***	-3.905**	-8.655***
	(1.586)	(1.989)	(3.193)
Constant	5,458.324***	6,842.807***	1,097.864
	(1,711.121)	(2,232.950)	(3,011.943)
Observations	257	148	109
R-squared	0.2	0.062	0.164
chi2	33.40	19.01	40.91

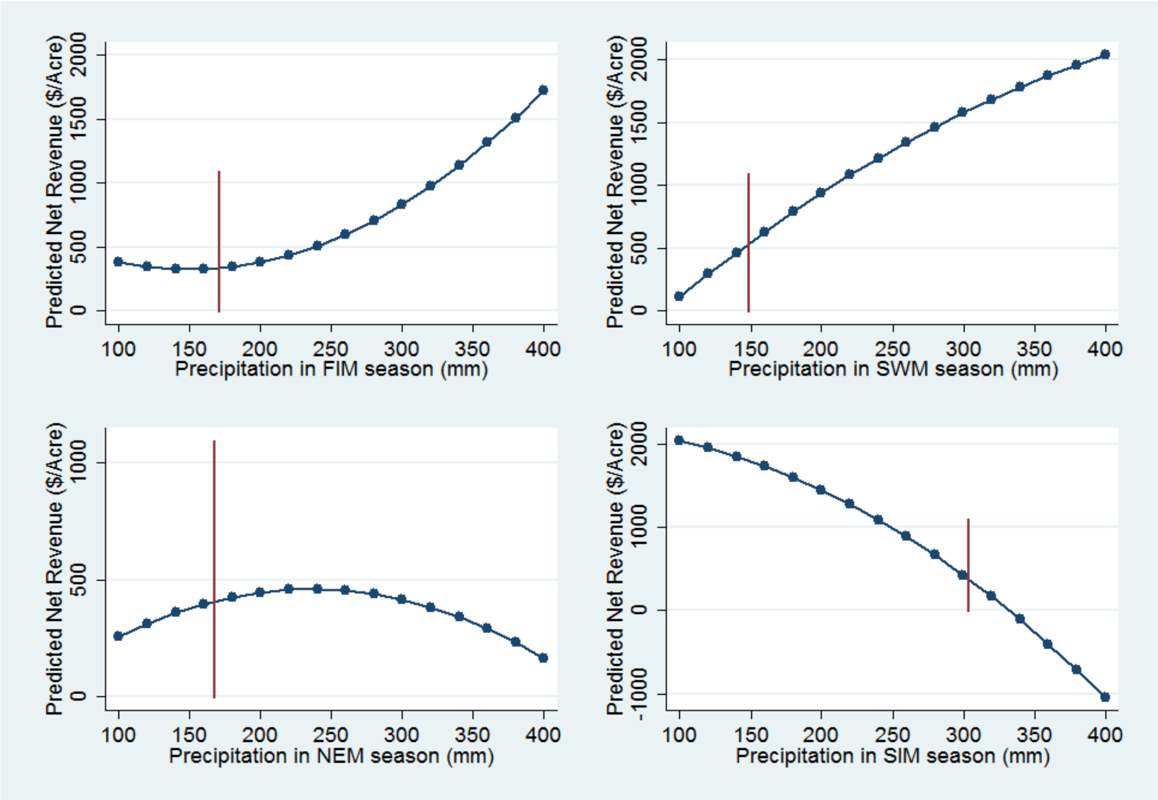
Notes: Standard errors in parentheses. (***), (**) and (*) significant at 1%, 5% and 10%, respectively. Instruments for temperature include altitude and slope.

Table 9: The Ricardian model showing the relationship between climate variables and net revenue

Marginal Impact of Precipitation			
FIM precipitation	-1.998	-4.475***	1.216
	(1.537)	(1.692)	(2.681)
SWM precipitation	-2.862**	-3.378	-2.491
	(1.351)	(2.066)	(2.110)
SIM precipitation	3.553	5.870*	-1.058
	(2.538)	(3.030)	(4.309)
NEM precipitation	0.097	-0.159	1.690*
	(0.472)	(0.484)	(0.953)

Notes: Standard errors in parentheses. Note: (***), (**) and (*) significant at 1%, 5% and 10%, respectively. Instruments for temperature include altitude and slope.

Figure 9: Predicted net revenue (NR) per acre using the Parsimonious Model



ESTIMATING THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE

In this section, the impact of climate change on agriculture is further evaluated using climate change projections for the country. Future changes in precipitation and temperature for each district are estimated using 12 coupled ocean-atmosphere general circulation models (GCMs), using data from the Coupled Model Intercomparison Project (CMIP5) website[15] (Taylor, Stouffer and Meehl, 2012). Details of the three GCMs used in this study and their associated institutions are provided in Table 10. which provided precipitation and surface temperature data used to estimate average changes in each district, under an assumed RCP8.5 scenarios[16]. Simulated daily surface precipitation and mean temperatures from each model are averaged to produce estimates of monthly mean climatological changes (absolute temperature changes and relative percentage precipitation changes) for the periods 2031-2060, 2051-2080 and 2071-2100 (relative to the historical 1971-2000 period) under an assumed Representative Concentration Pathway RCP8.5 (van Vuuren et al., 2011). Note that the RCP8.5 assumes a high emission scenario on the high end of plausible Business as Usual (no mitigation) scenarios. The temperature change by 2100 is assumed to be between 1.5 - 4.5Co (IPCC) above pre-industrial level, which is 0.5 - 3.5C o above 2010 temperatures.

The WUX package[17], implemented using the statistical open source package R, is used to both calculate the average changes and spatially aggregate the district-level data, based on the extent of each district in each country, as defined by shapefiles of global administrative areas downloaded from www.gadm.org/country. The fractional area of each district falling within each GCM grid cell is used to weight the calculation of the mean for a particular district.

Table 10:Three coupled atmosphere-ocean models from the CMPIP5 archive

Modeling Center (or Group)	Institute ID	Model Name
College of Global Change and Earth System Science, Beijing Normal University	GCESS	BNU-ESM
Canadian Centre for Climate Modeling and Analysis	CCCMA	CanESM2
Centro Euro-Mediterraneo per I Cambiamenti Climatici	CMCC	CMCC-CESM

Table 11 shows the different climate projections by model for each season. The projections for temperature across the three models are consistent in terms of sign. The gradual increase in climate projections from the period of 2031-60 to 2071-2100 is also visible. The highest numbers have been estimated by the CCCMA modelling centre and its predictions are consistent across the FIM, SWM and SIM seasons. The projections on precipitation are presented in Table 12, while the results in Table 13 are in a percentage form. For the seasons of FIM and NEM, there is a negative sign and therefore the impact of precipitation on NR is negative.

15 CMIP5 Coupled Model Intercomparison Project, see http://cmip-pcmdi.llnl.gov/cmip5/data_portal.html

16 The authors wish to acknowledge the World Climate Research Programme's Working Group on Coupled Modelling, which is responsible for CMIP. Thanks are due to the climate modeling groups for producing and making available their model output. For CMIP the U.S. Department of Energy's Program for Climate Model Diagnosis and Intercomparison provides coordinating support and led development of software infrastructure in partnership with the Global Organization for Earth System Science Portals.

17 https://cran.r-project.org/web/packages/wux/wux.pdf

Table 11: Projected change in temperature (°C)

	Climate Projection	2031-60	2051-80	2071-2100
FIM Temperature	BNU-ESM	1.40	2.19	2.89
	CanESM2	1.94	2.79	3.67
	CMCC-CESM	1.63	2.75	3.88
SWM Temperature	BNU-ESM	1.48	2.35	3.03
	CanESM2	1.99	2.84	3.87
	CMCC-CESM	1.45	2.69	3.88
SIM Temperature	BNU-ESM	1.41	2.01	2.78
	CanESM2	1.83	2.73	3.72
	CMCC-CESM	1.24	2.20	2.99
NEM Temperature	BNU-ESM	1.39	2.04	2.64
	CanESM2	1.86	2.75	3.63
	CMCC-CESM	1.41	2.35	3.37

Table 12: Projected change in precipitation

	Climate Projection	2031-60	2051-80	2071-2100
FIM Precipitation change	BNU-ESM	0.9	-22.2	-18.3
	CanESM2	-26.4	-39.3	-46.2
	CMCC-CESM	-9.6	-20.4	-28.2
SWM Precipitation change	BNU-ESM	28.8	21.3	43.5
	CanESM2	48.9	81.3	92.7
	CMCC-CESM	28.8	32.1	33.9
SIM Precipitation change	BNU-ESM	62.4	112.2	135.3
	CanESM2	5.7	33.6	58.5
	CMCC-CESM	30.6	54.6	86.4
NEM Precipitation change	BNU-ESM	-6.6	-30	-5.7
	CanESM2	-25.2	-45.9	-52.5
	CMCC-CESM	18	34.2	37.2

Table 13: Projected percentage change in precipitation

	Climate Projection	2031-60	2051-80	2071-2100
FIM % Precipitation	BNU-ESM	6.71	-39.11	-33.06
	CanESM2	-21.15	-30.52	-36.00
	CMCC-CESM	-18.57	-31.90	-46.50
SWM % Precipitation	BNU-ESM	15.26	11.22	22.81
	CanESM2	37.13	66.14	74.71
	CMCC-CESM	24.60	24.18	23.63
SIM % Precipitation	BNU-ESM	21.10	38.85	47.49
	CanESM2	11.63	27.36	40.27
	CMCC-CESM	22.17	38.76	61.34
NEM % Precipitation	BNU-ESM	-14.76	-38.13	-25.48
	CanESM2	-16.58	-23.65	-34.40
	CMCC-CESM	53.24	88.58	87.92

Using the results from our model combined with the climate projections, the impact of climate change on crop farmers in Sri Lanka is estimated. The results are presented in the Tables 14, 15 and 16).[18] Starting with the 2031-2060 projections, the full sample result shows that the impact of climate change on NR per acre is negative with the highest impact estimated from the CCCMA model, at US$166.07 per acre reduction per year. BNU-ESM shows a negative impact of about US$119.17 per acre reduction per year. The impact on non-irrigated farmers is slightly smaller, but with higher standard error. The impact is consistently negative using the full sample for all the models and projections. The differences in impact are based on the different projections on temperature and precipitation changes; for precipitation it is largely due to which season the climate change occurs. On average, the impact of precipitation forecasts is positive for irrigated farmers and negative for non-irrigated farmers, but the temperature effect outweighs any gain from precipitation to irrigated farmers. The impact is incremental across the projection years. CCCMA models (highest negative precipitation projection for the FIM season) predict a strong negative impact of precipitation in 2030 and 2050 for non-irrigated farmers.

Table 14: Impact of climate change on net revenue, 2031-2060

	BNU-ESM	CMCC-CESM	CMCCA-CESM2	BNU-ESM (non-irrigated farm)	CMCC-CESM (non-irrigated farm)	CCCMA-CANESM2 (non-irrigated farm)	BNU-ESM (irrigated farm)	CMCC-CESM (irrigated farm)	CCCMA-CANESM2 (irrigated farm)
Temperature change	-123.90***	-123.12***	-163.83***	-74.80	-74.33	-98.91	-140.49***	-139.61***	-185.77***
	(43.20)	(42.93)	(57.12)	(75.06)	(74.59)	(99.25)	(52.18)	(51.86)	(69.00)
Precipitation change	4.72	1.65	-2.24	-3.36	-2.00	-7.00*	13.29**	6.63**	2.65
	(4.28)	(1.99)	(1.82)	(7.30)	(3.25)	(3.64)	(6.13)	(2.88)	(2.13)
Climate change	-119.17***	-121.46***	-166.07***	-78.17	-76.33	-105.91	-127.20***	-132.98***	-183.12***
	(40.27)	(41.91)	(57.54)	(70.34)	(73.02)	(100.43)	(47.36)	(49.85)	(69.08)
Observations	257	257	257	109	109	109	148	148	148

Notes: Standard errors in parentheses. Note: (***), (**) and (*) significant at 1%, 5% and 10%, respectively.

18 The standard error calculations are based on the delta method with linear combination of the parameters.

Table 15: Impact of climate change on net revenue, 2051-2080

	BNU-ESM	CMCC-CESM	CCCMA-CANESM2	BNU-ESM (irrigated farm)	CMCC-CESM (irrigated farm)	CCCMA-CANESM2 (irrigated farm)	BNU-ESM (irrigated farm)	CMCC-CESM (irrigated farm)	CCCMA-CANESM2 (irrigated farm)
Temperature change	-184.42***	-214.79***	-238.78***	-111.35	-129.68	-144.17	-209.13***	-243.56***	-270.77***
	(64.30)	(74.89)	(83.25)	(111.73)	(130.13)	(144.67)	(77.68)	(90.47)	(100.58)
Precipitation change	13.21	5.12	-1.06	-4.16	-1.34	-11.71**	32.34**	14.45**	9.89**
	(10.12)	(4.29)	(3.44)	(16.97)	(7.14)	(5.95)	(14.54)	(6.28)	(4.44)
Climate change	-171.21***	-209.67***	-239.85***	-115.51	-131.02	-155.87	-176.79***	-229.11***	-260.88***
	-171.21***	-209.67***	-239.85***	-115.51	-131.02	-155.87	-176.79***	-229.11***	-260.88***
Observations	257	257	257	109	109	109	148	148	148

Notes: Standard errors in parentheses. Note: (***), (**) and (*) significant at 1%, 5% and 10%, respectively.

Table 16: Impact of climate change on net revenue, 2071-2100

	BNU ESM	CMCC CESM	CCCMA-CANESM2	BNU- ESM (irrigated farm)	CMCC-CESM (irrigated farm)	CCCMA-CANESM2 (irrigated farm)	BNU -ESM (irrigated farm)	CMCC-CESM (irrigated farm)	CCCMA-CANESM2 (irrigated farm)
Temperature change	-243.79***	-303.37***	-319.86***	-147.19	-183.16	-193.12	-276.44***	-344.01***	-362.71***
	(85.00)	(105.77)	(111.52)	(147.70)	(183.79)	(193.79)	(102.68)	(127.78)	(134.73)
Precipitation change	13.86	9.42	1.39	-5.15	-1.36	-13.31	35.13**	24.06**	16.85**
	(10.96)	(7.25)	(5.14)	(18.24)	(12.09)	(8.42)	(15.83)	(10.58)	(7.03)
Climate change	-229.93***	-293.95***	-318.47***	-152.34	-184.52	-206.43	-241.32***	-319.95***	-345.86***
	(77.49)	(101.03)	(109.29)	(135.49)	(175.92)	(190.87)	(90.18)	(119.51)	(130.15)
Observations	257	257	257	109	109	109	148	148	148

Notes: Standard errors in parentheses. Note: (***), (**) and (*) significant at 1%, 5% and 10%, respectively.

Finally, the analysis focuses on the impact of climate change by district. Using the model described above, the impact of changes in temperature and precipitation is estimated based on the climate projections model BNU-ESM and farm area by district (Table 17). Impacts are calculated based on agricultural planted area and can be interpreted as the potential loss in agricultural revenue by 2030.

Table 17: Total impact of climate change in terms of lost net revenue by total land extent and districts in Sri Lanka (10, 000 LKR, or US$68.61)

District	Extent in Acres	BNU-ESM*
Colombo	70 102	-835.41
Gampaha	19 4094	-2 313.02
Kalutara	22 4869	-2 679.76
Kandy	23 3803	-2 786.23
Matale	16 9747	-2 022.87
Nuwaraeliya	21 4331	-2 554.18
Galle	21 8095	-2 599.04
Matara	20 0617	-2 390.75
Hambantota	22 1490	-2 639.50
Jaffna	41 836	-498.56
Kilinochchi	39 351	-468.95
Mannar	22 021	-262.42
Vavuniya	34 168	-407.18
Mullativu	40 224	-479.35
Batticaloa	85 159	-1 014.84
Ampara	18 0671	-2 153.06
Trincomalee	55 487	-6 61.24
Kurunegala	67 1802	-8 005.86
Puttalam	22 4883	-2 679.93
Anuradhapura	37 5112	-4 470.21
Polonnaruwa	17 5802	-2 095.03
Badulla	26 3606	-3 141.39
Moneragala	23 8091	-2 837.33
Ratnapura	34 9095	-4 160.17
Kegalle	25 2548	-3 009.61
Sri Lanka	47 97004	-5 7165.90

Source: Extent data from Sri Lanka Agricultural statistics (2000).

Note: *The analysis uses the College of Global Change and Earth System Science, Beijing Normal University (BNU-ESM) results from Table 13.

CLIMATE CHANGE AND POVERTY

Climate change can impact households through different channels. One major channel involves changes in the production function, and climate change can also affect price and consumption. In the majority of the least developed countries, where households largely rely on agriculture, climate change can potentially affect their productive assets and activities, making them more vulnerable. Any external shock could potentially increase their level of poverty.

While the model does not explicitly analyse changes in price and consumption, the study models the productive activities of the households, which are presumably a major part of their income, and assumes that households consume a large proportion of what they produce. In the following section, this assumption is used to estimate the impact of climate change on poverty in the country.

The 2002 Household Income and Expenditure Survey (HIES) shows that 22.7 per cent of the population of Sri Lanka is poor. The 2012/13 HIES survey, however, shows a 16 per cent absolute reduction, with the new poverty rate at 6.7 per cent. This progress in poverty reduction is, however, at risk from climate change, with agriculture still contributing a large proportion of the 5.5 per cent average growth experienced between 2002 and 2013. For this growth rate to continue and the poverty rate not to fall back to the 2002 level, strategic climate change adaptation measures will be needed. [19]

According to Sri Lanka's Household Income and Expenditure Survey (2012/2013), the official poverty line (OPL) was estimated at LKR3,624 per person per month for the year. Based on the exchange rate used in this analysis, this is a monthly value of about US$27 per person per month (or less than US$1/day). Using an average household of about four people, the OPL per household can be estimated as approximately LKR14,496 per month (US$108).[20] Table 18 contains information on household income by decile showing that the poor in the country are in decile Group 1 given the current poverty rate of 6.7 per cent - with income less than LKR10,836 (US$73) per month. This will be uses for our impact analysis.

Using the impact of climate change estimated in the previous section, at an average household planted area of about 7 acres per year, the household income from crop farming that will be lost per month can be estimated as 119.17*7/12 = US$40.8 or about LKR6,026.98. If this is used to estimate the impact on poverty, the poverty level based on loss of income of this amount will place 26.4 per cent of the households in the top of decile 1 in chronic poverty (10 per cent of the population) and another 26.4 per cent of those in deciles two, three and four also pushed into poverty – assuming that 26.4 per cent of the households in each of these deciles are farmers.[21] This will add a minimum of 7.92 per cent of households to the poverty rate in the country at a minimum.

19 For further details on Sri Lanka's economic growth, see www.statistics.gov.lk/national_accounts/Press%20Release/2014ANNUAL.pdf and to find out more about the HIES methodology, see www.statistics.gov.lk/HIES/HIES2012_13FinalReport.pdf

20 Sri Lanka uses what is referred to as the Official Poverty Line (OPL) The OPL was established by the Department of Census and Statistics (DSC) to measure poverty. The value of OPL is based on HIES data. OPL, which was established in 2004, was LKR1,423 (real total expenditure per person per month) and is updated for the inflation of prices through the Colombo Consumer Price Index (CCPI) calculated monthly by the DCS. According to the average price index values adjusted for HIES survey months, DCS publishes head count index for each survey periods.

21 Typically, a larger percentage of households in the lower deciles are engaged in agriculture which makes this estimate a lower bound. Sri Lanka Labour Force Survey 2014 shows that 26.4 per cent of households are employed in agriculture. Sri Lanka Labour Force Statistics Quarterly Bulletin (2014).

The analysis looks into the impact of climate change by farm size. Poor farmers typically have very small land area to plant with. This can also give us an indication of the impact of climate change on poverty. Given that farms with smaller farm areas have higher NRs per acre, as shown in the earlier figures, the analysis investigates how much of that revenue will be reduced by climate change. The results show that farmers with less than one acre of land will be affected, but not as much as the average farmer in quantity, which is about a US$94.37 reduction in NR per acre. However, medium-scale farms of about 20 acres of land will be affected more, with a loss of about US$148.75 (more than US$50 per acre than small farmers). [22]

Table 18: Mean and median monthly household income by national household income decile (2012/2013)

Decile group	Range (LKR)	Mean (LKR)	Median (LKR)
All groups		45 878	30 814
1	Less than 10,836	6 700	7 029
2	10,836 - 16,531	13 790	13 850
3	16,532 - 21,286	18 962	18 944
4	21,287 - 25,903	23 589	23 563
5	25,904 - 30,814	28 291	28 236
6	30,815 - 36,758	33 597	33 500
7	36,759 - 45,000	40 582	40 543
8	45,001 - 57,495	50 640	50 425
9	57,496 - 83,815	68 362	67 173
10	More than 83,815	174 376	121 429

22 Although the survey collected information on income oh household, the majority of the households did not report income leve,l so those income levels to estimate poverty impact could not be used.

Photo Credit: UNDP

HOW ARE FARMERS ADAPTING TO THE IMPACT OF CLIMATE CHANGE?

In the survey undertaken for this study, farmers were asked about their perception of the long-term shift in temperature and rainfall on their land. A follow-up question was also asked on what kind of adaptations they have made for temperature shifts and rainfall. Farmers were asked to indicate whether they: (i) changed planting dates; (ii) changed crop types; (iii) used different crop varieties (hybrid or genetically modified); and (iv) made irrigation investments (such as sprinklers or groundwater pumps).

Fifty-two per cent of the respondents said that they made irrigation investments as a way of adapting to climate change, while 32.15 per cent either changed crop dates or crop types, or used different crop varieties. However, 16.51 per cent of the sample did not adapt to climate change. The question, then, is what factors determine the choice of adaptation by the farmers?

To model adaptation, the Multinomial Logit model is used providing three adaptation options – irrigation adaptation; crop type adaptation (aggregating all the crop adaptation options); and finally, no adaptation. It is chosen to aggregate all crop type adaptation, rather than make the options mutually exclusive, because the number of farmers that selected each adaptation option was in some cases too small to be able to predict the likelihoods with confidence. A variable on soil characteristics has not been included, given the similarities of soils across the country within the crop alternatives.

Table 19 presents the marginal effects for the variables included in the regression and their impact on choosing each of the alternatives. As a first step, the report looks at the climate variables. The result shows that higher rainfall during the NEM season will reduce the likelihood of using irrigation as an adaptation option but increase the likelihood of choosing cropping as an adaptation option relative to no adaptation. There is little evidence that temperature influences the decision to adapt irrigation or cropping. A 1°C warming in the SIM period increases the likelihood of adapting to climate change (reducing the probability of choosing the status quo by 48 per cent). The impact of higher temperature in the SWM period seems counterintuitive unless comparing the impact with the base model. The base model, without controlling for extension activities and access to credit, shows that the higher temperature reduces the status quo. However, with the farmers having access to extension services, the likelihood of not engaging in activities individually actually increases. This is noteworthy because the model shows that an increase in the probability of not consciously adapting (status quo) can be influenced by other entities doing the adaptation for them.

While efforts were made to help farmers differentiate between climate change adaptation and adapting to change, the results from this model suggest that farmers are merely discussing how they have adapted to change and not climate change specifically.

The decision to adapt could be explained, based on the following factors:

Farm experience: The results indicate that farmers with more experience are more likely to adapt. It is likely that farmers with many years of experience will have a better understanding of the changes in temperature and rainfall over time, and how it has affected their profitability over time. However, the result also shows that factors such as the provision of extension services and education, and the presence of cooperatives also influence the decision to adapt. Policymakers and development agencies working on climate change adaptation should pay attention to ways in which education and extension can be improved. The literature also suggests that early warning systems and advisory services delivered via trusted extension services increase the likelihood that farmers will face fewer constraints to adapt to climate change.

Cooperative societies and extension services: The role of cooperative societies and extension services in adaptation decisions is studied. About 35 per cent of the farmers sampled were members of a cooperative society – 35 per cent input cooperatives and 30 per cent output cooperatives (Table 19). Cooperatives are expected to be a good way to influence adaptation decisions given that they have a greater influence on input and output procurements.

Table 19: Distribution of farmers by cooperative

	Input cooperative		
Output cooperative	0	1	Total
0	57.94	11.84	69.78
1	6.85	23.36	30.22
Total	64.8	35.2	100

Because of potential endogeneity issues, neither cooperatives that the farmers can sign up for have been included, nor cooperatives that are provided at a fee. The model instead controlled for extension services.

The model controls for extension services such as national government extension services, local government extension services, private extension services, NGOs, input company and marketing company. The results show that out of all the extension services, national government extension services significantly influence the decision to adapt to climate change.

Other variables: Distance to market does not have a significant impact on crop adaptation and irrigation except by reducing the likelihood of choosing the status quo. One explanation is that farmers in remote areas may pay more attention to their yields and have more extension service visits than farmers closer to the market. Distance to market can also serve as a proxy for rural farming – with different methods of predicting climate in the rural areas, farmers are typically more in tune with their environment and traditional methods of predicting climate. However, this is not translating into a significant increase in adaptation options, such as changing cropping patterns or the use of improved seed. Further investigation is needed. The model also looks at the role of age, household size, and education on adaptation decisions. There is no evidence that they influence the likelihood of adaptation.

Table 20: Climate change adaptation model, Sri Lanka

Variable	Irrigation	Crop Adaptation	Status Quo	Irrigation	Crop Adaptation	Status Quo	Irrigation	Crop Adaptation	Status Quo
Farm experience (years)	-0.008***	-0.001	-0.006***	-0.009***	0.009***	-0.000	-0.009***	0.009***	-0.000
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
Perceived temperature shift	0.043	0.421	-0.247	0.058	0.105	-0.163***	0.067	0.101	-0.168***
	(0.074)	(20.733)	(6.701)	(0.074)	(0.074)	(0.016)	(0.075)	(0.075)	(0.018)
FIM temperature	-0.120	-0.023	-0.188	-0.142	0.144	-0.001	-0.098	0.142	-0.045
	(0.155)	(0.089)	(0.162)	(0.163)	(0.150)	(0.113)	(0.164)	(0.152)	(0.109)
SWM temperature	-0.140	0.134	-0.504***	-0.162	-0.066	0.228**	-0.133	-0.073	0.206**
	(0.144)	(0.085)	(0.146)	(0.146)	(0.132)	(0.090)	(0.150)	(0.138)	(0.086)
SIM temperature	0.498	-0.433	1.351***	0.566	0.001	-0.567**	0.485	0.004	-0.489**
	(0.445)	(0.272)	(0.472)	(0.448)	(0.401)	(0.251)	(0.457)	(0.412)	(0.244)
NEM temperature	-0.211	0.300*	-0.621**	-0.232	-0.076	0.308**	-0.223	-0.073	0.295**
	(0.286)	(0.178)	(0.292)	(0.288)	(0.262)	(0.135)	(0.292)	(0.267)	(0.134)
FIM precipitation	-0.000	-0.002*	0.003	-0.001	0.003	-0.002**	-0.000	0.003	-0.002**
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
SWM precipitation	-0.001	-0.001	0.000	-0.001	0.001	-0.000	-0.001	0.001	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
SIM precipitation	0.001	0.002	-0.004	0.001	-0.003	0.002	0.000	-0.002	0.002
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.001)	(0.003)	(0.003)	(0.001)
NEM precipitation	-0.002**	0.000	-0.004***	-0.002**	0.003***	-0.000	-0.002**	0.003***	-0.001
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Farm output sell time (hours)				0.031	0.004	-0.035**	0.028	0.004	-0.032*
				(0.019)	(0.017)	(0.018)	(0.019)	(0.017)	(0.018)
Receiving extension from national gov				0.018	0.082	-0.100***	0.018	0.088*	-0.105***
				(0.055)	(0.051)	(0.035)	(0.056)	(0.051)	(0.036)
Receiving extension from local gov				0.045	-0.024	-0.021	0.057	-0.026	-0.032
				(0.067)	(0.064)	(0.036)	(0.068)	(0.064)	(0.036)
Receiving extension from NGO				-0.080	0.051	0.028	-0.073	0.056	0.016
				(0.078)	(0.073)	(0.050)	(0.078)	(0.073)	(0.051)
Receiving extension from marketing comp				0.012	0.032	-0.045	0.004	0.026	-0.031
				(0.063)	(0.058)	(0.043)	(0.064)	(0.059)	(0.042)
Credit account				-0.053	0.011	0.042	-0.065	0.008	0.057
				(0.077)	(0.071)	(0.048)	(0.078)	(0.072)	(0.050)
Credit account bank				-0.005	0.039	-0.034	0.002	0.041	-0.043
				(0.072)	(0.067)	(0.046)	(0.073)	(0.068)	(0.046)
Age							-0.000	-0.001	0.001
							(0.002)	(0.002)	(0.001)
Household size (members)							0.079	-0.024	-0.055
							(0.067)	(0.064)	(0.035)
Education							-0.005	-0.002	0.007
							(0.008)	(0.007)	(0.005)
Observations	321	321	321	321	321	321	321	321	321

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Finally, the analysis examines the predicted probabilities of a farmer choosing to irrigate, change crops or not adapt at all across ranges of temperature and precipitation. The results (Figures 10 and 11) indicate with what might be expected – no adaptation is associated with lower temperature while the warmer it gets more likely it is that farmers will adapt. It is also evident that as it gets warmer, the probability of adopting irrigation increases. The probability of choosing to adapt by adjusting crops (mix, type, etc.) increases up to a point, but then it drops. It appears that beyond a specific temperature range, crop selection itself is not sufficient. Given a mean annual temperature of 25.4 °C, any more warming beyond this point favours more irrigation investment than crop changed mix. The opposite is observed for precipitation – the more rain there is, the lower the probability of irrigation and the higher the probability of crop adaptation. The mean precipitation is 183 mm, and climate change projection of lower rainfall will support more irrigation investment over crop switch strategies.

Figure 10: Estimated probabilities for farmers to choose the adaptation to climate change option over temperature (annual temperature in °C)

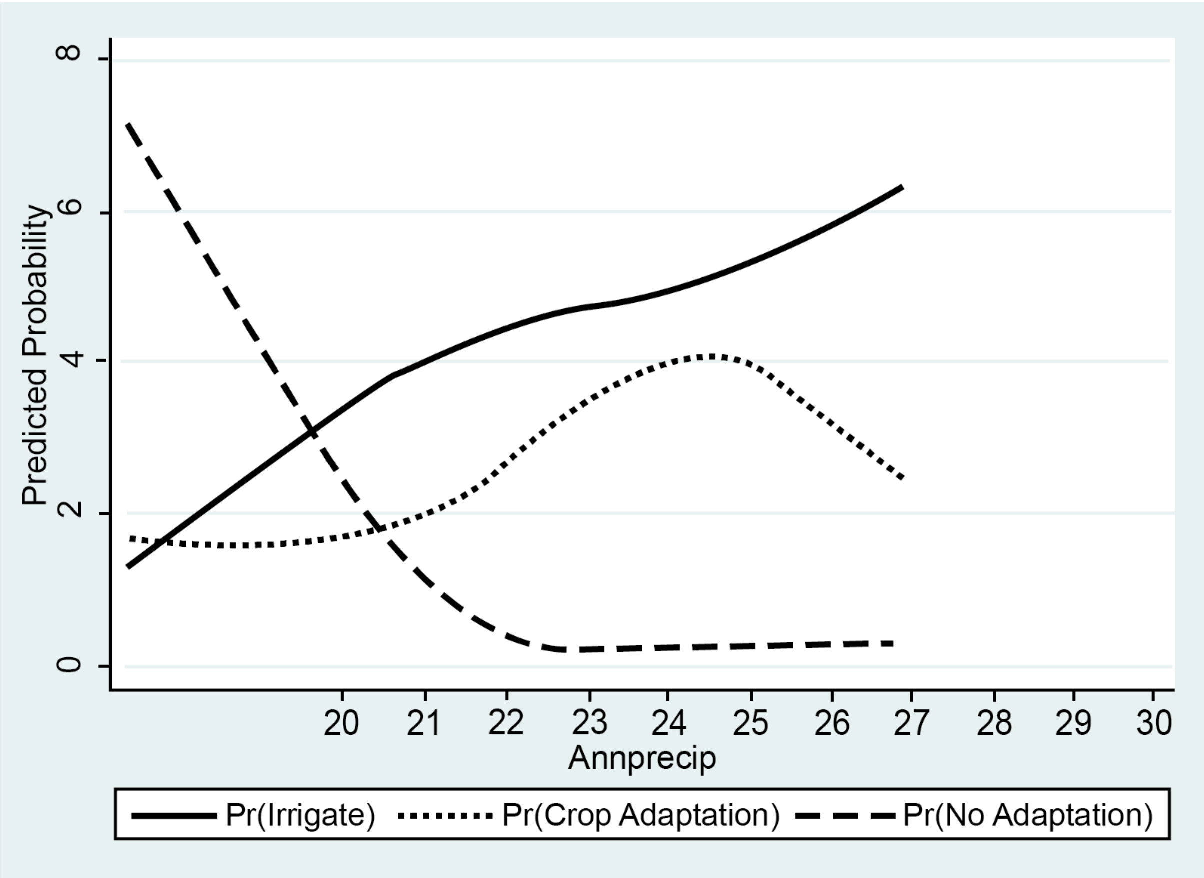
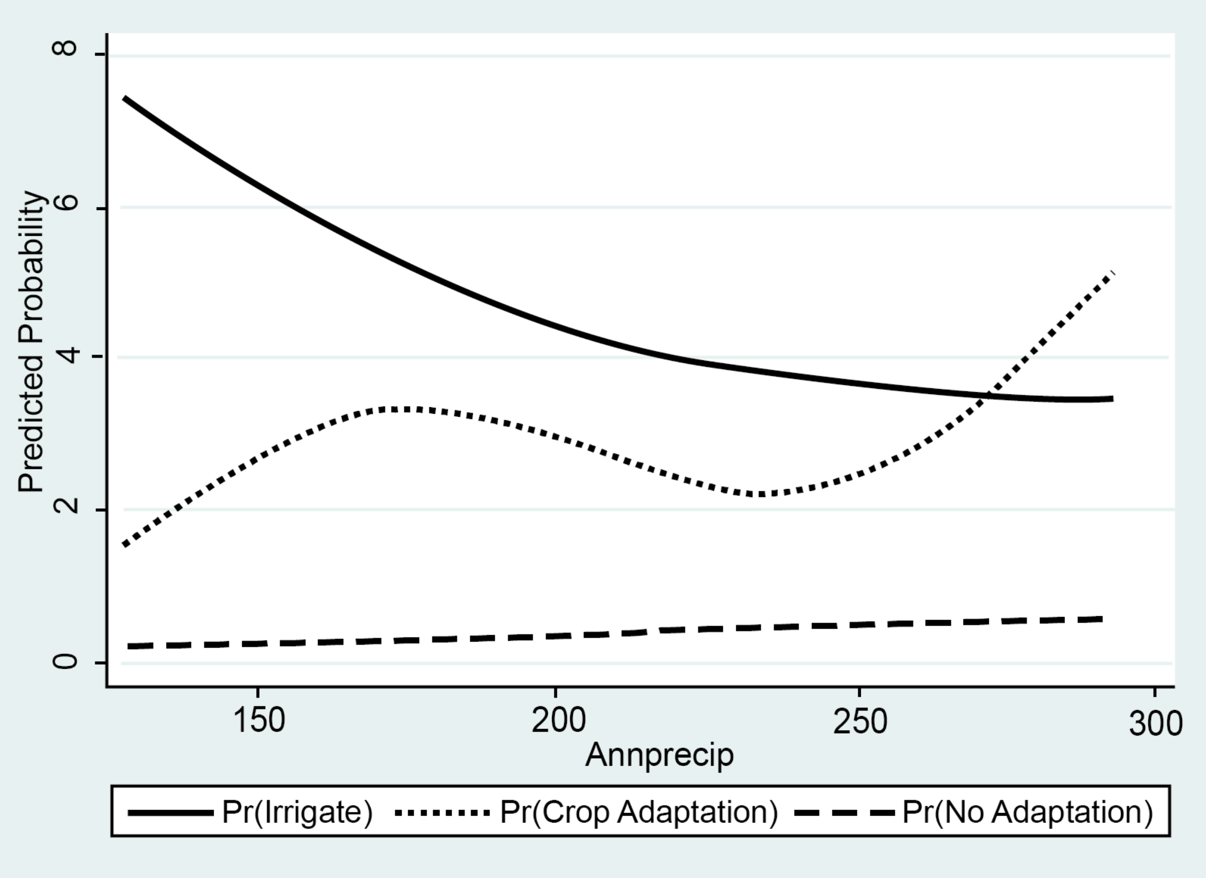


Figure 11: Estimated probabilities for adaptation to climate change option to be chosen over precipitation (Annual precipitation in mm)



MODELLING-REVEALED CLIMATE CHANGE ADAPTATION

Given that changing crop is one of the major adaptation options, the analysis looks into which type of crops the farmers should invest in given different levels of precipitation and temperature. The probability of choosing each crop is assumed to be a function of FIM, SWM, SWM and NEM temperature and precipitation as modelled in the impact study.

The results presented in Table 21 show that higher temperature (FIM, SWM and SIM seasons) and higher precipitation (SWM, SIM, and NEM seasons) increase the likelihood of choosing cereal crops (barley, maize, wheat, etc.), although impact is not significant. Except for paddy, all the other crop choices have at least one significant climate coefficient. Climate coefficients also influence the decision to grow rice, although the evidence is not strong. Rice and cereal are major crops in Sri Lanka and are grown in most areas of the country. In contrast, vegetables, fruits, plantation and other crops are more specialized and are grown only in specific areas based on climate.

Vegetables are sensitive only to precipitation in the NEM season. Precipitation is significantly important in the SIM season for increasing the likelihood of planting fruit and for reducing the likelihood in the SWM season. Higher temperature in the NEM increases the likelihood of choosing fruit. Plantation crops such as tea, cocoa, coconut and cotton are sensitive to temperature in the SWM season. Other crops such as chili are more likely to be grown if temperature increases in the FIM and SWM seasons but less likely with higher temperature during the NEM season. Precipitation in the SWM season is advantageous for other crops.

As shown in Tables 21 and 22, crop choice varieties in Sri Lanka are climate-sensitive. The probability of choosing rice and cereal is at the highest when temperature is about 21°C but continues to fall as it gets warmer. Fruit and plantation crops are highly sensitive to temperature and have the likelihood of not being chosen at all the ranges of temperature – this shows the risk to these crops in the country as climate changes. However, rice, vegetables and cereals are always chosen except for cold temperature ranges below 21°C that threaten cereal and other crops.

In order to understand the effect of changes in temperature and precipitation on crop choice, the marginal effects of a slight temperature increase and precipitation is calculated at the mean climate of the sample. A 1°C increase in temperature will tend to make farmers choose rice, cereal and vegetables more, while plantation, fruit and other crops will be less preferable. Also, if precipitation increases by 1 mm, farmers move away from rice and vegetables and move towards fruit, cereal and plantation crops.

Photo Credit: UNDP

Table 21: Marginal effect from multinomial logit crop selection model for the 2014 season (fruit as base outcome)

Variable	Rice	Cereal	Vegetables	Fruit	Plantation	Others
FIM temperature	0.178	0.023	0.056	-0.204	-0.665	0.612***
	(0.330)	(0.142)	(0.267)	(0.178)	(0.454)	(0.231)
FIM precipitation	-0.003	-0.002	-0.000	0.004	-0.001	0.002
	(0.004)	(0.002)	(0.003)	(0.003)	(0.005)	(0.002)
SWM temperature	-0.689	0.037	0.037	0.435	-0.793**	0.973**
	(0.491)	(0.260)	(0.371)	(0.338)	(0.358)	(0.434)
SWM precipitation	0.005	0.001	-0.001	-0.009**	-0.001	0.006**
	(0.004)	(0.002)	(0.003)	(0.004)	(0.003)	(0.003)
SIM temperature	0.817	0.108	-0.332	-1.049	1.663	-1.208*
	(1.058)	(0.557)	(0.847)	(0.690)	(1.028)	(0.693)
SIM precipitation	-0.011	0.001	-0.004	0.013**	0.007	-0.006
	(0.007)	(0.004)	(0.005)	(0.006)	(0.007)	(0.004)
NEM temperature	-0.105	-0.152	0.299	0.700**	-0.261	-0.481
	(0.529)	(0.376)	(0.442)	(0.317)	(0.307)	(0.305)
NEM precipitation	0.003	0.000	-0.003**	0.000	0.000	0.000
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Price of rice	0.006*	0.003***	-0.009**	0.003**	0.003***	-0.005
	(0.004)	(0.001)	(0.004)	(0.001)	(0.001)	(0.003)
Price of cereal	0.004	-0.001	-0.002	-0.003	-0.001	0.002
	(0.003)	(0.001)	(0.003)	(0.002)	(0.001)	(0.002)
Price of vegetables	-0.014***	-0.005	0.013***	0.002	0.003**	0.001
	(0.005)	(0.003)	(0.004)	(0.001)	(0.001)	(0.002)
Price of fruit	-0.001	0.000	-0.001	-0.000	0.002	0.000
	(0.003)	(0.001)	(0.003)	(0.000)	(0.002)	(0.002)
Price of plantation	-0.001	0.006	-0.001	-0.001	-0.003	0.000
	(0.010)	(0.011)	(0.008)	(0.003)	(0.002)	(0.006)
Price of other crops	-0.002	0.001	-0.001	-0.000	0.005	-0.002
	(0.003)	(0.002)	(0.003)	(0.001)	(0.004)	(0.001)
Farm output sell time (hours)	-0.017	-0.014	0.027	0.012	-0.007	0.000
	(0.023)	(0.014)	(0.017)	(0.013)	(0.019)	(0.011)
Output cooperative	-0.124*	-0.011	0.079	-0.041	0.039	0.058
	(0.074)	(0.040)	(0.064)	(0.036)	(0.029)	(0.039)
Input cooperative	0.152**	-0.004	-0.070	0.010	-0.059*	-0.028
	(0.073)	(0.040)	(0.065)	(0.029)	(0.033)	(0.042)
Receive extension from the national government	-0.023	0.032	-0.104**	0.087**	0.006	0.003
	(0.062)	(0.034)	(0.050)	(0.038)	(0.031)	(0.030)
Receive extension from private company	0.065	0.059*	-0.028	-0.017	0.019	-0.097**
	(0.068)	(0.035)	(0.060)	(0.028)	(0.033)	(0.048)

Table 21: Marginal effect from multinomial logit crop selection model for the 2014 season (fruit as base outcome) (cont.)

Variable	Rice	Cereal	Vegetables	Fruit	Plantation	Others
Receive extension from NGO	-0.211**	0.047	0.058	0.007	0.033	0.066
	(0.092)	(0.041)	(0.076)	(0.035)	(0.051)	(0.053)
Receive extension from input company	0.168**	-0.064	0.084	0.060*	-0.212***	-0.036
	(0.080)	(0.047)	(0.068)	(0.032)	(0.082)	(0.045)
Bank credit account	0.016	-0.021	0.092*	0.010	-0.093***	-0.004
	(0.056)	(0.031)	(0.047)	(0.025)	(0.031)	(0.029)
Flat land	-0.013	0.071	0.094	-0.196	0.003	0.042
	(0.268)	(0.102)	(0.223)	(0.169)	(0.423)	(0.085)
Steep land	0.112	0.130	0.290	-0.412**	-0.233	0.113
	(0.239)	(0.084)	(0.189)	(0.170)	(0.395)	(0.081)
Clay soil	-0.086	-0.012	-0.149	0.349*	-0.005	-0.097*
	(0.162)	(0.061)	(0.100)	(0.194)	(0.091)	**(0.057)**
Observations	315	315	315	315	315	**315**

Notes: Standard errors in parentheses. Note: (***), (**) and (*) significant at 1%, 5% and 10%, respectively.

Table 22: Marginal effect of climate change on crop choice in Sri Lanka

Variable	Rice	Cereal	Vegetables	Fruit	Plantation	Others
Cumulative temperature	0.151	0.089	0.092	-0.326**	-0.004	-0.002
	(0.125)	(0.086)	(0.077)	(0.142)	(0.055)	(0.059)
Cumulative precipitation	-0.018**	0.006	-0.019*	0.016**	0.016	-0.001
	(0.009)	(0.007)	(0.010)	(0.007)	(0.016)	(0.003)
Observations	315	315	315	315	315	315

Notes: Standard errors in parentheses. Note: (***), (**) and (*) significant at 1%, 5% and 10%, respectively.

Finally, using the same climate projections described earlier in the impact section, it is possible to predict what farmers will choose by 2030, 2050 and 2070. In 2030, the changes in probability are not consistent across the models. For BNU for instance, the predictions indicate that farmers will prefer rice, cereal, and vegetables but not fruit and other crops. The CMCC-CESM model, in contract, predicted that the probability of choosing rice will decrease by 0.135 and the crops of cereal, vegetables, fruit and plantation will have an increase in likelihood of being chosen by 2030, with the exception of the category classified by others. The CCCMA model is also similar to the CMCC prediction, but the probability of choosing others is down from 0.374 to 0.207. In two of the three models for each climate projection, the likelihood of choosing rice is going to reduce. According to the 2071-2100 projection, the likelihood of choosing vegetables, fruit and plantation are consistently negative across the models. Warming may be good for cereal – the CMCCA model projected an increase in precipitation across the seasons for 2071-2100.

Photo Credit: UNDP

TABLE 23: Effect of climate change on crop choice in Sri Lanka (change in probability of choosing the crop)

	Rice	Cereal	Vegetables	Fruit	Plantation	Other Crops
2030						
BNU-ESM	0.162	0.071	0.037	-0.059	0.001	-0.211
CMCC-CESM	-0.135	-0.044	-0.122	-0.059	-0.014	0.374
CCCMA-CANESM2	-0.047	0.014	-0.090	-0.073	-0.012	0.207
2050						
BNU-ESM	-0.127	-0.029	-0.120	-0.059	-0.014	0.350
CMCC-CESM	-0.141	-0.052	-0.125	-0.078	-0.014	0.410
CCCMA-CANESM2	0.264	0.138	-0.004	-0.082	-0.007	-0.309
2070						
BNU-ESM	-0.033	0.043	-0.096	-0.082	-0.010	0.179
CMCC-CESM	-0.141	-0.049	-0.125	-0.086	-0.014	0.415
CCCMA-CANESM2	0.343	0.251	-0.014	-0.085	-0.001	-0.493

Figure 12: Estimated probabilities for crops to be chosen over temperature (Annual Temperature in °C)

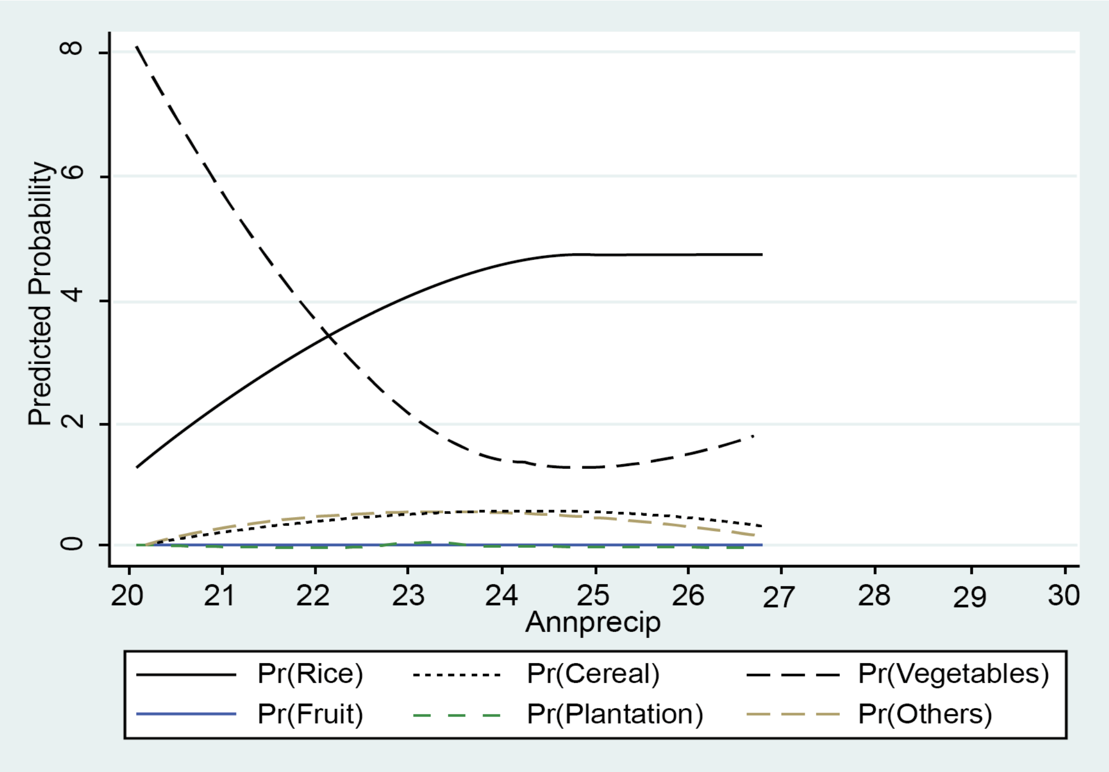
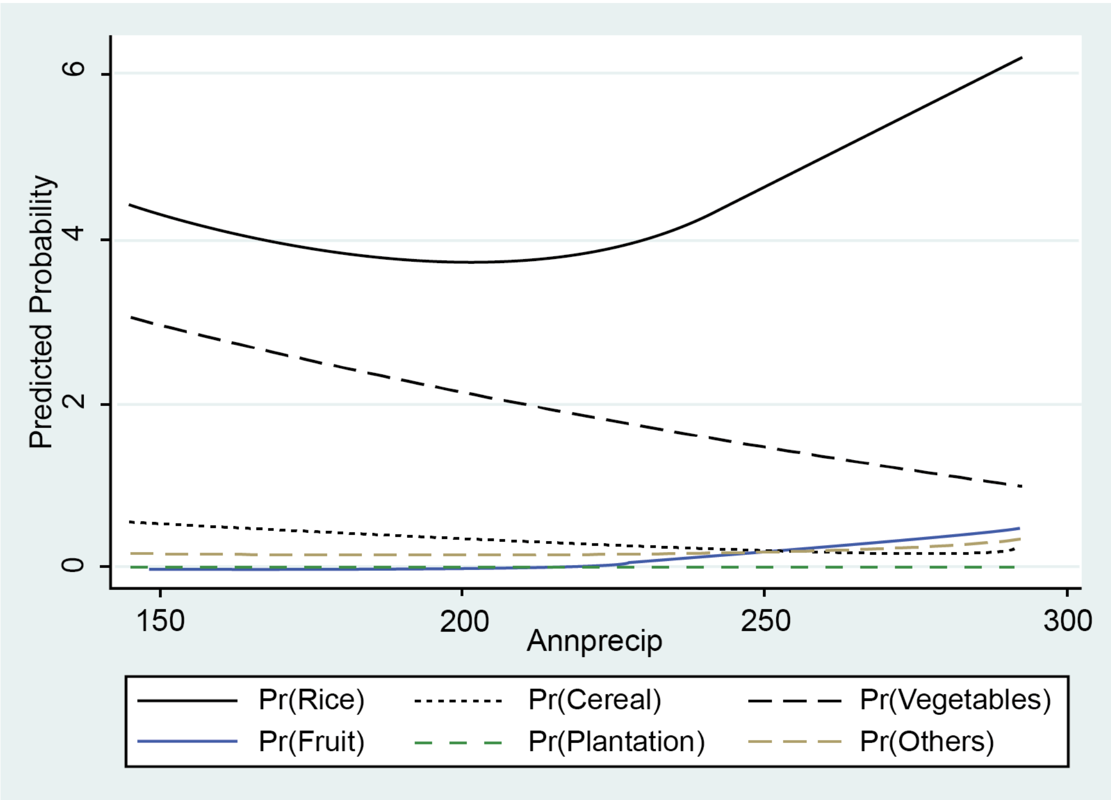


Figure 13: Estimated probabilities for crops to be chosen over precipitation (annual precipitation in mm)



POLICY RECOMMENDATIONS AND CONCLUSION

The report sheds light on the vulnerabilities to climate change of the agriculture sector, one of the major sectors in Sri Lanka, employing over 33 per cent of its population. The results are based on detailed farm level information from 321 households, interviewed across the agro-ecological zones of Sri Lanka. The aim of the Capacity Building Programme on the Economics of Climate Change (ECCA) was to build the capacity of technical offices supporting the Ministry of Agriculture to be able to answer several questions, including: What is the likely impact of climate change on the agriculture sector? What can be learned about adaptation options? What is the level of awareness among farmers of the current changes in climate and what measures have been taken in order to face the challenges ahead?

The factors that contribute to an increase or decrease of farm NRs are analysed as well as their impact based on irrigated or non-irrigated land. Based on the analysis, a series of recommendation become evident. Projections for temperature and precipitation are used to produce monthly mean climatologically changes for the periods of 2031-2060, 2051-2080 and 2071-2100 and, combining it with the data collected from households, estimated the impact of climate change on NR per acre and on household income per month. The adaptation choices that farmers currently undertake in response to a shift in temperature and rainfall are studied, such as irrigation, crop type adaptation or no adaptation, and the factors that drive them. One of the major adaptation options was crop changes, and the analysis looked into which types of crops farmers are likely to invest in, given the diverse level of warming and precipitation. Using this information, the analytical framework is used to predict which crops farmers are likely to select by 2030, 2050 and 2070.

Key conclusions and recommendations that emerge from the analysis include the following:

- *The level of awareness is exceptionally high, with 92 percent of the surveyed households having noticed a long-term shift in temperatures and 95 percent having noticed a shift in rainfall.* This suggests that almost all households are aware that the climate is changing, that these changes are long-lasting, and that the changes go beyond expected variation in weather. Even though 92 per cent of the respondents observed a change in climate, 17 per cent of them are not taking any additional measures in their current practices.

- On the basis of assessments on the marginal impact of climate change on NR, an implication is that assistance in the form of extension services or cooperatives needs to be provided to farmers during periods of increased temperature and precipitation (see below). Results have been summarized in the following table:

Table 24: Relationship between precipitation, temperature and net revenue

Seasons	Temperature	Precipitation
First Inter-monsoon	An increase of 1°C above the mean (26.5°C) would increase net revenue.	A 1 mm increase beyond 200 mm increases net revenue.
Southwest-monsoon	An increase of 1°C above the mean (26°C) would increase net revenue.	A 1 mm increase above the mean (150 mm) increases net revenue.
Second Inter-monsoon	An increase of 1°C above the mean (25°C) would increase net revenue.	A 1 mm increase above the mean (300 mm) decreases net revenue.
Northeast-monsoon	An increase of 1°C above the mean (24°C) would decrease net revenue.	A 1 mm increase above the mean (160 mm) increases net revenue, but any rainfall beyond 250 mm decreases it.

- *The overall impact of climate change on net revenue is negative.* By modelling irrigated versus non-irrigated farms, estimates have indicated a higher impact of temperature for irrigated farms. An increase of average temperature by 1°C would lead to a decrease of US$85.95 or (18 per cent of the total average NR) in NR per acre. Change in precipitation is not beneficial for agricultural productivity. A decrease of 1mm in precipitation during the NEM period would lead to a US$1.69 decrease in NR per acre. These results could also give an indication of the impact of climate change on poverty levels. An average farmer would lose as much as US$94.37 of revenue per acre due to climate change, whereas a medium-scale farm would lose US$148.75 of NR per acre. These results provide clear evidence that policymakers need to provide support for farmers in reducing climate variability induced hazards, particularly in the season of NEM. The Government of Sri Lanka has strategically undertaken policies aimed at providing and ensuring access to water sources. Given the climate change projections and the findings of this study, this support may need to continue.

- *Policy responses such as national government extension services have been shown to be effective in increasing the likelihood of adapting to climate change (as well as the likelihood of choosing cropping as an adaptation method).* Results have shown farm experience to be a major factor determining the choice of adaptation. An implication for policy makers is the necessity for strengthened information, equally distributed across the country, and improved education. Local governments need to work towards engagement in outreach and dissemination programs on measures to combat climate change. A study by Wanigasundera and Fernando (2012) has indicated that despite the widespread demand for training programmes, very few have been organized for extension officers.

- Based on climate projections, the impact of future changes in temperature and precipitation on crop farmers was analysed. Changes in future temperature and precipitation would result in vast losses of farmers' NR, with the highest estimation for irrigated farms in the 2031-2060 projections at US$183.12 per acre reduction per year (CCCMA-CANESM2 model) in comparison with US$166.07 reduction for the baseline scenario. Losses would gradually increase over time. Temperature plays a lead role in reducing farmers' NR and accounts for US$163.83 in the 2031-2060 projections, US$238.78 in the 2051-2081 projections, and US$319.86 reductions in the 2071-2100 projections. Precipitation forecasts are positive for irrigated farms and negative for non-irrigated. Based on these findings, it is clear that there is a need for the introduction of new cultivation techniques and crops resistant to high temperatures.

- When controlling for districts, the largest impact has been estimated in the districts of Kurunegala and Anuradhapura. Based on these estimations, household farmers would experience a loss of approximately LKR6,026.98 (or about US$40.8), which would bring 26.4 per cent of the farmers into chronic poverty. Despite the encouraging progress that has been made in poverty alleviation to below 7 per cent of the population, special attention has been directed towards achieving Sustainable Development Goal (SDG) 1 (World Bank, 2016). These results suggest that if no efforts are undertaken by 2031 to combat climate change and its adverse effects, the poverty rate in Sri Lanka could rise as up to 20 per cent from the current 6.7 per cent.

- The analysis suggests that the most preferred adaptation practice was crop substitution. The types of crops to be invested in based on future variation in temperature and precipitation were studied. As summarized in Table 25, it is very likely that as temperature rises, farmers would focus on annual crops such as rice, cereals and vegetables and would not invest in fruits, plantation and others. As precipitation increases, farmers would invest in fruit, cereal and plantation and would move away from rice, vegetables and other crops. Finally, based on climate projections, by 2070, the likelihood of choosing rice will be decreasing. By 2030, farmers will choose cereal and other crops, whereas by 2050 and 2070, farmers will invest in rice and cereal and less in any other type of crops. While distance to market has shown not to have an impact on crop adaptation and irrigation, further research in the remote areas of Sri Lanka is needed to ensure coherency across adaptation measures.

Table 25: Results on marginal effect of climate change on crop choice

Variable	Rice	Cereal	Vegetables	Fruit	Plantation	Others
Annual Temperature	✓	✓	✓	X	X	X
Annual Precipitation	X	✓	X	✓	✓	X

- Given the importance of the agricultural sector for the economic and social development of Sri Lanka and based on the results from this study, efforts must be undertaken to combat climate change and its adverse effects. Based on these findings, strengthening research capacity is an important step in the development of new techniques and cultivation methods in accordance with changes in climate. The government needs to work towards the introduction of new crop varieties that will be better suited for the weather conditions, predicted from our analysis.

Photo Credit: UNDP

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APPENDIX

Table 1: Estimate of the impact of climate change using the Ricardian model

Variable	Base Model NR	Base Model NR and Control	Temperature Precipitation inter	Temperature Precipitation inter control
FIM Temperature	-9,439.275**	-9,666.262**	-11,696.619**	-11,220.999**
	-3,799.46	-3,847.47	-5,170.62	-5,088.16
FIM Temperature Squared	174.289**	179.148**	207.662**	199.512**
	-70.316	-71.286	-92.576	-91.113
SWM Temperature	2,875.29	3,273.09	5,649.42	5,793.28
	-2,731.96	-2,757.83	-3,537.39	-3,756.64
SWM Temperature Squared	-57.008	-63.675	-102.859	-104.258
	-48.433	-48.887	-64.143	-68.026
SIM Temperature	-5,513.65	-5,721.58	-13,534.61	-14,094.66
	-4,913.38	-4,934.89	-9,236.15	-9,547.17
SIM Temperature Squared	111.039	112.838	276.165	282.715
	-90.801	-91.319	-177.037	-182.915
NEM Temperature	10,410.760***	10,488.657***	17,779.868***	17,814.252***
	-2,786.45	-2,880.71	-5,359.05	-5,826.00
NEM Temperature Squared	-204.955***	-205.829***	-361.442***	-362.229***
	-56.034	-58.129	-108.695	-118.019
FIM Precipitation	-1.874	-2.895	-101.110**	-97.299**
	-5.954	-6.073	-40.973	-41.273
FIM Precipitation Squared	-0.005	-0.003	0.025	0.022
	-0.018	-0.018	-0.022	-0.022
SWM Precipitation	5.091*	5.536**	-34.742*	-36.420*
	-2.746	-2.804	-18.075	-18.536
SWM Precipitation Squared	-0.011**	-0.012**	-0.009	-0.009
	-0.005	-0.006	-0.006	-0.006
SIM Precipitation	-12.988*	-14.786**	84.073**	74.563**
	-7.045	-7.452	-35.713	-35.472
SIM Precipitation Squared	0.022*	0.025*	-0.027	-0.022
	-0.013	-0.013	-0.02	-0.021
NEM Precipitation	5.711	6.066	-16.188	-21.923
	-4.292	-4.461	-17.024	-18.205
NEM Precipitation Squared	-0.009	-0.01	-0.012	-0.011
	-0.011	-0.011	-0.013	-0.013
FIM Temperature*Precip			3.556**	3.443**
			-1.403	-1.41

Table 1: Estimate of the impact of climate change using the Ricardian model (cont.)

Variable	Base Model NR	Base Model NR and Control	Temperature Precipitation inter	Temperature Precipitation inter control
SWM Temperature*Precip			1.732**	1.810**
			-0.774	-0.79
SIM Temperature*Precip			-3.174***	-2.942***
			-1.1	-1.074
NEM Temperature*Precip			0.913	1.117*
			-0.587	-0.638
Flat	-123.874	-103.804	-155.627	-145.504
	-90.552	-97.841	-97.894	-108.506
Steep	136.693	141.163*	268.076***	257.190***
	-82.882	-82.838	-91.972	-93.784
Clay	20.079	14.773	31.299	27.03
	-79.012	-83.677	-82.163	-89.925
Farm area		-5.840*		-5.473
		-3.274		-3.373
Farm area squared		0.075**		0.071**
		-0.035		-0.035
Electricity		49.678		88.04
		-68.861		-80.928
Household size (members)		2.44		-25.826
		-42.434		-44.957
Age		7.885		6.366
		-5.327		-5.348
Age squared		-0.087		-0.074
		-0.054		-0.055
Education		6.135		6.082
		-4.661		-4.675
Gender		-46.202		-42.253
		-121.87		-117.442
Constant	29,431.004***	29,051.885***	33,875.572***	34,243.259***
	-9,164.10	-9,252.04	-9,357.24	-9,182.44
Observations	257	257	257	257
R-squared	0.171	0.196	0.207	0.232

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1


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