POLICY RESEARCH CAPACITY AND INFLUENCE (PRCI)

Impacts of Climate Change on Food Security and Livelihoods

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Contents

1. Background

Sri Lanka is a small tropical island and agriculture is an important part of the socio-economy of Sri Lanka. Primary production in agriculture accounted for 7.5 percent of the country's Gross Domestic Product (GDP) and generated 19.6% of national export earnings equivalent to USD 2,568 million in 2022 (Central Bank of Sri Lanka (CBSL), 2023). Agriculture employs about 2.072 million persons, equivalent to a quarter of the country's labor force (Department of Census and Statistics (DCS), 2019). It is of key importance in rural areas where agriculture engages over half of the workforce. From the crop sub-sector, coconut (0.9 percent) contributes the highest to the GDP followed by rice, vegetables, and spices with 0.8 percent GDP contribution. Contribution from the fruits and tea sectors to GDP is 0.6 percent and 0.5 percent respectively (CBSL, 2023). Despite the declining contribution to GDP and export earnings, agriculture still makes a significant contribution to the economic and social development of Sri Lanka while contributing significantly to rural employment and income generation as well as national and household food and nutrition security.

The country has warm tropical conditions throughout the year and there is no significant annual variation in temperature due to latitude. Seasonal change in precipitation is the main factor determining local climatic variability. However, altitude is a factor that causes significant regional variation in temperature. The average annual temperature usually varies from around $26.5^0 – 28.5^0$ C in lowland areas to around 15^0 C in central highlands. Rainfall is the key climatic parameter that determines all operational aspects of farming. Rainfall distribution could range from 900 mm to 5000 mm with mean annual rainfall around 1850 mm. According to the rainfall variation, Sri Lanka's climate is divided into four rainfall seasons: (i) First inter-monsoon season (March-April); (ii) Southwest monsoon season (May-September); (iii) Second inter-monsoon season (October-November); and (iv) Northeast monsoon season (December-February). According to the mean annual rainfall, Sri Lanka is divided into three major climatic zones Wet zone (> 2500 mm); Intermediate zone (1750-2500 mm); and Dry zone (<1750 mm). These are further subdivided according to three elevation categories (low-country- <300m; mid-country- 300-900m; up-country- >900m) giving rise to 46 agroecological zones. This classification is being used for various decisions in the agriculture sector such as recommendation of crop varieties, use of agronomic and water management practices, etc.

As highlighted in the Climate Change Secretariat (2016), researchers suggest that Sri Lanka's climate is changing gradually. Key climatic parameters that received the attention of researchers were ambient air temperature, precipitation patterns, and observations of extreme climatic events. Evidence suggests that atmospheric temperature is gradually rising almost everywhere in the country. Unlike in the case of rising temperature, no clear pattern or trend in changes in precipitation has been identified and researchers. However, in general, Researchers suggest that changes in distribution and variability are the key factors to the changes in the total amount of rainfall (Ratnayake and Herath 2005; Premalal 2009; Eriyagama et al, 2010). Also, evidence suggests that the intensity and frequency of extreme events like floods, landslides, and droughts have increased in recent times (Imbulana et al. 2006; Ratnayake and Herath 2005). Significant impacts on livelihoods have been observed due to climate change in Sri Lanka and these impacts are expected to intensify in the coming years.

Against this backdrop, the study's overall objective is to understand the impact of climate change on the food security and livelihood of farm households in Sri Lanka. More specifically, this study explores the impacts of climate change on food availability, access to food, stability, and climate resilience aspects and evaluates the impacts on employment and food coping strategies. The organization of the paper is as follows. Section two will give an overview of climate change in Sri Lanka followed by the analytical methodology that includes the conceptual framework, methods, and data in Section three. Section four will discuss the results. The final section concludes the paper with the way forward.

2. Overview of Climate Change in Sri Lanka

A change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties that persists for an extended period, typically decades or longer is considered a climate change (IPCC, 2012). Climate changes can be a result of natural internal processes, external forcings, and or persistent anthropogenic changes in atmospheric composition or land use. However, human activities are considered the primary cause of climate change, owing to the large-scale combustion of fossil fuels such as coal, oil, and gases that produce greenhouse gases while trapping the sun's heat and rising temperatures. Several recent studies have indicated that climate patterns in Sri Lanka are changing based on the observed changes in climate and projected changes in climate.

2.1 Observed changes in climate

Researchers have conducted several studies on historically recorded meteorological data over several years across several locations in the country to identify climatic trends and suggest that Sri Lanka's climate is changing gradually. Ambient air temperature, precipitation patterns, extreme events, and sea level rise have been the key parameters that attracted the focus of past researchers.

Evidence suggests that atmospheric temperature is gradually rising almost everywhere in the country (Chandrapala, 1996; De Costa, 2008; Sathischandra et al., 2014). Analysis of the change seen in the average temperature suggests Sri Lanka experienced warming of around 0.008°C per year during the 20th Century (Carbon Brief, 2018). Annual mean air temperature anomalies have shown significant increasing trends during the recent few decades in Sri Lanka. For example; the rate of increase in temperature was 0.016 Celsius per year from 1961 to 1990 (Chandrapala 1996) however, around 0.025 Celsius per year rate of increase has been reported in recent years (Fernando 1997). Temperature rise has accelerated toward the end of the 20th century (Esham & Garforth, 2013). Further, some studies have reported that mean daytime maximum and mean nighttime minimum ambient temperatures also have changed in the Yala and Maha seasons from 1960-2001 (Basnayake et al. 2002; Zubair et al. 2005).

According to the Climate Risk Country Profile: Sri Lanka (2021), Sri Lanka's complex and spatially variable precipitation regime makes estimation of change over time difficult. Several studies have attempted to assess the trends in precipitation without consensus on the pattern of change (Eriyagama and Smakhtin, 2010). For example; compared to the estimates from 1931-1960, the mean annual precipitation has decreased by 7% during the period 1961-1990 (Jayatillake et al. 2005). It has also been observed that the number of consecutive dry days has increased and the consecutive wet periods have decreased (Ratnayake and Herath 2005; Premalal 2009). Recent studies have indicated changes in agroecological boundaries (Eriyagama et al, 2010). Overall, unlike in the case of rising temperature, no clear pattern or trend in changes in precipitation has been identified and researchers have expressed contradicting views.

Evidence suggests that the variability of climate has increased and the intensity and frequency of extreme climatic events like floods and droughts have been increasing (Esham and Garforth, 2013; Imbulana et al. 2006; Ratnayake and Herath 2005). High rainfall intensities and the locations of landslides show a very strong correlation (Ratnayake and Herath 2005). There is evidence of accelerated sea level rise in the Asian region, but country-specific information on the rise of sea levels around Sri Lanka is limited.

2.2 Projected changes in climate

Some researchers have also made an effort to project likely future changes in key meteorological parameters of Sri Lanka using downscaled global climate models for future periods. As observed with the past data, model projections also confirm that Sri Lanka will become increasingly warmer (Cruz et al, 2007). Accordingly, the projections for 2070-2099 suggest that the temperature could increase by 5.44C and 2.93C under IPCC emission trajectories A1F1 and B1[1], respectively. Ahmed and Supachalasai (2014) predicted that temperature could rise by 3.6 C, 3.3 C, and 2.3 C under A2, A1B, and B1 IPCC emission trajectories respectively by 2080. According to the Climate Risk Country Profile: Sri Lanka (2021) of the World Bank Group and the Asian Development Bank, under the highest emissions pathway (RCP8.5) temperatures are projected to rise by 2.9°C–3.5°C by the 2090s, over the 1986–2005 baseline. Warming of 0.8°C–1.2°C is projected over the same period on the lowest emissions pathway (RCP2.6). Maximum and minimum temperatures are projected to rise faster than the average pushing ambient temperatures over 30°C regularly and considerably increasing the frequency of temperatures over 35°C. Also, the model has projected highly seasonal temperature rises with faster rises in March to July than in August to February.

Like in the case of observed changes, projections also are less certain about the changes in rainfall patterns compared to the temperature. Some of the models project a higher mean annual rainfall (MAR) while others project the opposite (Climate Risk Country Profile: Sri Lanka, 2021; Eriyagama et al 2010).

Climate Risk Country Profile: Sri Lanka (2021) found increases in median annual rainfall under all emissions pathways though with high uncertainty in the estimates. Ahmed and Supachalasai (2014) also predicted increases in precipitation levels by 39.6, 35.5, and 31.3 percent respectively under A2, A1B, and B1 IPCC emission scenarios by 2080. While some studies found an agroecological variation in the precipitation. Basnayake and Vithanage 2004 projected increased rainfall in the wet zone, intermediate zones, and north and south-western dry zones and decreased

[1] A1F1 and B1 are two of the emission scenarios developed by IPCC. The A1F1 scenario represents a fossil fuel intensive emission trajectory. The B1 scenario envisages reductions in material intensity, introduction of clean and resource efficient technologies.

rainfall in other areas of the dry zone by 2050. De Silva (2006) projected an increase in mean annual rainfall by 14% for A2 and 5% for B2 emission scenarios by 2050s compared with 1960-1991 with a reduction of rainfall in the upper Mahaweli watershed in the central highlands by 2025. Also, some studies have projected an increased incidence of extreme weather events including heat waves and intense precipitation events (Cruz et al, 2007; Ahmed et al, 2009)

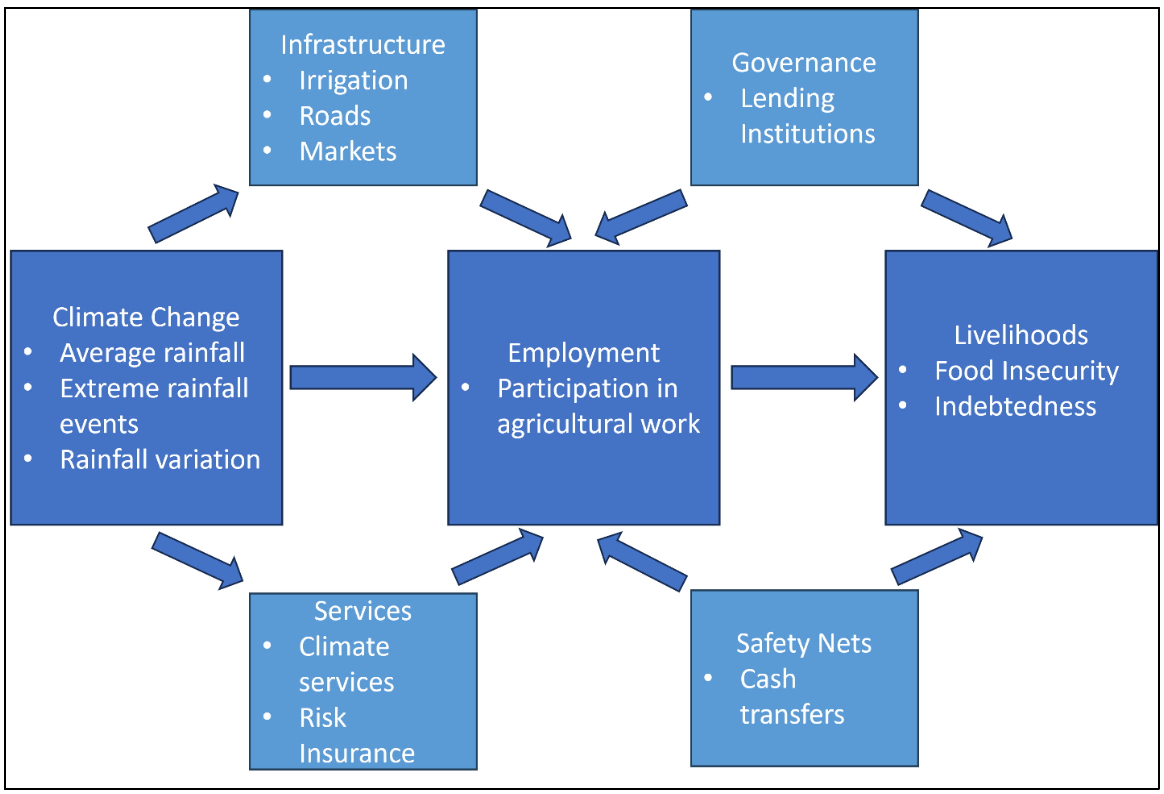
3. Analytical Methodology

3.1 Conceptual Framework

Faced with the challenges posed by climate change, rural households engage in income diversification as a common coping strategy to mitigate the risks associated with agricultural dependency. Several non-agricultural income diversification mechanisms include increased engagement in sectors such as construction, services, and small-scale enterprises (Senevirathna and Dharmadasa, 2020) or rural-urban migration as individuals seek better employment opportunities in urban centers (de Moore et al. 2019). The vulnerability of rural communities to climate change is further exacerbated by socio-economic factors such as poverty, limited access to resources, and inadequate infrastructure. However, effective water management practices and the introduction of drought-tolerant rice and other crops can help mitigate the impact of climate variability on crop yields (ADB, 2016). Government policies and institutional frameworks, as outlined in the National Adaptation Plan for Climate Change Impacts in Sri Lanka, play a pivotal role in providing the necessary support mechanisms, including financial assistance, technical training, and infrastructure development, to bolster rural communities.

Figure 1 illustrates the complex system in which various factors interconnect to influence employment and livelihoods for rural households in Sri Lanka. It particularly focuses on the role of climate change and its effects, demonstrating how climate change impacts agricultural employment, which in turn affects livelihoods. The figure also highlights the potential of various mechanisms to either mitigate or exacerbate these effects. First, we consider the exogenous events of climate change. Rainfall can alter agricultural productivity, affecting the amount of work available in farming, and extreme rainfall events, such as floods or droughts, can disrupt agricultural activities, leading to reduced employment opportunities. In addition, climate change through unpredictable and inconsistent rainfall patterns can make farming less reliable, thus impacting agricultural employment. As a result, employment and participation in agricultural work are often complex for rural workers. Infrastructure, in the form of improved irrigation systems, can mitigate the adverse effects of erratic rainfall, better road networks enhance market access, allowing farmers to sell their produce more efficiently may mitigate the negative effects of climate change, and could encourage agricultural work. Services such as the provision of weather forecasts and climate information can help farmers plan their activities better, and insurance schemes can provide financial protection against crop failures and other climate-related risks. Thus, a set of exogenous factors from the perspective of a household impacts the way employment decisions are made in response to climate change.

Figure 1: Schematic Illustration of the Conceptual Framework of the Study



Source: Authors own illustration based on the literature

The availability and quality of jobs are crucial for the livelihoods of rural populations. As such, following the employment decisions, resulting profits and income influence the critical aspects of food Insecurity as reduced agricultural productivity due to climate change can lead to food shortages and increased food insecurity, or people may opt out of agricultural work to meet their food demands. Governance may play a key role in how employment decisions affect the critical outcomes of food security as lending institutions and access to credit and financial services can help farmers invest in resilient agricultural practices and recover from climate-related losses, and safety nets such as cash transfers provide financial support to vulnerable households to alleviate immediate financial stress. Such services provide relief and long-term livelihood stability, especially during employment instability because of climate change. The figure captures the nature in which climate change's role in influencing agricultural employment affects rural livelihoods in Sri Lanka. It also highlights the importance of various support systems—including infrastructure, governance, services, and safety nets—in mitigating the adverse effects of climate change, thereby ensuring households can employ various adaptation responses to climate change. Understanding these interconnections is crucial for policymakers aiming to support the adaptation responses of households and strengthen the adaptation capacity.

3.2 Methods

This section outlines the methodological approach employed to examine the impact of climate change on employment in agricultural work and food coping strategies in rural Sri Lanka. The methodology is structured around three key analyses: the impacts on food security, the impacts on employment, and the impact on food coping strategies.

3.2.1 Impacts on Food Security

Based on the observed and projected changes, Sri Lanka's climatic conditions have been facing four major types of climate effects, namely: a gradual increase in ambient air temperature; changes in the distribution pattern of rainfall; an increase in the frequency and severity of extreme weather events and sea level rise. While the impact of sea level rise on agricultural livelihood and food security is minimal, the effects of the other three climatic events can generate several physical impacts such as water stress, heat stress, droughts/floods, etc. which can eventually result in negative implications on both the food security and the household livelihoods. The threat of future uncertainties due to global climate change introduces new challenges to agriculture making it even more difficult for achieving the goals of food security and improved livelihoods.

The FAO Draft Declaration of the World Summit on Food Security 2009 highlights that food security exists 'when all people at all times have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life'. This definition covers the four main components – food availability, food access, food stability, and food utilization – that are important to ensure the food and nutrition security of an individual. The impacts of climate change on food security have primarily been felt in food availability because these changes are most likely and the soonest to be felt in food production. However, climate change is expected to affect all four components of food security. Food utilization means using an adequate diet, clean water, sanitation, and health care to reach a state of nutritional well-being where all physiological needs are met. This brings out the importance of non-agricultural inputs in food security and we exclude it from the current analysis.

Hence, the current analysis of the impacts of food security will be based on the tabular and graphical analysis of the observed and projected impacts of climate change on food availability, access to food, stability, and climate resilience.

3.2.2 Impacts on Employment

First, we estimate the impact of climate change on employment in agricultural work. The binary dependent variable, E, represents participation in agricultural work. The probability of participation in agricultural work is modeled as follows:

$$\Pr\,(E_{i,d} = 1) = \phi(\beta X_{i,d} + \alpha Z_d)$$

Where X is a vector of independent variables such as individual characteristics and access to facilities, and Z is a vector of weather variables for individual i in district secretariat (DS), d. ϕ denotes the cumulative distribution function of the standard normal distribution, and β and α represents the vector of coefficients to be estimated. Average 10-year rainfall, average 10-year high rainfall (regions reporting the lowest 10 percent in the rainfall distribution), average 10-year low rainfall (regions reporting the highest 10 percent in the rainfall distribution), standard deviation of 10-year rainfall and current rainfall are the key variables of interest. Individual characteristics such as age, gender, marital status, education status and household characteristics are controlled. Access to facilities such as irrigation facilities at the DS level and household proximity to other government services control for exogenous factors affecting household employment decisions. Note that a limitation of the model is the exclusion of employment history due to the lack of data. However, spatial variation in employment decisions as households are differently exposed to rainfall is the key outcome of interest. The probit model is estimated using maximum likelihood estimation (MLE). The model will provide estimates of the probability that an individual is employed in agricultural work, given the set of independent variables.

3.2.3 Impact on Food Coping Strategies

To analyze the impact of climate change on food coping strategies, we use an instrumental variables probit model to account for the potential endogeneity of employment decisions. The binary dependent variable represents the use a food coping strategy, where the food coping strategies range from relying on less preferred, cheaper food, purchasing food on credit, reduced proportions of meals, reduced number of meals per day, skipped days without eating, or providing food only to children or elders at home. The model is specified as follows:

$$\Pr\left(E_{i,d} = 1\right) = \phi\left(\beta X_{h,d} + \alpha A_{h,d}\right)$$

Where A is the endogenous variable representing if a household in an agricultural household and X is a vector of independent variables, including average rainfall, extreme rainfall events, household characteristics, access to facilities, and other control variables for households h in DS d. To address the endogeneity of the employment variable, A, we use an instrumental variable (IV) approach. The instrument for employment is the availability of location-specific irrigation facilities. The rationale for this instrument is that irrigation facilities directly affect agricultural productivity and employment but are plausibly exogenous to individual decisions to borrow for food. The instrumental variables probit model is estimated using two-stage least squares (2SLS) within a probit framework. This two-stage approach allows us to obtain consistent estimates of the impact of employment on the use of food coping strategies.

This methodology provides a framework to analyze the effects of climate change on employment in agricultural work and food insecurity coping strategies in rural Sri Lanka. By using instrumental variables, we aim to address potential endogeneity issues and provide reliable estimates of the impacts of various climate variables and interconnected systems on households highlighted in Figure 1.

3.3 Data and Data Collection Methods

The current study uses secondary data for the analysis. Secondary data includes the compilation of documentary evidence that has direct and indirect relevance for the research study by a desk review. Sources of documentary evidence include local, regional, and national journals, articles, reports, documents, policies, web-based publications, and nationally published data sources. The sources for secondary data include the climate data (Rainfall, temperature, drought incidence, etc.) from the Department of Meteorology (DOM); UNDP Multidimensional Vulnerabilities Index data, production data (production, extent, yield, input use) from the Department of Agriculture of Sri Lanka; price data (farm gate, wholesale and retail in different markets) from the Hector Kobbekaduwa Agricultural Research and Training Institute (HARTI); import data from the Central Bank of Sri Lanka (CBSL) and the Customs. These methods allow for more in-depth exploration that can facilitate a deeper understanding of the impacts of climate change on the farmers in the value chain.

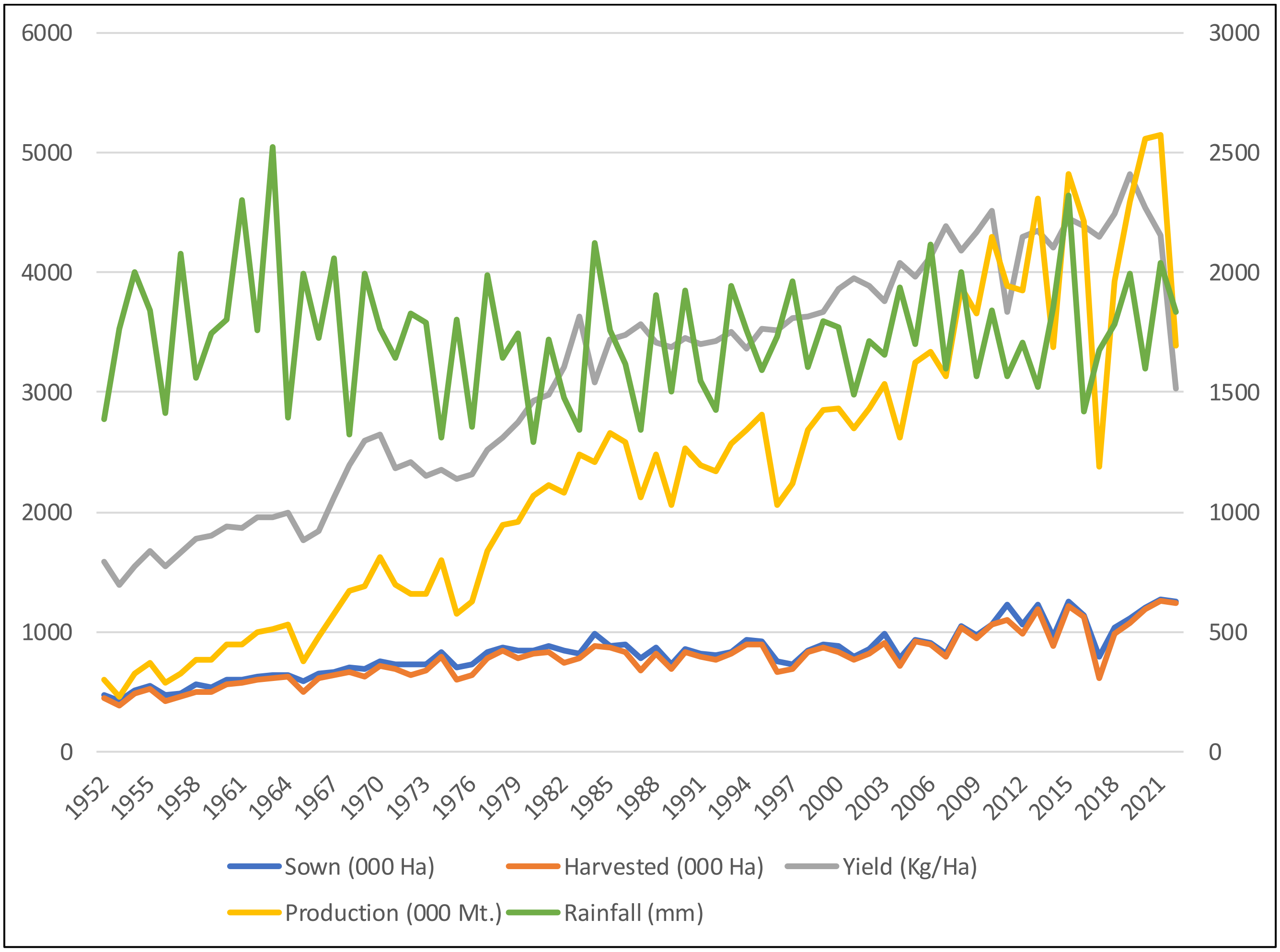
4. Results and Discussion

4.1 Climate Change Impacts on Food Security

4.1.1 Observed Impacts of Climate Change on Food Availability

Climate change affects food availability through its impacts on food production. The direct impacts on food production come through changes in agroecological conditions, while the indirect impacts include changes in economic growth and distribution of incomes, which in turn affect demand for agricultural produce and food production (World Food Programme, 2012). Adverse climate trends such as changes in rainfall patterns can reduce the quantity of land available for crop production; increasing ambient temperature can reduce crop productivity and yield levels; in turn, the income levels of farmers will suffer. Gradual changes in climatic conditions have already affected the production of domestic crops, including Sri Lanka's staple food rice, and extreme climate events threaten to worsen this. Figure 2 illustrates the fluctuation of rice cultivated extent, yield, and production with the mean annual rainfall in the country. It shows that despite the overall increasing trend in rice production in the country, it has some relationship with rainfall fluctuations.

Figure 2: Paddy sector performance with the rainfall changes (1952-2022)



Source: Department of Census and Statistics of Sri Lanka

For example, at the beginning of 2016, Sri Lanka faced the worst drought in 40 years, severely affecting the agricultural production in the country (Food and Agriculture Organization, World Food Programme, 2017). This situation was further exacerbated by severe floods in mid-2017 in the south-western parts of Sri Lanka. The impact of continuing dry spells and severe floods was disastrous for the country's food production. The Yala 2016 (May-September) – the first cultivation season following the drought – recorded a 20 percent drop in both production as well as the extent of cultivation of rice relative to comparative figures for 2015. The main harvest season of Maha 2017 (December 2016-February 2017) achieved only half of the rice production of Maha 2016 (Table 1). The Yala 2017 output too showed a further drop in production. Sri Lanka also experienced a similar drop in production in other seasonal food crops too.

Table 1: Recent Trends in the Production of Major Food Items (Maha 2015--Yala 2017)

Food Item	Production (Mt)					
	2015		2016		2017	
	Maha	Yala	Maha	Yala	Maha	Yala
Paddy	2,877	1,942	2,903	1,517	1,474	909
Kurakkan (Millete)	7,410	1,510	7,060	1,500	4,468	1,106
Maize	230,870	30,240	207,070	36,890	163,733	32,011
Green gram	7,620	7,440	7,980	6,570	4,896	4,496
Cowpea	7,240	5,040	8,810	4,930	4,937	3,639
Black gram	10,610	1,290	9,000	2,200	5,207	2,082
Gingelly	3,190	10,090	2,490	9,930	2,054	5,700
Potatoes	54,310	43,080	48,540	47,260	28,381	44,977
Red onion	35,210	25,990	35,480	28,190	33,407	24,340
Big onion	4,590	84,740	7,550	57,670	3,226	50,377
Chillies (Green)	42,830	20,040	50,720	21,590	30,690	21,137

Source: *Agriculture Statistics*. Department of Census and Statistics, Colombo. Retrieved from http://www.statistics.gov.lk/agriculture/

A significant amount of foreign exchange is spent annually on the import of sugar, wheat, milk, and fish which are the biggest imported food items in value terms. These three items accounted for 52% of total food and beverages import expenditure and 10% of total imports in 2017.[2] Though Sri Lanka has almost achieved self-sufficiency in its staple food, rice, it is compelled to import rice during periods of adverse weather conditions in the country to fill the shortfall and to control escalating prices. In its history, Sri Lanka spent the largest amount on importing rice in 2017, when production dropped by 46% due to adverse weather conditions (Table 2). The escalation of imports due to climate change added a significant burden on the local economy.

Table 2: Recent Trends in Major Food Imports (Rs. Million) (2015 -2017)

Food Item	2015	2016	2017
Food & Beverages	269,486	273,257	335,040
Sugar	34,164	49,919	39,041
Milk	34,088	36,338	48,145
Fish	29,799	34,130	32,685
Wheat & Maize	48,658	36,221	54,394
Rice	17,956	1,872	45,881

Source: Central Bank of Sri Lanka. (2017). *Annual report*. Colombo, Sri Lanka: Central Bank of Sri Lanka.

[2] Wheat and maize which have been categorized as intermediate goods in CBSL *Annual Report 2016* have been considered under food and beverages for statistical purposes.

4.1.2 Projected Impacts of Climate Change on Food Availability

Studies have also projected that climate change will negatively affect rice yields in different agro-climatic zones of Sri Lanka (Ahmed and Supachalasai, 2014). The projected drop in rice yields can vary from 1.3 percent in upcountry intermediate zones during the Maha season to 6.5 percent in low-country dry zones during the Yala season by 2030 (Table 3). Similar variations could be seen in 2050 and 2080 projections. Overall, the projected yield drop is higher in the Yala season and low country dry and intermediate zones which are predominantly agricultural, and is indicative of the significant impact of climate change on Sri Lanka's food production.

Table 3: Impact of Climate Change on Rice Yield in Different Agroclimatic Zones in Sri Lanka

Agro-climatic zone	Current yield (kg/ha)		% change in 2030		% change in 2050		% change in 2080	
	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala
Dry-Low	3,498	3,863	-4.2	-6.5	-16.1	-19.8	-29.1	-34.2
Intermediate-Low	4,885	4,612	-2.7	-3.5	-10.6	-15.1	-24.8	-31.5
Intermediate-Mid	4,992	4,761	-1.9	-3.1	-9.3	-12.7	-22.5	-30.3
Intermediate-Upland	3,492	2,955	-1.3	-2.7	-7.5	-11.4	-20.3	-27.5
Wet-Low	3,910	3,711	-0.9	-1.5	-6.0	-10.4	-19.4	-25.1
Wet-Mid	3,538	2,795	-0.8	-1.4	-3.6	-8.2	-18.3	-23.6
Wet-Upland	3,134	2,706	5.7	3.1	2.1	-2.0	-8.6	-12.4

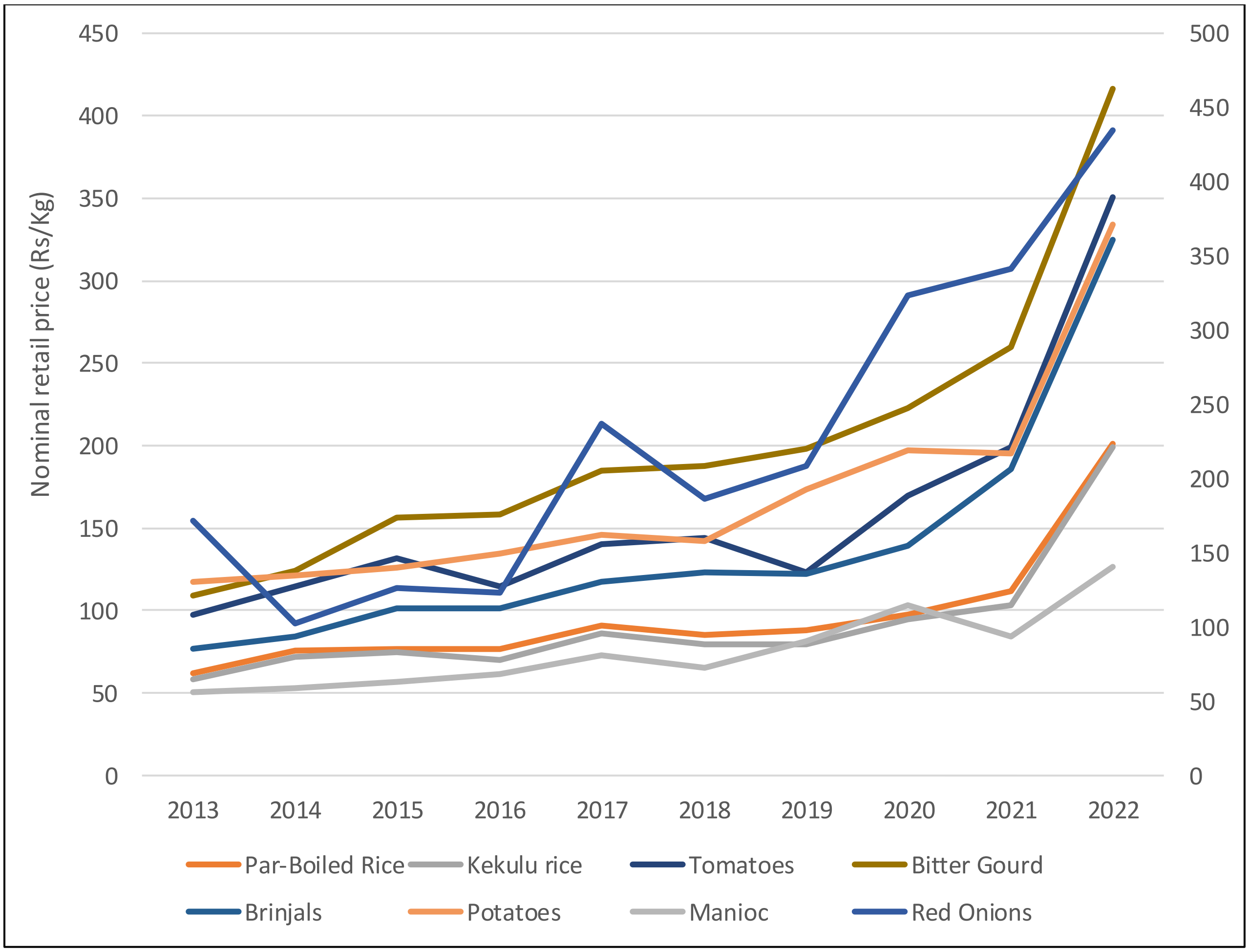
Source: Ahmed, M., and Suphachalasai, S. (2014)

Other seasonal crops too will face similar consequences from climate change. Temperature and rainfall variability were found to influence maize production, which is the second-largest cereal crop grown in the country. Higher temperature negatively affects the maize yield, while higher rainfall has a positive influence. Research indicates that each 1^0C increase in temperature reduced yield by 5 percent during the period 1990–2010 (Karunaratne and Wheeler 2015). Since the temperatures in the major maize-growing areas are above the optimum temperature, further temperature increases will potentially have a significant negative impact on maize production in the future (Jacobs et al. 2017).

4.1.3 Climate Change Impacts on Access to Food

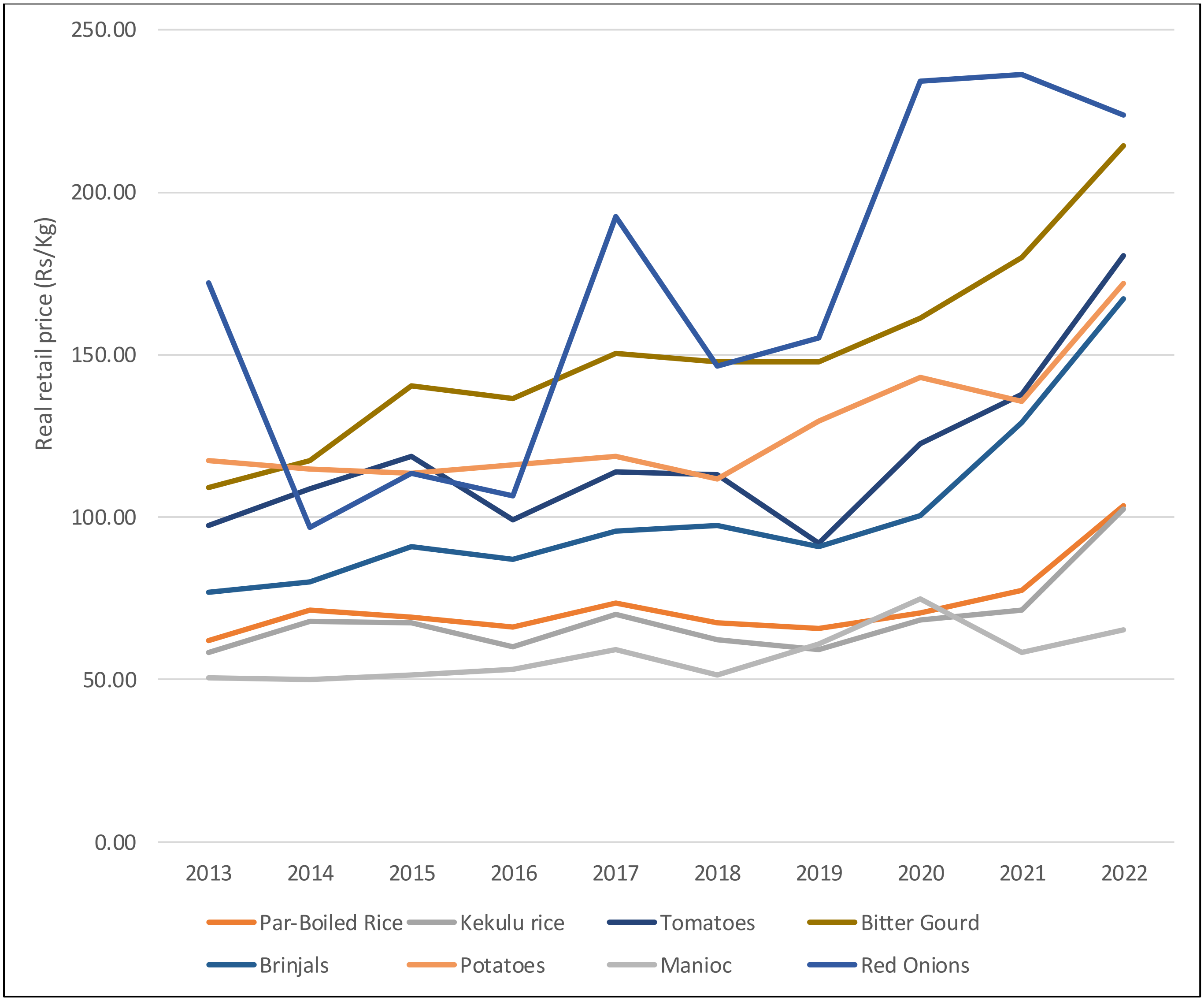
Climate change can affect food access – that is, the ability of individuals to obtain sufficient quantities of good-quality food. Food prices and income are the two major factors determining access to food by households. Climate change-induced low agricultural production levels can result in diminished incomes for farmers and higher food prices for consumers. Figures 3 and 4 illustrate the nominal and real prices of selected food crops. Historically, nominal retail prices have been increasing while real retail prices have been declining or stagnant except for special crises like the COVID-19 pandemic, economic turmoil, and extreme climatic events. For example, COVID-19 and the economic crisis in the country since 2020 have resulted in burgeoning nominal and real prices of food commodities. Similarly, the prolonged extreme climatic situation in 2016 and 2017 caused both the nominal and real prices of food to rise rapidly highlighting the vulnerability of poor and marginal households to price shocks. This has undeniably reduced the purchasing power of people and thereby limited their access to food. The rural poor are especially vulnerable.

Figure 3: Average Nominal Consumer Prices of Some Selected Food Commodities



Source: Central Bank of Sri Lanka. (Various Years). *Economic and Social Statistics of Sri Lanka*. Colombo, Sri Lanka: Central Bank of Sri Lanka.

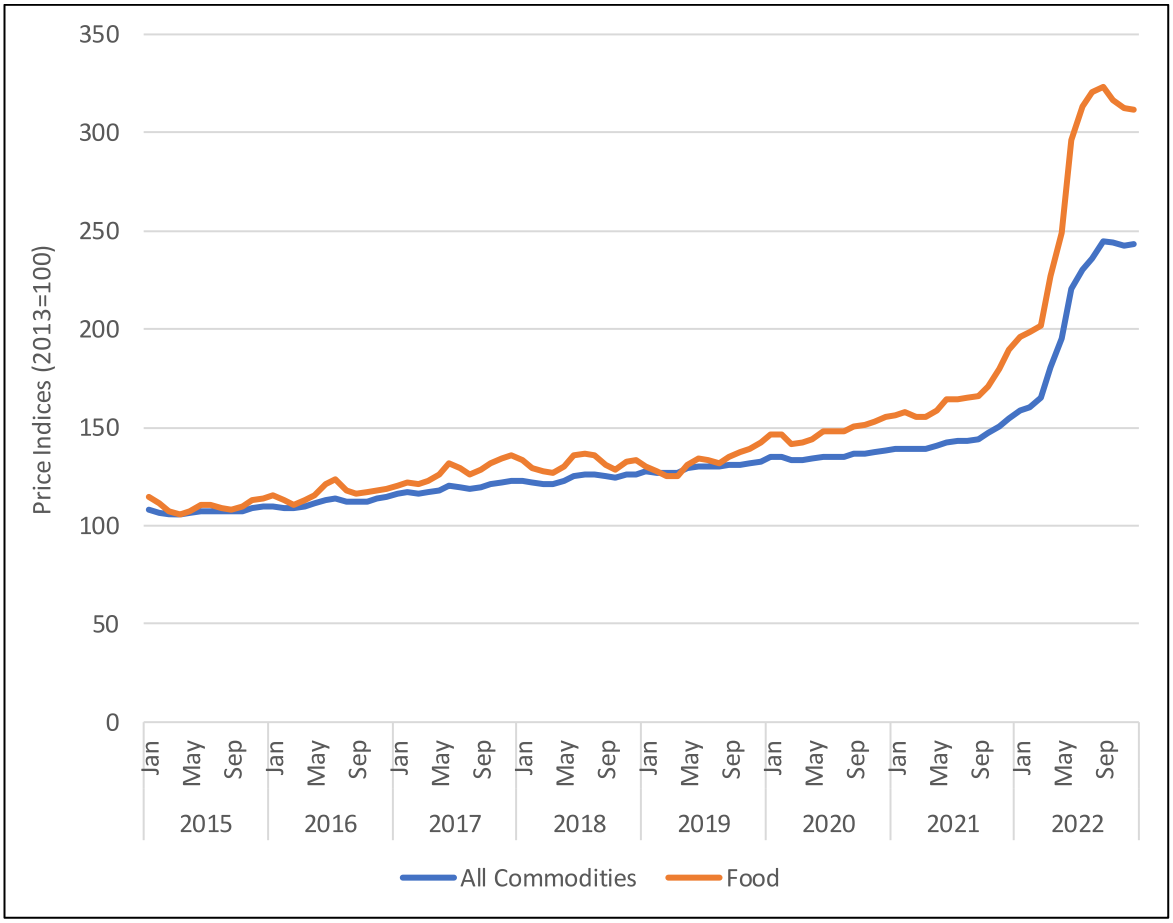
Figure 4: Average Real Consumer Prices of Selected Food Commodities (Rs./Kg)



Source: Central Bank of Sri Lanka. (Various Years). *Economic and Social Statistics of Sri Lanka*. Colombo, Sri Lanka: Central Bank of Sri Lanka.

The Food Price Index (FPI) relates the changes in cost and economic access to food by consumers. Up until 2015, the FPI was moving in parallel to the All-item Price Index (AIPI) as seen in Figure 5. However, since then, the FPI started to deviate from the AIPI with the impacts of climate changes on domestic food production. The FPI increased by a staggering 22 percent from 104.3 in 2014 to 127.5 in 2017, compared to a 10 percent increase in the NFPI during the same period.

Figure 5: Movement of Price Indices (Food, and All Items)

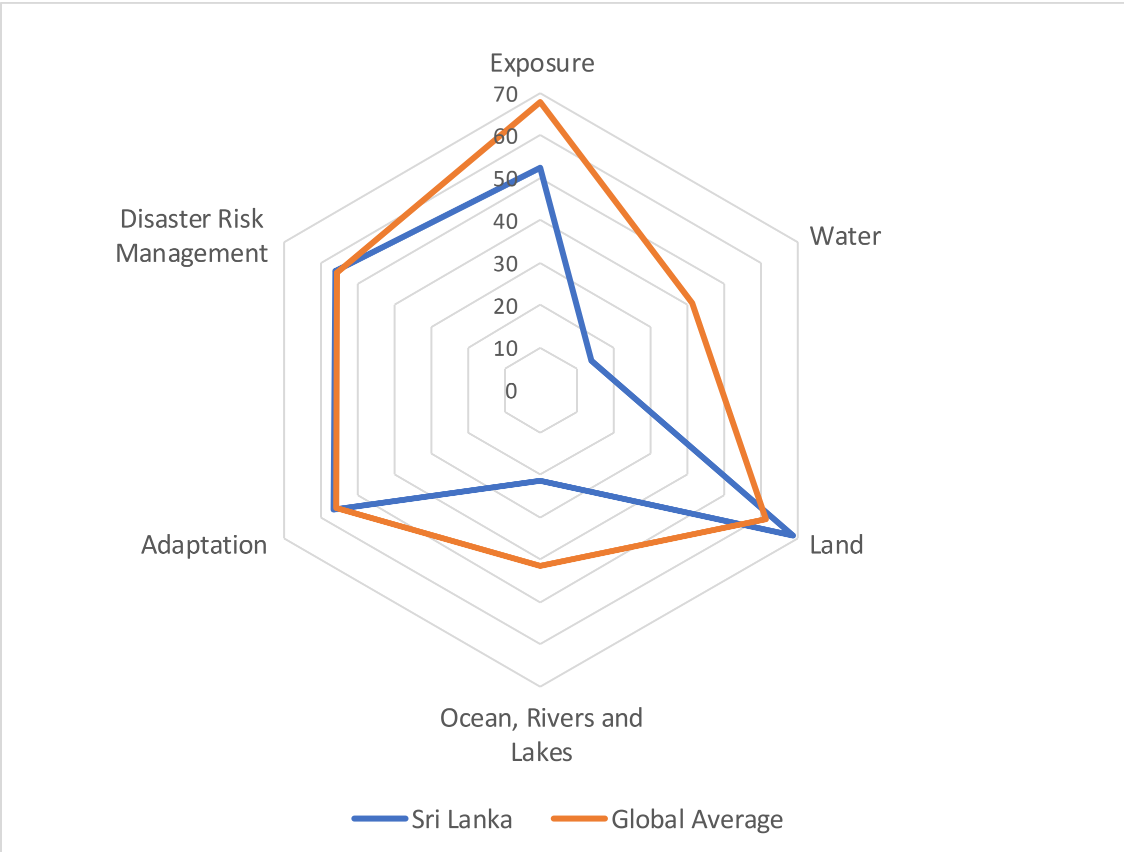


Source: Central Bank of Sri Lanka. (2023). *Annual report.* Colombo, Sri Lanka: Central Bank of Sri Lanka.

4.1.4 Stability and Climate Resilience

Despite improved food availability and access in Sri Lanka, whether the country is producing enough food for its future is a serious challenge due to the constantly rising national requirement, owing to population growth and the growth of real per capita income. Climate change affects both food supply stability and food consumption stability through its impacts on food production and access to food as discussed previously. Thus, improving climate resilience for farmers to manage the shocks with no long-lasting adverse effects is very important to achieve the stability aspect of food security. However, the GFSI shows that Sri Lanka's resilience to natural resource and climate-related risks is at an average level, posing long-term threats to food security in the country (Figure 6). Based on the Sustainability and Adaptation indicator, Sri Lanka is placed at the 87th position of 113 countries with an average score of 45.3. It's important to note that under the adaptation component, even though Sri Lanka has scored full marks for the national adaptation policy for agriculture and sustainable agriculture policy, the country poorly performs in climate-smart agriculture, environmental economic accounting implementation, and commitment to managing the exposure.

Figure 6: Resilience to Natural Resource and Climate-Related Risks



Note: Score 0-100 where 100 is the best.
Source: The Economist. (2023)

Nearly 80 percent of Sri Lanka's population is considered rural, and those rural livelihoods are greatly reliant on agriculture and allied industries. Based on 20 different livelihood zones identified by the WFP, the most resilient livelihood group in Sri Lanka belongs to the Mahaweli mixed farming and livestock zone and the coconut triangle zone, primarily due to the high diversity of income and food sources, relatively good access to major economic cities and access to micro tanks (World Food Programme and Ministry of Economic Development, 2015). While these zones have relatively better food security, higher livelihood diversity, and less climate sensitivity, the livelihood resilience of these zones could be easily challenged by extreme climate conditions such as droughts. The least resilient groups are the poor households in the north, tea estates, and south-eastern parts of the country. Northern fishers have low resilience due to frequent storms and cyclones, while the poorest households in the tea estates have low resilience due to very limited livelihood diversity. The south-eastern rain-fed farming zone also has poor levels of resilience due to the high sensitivity of their income source to climate variability.

4.2 Climate Change and the Impact of Rural Livelihoods

4.2.1 Impact on Employment

Climate change poses significant challenges to rural livelihoods and employment, particularly in agrarian economies such as Sri Lanka. Rural communities, heavily dependent on agriculture and related activities, are especially vulnerable to climatic variations and extreme weather events. Climate change has disrupted traditional farming practices through increased temperature, altered rainfall patterns, and the prevalence of extreme weather events such as droughts and floods. Reduced crop yields not only threaten food security but also lead to decreased agricultural income, compelling farmers to seek alternative employment opportunities.

Table 4: The Effects of Climate Change on Agricultral Employment

	Sample	Male	Female
Agricultural Household	-0.130**	-0.149**	-0.091**
Average 10-year rainfall	0.082**	0.080**	0.078**
Average 10-year Low	-0.137**	-0.147**	-0.122**
Average 10-year High	0.037**	0.051**	0.012
SD 10-year rainfall	0.051**	0.056**	0.040**
Current rainfall	-0.130**	-0.149**	-0.091**
Control Variables			
Household Characteristics	X	X	X
Access to Facilities	X	X	X
Sample Size	19,111	12,921	6,190

Data Sources: UNDP MVI Data 2022, Rainfall Data from MET

Notes: Household characteristics include variables such as family size, education levels, and other socio-economic factors. Access to facilities encompasses infrastructure such as roads, irrigation systems, and markets. The statistical significance is indicated by asterisks, with $^{**}p < 0.01$, $^{*}p < 0.05$.

Table 4 highlights the estimated effects of various measures of rainfall on agricultural employment, disaggregated by gender. The key variables of interest are average 10-year rainfall, average 10-year high rainfall, average 10-year low rainfall, standard deviation of 10-year rainfall, and current rainfall, which show variation across divisional sectriats in Sri Lanka. Often, the unpredictability of rainfall patterns has led to a mismatch in the agricultural calendar. Farmers face difficulties in planning sowing and harvesting, which often results in prolonged periods of inactivity or seasonal unemployment. De Silva and Kawasaki (2018) note that the shift in agricultural seasons has forced many farmers into temporary or irregular non-agricultural jobs, affecting the stability and quality of rural employment. As such, the 10-year averages and standard deviation, as well as the occurrence of 10-year high and 10-year low rainfall capture the non-linear response of workers to historical rainfall levels and uncertainty.

The results show that higher average rainfall over the past ten years is associated with a reduction in agricultural employment. This effect is statistically significant for both men and women with men observing a stronger effect by an additional 5.8 percent. While higher average long-term rainfall might be detrimental to agricultural employment, possibly due to increased flooding or soil saturation that hinders agricultural activities, non-linear relationships between rainfall and agricultural farm work are highlighted through other variables of interest. The average 10-year high rainfall coefficient shows that workers in regions that are in the top ten percent of the rainfall distribution are associated with increased participation in agriculture. Conversely, the 10-year low rainfall coefficient shows that workers in regions that are in the bottom ten percent of the distribution are associated with low participation in agriculture. The 10-year standard deviation positively impacts the participation in agricultural work for men, with women not observing a statistically significant effect. This could highlight the lack of employment opportunities for women relative to men or that women are less responsive to information on rainfall variability. Finally, current rainfall positively influences agricultural employment, as adequate water availability directly supports current agricultural activities and labor requirements.

The results indicate that climate change, through various dimensions of rainfall, significantly affects agricultural employment in rural Sri Lanka. Both average and extreme rainfall patterns have nuanced impacts on employment, with variations across genders. These findings underscore the importance of developing adaptive strategies to mitigate the adverse effects of climate change on rural livelihoods and employment.

4.2.2 Impact of Food Coping Strategies

Table 5 presents the estimated effects of various measures of rainfall on food insecurity coping strategies, with a specific focus on comparing the overall sample to female-led households. The results indicate that agricultural households are 73.8 percent more likely to not face food insecurity relative to non-agricultural households. Irrigation facilities account for the endogeneity of participation in agriculture, suggesting that households' involvement in agricultural work is done considering that households can meet their subsistence needs. However, the effect is insignificant for female-led households, indicating that their participation in agricultural work does not guarantee food security. This suggests that female-led households face unique challenges and have a lower adaptive capacity to guarantee food security.

Table 5: The Effects of Climate Change on Food Insecurity Coping Strategies

	Sample	Female-led HH
Agricultural Household	-0.738**	-0.325
Average 10-year rainfall	-0.132**	-0.146**
Average 10-year Low	0.078**	0.128**
Average 10-year High	-0.053**	-0.087**
SD 10-year rainfall	0.016	-0.005
Current rainfall	0.059**	0.064**
Control Variables		
Household Characteristics	X	X
Access to Facilities	X	X
Sample Size	14,742	4,997

Data Sources: UNDP MVI Data 2022, Rainfall Data from MET

Notes: Household characteristics include variables such as family size, education levels, and other socio-economic factors. Access to facilities encompasses infrastructure such as roads, irrigation systems, and markets. The statistical significance is indicated by asterisks, with **p <0.01, *p <0.05.

Average 10-year rainfall is associated with a reduction in food insecurity coping strategies. Negative coefficients suggest that higher average long-term rainfall might improve agricultural productivity and water availability, reducing the need for food insecurity coping strategies. This effect is more pronounced in female-led households. The average 10-year low rainfall coefficient shows that households in regions that are in the bottom ten percent of the rainfall distribution display an increased reliance on food insecurity coping strategies. Lower average rainfall reduces water availability and agricultural productivity, reducing food supply and the ability to meet subsistence needs. The average 10-year high rainfall coefficient shows that households in regions that are in the top ten percent of the rainfall distribution are less reliant on negative food coping strategies. The coefficient on the standard deviation of 10-year rainfall shows that variability in rainfall over ten years leads to an increased use of food insecurity coping strategies for either the general sample or female-led households.

The results indicate that climate change, through various dimensions of rainfall, significantly affects food insecurity coping strategies in rural Sri Lanka. Both average and extreme rainfall patterns have impacts on food insecurity, with varied results for female-led households. Female-led households exhibit distinct vulnerabilities to climate-induced food insecurity, highlighting the need for targeted interventions to support these households and increase their adaptive capacities. The findings underscore the importance of developing and supporting adaptive strategies to mitigate the adverse effects of climate change on rural livelihoods and food security.

5 Conclusion & the Way Forward

Agriculture plays a pivotal role in the economy of Sri Lanka occupying around one-third of the labour force of the country and remaining as the main source of livelihood for many areas of the country. Climate change has emerged as a major challenge to achieving the food security goals of the country. It has the potential to create significant losses to the livelihoods of farmers unless addressed as a priority. Overall, information on observed and projected changes suggests that the climate of Sri Lanka is undergoing four major types of changes; Gradual increase in ambient air temperature; Changes in the distribution pattern of rainfall; Increase in frequency and severity of extreme weather events; and Sea level rise. All these have profound implications for the food security of the country and the livelihood of the people engaged in agriculture.

Results indicate that climate change is hurting the country's ability to secure adequate food resources at affordable prices for its population regularly. Results also indicate that climate change, through various dimensions of rainfall, significantly affects agricultural employment and food coping strategies in rural Sri Lanka. Both average and extreme rainfall patterns have nuanced impacts on employment and coping strategies with variations across genders. These findings underscore the importance of developing gender-sensitive adaptive strategies to mitigate the adverse effects of climate change on rural livelihoods in terms of employment and food security.

The most important way to address the combined issues of climate change, food security, and rural livelihood is to invest in agricultural adaptation. Adaptation is a response strategy for overcoming the impacts of observed and projected climate changes. Throughout history, farmers have engaged in a continuous struggle for adaptation to climate variability and shocks, and therefore adaptation is not something new to farmers. However, climate change is a new and evolving phenomenon in terms of scale and rate of change, and therefore their adaptive capacity has to be enhanced to face the future threats of climate change. Moreover, the losses and damages encountered by farmers due to unanticipated changes in the climate indicate the importance of enhancing the adaptive capacity of farmers to face this challenge. Given the burgeoning threat of climate change on food security and rural livelihoods, investments in climate adaptation should be given high priority in the future.

Climate-smart agriculture (CSA) is an approach that transforms agricultural systems to effectively support farming livelihoods and ensure food security in the current context. CSA can prevent the worst impacts of climate change on farm livelihoods, and help make people less vulnerable to food insecurity and poverty. CSA highlights that climate threats can be reduced by increasing the adaptive capacity of farmers, as well as by increasing the resilience and efficiency of resource use in agricultural production systems. While reducing the agriculture sector's contribution to climate change is less of a priority for Sri Lanka, more importantly, farming communities need to adjust their livelihood patterns to sustainably increase their production and income. This demonstrates that the solutions for climate risks and thereby food insecurity and rural livelihood issues can be derived from making agriculture climate smart.

While farmers individually have to search for innovative ways of adapting to pending threats. policymakers also have an important role to play by introducing appropriate policies, institutions, and support facilities to enhance and facilitate the adaptation choices of farmers. The government has developed a National Adaptation Plan (NAP) to help adapt to climate change and some of the major policies have been mainstreamed with climate adaptation. However, the implementation of the plans and strategies has been still poor. While different CSA strategies, including developing tolerant varieties, promoting water-efficient farming methods, and adjusting cropping calendars according to climate forecasts, have been proposed and initiated, Sri Lanka is still behind in terms of scaling up such initiatives. Moreover, developing systems for timely issuing and communicating climate information to farmers is another aspect that needs to be taken care of as a top priority. More specifically, CSA practices should be tailored to the specific characteristics of the local farming systems and local socio-economic conditions, and require a well-articulated information management system coupled with improved smallholder access to finances, resources, and markets.

Given the large uncertainties of unforeseen effects associated with the climate as well as socio-economic change, prescribing a pre-determined list of adaptation measures is an uphill task. Thus, it is important to understand factors that affect the situation of farmers' vulnerability and key components that build up their adaptive capacity which is the next step of this study that would be undertaken by using primary data collected through a questionnaire survey. This would help to identify appropriate adaptation strategies in a dynamic setting, minimizing the risk and uncertainties involved in any given scenario of climate and socio-economic change so that suitable policy and institutional supports that enhance the adaptive capacity of farmers can be introduced.

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