# Assessing Vulnerability to Climate Change: A Study on Farmer Communities in the Dry Zone of Sri Lanka

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# FOREWORD

Diabolical effects of climate change are apparent in every sector across the globe. Agriculture, one of the key climate-sensitive sectors is a vital source of employment in Sri Lanka despite its diminishing contribution to the country's Gross Domestic Production over the past four decades.

In this context, the smallholder farming community that constitutes the majority of the farming population and the leading contributors to the annual food production are overly threatened. Hence, formulation of climate change mitigation and adaptation strategies for sustenance of farming communities as well as ensuring food security of the country has become government's top priority. Nevertheless, efforts to support farmer adaptation are hindered by dearth of crop production system level information relating to farmers' experience and their response to climate change impacts. Further, to evolve appropriate strategies a clear understanding of the farmers' perception of climate change, actual adaptations at farm-level and crop production system level as well as the factors contributing to their current level of vulnerability play a vital role.

Therefore, I believe this report 'Assessing Vulnerability to Climate Change: A Study on Farmer Communities in the Dry Zone of Sri Lanka' will prove beneficial to all stakeholders involved in assisting the targeted communities tailoring climate adaptation programmes which will return maximum benefits to the investments.

**Senior Professor Ranjith Premalal De Silva**
**Director/Chief Executive Officer**

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# EXECUTIVE SUMMARY

According to recent climate change projections, farming community in the dry zone of Sri Lanka will be the worst affected. Vulnerability assessment is considered the best tool to understand the level of vulnerability and nature of vulnerability at grassroots level. In this background, this study was carried out to identify the comparative vulnerability status of the farming communities engaged in field crop cultivation in the dry zone areas and determine the factors contributing to climate vulnerability at household level and at crop production system level.

Comparative vulnerability of communities was assessed for 13 selected crop production systems of eight districts across the dry zone of Sri Lanka. This study adopted the integrated approach (IA) and composing of a livelihood vulnerability index for vulnerability calculation. A structured questionnaire-based household survey was conducted on 558 randomly selected farm households representing different crop production systems in the latter part of 2017 and early 2018. The multi-stage sampling technique was applied in selecting the sample representing six specific crops spread over 14 Agrarian Service Center (ASC) areas in eight administrative districts. . In addition, quantitative and qualitative data was collected by employing participatory data collection tools such as focus group discussions (FGDs) and key informant interviews (KIIs).

Climate vulnerability was measured using the indicator method. The Livelihood Vulnerability Index (LVI) was calculated to obtain the overall vulnerability status at community and household levels. The LVI was composed using multiple indicators to assess exposure, sensitivity and adaptive capacity pertaining to the adverse impacts of climate change. The Multiple Linear Regression Model was used to examine the relationships between the agricultural vulnerability to climate change and its determinants at farmer level.

The highest overall exposure level was recorded in Hambantota district. Therefore, green gram cultivated in the Hambantota district under rainfed and major irrigation systems recorded the highest exposure levels while the Matale district was reported to be the lowest.

Three sub-indicators make up the overall sensitivity: household sensitivity, financial sensitivity and household sensitivity. The lowest household sensitivity (0.042) was observed for groundnut cultivated under rainfed conditions in Mullaitivu district while the highest being recorded for green gram under the same rainfed conditions in the Moneragala district. The highest value for financial sensitivity was computed using two indicators; income ratio and unsettled loans. It was also observed for groundnut rainfed farming systems in Mullaitivu district. It was noted that the agricultural sensitivity, was generally higher in rainfed systems compared to the major and minor irrigation systems.

The indices, Social Capacity Index, Human Capital Index and Asset Index form the overall adaptive capacity of a given crop production system. The human capital index derived from the level of education of the farmer and his/her experience in farming and the asset index has not shown much difference among crop production systems

With regard to vulnerability of the crop production the least vulnerability is reported in black gram production in the Vavuniya district followed by big-onion production system in Dambulla, one of the dry areas in the Matale district. The least vulnerability for black gram can be attributed to the relatively low sensitivity and least exposure (0.25) to adverse of climate change impacts. As a crop with low water requirement, black gram production is mostly practiced under rainfed condition in rainy *Maha* season. The big onion production system records relatively low sensitivity and higher adaptive capacity with the system and the farming community. The onion production systems mostly undertaken with the assured minor irrigation systems and supplementary irrigations coupled with high-efficiency micro irrigation techniques are mostly safe from the extreme events such as prolonged dry spells and droughts. Despite of the relatively higher exposure to the climate change impacts, the higher adaptive capacity of the community has eased the vulnerability. The highest vulnerable crop production system is reported to be green gram cultivated under rainfed conditions in the Hambantota district where the higher sensitivity and exposure levels are prevailing while low adaptive capacity of the community is recorded.

Econometric analysis on determining the factors that influence the farmer level (farm household level) vulnerability to climate change revealed that education level of the household head, access to information are positively contributing to reduce farmer level vulnerability. However, increased land extent cultivated with a particular field crop and being fulltime farmers lead to increased farmer vulnerability to climate change. Geographical location is a major determinant of vulnerability. Farmers in the Hambantota district are the most vulnerable community followed by those of Anuradhapura and Moneragala. Farming community in the Jaffna district are the least vulnerable for the fact that groundwater being the main source of water and the district is not prone to floods by nature.

The study found that factors causing the differences in vulnerability among communities under different crop production systems in the dry zone are mostly similar irrespective of the geographical locations and socio-economic differences. Thus, providing training opportunities to farmers and educate them on available novel technologies, diversified agricultural practices can lead to reducing climate vulnerability.

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| | | |
|---|---|---|
| ADB | - | Asian Development Bank |
| ASC | - | Agrarian Service Center |
| CCSSL | - | Climate Change Secretariat of Sri Lanka |
| CRI | - | Climate Risk Index |
| FAO | - | Food and Agriculture Organization |
| FGD | - | Focus Group Discussions |
| HH | - | House Holds |
| IPCC | - | Inter Governmental Panel on Climate Change |
| LVI | - | Livelihood Vulnerability Index |
| OFC | - | Other Field Crops |
| SDG | - | Sustainable Development Goals |
| UN | - | United Nations |

# CHAPTER ONE

# Introduction

## 1.1 Background

Climate change is a creeping disaster sprawled in nearly all the countries and sectors. Climate change predictions held that human induced climate change is set to continue and will further aggravate if global emissions of heat trapping gases continue to rise unchecked. Though the severity of effects of climate change varies across the world, the developing countries are the worst hit for their economies mainly dependent on natural resources which are vulnerable to climate change. Majority of the rural population of these countries relies on agriculture and related activities as their main source of livelihood. The impact of climate change on crop and livestock productivity is dreadful and is escalating in developing countries (FAO, 2016). Limited resources, technologies and institutional capacities also make these countries more vulnerable to climate change. The South Asian region, where nearly one third of population still living in poverty, is more likely to experience the impact of climate change that will result in grave economic, social and environmental consequences that slacken their growth potential and poverty reduction efforts (ADB, 2013).

According to the United Nations' sustainable development goals (SDGs), it is expected to achieve world's food security and promote sustainable agriculture while doubling the incomes of small-scale food producers by 2030 (UN, 2015). Therefore, acting with urgency to increase resilience of the respective systems and communities is vital. Resorting to possible mitigating actions and facilitation to adapt to the situation can be regarded timely.

In adaptation planning, vulnerability assessment is a useful tool that aids policymakers formulate rational and effective adaptation strategies (Tao et al., 2011; Mallari, 2016). The vulnerability assessment describes the seriousness of potential threats from known hazards and the level of vulnerability at household level and community level. Vulnerability information can translate early warning information into preventive action (Loria et al., 2015).

## 1.2 Significance of the Study

The Global Climate Risk Index[1] (CRI) has rated Sri Lanka the second in the list of the most affected countries by impacts of weather-related loss events in 2017. Though

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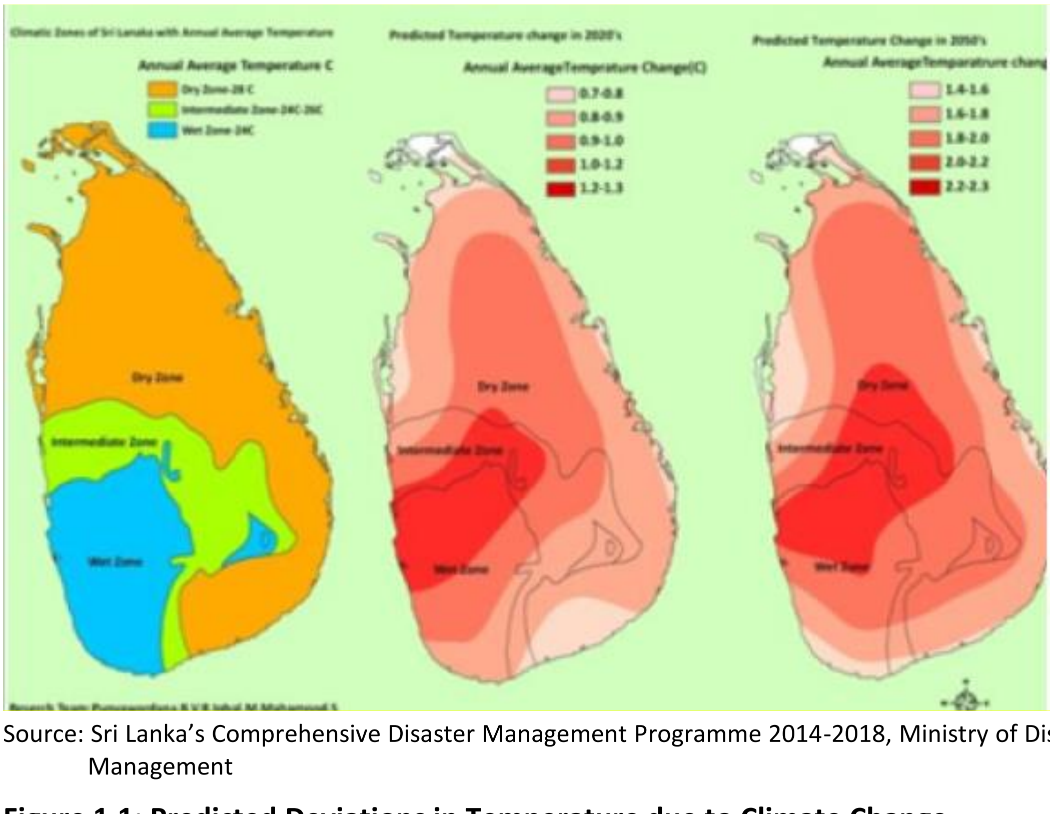
[1] The Global Climate Risk Index (CRI) developed by German watch analyses quantified impacts of extreme weather events both in terms of fatalities as well as economic losses that occurred based on data from the Munich Re NatCatSERVICE, which is worldwide one of the most reliable and complete databases on this matter.

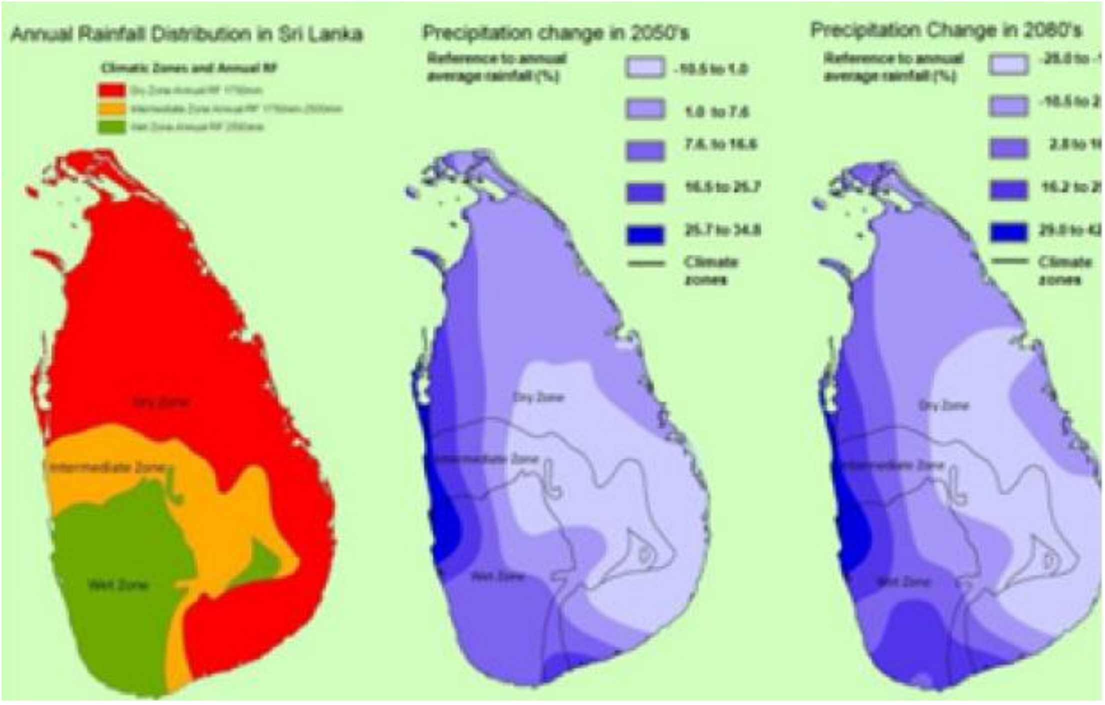
CRI does not provide a comprehensive analysis of the risks of anthropogenic climate change, it explains countries' exposure and vulnerability to climate related risks. Further, a sizable population of the country is engaged in agriculture-related economic ventures. Most of these farming communities comprise of smallholder subsistence farmers with low adaptation capacity with regard to climate change and therefore subject to a greater level of vulnerability (De Costa, 2010). Climate change impacts on agriculture invariably impact the country's economy (Eriyagama and Smakhtin, 2010). Seo et al. (2005) find that nationally, the impact on agriculture will result in economic impacts in a large range. Besides the economic factor, agriculture provides a social safety net and food security for majority of the rural populations. Therefore, effects of climate change will be felt by all sectors of the economy and layers of the society (CCSSL, 2016).

Among the adverse effects of extreme weather events experienced by Sri Lanka's agriculture are slow and steady increase of ambient temperature, high intensity erosive rainfall, salt water intrusion to soils and aquifers, tornado type winds and ever-increasing extreme droughts and floods (World Bank, 2016; Hirji et al., 2017: Gopalakrishnan et al., 2019). In addition, information on observed and projected changes suggests that wet areas will become wetter and dry areas will be drier due to changes in rainfall distribution pattern of Sri Lanka (ibid).




Source: Sri Lanka's Comprehensive Disaster Management Programme 2014-2018, Ministry of Disaster Management

**Figure 1.1: Predicted Deviations in Temperature due to Climate Change**




Source: Sri Lanka Comprehensive Disaster Management Programme 2014-2018, Ministry of Disaster Management

**Figure 1.2: Predicted Deviation of Rainfall due to Climate Change**

Though the annual rainfall variability has increased almost all over the country, rainfall variability is high in Dry Zone than the other parts of the country (Premalal, 2009). The North-East monsoon is the major source of water for the dry zone of the country. However as per the climatic predictions, rainfall received from North East monsoon will decrease by 34 per cent by 2050s. Predicted decrease in rainfall in dry zone areas with the temperature increase will have serious impacts in potential soil moisture deficits which will determine the irrigation requirement for paddy and other field crops. Therefore, agricultural activities in the dry zone will be severely affected (De Silva, 2006). Thus, the present study was planned to observe the level of vulnerability of farming communities attached to different crop production systems operating in the dry zone of Sri Lanka.

## 1.3 Research Problem

Though a significant number of studies has been undertaken on climate change vulnerability at national and regional levels, the micro-level situation has largely been neglected. As per the Fifth Assessment Report of the IPCC, addressing impacts of climate change and climate risk management requires sound adaptation strategies as well as proper mitigation steps (IPCC, 2014). Having reviewed the sector vulnerability profiles prepared for each sector, Second National Communication on Climate Change for Sri Lanka prepared by the Ministry of Environment also highlighted the need for further research to identify vulnerable areas in respect of crops in different agro-ecological regions (CCSSL, 2011).

Jayasooriya (2017) also claims that a number of adaptation programmes have failed in their objective as the vulnerability at the grassroots level was not correctly identified. Hence for formulating comprehensive and efficient adaptation and mitigation strategies more vulnerable farming communities and factors that contributed in increasing the vulnerability need to be identified.

## 1.4 Objectives of the Study

**General Objective:**

This study focused on understanding the comparative vulnerability of farming communities associated with selected other field crops cultivated in the dry zone of Sri Lanka.

**Specific Objectives:**

a) To identify comparative vulnerability status of the farming communities undertaking different OFC cultivation.
b) To determine factors contributing to the vulnerability at farm household and crop production system level.
c) To provide a scientific basis for decision making on climate actions relating to selected crop production systems in the dry zone.

# CHAPTER TWO

# Review of Literature

## 2.1 Agricultural Vulnerability

The term vulnerability has been hypothesized differently by various subject area specialists according to their discipline of work. Conceptual approaches as well as methodologies on vulnerability analysis have been widely discussed ( Adger, 1999; Alwang et al.,2001; Fussel & Klein, 2006; Fussel,2007). Hence it is evident that the definition and the methodological approach to assess vulnerability vary largely(Deressa et al., 2008).

The IPCC Third Assessment Report (TAR) describes vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, 2001, p. 995). It describes the relationship between climate change sensitivity, adaptation and vulnerability as Equation 1 as described by McCarthy et al., 2001; Adger, 2003; Smit & Pilifosova, 2003 and Tiani et al., 2015.

Equation 1: Vulnerability = *f* (Exposure, Sensitivity, Adaptive Capacity)

## 2.2 Major Conceptual Approaches to Analyze Vulnerability to Climate Change

Three major conceptual approaches could be identified in the scientific literature when analyzing any system's vulnerability to climate change. The first is socio-economic, the second is bio-physical (impact assessment) and the third is integrated assessment approach (Basu, 2017). Furthermore, based on the direction of the approach taken to assess the climate vulnerability, there are three systems named top-down approach, bottom-up approach and integration of top-down and bottom-up approaches (Satapathy et al., 2014).

### 2.2.1 Socio-economic Approach

Adoption to climate change includes adjustments in socio-economic systems to reduce their vulnerability both to long-term shifts in average climate and changes in the frequency and magnitude of climatic extremes (Smit & Pilifosova, 2003). Thus, it is imperative to consider the socio-economic and institutional set up within the given community for the climate adaptation and enhanced resilience. This approach mainly focuses on the socio-economic and political status of individuals of social groups (Adger, 1999). Individuals in a community differ in respect of education, gender, wealth, health status, access to credit and etc. The socio-economic approach focuses on identifying the adaptive capacity of individual or communities based on their internal characteristics (Adger and Kelly, 1999). The main limitation of this approach is focusing only on variations within the society. However, societies vary not only due to socio-political factors but also due to environmental factors. This approach does not consider environmental based intensities, frequencies, probabilities such as drought and flood incidents. Further, availability of natural resource bases to potentially counteract the negative impact of this environmental shock is also not taken into account (Deressa et al., 2008).

### 2.2.2 Biophysical Approach

The biophysical approach focuses on sensitivity (like change in yield, income and health etc.) to climate change (Basu, 2017). This approach assesses the level of damage that a given environmental stress causes on both social and biological systems. Despite being highly informative, focusing mainly on physical damages (yield, income etc.) remains a major limitation. It fails to demonstrate the particular lost mean for different people. For example, a particular amount of yield loss incurred due to climate change does not account for similar implications for poor farmers and rich farmers alike (Deressa et al., 2008). However, although, capable of providing an overall understanding of the physical processes generating exposure, this perspective or the approach is limited as it excludes social, political, cultural, and economic factors that need to be addressed in the estimation of the climate vulnerability (Ford, 2002; Cardona, 2004). Therefore, this approach misses much of the adaptive capacity of individuals or social groups which is more explained by their inherent or internal characteristics (Adger,1999: Basu, 2017).

### 2.2.3 The Integrated Assessment Approach

The integrated assessment approach combines both socio-economic and biophysical approaches to determine vulnerability (ibid). In this approach both biophysical and socio-economic approaches are systematically combined to determine vulnerability (eg. Vulnerability mapping approach). By attempting to blend the two conventional perspectives on vulnerability, this approach is perceived as capable of providing a better and clearer understanding of the multiplicity of processes and dynamics affecting the vulnerability of the coupled system to climate change. This is particularly important in the context of policy-driven assessments aiming to provide measures to inform adaptation policy towards reducing vulnerability to climate change (Fussel and Klein, 2006). The main limitation of this approach is absence of a standard method to combine the biophysical and socio-economic indicators. This approach uses different data sets such as socio-economic data and biophysical data and these data sets have different yet unknown weights. Another weakness of this approach is the failure to account for the dynamism in vulnerability. Despite of those weaknesses this approach is highly useful in terms of making policy decisions (Eriksen and Kelly, 2007; Deressa, Hassan & Ringles, 2008).

## 2.3 Methods to Measure Vulnerability to Climate Change

There are two types of analytical methods for measuring vulnerability. One is Econometric Method and the other is Indicator Method.

### a) Econometric Method

This method uses household level socio-economic survey data to analyze the level of vulnerability of different social groups. It involves measuring the level of vulnerability of such social groups using socio-economic data sets from households. In this method three categories could be identified as vulnerability as expected poverty (VEP), vulnerability as low expected utility (VEU) and vulnerability as uninsured exposure to risks (VER). Regardless of the differences all these three categories construct a measure of welfare loss attributed to shocks but differ in that VEP and VEU measure ex-ante welfare loss whereas VER measures ex-post welfare loss due to shocks (Deressa et al., 2009). This approach employs regression analysis methods. The main limitation of the econometric approach is the testing of several econometric assumptions based on hypothesis, confidence intervals and standard errors, and also attributing causation without stringent assumptions (Kuwornu, 2019).

### b) Indicator Method

This method of quantifying vulnerability is based on selecting some indicators from the whole set of potential indicators and systematically combining the selected indicators to indicate the level of vulnerability. Using these composite indicators vulnerability could be analyzed at local, national and global scales (ibid). Two options are available for calculating the level of vulnerability using this method at any scale. The selected indicators should be able to represent both biophysical conditions of the study area as well as the socio-economic conditions of respective farming communities (Gbetibouo, Ringler & Hassan, 2010).

Two common assumptions in the process of using indicators to calculate vulnerability prevail:

1. Assuming that all indicators of vulnerability have equal importance and therefore giving them equal weights.
2. Assigning different weights to avoid uncertainty of equal weight in given the diversity of indicators use. Certain methodological approaches suggested to adopt in assigning weights to indicators could be found in the scientific literature. Some of these approaches are as follows:
    - I. Use of expert judgement (Kaly & Pratt,2000)
    - II. Principal component analysis (Easter, 1999; Cutter, Boruff & Shirley,2003)
    - III. Co-relation with past disaster events (Brooks, Adger & Kelly, 2005)
    - IV. Use of fuzzy logic (Eakin & Tapia, 2008)

A limitation of this method is its appropriateness remain skeptical due to absence of a standard way in method against which each method is tested for precision.

The likely subjectivity on the part of the researcher in selecting the components to be included in computing the index is also a major limitation of this approach. However, the indicator approach is preferred to the econometric approach because of its practicality and ease of interpretation (Basu, 2017). In using indicators for vulnerability calculation, two methods have been used in the literature; livelihood vulnerability index (LVI) and vulnerability index as per the IPCC approach. In addition to describing the vulnerability to environmental stresses the LVI takes into consideration the current level of vulnerability which is useful for current planning (Hahan, Riederer & Foster, 2009).

# CHAPTER THREE

# Research Methodology

## 3.1 Conceptual Framework of the Study

As per the definition of the IPCC on climate change and the strengths and weaknesses of the available vulnerability assessment approaches the present study adopted the integrated vulnerability assessment approach which considers both biophysical and socio-economic indicators in assessing the vulnerability.

Therefore, vulnerability of a crop production system to climate change is conceptualized as a function of the system's exposure to climate change and its capacity to adapt to the impacts (Figure 3.1). That is basically a system which is more exposed to climate stimuli and more sensitive to damages assuming constant adaptive capacity and vice versa (Table 3.1 and Table 3.2).

**Table 3.1: Two Dimensions of Vulnerability**

| | **Sensitivity Level** | **Resilience** | |
|---|---|---|---|
| | | **High** | **Low** |
| Sensitivity | High | Vulnerable | Very Vulnerable |
| | Low | Not Vulnerable | Vulnerable |

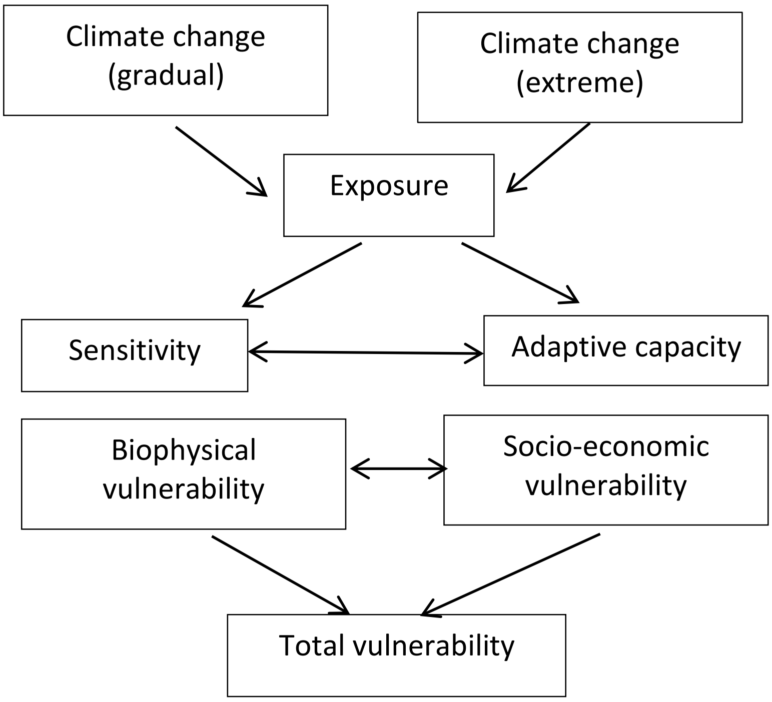
Source: Alwang, Siegel & Jorgensen (2001)

**Table 3. 2: Vulnerability: Hazard Exposure and Capacity to Cope**

| | **Exposure Level** | **Capacity to Cope** | |
|---|---|---|---|
| | | **High** | **Low** |
| Hazard Exposure | High | Low Vulnerability | High Vulnerability |
| | Low | Very Low Vulnerability | Low Vulnerability |

Source: Alwang, Siegel & Jorgensen (2001)

Farmers are exposed to both gradual and extreme climate change events. Exposure has an impact on sensitivity. The exposure to higher frequencies and higher intensities of climate risk highly affects the outcome (yield, income, health). Exposure is also linked to adaptive capacity. Higher adaptive capacity reduces the potential damage from higher exposure. Sensitivity and adaptive capacity are also linked; under a fixed level of exposure the adaptive capacity influences the level of sensitivity. Higher adaptive capacity (socio-economic vulnerability) results in lower sensitivity (biophysical vulnerability) and vice versa. Therefore, sensitivity and adaptive capacity add up to total vulnerability.




Source: Adapted from Deressa et al. (2008)

**Figure 3.1: Conceptual Framework for Vulnerability Assessment**

For measuring the vulnerability, the indicator method was used. The Livelihood Vulnerability Index (LVI) was calculated to obtain the overall vulnerability status of communities and households. The LVI was composed using multiple indicators to assess exposure, sensitivity and adaptive capacity.

## 3.2 Selection of Indicators

Selection of indices for the present study was carried out carefully in several steps. Initially a comprehensive review of literature was undertaken. As the next step, potential indicators were chosen from the whole set of indicators. The Table 3.3 presents the comprehensive set of indicators used in assessing the level of vulnerability to the climate change in previous studies in different agricultural and agrarian set ups. The agrarian context of Sri Lanka and the availability of data at field level and using the knowledge and experience of key informants and members of the research team were taken into account in selecting the indicators. Two sets of data were used to calculate two vulnerability levels: the system level vulnerability and the household level vulnerability. The selected indicators are described in the following sections.

**Table 3.3: Indicators Used in Climate Vulnerability Assessment Studies**

| Determinant of vulnerability | Indicator | Subcomponent | Reference |
|---|---|---|---|
| Sensitivity | (LVI - IPCC) | | Hahn et al., 2009; Ashok and Sasikala, 2012; Khajaria and Ravindranath, 2012; Etwire et al., 2013 |
| | Health | Average time to health facility | |
| | | No. of HH with family member with chronic diseases | |
| | | No. of HH where family member had to miss work or school in the last weeks due to illness | |
| | Food | % of HH dependent on family farm for food | |
| | | Average no. of months HH struggle to find food | |
| | | Average crop diversity index | |
| | | % of HH that do not save harvest | |
| | | % of HH that do not save for seeds | |
| | Water | % of HH reporting water conflicts | |
| | | % of HH that utilize natural water source | |
| | | Average time to reach the water source | |
| | | % of HH that do not have a consistent water supply | |
| | | Inverse of the average volume of water (litres) stored per HH | |
| | Human sensitivity | Rural population density | Eriyagama, 2010 |
| | | % employed in agriculture | |
| | | % of paddy area served by major irrigation schemes | |
| | | Farm diversity ( Crop diversity index, livestock number, Fish production quantity) | |
| | Rainfall volume | Average daily values for 10 years | Mallari and Alyosha, 2016 |
| | Average typhoon wind speed | | |
| | Plant growth stage during typhoon | | |
| | Extreme climate | Frequency of floods and drought | Deressa et al., 2008 |
| | Fatalities | Death of family member due to climate related disaster (10 yrs) | Piya et al., 2012 |
| | Damage to properties | Total land damaged by flood/landslide (10 yrs) | |
| | | Total livestock death | |
| | | Total crop damage | |

| Determinant of vulnerability | Indicator | Subcomponent | Reference |
|---|---|---|---|
| Sensitivity | Income structure | Share of natural resource based income to total income | |
| | | Share of non natural based remunerative income to total income | |
| | Net sown area/geographical area | | Sehgal et al., 2013 |
| | Productivity | | |
| | Water holding capacity of soil | | |
| | Organic carbon content in soil | | |
| | Average landholding of farmer | | |
| | Human population density | | |
| | | | |
| Adaptive capacity | Socio demographic profile | Dependency ratio | Hahn et al., 2009; Ashok and Sasikala, 2012; Khajaria and Ravindranath, 2012; Etwire et al., 2013 |
| | | % of female headed HH | |
| | | % of HH where head of HH not attended school | |
| | | % of HH with orphans | |
| | Livelihood strategies | % of HH with family member working in a different community | |
| | | % of HH depend solely on agriculture as income | |
| | | Average agricultural diversification index | |
| | Social networks | Average receive: give ratio | |
| | | Average borrow: lend money | |
| | | % of HH that have not gone to their local government for assistance in the past 12 months | |
| | | | |
| | Technology | Age | Ashok and Sasikala, 2012 |
| | | Education | |
| | | Household size | |
| | | Farming experience | |
| | | Extension services | |
| | | Climate information | |
| | | Land ownership | |
| | | Insecticide and pesticide supply | Deressa, et al., 2008 |
| | | Fertilizer supply | |
| | | Improved seed supply | |

| Determinant of vulnerability | Indicator | Subcomponent | Reference |
|---|---|---|---|
| Adaptive capacity | Irrigation | % of HH with well irrigation | Ashok and Sasikala, 2012 |
| | | % of irrigated area | |
| | | % of HH buying well water | |
| | | Irrigation potential | Deressa et al., 2008 |
| | Socio economic assets | % population pasing Ordinary Level Examination | Eriyagama, 2010 |
| | | Poverty head count index | |
| | | Poverty gap ratio | |
| | | Share of agricultural drought | |
| | Infrastructural assets | Road density | Eriyagama, 2010 |
| | | % of houses having electricity | |
| | | Communication index ( composite index, landlines, cellular subscribers, number of internet users | |
| | Infrastructure and institutions | All weather roads | Deressa, et al., 2008 |
| | | Health services | |
| | | Telephone services | |
| | | Primary and secondary schools | |
| | | Veterinary services | |
| | | Food market | |
| | | Microfinance | |
| | **Institution** | | Mallari and Alyosha, 2016 |
| | Access to crop insurance | | |
| | Access to weather forecasting information | | |
| | Update of crop calendar | | |
| | Wealth | Livestock ownership | Deressa, et al., 2008 |
| | | Ownership of radio | |
| | | Quality of residential home | |
| | | Non-agricultural income | |
| | | Gift and remittance | |
| | Literacy rate | Literacy rate age 10 years and older | |
| | Physical assets | Type of house | Priya et al., 2012 |
| | | Have device to access information (mobile, radio) | |
| | | Walking distance to nearest motor road | |
| | | Irrigated land | |
| | Human assets | Highest qualification in family | |
| | | Dependency ratio | |

| Determinant of vulnerability | Indicator | Subcomponent | Reference |
|---|---|---|---|
| | | Training or vocational course attended by family member | |
| | Natural assets | Share of more productive land possessed | |
| | | Share of less productive land | |
| | | Have bullock | |
| | Financial assets | Gross household annual income | |
| | | Livelihood diversification index | |
| | | Total HH savings | |
| | | Ownership of livestock | |
| | Social assets | Membership in organizations | |
| | | Access to credit | |
| | Irrigated area | | Shegal, et al., 2013 |
| | Human development index | | |
| | Cropping intensity | | |
| | Livestock density | | |
| | Villages electrified | | |
| | Villages with paved roads | | |
| | Fertilizer consumption | | |
| Exposure | Natural disasters and climate variability | Average no. of flood and droughts | Hahn, et al., 2009; Ashok and Sasikala, 2012; Khajuria and Ravindranath, 2012, Etwire, et al., 2013 |
| | | % of HH that did not receive a warning about the pending natural disasters | |
| | | % of HH with injury or death due to natural disasters | |
| | | Daily precipitation data | |
| | | Daily temperature data | |
| | Frequency of exposure to droughts and floods | | Eriyagama, 2010 |
| | change in climate | Change in temperature and precipitation | Deressa, et al., 2008 |
| | Historical change in climate variables | Rate of change in average annual min. temperature | Piya, et al., 2012 |
| | | Rate of change in average annual max. temperature | |
| | | Rate of change in average annual precipitation | |
| | Extreme climate events | Frequency of climate related natural disasters (10 years) | |

| Determinant of vulnerability | Indicator | Subcomponent | Reference |
|---|---|---|---|
| | Rate of change in max, min temperature | | Shegal, et al., 2013 |
| | Frequency of low, high rainfall | | |
| | Severity of low, high rainfall | | |
| | Production areas affected | | Mallari, 2016 |
| | No. of affected farmers | | |
| | Extent of affected farm houses, infrastructure, post harvest equipment | | |
| | No. of typhoons in 5 years | | |

### 3.2.1 Indicators Used in Calculating System Level Vulnerability

Considering the availability and the practicability of obtaining data and information with the necessary accuracy, of a total of 53 indicator (consisting of 122 sub components) compiled, 19 key indicators were selected for this study (Table 3.4 and Table 3.5).

#### 3.2.1.1 Indicators of Adaptive Capacity

1. Own Land Extent
   Land ownership is a physical asset to the farmer (Khoshnodifar, Sookhtanlo & Gholami, 2012). The higher land extent increases farmers' adaptive capacity and reduce the level of vulnerability (Piya *et al.,* 2012). Certain studies have considered land ownership and extent as an indicator for sensitivity (Gbetibouo, Ringler & Hassan, 2010). In this study total land extent owned by farmer is taken as an indicator to represent the adaptive capacity.

2. Total Crop Production
   Production from different crops increases farmers' income as well as the level of resilience to the climate change impacts than that from a single crop (Wirehn, 2018). Therefore, total yield from different crops increases farmers' adaptive capacity and reduce the level of vulnerability. Total crop yield from all crops cultivated at the reference period was used to represent this indicator.

3. Income

   Total income of the family is a major factor that determines their adaptive capacity to face difficult conditions. Income from different economic activities increases their adaptive capacity. The higher total income of the family increases the adaptive capacity and reduces the level of vulnerability (Gbetibouo*,* Ringler & Hassan, 2010; Khoshnodifar et al*.,* 2012; Below et al., 2012; Piya et al*.,* 2012). Total income from all activities by all family members in a given household during the entire year is considered in this indicator.

4. Dependency Ratio

   Dependency ratio of a household is the ratio of the number of family members under 15 and over 65 years to the number of economically active family members (Ashok and Sasikala, 2012). Higher dependency ratio results in lower adaptive capacity in the households and increases the level of vulnerability (Hahan, Riederer & Foster, 2009; Below et al., 2012; Piya et al., 2012; Mendoza et al., 2014). Dependency ratio is calculated for individual households as follows (UN, 2006).

   Equation 2:

$$Dependency\ ratio = \frac{Family\ members\ below\ 15\ years\ age\ and\ over\ 65\ years\ age}{Economically\ active\ family\ members}$$

5. Level of Education

   Educational level of a farmer increases the adaptive capacity by increasing access to information, decision making and enhance their ability to cope with adverse climatic conditions. The higher educational level of a farmer will reduce the level of vulnerability. (Gbetibouo*,* Ringler & Hassan, 2010; ; Khoshnodifar et al., 2012; Mendoza et al., 2014; Nauman et al., 2014 ,).

6. Agriculture Diversification Index

   Climate change affects varied agricultural activities differently. Therefore, diversification of agricultural activities may reduce the level of vulnerability to climate change (Reidsma, Ewert & Lansink, 2007). In a few studies, agriculture diversification index is used as an indicator of sensitivity (Gbetibouo*,* Ringler & Hassan, 2010). However, in this study it is considered an indicator of adaptive capacity as farmers with different agricultural activities are more adaptive to climate change. Agriculture diversification reduces the vulnerability of a farmer to climate change and it is calculated as follows (Etwire et al., 2013; Khajaria and Ravindranath, 2012).

   Equation 3:

$$Agriculture\ diversification\ index = \frac{1}{(Number\ of\ agricultural\ activities + 1)}$$

7. Household Size
   Household size or the number of family members is a major factor that determines the climate vulnerability of a household. Larger families with more economically active members can be considered human capital which increases adaptive capacity and reduces the level of vulnerability. (Below et al., 2012: Khajuria & Ravindranath, 2012). Gbetibouo*,* Ringler & Hassan (2010) has considered family size an indicator to determine the sensitivity. However, in this study it is used to determine the adaptive capacity.

8. Farming experience
   A number of years that household head has worked as an independent decision maker for farming activities is considered as farming experience of that household (Below et al., 2012). More the experience higher the ability of farmer in decision making in extreme situations. Therefore, it increases farmers' and household's adaptive capacity while reducing the level of vulnerability (Gouda, 2020).

9. Membership in Organizations
   Having membership in different organizations is a social capital to the farmer (Gbetibouo*,* Ringler & Hassan, 2010). Membership in organizations creates social networks and it helps make financial support, access to information on new technologies and overcome the problems faced during farming (Deressa, Hassan & Ringles, 2008; Khoshodifar et al*.,* 2008; Piya et al*.,* 2012). Therefore, being a member/s in organizations increases the level of adaptive capacity and reduces the level of vulnerability to changing climate. In this study, the total number of memberships in organizations that all family members have is taken into account to represent this indicator.

#### 3.2.1.2 Indicators of Sensitivity

1. Total Cultivated Land Extent
   Farm land size is major factor that determines the sensitivity of farmer to climate changes (Khoshnodifar et al*.,* 2012). Higher cultivated land extent increases the sensitivity of the farmer and increases the level of vulnerability. Total cultivated land extent of specific crop in three seasons (*Yala, Maha* and intermediate) during the reference period is considered to represent the land extent indicator for this study.

2. Production Loss due to Drought/Flood
   Production loss due to extreme climate events increases the sensitivity of household and increases their vulnerability to climate changes (Piya et al., 2012; Khajuria & Ravindranath, 2012). Long dry spells and drought were the major extreme climatic events faced by dry zone farmers during the reference period of the study. Therefore, production loss due to prolonged dry spell/drought in the major crop cultivated by each farmer is considered as the indicator to represent the sensitivity of the individual household.

3. Suitability of Soil
   Soil is considered a main natural resource that supports crop growth. Different crops perform different growth patterns in different soil conditions. Therefore, suitability of soil for the particular crop is an indicator of the better plant growth while it assists in reducing the impacts of extreme climatic events on crop growth (Swain & Swain, 2011; Below et al., 2012; Murthy et al., 2014: Singh & Singh, 2017). Higher suitability of soil for selected specific crop reduces the sensitivity and the vulnerability to climate change.

4. Type of Water Source for Cultivation
   Water source is a major determinant of the crop cultivation and it has been a key plant growing factor having adverse impacts of climate change. As described in previous sections, the impacts of the changing climate would be large in the dry zone areas where a agriculturally intensive areas located and are experiencing water stress (Eriyagama et al., 2010). The source of irrigation water for crop production has been considered an important indicator in climate sensitivity (Pulhin et al., 2016). Farmers using major and minor irrigation schemes as their water source of irrigation is comparatively less sensitive as opposed to those use agro-well or tube well who are moderately sensitive. Rainfed farmers are highly sensitive and highly vulnerable to climate change.

5. Income Ratio
   Households that solely depend on agriculture are more vulnerable to climate change impacts (Ashok & Sasikala, 2012). Availability of alternative economic activities provides an indicator of the ability of farmers in a region to shift to other economic activities in response to reduced agricultural income possibly due to adverse climatic conditions such as droughts (Gbetibouo et al, 2010). Therefore, the income of different economic activities was selected to represent the sensitivity of household to climate change. The income ratio of the household is calculated as follows.

   Equation 4:

   $$\text{Income ratio} = \frac{\text{On farm income}}{\text{Total income (Off farm income + non-farm income)}}$$

6. Number of Family Members with Chronic Diseases
   A family member with chronic disease requires extra attention and time. Generally, a person with chronic disease cannot survive on her/his own. Such a situation increases the sensitivity level of that household specially in extreme situations (Ashok & Sasikala 2012; Hahn et al., 2009).

7. Number of Sick Days
   Human health performs both as a contributor to practice and as an outcome of climate change-related circumstances (Berry et al., 2011). Health is an essential component of the capacity to adapt to climate change and psychological health is

an essential component of resilience (Drought Policy Review Expert Social Panel, 2008). Number of sick days of any family member will affect his/her involvement in income generation activities (Ashok & Sasikala 2012; Hahn, et al., 2009). Higher number of sick days increases the sensitivity and the vulnerability level. In this study, the total number of sick days of all family members during the reference year is used to represent this indicator.

8. Total Medical Cost
   The total cost spent on medical treatment during the reference period was considered as an indicator of sensitivity in household. There is a positive co-relation between the medical cost and the sensitivity of household as well as the level of vulnerability.

9. Average Days of Food Shortages
   The total number of days that the households experience food shortage during the reference period was counted. Again the number of days with food shortages has a positive correlation with the sensitivity of households the level of vulnerability (Hahn, et al., 2009; Khojuria and Ravindranath, 2012).

10. Unsettled Loans
   Unsettled loans and or debt of any household contribute to increased sensitivity of the particular household thereby raising the level of vulnerability (Niles et al., 2015). The total amount of unsettled loans during the reference period was considered to represent this indicator.

Equation 5:

$$Total\ amount\ of\ unsetteld\ loans = Total\ amount\ obtained\ through\ loans - Total\ amount\ repaid$$

**3.2.1.3 Indicators of Exposure**

This refers to the frequency of a crop production system exposed to extreme weather events such as floods, droughts, landslides and cyclones. Since this study considers only crop production systems operating in the dry zone, only drought and flood events were considered extreme climatic events. Thus, the sub-indices of exposure are drought hazard index and the flood hazard index (Anandhi, et al., 2016).

Equation 6:
Exposure Index = Drought Hazard Index + Flood Hazard Index

For a better understanding about the exposure level of households/crop production systems data over a considerable time period is needed. Since the site-specific information (on farm lands/crop production sites) could not be received for a considerable period, the average values at district levels were considered in this study. The exposure maps developed on district basis (Figure 3.1 and Figure 3.2) using long term data were utilized in this study. Further, the information derived from the maps was validated through key informant discussions. It was hypothesized in this study that higher the incidence of extreme events, higher will be the exposure of those communities and crop production systems.

Table 3.4 and Table 3.5 describe the indicators used in analyses and their functional relationships to the chosen indicators and methods of measurements.

**Table 3.4: Indicators for Adaptive Capacity**

| Indicator | Description | Expected Relationship with the Vulnerability | Scale of Analysis | Unit |
|---|---|---|---|---|
| 1. Own land extent | Total land extent owned by the farmer | Higher the land extent, higher the adaptive capacity, and lower the vulnerability (Positive) | Household level | ha |
| 2. Crop Production | Average production of all crops in *Yala*, *Maha* and intermediate seasons | Higher the production, higher the adaptive capacity, and lower the vulnerability (Positive) | Household level | kg |
| 3. Income | Total annual household income from all family members | Higher the income, higher the adaptive capacity, and lower the vulnerability (Positive) | Household level | Rs. |
| 4. Dependency ratio | Ratio of the number of family members under 15 and over 65 years age to the number of family members between 15 to 64 years age | Higher the dependency ratio, lower the adaptive capacity and higher the vulnerability (Negative) | Household level | No value |
| 5. Education level | The level of education of the household head | Higher the educational level, higher the adaptive capacity, and lower the vulnerability (Positive) | Household level | No of Years |
| 6. Agriculture diversification index | Total number of agricultural activities which the family members are engaged in | Higher the index value, higher the adaptive capacity, and lower the vulnerability (Positive) | Household level | No value |
| 7. Household Size | Total number of members in household | Higher the number of members, higher the adaptive capacity, and lower the vulnerability (Positive) | Household level | Number of members |
| 8. Farming experience | Total number of years engaged in farming activities | Higher the number of years, higher the adaptive capacity, and lower the vulnerability (positive) | Household level | Number of years |
| 9. Memberships in organizations | Total number of organizations in which the membership is held by any family member | Higher the number of memberships, higher the adaptive capacity, and lower the vulnerability (positive) | Household level | Number of organiza-tions |

**Table 3.5: Indicators for Sensitivity**

| Indicator | Description | Expected relationship with vulnerability | Scale of analysis | Unit |
|---|---|---|---|---|
| 1. Land extent of specific crop | Annual total land extent (*Yala, Maha*, intermediate seasons) of the specific crop/s | The higher the land extent, higher the sensitivity and higher the vulnerability (negative) | Household level | ha |
| 2. Production loss due to drought | Average production loss due to drought during the reference period for the specific crop/s | The higher the production loss, higher the sensitivity, the higher the vulnerability (negative) | Household level | % |
| 3. Soil | Suitability of soil for the specific crop/s | Higher the soil suitability for the specific crop/s, lower the sensitivity and lower the vulnerability (positive) | Household level | Weighted score<br>1 – Highly suitable<br>2 – Suitable<br>3 – Moderately<br>4 – Not suitable |
| 4. Type of water source for cultivation | Major water source used for crop cultivation | Higher value, lower the sensitivity and lower the vulnerability (positive) | Farming system (Community level) | Weighted score<br>1 – Rainfed<br>2 – Agro-well<br>3 – Minor irrigation<br>4 – Major irrigation |
| 5. Income ratio | Ratio between total non-farm income in household and total on-farm and off-farm income | Higher the income ratio, lower the sensitivity, and lower the vulnerability (positive) | Household level | No. Unit. proportion |
| 6. Number of family members with chronic diseases | Number of family members with chronic diseases | Higher the number of family members with chronic diseases, the higher the sensitivity and higher the vulnerability (negative) | Household level | No. unit. Number |
| 7. Number of sick days | Total number of sick days for all family members in reference period | Higher the number of sick days, higher the sensitivity and higher the vulnerability (negative) | Household level | No. of days |
| 8. Medical cost | Total medical cost for all family members in the given reference period | Higher the medical cost, higher the sensitivity and higher the vulnerability (negative) | Household level | Rupees |
| 9. Days of food shortage | Total number of days with food shortages in reference period | Higher the number of days, higher the sensitivity, and higher the vulnerability (negative) | Household level | Number of days |
| 10. Unsettled loans | Total amount due | Higher the amount of remaining loans to be paid, higher the sensitivity, and higher the vulnerability (negative) | Household level | Rupees |

### 3.3 Study Area and Sample Selection

The multi stage sampling technique was employed to draw the sample of this study. The sample unit was the farm households (farmers) involved in crop production in the dry zone areas of Sri Lanka. In the first stage, the main crop production systems other than paddy undertaken in the dry zone were selected considering the cultivation extent under each production system. In that case, crops selected to be studied on the vulnerability status were maize, green gram, black gram, big onion, red onion and groundnut. In the next stage, the geographical locations (District and Agrarian Service Center Area) in which the said crop production systems are intensively practiced were selected taking the extent and type/s of irrigation system into consideration.

In the final stage, the sample farmers (farm households) were randomly selected from the list of purposively selected farmers who have been continuously undertaking farming during the last 10 years. The said list of farmers were prepared beforehand with the consultation of extension managers and extension workers (Divisional Development Officers, Agricultural Instructors and Agricultural Research and Production Assistants) in respective study locations. Forty 40 farmers were randomly selected from each location considering the time and resource availability. The details of the sample are given in Table 3.6.

**Table 3.6: The Details of the Sample Distribution**

| Crop | Type of Irrigation | Location | | Sample Size |
|---|---|---|---|---|
| | | **District** | **Agrarian Service Center** | |
| Maize | Rainfed | Anuradhapura | Galenbindunuwewa | 40 |
| | Major | Anuradhapura | Nochchiyagama | 40 |
| Big onion | Minor | Matale | Dambulla | 40 |
| | Major | Anuradhapura | Negampaha, Ipalogama | 40 |
| Red onion | Agro-well | Jaffna | Urampirai | 38 |
| | Agro-well | Puttalam | Palakuda | 41 |
| Greengram | Major | Moneragala | Buththala | 41 |
| | Rainfed | Moneragala | Thanamalwila | 32 |
| | Major | Hambantota | Weerawila | 40 |
| | Rainfed | Hambantota | Yodakandiya | 44 |
| Blackgram | Rainfed | Anuradhapura | Pemaduwa | 40 |
| | Rainfed | Vavuniya | Chettikulama | 40 |
| Groundnut | Rainfed | Mullaitivu | Alambal | 42 |
| **Total** | | | | **518** |

### 3.4 Data Collection

The study was conducted using both primary and secondary data and information collected applying different data collection tools. The primary data was mainly collected through administering a structured questionnaire-based household survey over 518 farm households described in the previous section. The questionnaire was pre-tested over two rounds to ensure that it covers all the aspects needed to be studied. The household survey was conducted following the face-to-face interview method by a group of agricultural graduates recruited as the enumerators for this study. The enumerators were trained on conducting the particular survey using the designated questionnaires. In the field level, the enumerators were supervised by the researchers and the statistical staff of this study. The comprehensive structured questionnaire was used to gather farmers' socio-economic conditions, agricultural and other livelihood information as well as the information on exposure, sensitivity and the adaptive capacity with regard to the climate vulnerability of the target farming communities.

In addition to the questionnaire survey, the primary data and information was collected through conducting focus group discussions (FGDs) and key informant interviews (KIIs) as well. The FGDs and KIIs were very much useful to collect the information on common agricultural activities practiced by farmer communities and natural disasters occurred in the area concerned during the time period considered in this study.

## 3.5 Data Analysis

The data analysis was conducted targeting all the objectives.

**Specific Objectives a. and b.**

a. To identify comparative vulnerability status of the farming communities undertaking different OFC cultivation.
b. To determine factors contributing to the vulnerability at farm household and crop production system level.

Index values obtained for vulnerability, sensitivity and the exposure were used to achieve the specific objectives a. and b.

### Calculation of Vulnerability Index

Vulnerability Index (VI) was calculated adopting the following Equation (Fay & Ebinger, 2010);
Equation 7:

$$VI = (Exposure - Adaptive\ Capacity) * Sensitivity$$

Final exposure, adaptive capacity and sensitivity values were derived using number of sub components. Weights were assigned for each sub component using experiences of the research team and knowledge gained through the literature review. Overall sensitivity of the farming community was calculated considering the three sub components; —agricultural sensitivity, household sensitivity and financial sensitivity.

Agricultural sensitivity was composed using the indicators i.e. total cultivated area by the specific crop, average loss of production, suitability of soil for that particular crop and type of water source for irrigation. Indicators used in calculating household sensitivity was the number of family members with chronic diseases, number of sick days of the farmer, medical expenses of the household and average number of days suffered from food shortage. Financial sensitivity was obtained using income ratio and unsettled loans. It was assumed that contribution of subcomponents to the—agricultural sensitivity, household sensitivity and financial sensitivity —is 50 per cent, 25 per cent and 25 per cent respectively for the overall sensitivity.

Three sub components: social capital, human capital and asset index, were used in computing the final adaptive capacity of the respective farming community. Weights allocated for each subcomponent was 25 per cent for social capital, 25 per cent for human capital and 50 per cent for asset index. Indices considered in computing social capital were household size, number of memberships in community organizations and the dependency ratio. Level of education and farming experience were considered in calculating human capital index. Final asset index was obtained considering the indices: total own land extent, average production, total income of the household and agriculture diversification index.

Exposure of each farming community was obtained using respective flood index and drought index values as those two are the most relevant climate parameters for the study area considered in the present study. Thus, equal weight was given to those two parameters.

### 3.5.1 Analysis on Determinants of Farmer Vulnerability to Climate Change

The plight of farmers and effective adaptation strategies can only be articulated and mainstreamed into the nation’s climate change programmes when the determinants of agricultural vulnerability are appraised. Therefore, multiple linear regression model was used to examine the relationships between the agricultural vulnerability to climate change and its determinants at farmer level.

The index value for each individual farmer was calculated by using the exposure, sensitivity and adaptive capacity data and in this process, the calculated agricultural vulnerability index of the farmers to climate change was used as the dependent variable. It was assumed that this index provides a directly observable proxy for vulnerability and was necessary for determining the factors that influence households’ vulnerability to climate change impacts.

**Table 3.7: The Summary of the Explanatory Variables and Expected Signs Used in the Regression Model**

| Variable definition | Unit | Expected sign[a] |
|---|---|---|
| Age of the household head | Years | - |
| Household size | Number of family members | + |
| Farming experience | Years | - |
| Gender of the household head | Dummy 1 = male and 0 = female | - |
| Education | Years | - |
| Community membership | Number of community organizations involved | - |
| Land extent cultivated under specific crop | Acres | +/- |
| Agriculture diversification index | Index | - |
| Extension | Frequency of meeting extension officer | - |
| Location dummies (Matale district considered as the reference district) | | |
| Dis1 | Dummy 1 = Moneragala district and 0 = other | +/- |
| Dis2 | Dummy 1 = Anuradhapura district and 0 = other | +/- |
| Dis3 | Dummy 1 = Hambantota district and 0 = other | +/- |
| Dis4 | Dummy 1 = Jaffna district and 0 = other | +/- |
| Dis5 | Dummy 1 = Puttalam district and 0 = other | +/- |
| Dis6 | Dummy 1 = Mullaitivu district and 0 = other | +/- |
| Dis7 | Dummy 1 = Vavuniya district and 0 = other | +/- |
| Crop dummies (Groundnut considered as reference crop) | | |
| crop1 | Dummy 1 = Maize and 0 = other | +/- |
| crop2 | Dummy 1 = Big onion and 0 = other | +/- |
| crop3 | Dummy 1 = Black gram and 0 = other | +/- |
| crop4 | Dummy 1 = Green gram and 0 = other | +/- |
| crop5 | Dummy 1 = Red onion and 0 = other | +/- |
| Dummy variables for water source (Major irrigation considered as the reference) | | |
| water1 | Dummy 1 = Rainfed and 0 = other | + |
| water2 | Dummy 1 = Agro well and 0 = other | + |
| water3 | Dummy 1 = Minor irrigation and 0 = other | + |
| Primary employment | Dummy 1 = agriculture and 0 = other | + |

[a]The hypothesized influence of the variable, with positive indicating that a higher value of the variable is likely to increase vulnerability, while negative means a likely lower vulnerability

Table 3.7 presents the potential determinants and their influence hypothesized in the literature. To determine the extent to which these hypothesized variables capture different dimensions of vulnerability, the computed final vulnerability index was correlated with the factors hypothesized to influence the vulnerability. To determine the combined effect of the different hypothesized factors on households' vulnerability, regression analysis was performed using STATA for Windows, version 10 (SE). The regression analysis was used at five and one per cent levels of significance.

The econometric model used was;

Equation 8:

$$VI = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots \beta_k X_{ki}$$

Where;
VI = vulnerability index value for individual farmer
i = represent the *ith* observation in the sample
β 1, β 2… β k are regression coefficients of the explanatory variables to be estimated
X1, X2……. Xk are explanatory variables
$\beta_0$ is the constant term

**Specific Objective C:**

Scientific basis for decision making on climate action to minimize the vulnerability and for an enhanced climate resilience is provided using the findings of the 1st and 2nd objectives. The findings, conclusion and the recommendations derived in this study can be used as a scientific base for future climate actions with regard to different crop production systems in geographical locations studied in the dry zone of Sri Lanka. Further, the system-based approaches towards climate adaptation and enhanced resilience can also be determined using that scientific base. Even for a single specific crop cultivated in two different geographical locations under different irrigation and other conditions, the approach to be taken for enhanced climate resilience would be different, thus, in formulating such approach/es the findings of this study would be much useful as it can be considered as a scientific base.

# CHAPTER FOUR

# Results and Discussion

## 4.1 Comparative Vulnerability at Crop Production System Level

Owing to unavailability of long-term climate date for the respective Agrarian Service Center Areas, it was assumed that the exposure to climate change within the same district is similar in the present study. Therefore, if there are two crop production systems operating in a given district, difference in the vulnerability for two systems is solely attributed to the differences in sensitivity and the adaptive capacity.

### 4.1.1 The Exposure Levels of Study Area

In determining the exposure levels, the number of flood events as well as drought conditions occurred were considered. The mean number of days per year where rainfall is less than or equal to one millimeter was considered as the number of non-rainy days in a particular year. Only floods and droughts were considered in the exposure analysis as those two phenomena were the most common natural hazards in the study locations across the dry zone of Sri Lanka.

In computing exposure index of the Dambulla Agrarian Service Center (ASC) area, flood index values and drought incidence index values of the Anuradhapura district were considered as climatic parameters in Dambulla ASC area are similar to that of the Anuradhapura district though Dambulla belongs to the Matale administrative district. Both Dambulla and Anuradhapura areas share the same climatic and ecological characteristics as two areas belong to the same agro-climatic region, DL1.

The highest overall exposure level was recorded in the Hambantota district. Therefore, green gram cultivated in the district under rain fed and a major irrigation system is with the highest exposure levels (Table: 4.1). The different exposure level index of selected crop production systems are illustrated in Figure 4.1. The same condition has been highlighted in the Climate Change Vulnerability Data Book of the Ministry of Environment, Sri Lanka.

**Table 4.1: The Exposure Levels of Crop Production Systems in Respective Districts**

| District | Agrarian Service Center Area | Crop Production System | Flood Index | Drought Incidence Index | Exposure Index |
|---|---|---|---|---|---|
| Anuradhapura | Galenbindunuwewa<br>Nochchiyagama<br>Negampaha<br>Ipalogama<br>Pemaduwa | Blackgram - Rainfed<br>Big onion - Major<br>Maize - Major | 0.577 | 0.500 | 0.538 |
| Matale | Dambulla | Big onion - Minor | 0.577 | 0.500 | 0.538 |
| Hambantota | Weerawila<br>Yodakandiya | Green gram - Major<br>green gram - Rainfed | 0.731 | 1.000 | 0.865 |
| Jaffna | Urampirai | Red onion- Agro-well | 0.538 | 0.500 | 0.519 |
| Puttalam | Palakuda | Red onion- Agro-well | 1.000 | 0.500 | 0.750 |
| Mullaitivu | Alambal | Groundnut- Rainfed | 0.038 | 1.000 | 0.519 |
| Vavuniya | Chettikulama | Blackgram- Rainfed | 0.000 | 0.500 | 0.250 |
| Moneragala | Buththala<br>Thanamalwila | Maize- Rainfed<br>green gram- Major<br>green gram- Rainfed | 0.538 | 0.500 | 0.519 |

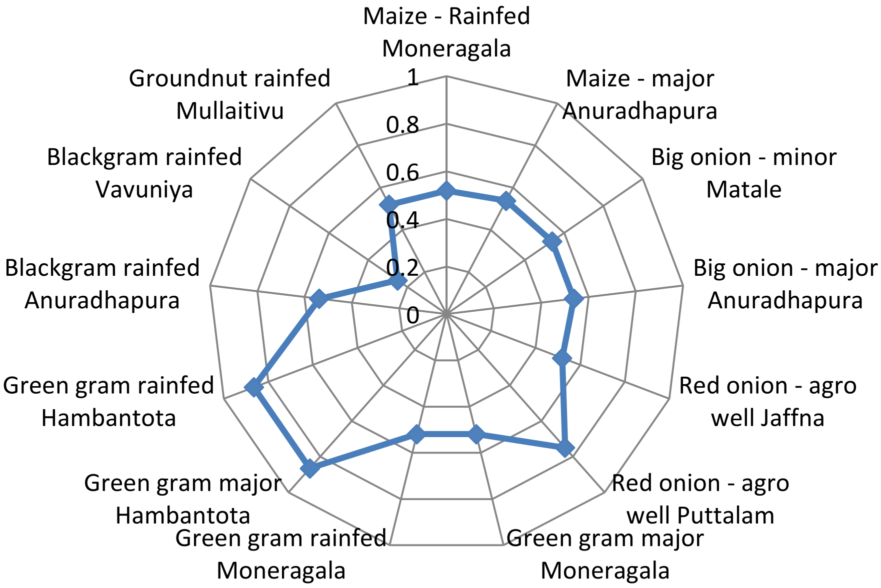



**Figure 4.1: The Exposure Levels of Different Crop Production Systems**

### 4.1.2 Sensitivity Levels of Communities

The household sensitivity describes each household's average medical costs, number of days of the year which farmer suffered from illness and unable to engage in farming activities (number of sick days) and average number of days that the household experienced food shortage. The sensitivity levels of farmer communities under different crop production systems, derived through the analysis of household level data is presented in the Table 4.2. Among three sub-indicators that make up the overall sensitivity, it could be observed that the household sensitivity is much diverse among different crop production systems. The lowest household sensitivity (0.042) was observed for groundnut cultivated under rainfed conditions in Mullaitivu district while the highest household sensitivity (0.131) was recorded in for green gram under the same rainfed conditions in the Moneragala district.

The highest value (0.580) for the financial sensitivity which was computed using two indicators; income ratio and unsettled loans, was also observed for groundnut farming under the rainfed systems in the Mullaitivu district (Figure 4.2). This situation can be attributed to the less opportunities for non-farm income earning activities in the civil war ravaged area. It was noted that the agricultural sensitivity that taken into the account of the indicators; total cultivated area by the specific crop, average loss of production, suitability of soil for that particular crop and type of water source for irrigation, was generally higher in rainfed systems compared to the crop cultivation major and minor irrigation schemes.

**Table 4.2: Sensitivity Status of Different Crop Production Systems**

| System | Sensitivity | | | Overall Sensitivity |
|---|---|---|---|---|
| | Agricultural Sensitivity (50%) | Household Sensitivity (25%) | Financial Sensitivity (25%) | |
| Maize – Rainfed, Moneragala | 0.390 | 0.099 | 0.509 | 0.116 |
| Maize – Major, Anuradhapura | 0.345 | 0.122 | 0.436 | 0.104 |
| Big onion – Minor, Matale | 0.290 | 0.042 | 0.389 | 0.084 |
| Big onion – Major, Anuradhapura | 0.229 | 0.065 | 0.496 | 0.085 |
| Red onion - Agro well, Jaffna | 0.437 | 0.028 | 0.422 | 0.110 |
| Red onion - Agro well, Puttalam | 0.326 | 0.042 | 0.488 | 0.099 |
| Green gram – Major, Moneragala | 0.272 | 0.072 | 0.387 | 0.084 |
| Green gram – Rainfed, Moneragala | 0.432 | 0.131 | 0.408 | 0.117 |
| Green gram – Major, Hambantota | 0.349 | 0.038 | 0.402 | 0.095 |
| Green gram – Rainfed, Hambantota | 0.438 | 0.125 | 0.288 | 0.107 |
| Black gram – Rainfed, Anuradhapura | 0.569 | 0.119 | 0.259 | 0.126 |
| Black gram – Rainfed, Vavuniya | 0.348 | 0.042 | 0.330 | 0.089 |
| Groundnut – Rainfed, Mullaitivu | 0.387 | 0.014 | 0.580 | 0.114 |

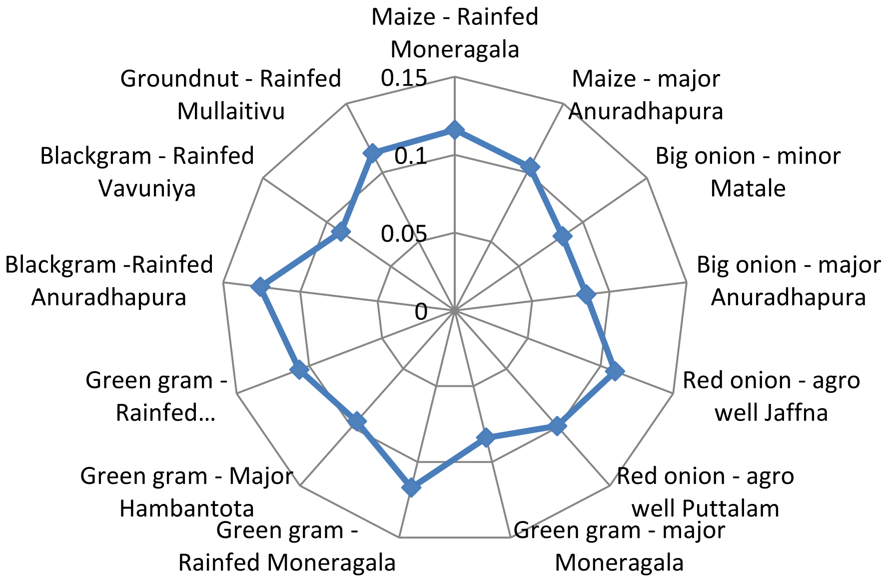



**Figure 4.2: The Sensitivity Status of Different Crop Production Systems**

### 4.1.3 Level of Adaptive Capacity of Communities

The indices; social capacity index, human capital index and asset index, form the overall adaptive capacity of a given crop production system. The human capital index derived from the level of education of the farmer and his/her experience in farming and the asset index have not shown much difference among crop production systems (Table 4.3).

**Table 4.3: Adaptive Capacity at Crop Production Level**

| Crop Production System | Adaptive Capacity | | | Overall Adaptive Capacity |
|---|---|---|---|---|
| | Social Capacity Index (25%) | Human Capital (25%) | Asset Index (50%) | |
| Maize – Rainfed, Moneragala | 0.409 | 0.489 | 0.266 | 0.119 |
| Maize – Major, Anuradhapura | 0.414 | 0.574 | 0.318 | 0.135 |
| Big onion - Minor, Matale | 0.428 | 0.535 | 0.255 | 0.123 |
| Big onion – Major, Anuradhapura | 0.409 | 0.511 | 0.238 | 0.116 |
| Red onion - Mgro well, Jaffna | 0.364 | 0.441 | 0.303 | 0.118 |
| Red onion - Agro well, Puttalam | 0.316 | 0.474 | 0.257 | 0.109 |
| Black gram – Major, Moneragala | 0.586 | 0.485 | 0.251 | 0.131 |
| Black gram - Rainfed, Moneragala | 0.528 | 0.445 | 0.286 | 0.129 |
| Black gram - Majo,r Hambantota | 0.394 | 0.408 | 0.353 | 0.126 |
| Black gram - Rainfed, Hambantota | 0.172 | 0.274 | 0.207 | 0.072 |
| Black gram - Rainfed, Anuradhapura | 0.482 | 0.509 | 0.259 | 0.126 |
| Black gram – Rainfed, Vavuniya | 0.344 | 0.377 | 0.251 | 0.102 |
| Groundnut – Rainfed, Mullaitivu | 0.257 | 0.383 | 0.280 | 0.100 |

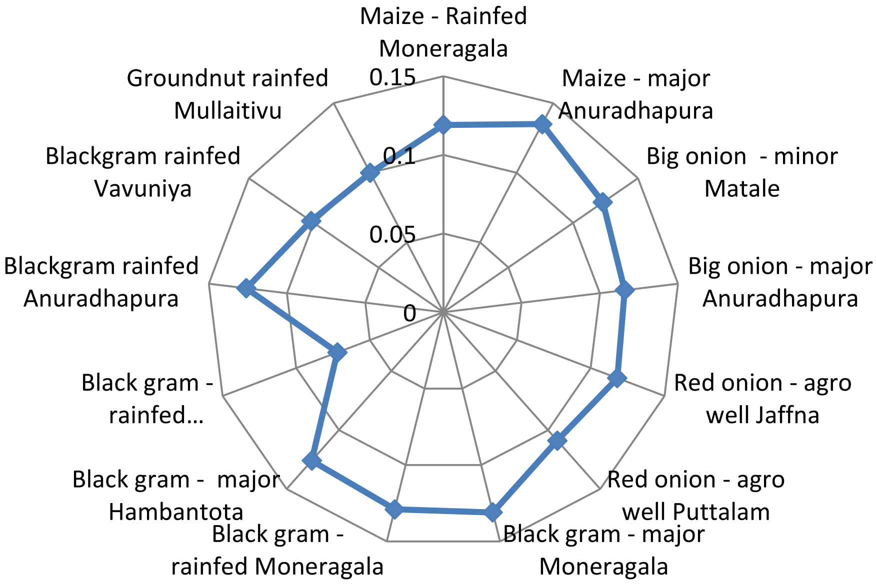



**Figure 4.3: The Adaptive Capacity of Different Crop Production Systems**

## 4.2 The Climate Vulnerability of Crop Production Systems/Agricultural Communities

The level of vulnerability of different crop production systems are presented, in the form of vulnerability index in Table 4.4 below. The vulnerability index for different crop production systems is ranging from 0.013 (black gram production system in Vavuniya) to 0.085 (green gram cultivation under rainfed condition in the Hambantota district). The highest vulnerable crop production system is reported to be as the green gram cultivation under rainfed conditions in the Hambantota district where the higher sensitivity and exposure levels prevail while low adaptive capacity of the community is recorded (Figure 4.4). Even in the case of green gram production system that is practiced under the major irrigation system there the district (Hambantota) demonstrates higher degree of vulnerability.

**Table 4.4 The Vulnerability Status of Agricultural Communities**

| Crop Production System | Overall Sensitivity | Exposure | Total Adaptive Capacity | Vulnerability Index |
|---|---|---|---|---|
| Maize – Rainfed, Moneragala | 0.116 | 0.519 | 0.119 | 0.046 |
| Maize – Major, Anuradhapura | 0.104 | 0.538 | 0.135 | 0.042 |
| Big onion – Minor, Matale | 0.084 | 0.538 | 0.123 | 0.035 |
| Big onion – Major, Anuradhapura | 0.085 | 0.538 | 0.116 | 0.036 |
| Red onion - Agro well Jaffna | 0.110 | 0.519 | 0.118 | 0.044 |
| Red onion - Agro well, Puttalam | 0.099 | 0.750 | 0.109 | 0.063 |
| Green gram – Major, Moneragala | 0.084 | 0.519 | 0.131 | 0.032 |
| Green gram - Rainfed, Moneragala | 0.117 | 0.519 | 0.129 | 0.046 |
| Green gram – Major, Hambantota | 0.095 | 0.865 | 0.126 | 0.070 |
| Green gram - Rainfed, Hambantota | 0.107 | 0.865 | 0.072 | 0.085 |
| Black gram - Rainfed, Anuradhapura | 0.126 | 0.538 | 0.126 | 0.052 |
| Black gram - Rainfed, Vavuniya | 0.089 | 0.250 | 0.102 | 0.013 |
| Groundnut - Rainfed, Mullaitivu | 0.114 | 0.519 | 0.100 | 0.048 |

Source: HARTI Survey data 2019

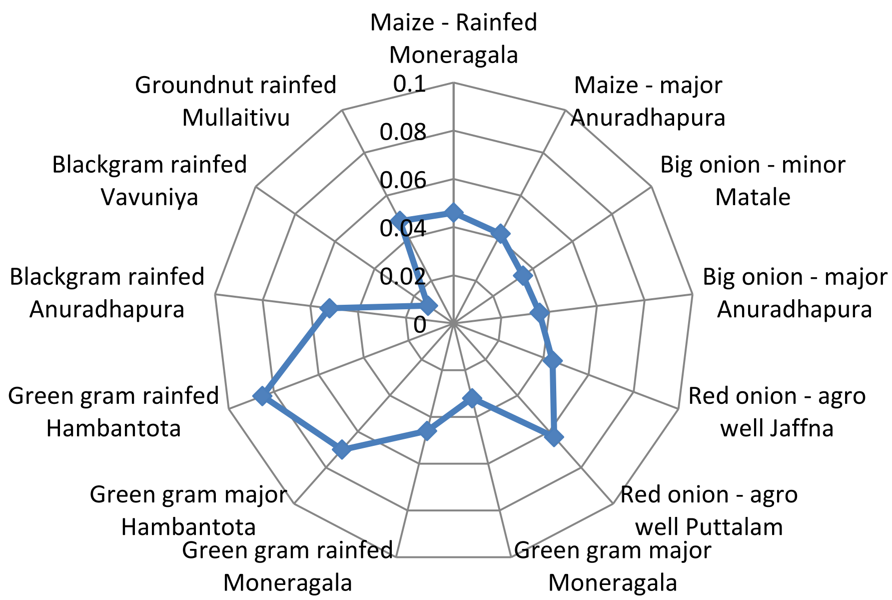


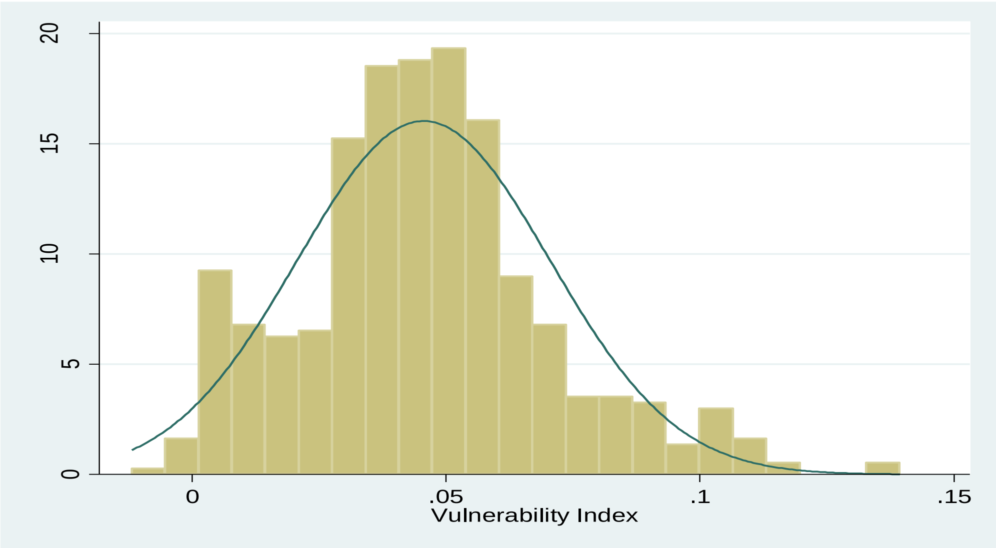

**Figure 4.4: The Vulnerability Status of Different Crop Production Systems**

The least vulnerability reported in black gram production in the Vavuniya district can be mainly attributed to the relatively low sensitivity and least exposure (0.25) to adverse of climate change impacts. The black gram production is mostly practiced under rainfed condition in rainy *Maha* season. As a crop with low water requirement, and being cultivated in rainy *Maha* season, with shifting the planting time to avoid floods in initial stage and crop damage due to rain during the harvesting stage, black gram cultivation in Vavuniya encounter minimum impacts posed by the climate change like water stress in dry spells. Thus the level of exposure and sensitivity of this crop is reported to be minimum. However, the black gram production in Anuradhapura where the crops are frequently damaged due to flood and water logging conditions are much vulnerable. The second least vulnerability reported in big-onion production in the Matale district can be mainly attributed to the relatively low sensitivity (0.084) and higher adaptive capacity (0.123). The onion production systems mostly undertaken with the assured minor irrigation systems as well as supplementary irrigations coupled with high-efficiency micro irrigation techniques are mostly safe from the extreme events such as prolonged dry spells and droughts. Though the said location/community has relatively higher exposure levels to climate change impacts, particularly the droughts and water scarcity, the higher adaptive capacity with the community has eased the degree of vulnerability.

### 4.3 Determinants of Household Vulnerability

Climate shocks appear to affect farm households in different ways. Also, vulnerability levels depend on the types of shocks that farm based livelihood systems undergo. Farm households in a particular geographic location are similarly exposed to climate shocks and that have the same sensitivity level but do not necessarily have the same vulnerability level. The lowest adaptive capacity does not essentially coincide with highest exposure and sensitivity. Therefore, vulnerability levels vary relatively across farm households' characteristics and identification of those characteristics are utmost important in formulating policy decisions for adaptation.

Based on the index method, vulnerability levels of individual farmers were calculated and the frequency histogram of the vulnerability index calculated for individual sample farmers is shown in Figure 4.5. Although the graph shows a slight shift to the right, statistical analysis on skewness and kurtosis proved that it is not skewed in any way (Skewness = 0). Also, the value of the kurtosis statistic is about zero (0.001). Therefore, the vulnerability index appears to have a normal distribution.




Source: HARTI Survey Data 2019

**Figure 4.5: Frequency Histogram of the Vulnerability Index**

When the correlation between factors is tested, four dummy variables representing the geographic Dis7 and one dummy variable representing the water source were found to be having a high correlation coefficient of greater than ρ < 0.5 and to be significantly (P < 0.001) correlated with other factors postulated to influence household vulnerability to climate change and variability. Consequently, they were dropped from subsequent regression analyses. The results of the regression analysis were summarized in Table 4.5. The $R^2$ and adjusted $R^2$ values of the estimated model are 72.26 per cent and 71.17 per cent respectively. It indicates that approximately 71.17 per cent of the sample variation in determinants of climate change vulnerability among dry zone farmers is explained by the model with those used explanatory variables.

**Table 4.5: Factors Influencing the Vulnerability of Households to the Climate Change**

| Postulated factor | Coefficient | SE | t value | P>\|t\| |
|---|---|---|---|---|
| Age of the household head | -.0000242 | 0000618 | -0.39 | 0.695 |
| Household size | -.0001206 | .0017612 | -0.07 | 0.945 |
| Farming experience | 6.24e-06 | .0000549 | +0.11 | 0.910 |
| Gender | -.0020077 | .0034071 | -0.59 | 0.556 |
| Education | -.0005288 | .0001805 | -2.93** | 0.004 |
| Community membership | -.0001772 | .0009123 | -0.19 | 0.846 |
| Land | .001112 | .0002125 | 5.23** | 0.000 |
| Agriculture diversification | -.0067498 | .0130481 | -0.52 | 0.605 |
| Extension | -.0002149 | .0000845 | -2.54** | 0.011 |
| Dis 1 | .0229536 | .0045317 | 5.07** | 0.000 |
| Dis2 | .0385816 | .0031822 | 12.12** | 0.000 |
| Dis3 | .0617294 | .0050653 | 12.19** | 0.000 |
| Dis4 | -.0154294 | .0032457 | -4.75** | 0.000 |
| crop1 | -.0349113 | .0041083 | -8.50** | 0.000 |
| crop2 | -.0384685 | .0046362 | -8.30** | 0.000 |
| crop3 | -.0373726 | .0030157 | -12.39** | 0.000 |
| crop4 | -.0277916 | .00555 | -5.01** | 0.000 |
| crop5 | .0254819 | .0035967 | 7.08** | 0.000 |
| water1 | .0129284 | .0017657 | 7.32** | 0.000 |
| water3 | .0037004 | .0044263 | 0.84 | 0.404 |
| Primary employment | .0043385 | .0024552 | 1.77* | 0.078 |
| _cons | .0404287 | .0097397 | 4.15** | 0.000 |
| R-squared = 0.7226 Adj R-squared = 0.7117 | | | | |

*significant at 5% and ** significant at 1% significance levels
Source: HARTI Survey Data 2019

The regression results show that the education level of the household head, access to extension services, land extent cultivated under specific crop referred in the study and the primary employment of the household head plays a significant role in influencing households' vulnerability to climate change and climate variability. In addition, all dummy variables that representing different geographical locations (districts) and crops are significant at one per cent significance level by depicting the changes in the level of vulnerability with respect to different localities and respective crops cultivated.

The number of years spent on education by household head was reported to be significant at one per cent significance level with the expected sign indicating that with higher educational attainments, farmers have been able to reduce the impacts of climate change. The underlying reason of this is with education has a positive impact on farmers' understanding on climate change and subsequently leads to effective use of climate change adaptation measures. It was observed that when the household heads had received more education they tend to make prudent and relatively more appropriate adaptation strategies to cushion their families from the adverse impacts of variable and changing climate

The results from the regression analysis indicate that when the land extent under cultivation of crops selected in this study is increased, farmers' level of vulnerable to climate change also rises. This finding is not totally unexpected since almost all field crops in Sri Lanka are cultivated in open fields exposed to all forms of environmental impacts. Hence, flood and/or drought hazards cause severe damages to the farm fields increasing the degree of vulnerability of the crop production system as well as the farm household. At the same time, with the increased land size the initial investment by the farmer has to be increased creating more hardships. Agricultural diversification can be identified as a strategy to reduce the risk associated with mono crop cultivation. However, the variable representing agricultural diversification is not reported to be significant in the regression model. The possible reason for this is the limited level of variation in the variable, agricultural diversification hence most of the farmers in the sample are not much diversified in terms of crop production, integrated livestock, aquaculture practices, and the like.

Most importantly, the variable used to represent the information availability is significant at one per cent significance level with the expected sign. It reveals that farmers having frequent contacts with Extension Officers are less vulnerable to climate change impacts. This highlights the importance of strengthening the agricultural extension system of the country. With the increased timely availability of relevant and updated information, farmers can plan out their cultivation appropriately while minimizing the associated climate risks.

The results further indicate that whose primary occupation is agriculture are more vulnerable to climate change than their counterparts. The demographic analysis of the sample also confirms that the majority of the farmers are fulltime farmers with a secondary source of income. In accordance with the literature in rural development in general and agro-pastoral development in particular (Little et al., 2001; Nyamwaro et al., 2006; Nkedianye et al., 2009;), shows the potential of income diversification to reduce households' vulnerability. This could be explained by the variety of roles that can be played by diversification, such as spreading of risk, providing flexibility among sources of income, stabilizing consumption, generating surpluses for investment, coping with climate variability and long-term changes (Hussein and Nelson 1998; Notenbaert et al., 2013).

Four district dummies introduced to capture the influence of location specific factor to climate vulnerability are significant at one per cent significance level in the model. According to the order of district numbers assigned in the analyses, the Matale district is considered as the reference location. In comparison to the farmers in the Matale district (big onion farmers under minor irrigation schemes with supplementary irrigation systems), the farming communities in the Anuradhapura and Hambantota districts are more vulnerable to the climate change impacts while the farmers in the Jaffna district are reported to be the least vulnerable group according to the locality dummy variable coefficients with minus value. This reiterates the findings revealed in the system level vulnerability analysis.

All dummy variables representing specific crops are significant at one per cent significance level and highlight the influence of type of crops cultivated on the level of farmer (household) vulnerability. Groundnut was taken as the reference crop and according to the estimated coefficients maize, green gram and black gram farmers are less vulnerable than big onion and groundnut farmers with the coefficients -0.038 and -0.37 respectively, while red onion farmers are the highest vulnerable group having the highest coefficient value (0.028). As expected, the dummy variable introduced for rainfed water source is significant with positive value (0.013) by circumstantiating the vulnerability of rainfed farmers to drought and flood hazards than farmers in major irrigation schemes with the coefficient value of 0.003.

## 4.4 Conclusion and Recommendations

### 4.4.1 Conclusions

This research analyzes vulnerability of farm-based livelihoods of different crop production systems to climate shocks mainly focusing on the drought and flood, by using indicators combined with an econometric analysis.

Econometric analysis determining the factors that influence the farmer level vulnerability to climate change indicates that education level of the household head, access to information are positively contributing to reduce farmer level vulnerability. However, increased land extent cultivated with a particular field crop and engaging in fulltime farming as the primary income source lead to increased farmer vulnerability to climate change.

Depending on the geographical location the level of vulnerability changes significantly. Farming communities in the Hambantota district cultivating green gram under rainfed conditions and major irrigation are the most vulnerable communities respectively followed by those cultivating red onion using agro wells in Puttalam and black gram rainfed farmers in Anuradhapura. The farming community in the Jaffna district are the least vulnerable according to the coefficients associated with the dummy variable for the district is naturally free from floods and most of the farmers use groundwater as the main source of water.

The dummy variables used to capture the influence of different crops on the level of vulnerability are significant in the model and highlight the importance of selecting the most suitable crop to minimize the climate risks. Among the selected six crops, red onion is the highest vulnerable followed by groundnut, green gram, maize, big onion and black gram.

The results indicate that factors causing the differences in the level of vulnerability among communities under different crop production systems in the dry zone are mostly similar irrespective of the geographical location and socio-economic differences. Providing training opportunities to farmers to raise awareness and educate them on available novel technologies, diversified - agricultural livelihoods could be used to minimize climate vulnerability. These technological, particularly the agronomic information should be coupled with climatic information along with the crop forecast, selection of appropriate crop variety/ies for a given cropping season, time of crop establishment, shifting the cropping season appropriately matching with the changing climate.

### 4.4.2 Recommendations

Based on the findings of the study the following recommendations can be made to strengthen policy interventions with regard to the increased adaptive capacity and enhanced climate resilience.

a) Farmer training towards precise decisions on climate actions
   To increase the adaptive capacity of farmers/farming communities and subsequently reduce the climate vulnerability, farmers should be provided training on receiving and utilization of updates on climate and weather parameters, availability of and access to agricultural inputs and novel and improved technologies.

b) Agricultural and livelihood diversification
   Individuals/farmers having diversified agricultural production systems largely contribute to increased adaptive capacity to climate change. Thus, it is prudent to promote agricultural diversification as a mean for enhanced resilience. Further, the as the average land size of farmer household is mostly inadequate to provide better income year around the farming activities should be promoted to be engaged as a part–time activity, with the introducing mechanization and novel technologies over the traditional system of farming.

c) Efficient and effective water governance
   The higher level of adaptive capacity of certain crop production systems displayed least climate vulnerability largely owing to adaptation of high efficient water management systems including application of micro irrigation systems. Thus, it is highly recommended to promote appropriate irrigation systems, wherever it is applicable, for better water productivity as well as increased climate resilience

# REFERENCES

Adger, W.N. (2003). Social Aspects of Adaptive Capacity. In. Climate Change, Adaptive Capacity and Development. Eds. Smith, J.B., Klein, R.J.T and Huq, S. Imperial College Press, London, UK. pp. 29-50.

Adger, W.N. (1999). Social Vulnerability to Climate Change and Extremes in Coastal Vietnam. World Development. vol.27(2). Available at: https://www.sciencedirect.com/science/article/abs/pii/ S0305750X98001363 (Accessed 12 October 2018)

Adger, W.N. and Kelly, P.M. (1999). Social Vulnerability to Climate Change and the Architecture of Entitlements. Mitigation and Adaptation Strategies for Global Change. vol.4, pp. 253–266. Available at: https://doi.org/10.1023/A:1009601904210 (Accessed 08 October 2018)

Alwang, J. Siegel, P.B. and Jorgensen, S.L. (2001). Vulnerability: A view from different disciplines. Available at: www.researchgate.net/publication/248360266_Vulnerability_as_Viewed_from_Different_Disciplines (Accessed 18 October 2018)

Anandhi, A., Steiner, J.L. and Bailey, N. A (2016). System's approach to assess the exposure of agricultural production to climate change and variability. Climatic Change 136, 647–659. Available at: https://doi.org/10.1007/s10584-016-1636-y (Accessed 12 October 2018)

Asian Development Bank (2013). The economics of climate change in South Asia, Adaptation and impact Assessment March, 2013, CASA Information update No.03 Asian Development Bank.

Ashok, K.R. and Sasikala, C. (2012) Farmers' Vulnerability to Rainfall Variability and Technology Adoption in Rain – fed Tank Irrigated Agriculture, Agriculture Economics Research Review, vol. 25(2); pp. 267-278

Basu, J.P. (2017). Climate Change Adaptation and Forest Dependent Communities: An Analytical Perspective of Different Agro-Climatic Regions of West Bengal, India. Springer International Publishing, Cham, Switzerland. pp.77

Below, T.B., Mutabazi, K.D., Kirschke, D, Franke, C, Sieber, S., Siebert, R. and Tscherning, K. (2012). Can farmers adaptation to climate change be explained by socio economic household level variables? In Global Environmental Change. vol. 22; pp. 223-235.Elsevier

Berry, H.L., Hogan, A., Suan P.N, and Parkinson, A. (2011). Farmer Health and Adaptive Capacity in the Face of Climate Change and Variability. Part 1: Health as a Contributor to Adaptive Capacity and as an Outcome from Pressures Coping with Climate Related Adversities. International Journal of Environmental Research and Public Health. vol. 8(10): pp. 4039–4054. Available at: doi:10.3390/ijerph8104039 (Accessed 28 October 2018)

Brooks, N., Adger, W.N. and Kelly, P.M. (2005). The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation. Global Environmental Change. vol. (15):2 Available at: http://climateknowledge.org/figures/Rood_Climate_Change_AOSS480_Documents/Brooks_Vulnerability_Adaptation_GlobEnvirChange_2005.pdf (Accessed 18 October 2018)

Cardona, O. (2004). The need for rethinking the concepts of vulnerability and risk from a holistic perspective: a necessary review and criticism for effective risk management", in Bankoff, G., Frerks, G. and Hilhorst, D. (Eds), Mapping Vulnerability: Disasters, Development and People, Earthscan, London, United Kingdom.

Climate Change Secretariat of Sri Lanka (2016). National Adaptation Plan for the Climate Change Impacts in Sri Lanka. Climate Change Secretariat of Sri Lanka, Ministry of Mahaweli Development and Environment, Colombo, Sri Lanka. pp.176

Climate Change Secretariat of Sri Lanka (2011). Second National Communication on Climate Change. Ministry of Environment, Colombo, Sri Lanka. pp.161

Cutter, S.L., Boruff, B.J. and Shirley, W.L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly Volume.* vol. 84(2); pp.243-261.

De Costa, W.A.J.M. (2010). Adaptation of agricultural crop production to climate change: A policy framework for Sri Lanka. In Journal of National Science Foundation of Sri Lanka. vol.38(2); pp.79-89.

Deressa, T., Hassan, R.M. and Ringler, C. (2008). Measuring Ethiopian Farmers' Vulnerability to Climate Change Across Regional States. Discussion Paper 00806, International Food Policy Research Institute. Available at: http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/13927

Deressa, T., Hassan, T., Ringler, R.M., Alemu, T. and Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change.* vol.19(2), pp.248-255.

De Silva, C.S. (2006). Impacts of climate change on water resources in Sri Lanka. Paper presented at the 32nd WEDC International Conference on Sustainable Development of War Resources, Water Supply and Environmental Sanitation, November 13-17, 2006, Colombo, Sri Lanka. Available at: https://www.researchgate.net/publication/305278637_Impacts_of_Climate_Change_on_Water_Resources_in_Sri_Lanka

De Silva, C. S. (2006). 'Impacts of Climate Change on Potential Soil Moisture Deficit and Its Use as a Climate Indicator to Forecast Irrigation Need in Sri Lanka'. In: Symposium Proceedings of the Water Professionals' Day, 2006, ed. N. D. K. Dayawansa.

Drought Policy Review Expert Social Panel (2008). It's About People: Changing Perspectives on Dryness—A Report to Government by an Expert Social Panel on Dryness. Commonwealth of Australia; Canberra, Australia. Available at: [Google Scholar]

Eakin, H., and Tapia, L. A.B. (2008). Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change*, vol.18(1), pp.112-127. Available at: https://doi.org/10.1016/j.gloenvcha.2007.09.001

Easter, C. (1999). Samll states development: A commonwealth vulnerability index. *The Round Table.* vol.351(1); pp.403-422.

Erikson, S.H. and Kelly, P.M. (2007). Developing Credible Vulnerability Indicators for Climate Adaptation Policy Assessment. Mitigation and Adaptation Strategies for Global Change. vol.12(4): pp.495-524. Available at: DOI:10.1007/s11027-006-3460-6

Eriyagama, N., Smakhtin, V., Chandrapala, L., & Fernando, K. (2010). Impacts of Climate Change on Water Resources and Agriculture in Sri Lanka: A Review and Preliminary Vulnerability Mapping. IWMI Research Report 135, Colombo: International Water Management Institute. vol.51-55. Available at: http://www.iwmi.cgiar.org/.../iwmi-research-report-135

Eriyagama, N. and Smakhtin, V. (2010). Observed and projected climatic changes, their impacts and adaptation options for Sri Lanka: a review. In Proceedings of the National Conference on Water, Food Security and Climate Change in Sri Lanka. vol.2; pp.99-117.

Etwire, P.M., Al-Hassan, R., Kowarnu, J.K.M and Owusu, Y.A. (2013). Application of Livelihood Vulnerability Index in Assessing Vulnerability to Climate Change and Variability in Northern Ghana. Journal of Environment and Earth Science. vol.3: pp.157-170.

Fay, M and Ebinger, J. (2010). A Framework for Developing Adaptation Plans. In. Adapting Climate Change in Easters Europe and Central Asia. Eds. Fay, M, Block, R.J. and Ebinger, J. The World Bank, Washington DC, USA.

Food and Agriculture Organization (2016). The State of Food and Agriculture, Climate Change, Agriculture and Food Security. Food and Agriculture Organization of the United Nations Rome. Available at: http://www.fao.org/3/a-i6030e.pdf

Ford, J.: 2002, Vulnerability: Concepts and Issues, Ph.D. Scholarly Field Paper, University of Guelph, Guelph, Canada.

Fussel, H. (2007). Vulnerability: A Generally Applicable Conceptual Framework for Climate Change Research. Global Environmental Change. vol.17(2). Available at: https://www.researchgate.net/publication/222425979_Vulnerability_A_generally_applicable_conceptual_framework_for_climate_change_research

Fussel, H.M. and Klein, R.J.T. (2006). Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking, Climate Change. vol.75(3). Available at: https://www.researchgate.net/publication/225490337_Climate_Change_Vulnerability_Assessments_An_Evolution_of_Conceptual_Thinking

Gbetibouo, G.A., Ringler, C. and Hassan, R. (2010). Vulnerability of the South African farming sector to climate change and variability: An indicator approach. Natural Resources Forum. vol.34(3); pp.175–187. Available at: DOI: 10.1111/j.1477-8947.2010.01302.x

Gopalakrishnan, T., Hasan, M.K., Haque A.T.M.S., Jayasinghe, S.L., and Kumar, L. (2019) Sustainability of Coastal Agriculture under Climate Change. Sustainability 2019, 11, 7200; Available at: doi:10.3390/su11247200

Gouda, M.D. (2020). Climate Change Agriculture and Rural Communities' Vulnerability in the Nile Delta. In. Climate change impacts on agriculture and food security in Egypt. Eds. Omran, E.E. and Negm, A.M. Springer Nature Switzerland AG, Cham, Switzerland.

Hahn M.B., Riederer A.M., and Foster S.O, (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change: A case study in Mozambique, Global Environment Change. vol.19; pp.74. Available at: doi:10.1016/j.gloenvcha (Accessed 02 November 2008)

Hirji, R., Nicol, A. and Davis, R. (2017). South Asia Climate Change Risks in Water Management. International Bank for Reconstruction and Development/The World Bank, Washington, DC.

Hussein K., and Nelson, J. (1998) Sustainable livelihoods and livelihood diversification. IDS Working Paper 69, Brighton, UK

Intergovernmental Panel on Climate Change(IPCC) (2014). Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130. Available at: https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_Glossary.pdf (Accessed 08 October 2018)

IPCC (Intergovernmental Panel on Climate Change) (2001). Impacts, Adaptation and Vulnerability. McCarthy J.J. et al eds. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Jayasooriya, H.J.C. (2017).Vulnerability of Rainfed Farmers to Drought and Potential Strategies to Enhance Resilience Capacity. Research Report No.211 Hector Kobbekaduwa Agrarian Research and Training Institute, 114, Wijerama Mawatha, Colombo 07.

Kaly, U. and Pratt, C. (2000). Environmental Vulnerability Index: Development and Provisional Indices and Profiles for Fiji, Samoa,Tuvalu and Vanuatu. Phase II Report for NZODA. SOPAC Technical Report 306.

Khajuria, A. and Ravindranath, N.H. (2012). Climate Change Vulnerability Assessment: Approaches DPSIR Framework and Vulnerability Index, Journal of Earth Science & Climate Change. vol.3(1); pp.109. Available at: DOI: 10.4172/2157-7617.1000109 (Accessed 21 November 2018)

Khoshnodifar Z., Sookhtanlo M. and Gholami H. (2012). Identification and measurement of indicators of drought vulnerability among wheat farmers in Mashhad country, Iran, Annals of Biological Research, vol.3(9); pp.4593-4600

Kuwornu, J.K.M. (2019). Climate Change and Sub-Saharan Africa: The Vulnerability and Adaptation of Food Supply Chain Actors. Vernon Press, Wilmington, Delaware, USA.

Little PD, Kevin S, Barbara CA, Layne CD, Christopher B (2001) Avoiding disaster: diversification and risk management among East African herders. Development Change. vol.32(3); pp.401–433

Loria,N.,Bhardwaj,S.K.,Mahajan,P.K., Sharma,D.P. and Sharma,R.(2015). Vulnerability assessment of farming community to environmental changes in low hills of Himachal Pradesh in India. In International journal of Current Microbiology and Applied Sciences. ISSN: 2319-7706. Vol.4(8). Available at: http://www.ijcmas.com (Accessed 05 April 2019)

Mallari A.E.C., (2016), Climate Change Vulnerability Assessment in the Agriculture sector; Typhoon Santi Experience, Procardia social and Behavioral Sciences. vol.216; pp.440-451

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, S.K. (eds.) (2001). Climate Change 2001: Impacts, Adaptation, and Vulnerability – Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, UK: Cambridge University Press.

Mendoza M.E.T., The B.D., Naret, H., Ballaran V.G., and Arias, J.K.B., 2014, Assessing Vulnerability to Climate Change Impacts in Cambodia, the Philippines and Vietnam: An Analysis at the Commune and Household level, Journal of Environmental Science and Management, vol.17(2): pp.78-91

Murthy, C.S., Laxman, B., Sai M.V.R.S. and Diwakar P.G, (2014). Analyzing agricultural drought vulnerability at sub district level through exposure, sensitivity and adaptive capacity based composite index, The international Archives of the photogrammetry, Remote sensing and Spatial Information Sciences. vol.XL.(8); pp.65 – 70

National Adaptation Plan for Climate Change Impacts in Sri Lanka, Climate Change Secretariat, Ministry of Mahaweli Development and Environment

National Adaptation Plan for Climate Change Impacts in Sri Lanka 2016-2025, Climate Change Secretariat, Ministry of Mahaweli Development and Environment, Sri Lanka.

Nauman G., Barbosa, P., Garrote, L., Iglesias, A. and Vogt, J. (2014). Exploring drought vulnerability in Africa: an indicator based analysis to be used in early warning systems, Hydrology and Earth system sciences, vol.18; pp.1591–1604

Niles, M.T., Lubell. M and Brown M. (2015). How limiting factors drive agricultural adaptation to climate change. Agriculture, Ecosystems & Environment, vol.200; pp.178-185. Available at: https://doi.org/10.1016/j.agee.2014.11.010

Nkedianye, D., Radeny, M., Kristjanson, P., Herrero, M., (2009). Staying Maasai? livelihoods, conservation and development in East African rangelands. In: Homewood, K., Kristjanson, P., Chevenix Trench, P. (eds) Assessing returns to land and changing livelihood strategies in Kitengela. Springer, Dordrecht, pp.115–150

Notenbaert, A., Karanja, S. N., Herrero, M., Felisberto, M., and Moyo, S. (2013). Derivation of a household-level vulnerability index for empirically testing measures of adaptive capacity and vulnerability. Regional Environmental Change. vol.13(2); pp.459-470.

Nyamwaro, S.O., Watson, D., Mati, B., Notenbaert, A., Mariner, J., Rodriguez, L.C., and Freeman, A. (2006). Assessment of the impacts of the drought response program in the provision of emergency livestock and water interventions in preserving pastoral livelihoods in Northern Kenya. Report of an ILRI Multidisciplinary Scientific Team of Consultants Assessing the Emergency Drought Response Project in Northern Kenya. ILRI, Nairobi, pp.123

Piya, L., Maharjan, K.L. and Joshi, N.P. (2012). Perceptions and realities of climate change among Chepang communities in rural mid-hills of Nepal. J Indian Contemp India Stud Space Society. vol.2; pp.35-50.

Premalal, K. H. M. S. (2009). 'Weather and Climate Trends, Climate Controls and Risks in Sri Lanka'. Presentation made at the Sri Lanka Monsoon Forum, April 2009. Department of Meteorology, Sri Lanka.

Pulhin, J.M., Peras, R.J.J., Pulhin, F.B. and Gevana, D.T. (2016). Farmers' Adaptation to Climate Variability: Assessment of Effectiveness and Barriers Based on Local Experience in Southern Philippines. Journal of Environmental Science and Management Special Issue 1-2016: pp.1-14.

Punyawardena, B.V.R., Mehmood, S., Hettiarachchi, A.K., Iqbal, M., Silva, S.H.S.A. and Goheer, A. (2013). Future Climate of Sri Lanka: An approach through dynamic downscaling of ECHAM 4 General Circulation Model (GCM). Tropical Agriculturist. vol.161; pp.35-50

Reidsma, P., Ewert, F. and Lansink, A.O. (2007). Analysis of Farm Performance in Europe Under Different Climatic and Management Conditions to Improve Understanding of Adaptive Capacity, Springer Science. Available at: https://link.springer.com/article/10.1007/s10584-007-9242-7 (Accessed 21 November 2018)

Satapathy, S., Porsché, I., Rolker, D., Bhatt, S., Tomar, S. and Nair, S. (2014). A Framework for Climate Change Vulnerability Assessment. Deutsche Gesellschaftfür Internationale Zusammenarbeit (GIZ) GmbH, India, New Delhi, India. pp.183.

Sehgal,V.K.,Singh,M.R.,Chaudhary,A.,Jain,N. and Pathak,H. (2013). Vulnerability of Agriculture to Climate Change: District Level Assessment in the Indo-Gangetic Plains. Indian Agricultural Research Institute, New Delhi pp.74.

Seo, S. N., Mendelsohn, R. and Munasinghe, M. (2005). 'Climate Change and Agriculture in Sri Lanka: A Ricardian Valuation'. Environment and Development Economics. vol.10; pp.581-596.

Singh, R. and Singh, G.S. (2017). Traditional agriculture: a climate-smart approach for sustainable food production. *Energ. Ecol. Environ.* vol.2; pp.296–316. Available at: https://doi.org/10.1007/s40974-017-0074-7 (Accessed 16 November 2018)

Smit, B and Pilifosova, O. (2003). From Adaptation to Adaptive Capacity and Vulnerability Reduction. In. Climate Change, Adaptive Capacity and Development. Eds. Smith, J.B., Klein, R.J.T and Huq, S. Imperial College Press, London, UK. 9-28pp.

Swain M. and Swain M. (2011). Vulnerability to Agricultural Drought in Western Orissa: A Case Study of Representative Blocks, Agricultural Economics Research Review, vol.24; pp.47-56

Tao, S., Xu,Y., Liu,K., Pan, J. and Gou, S. (2011). Research Progress in Agricultural Vulnerability to Climate Change. Advances in Climate Change Research, vol. 2(4). Available at: https://www.sciencedirect.com/science/article/pii/S1674927811500504?via%3Dihub (Accessed 12 November 2018)

Tiani, A.M., Besa, M.C., Devisscher, T., PAvageau, C. Butterfield, R., Bharwani, S. and Bele, M.Y. (2015). Assessing Current Social Vulnerability to Climate Change: A Participatory Methodology. Working Paper 169, Bogor, Indonesia: CIFOR.

United Nations, World Population Prospects: The 2006 Revision, vol. I: Comprehensive Tables. Available at: http://www.un.org/esa/population/publications/wpp2006/wpp2006.htm (Accessed on: 22 November 2018)

United Nations (2015). Transforming our World: The 2030 Agenda for Sustainable Development. New York, NY, USA.

United States Environment Protection Agency (2017) Climate Change Impacts, International Climate Impacts. Available at: https://19january2017snapshot.epa.gov/climate-impacts/international-climate-impacts_.html (Accessed 22 November 2018)

Wirehn, L. (2018). Climate vulnerability assessment methodology: Agriculture under climate chanin in the Nordic region. Linkoping University, Linkoping, Sweden. pp.97

World Bank (2016), International Center for Tropical Agriculture, Climate Smart Agriculture in Sri Lanka. Available at: file:///C:/Users/%20HP/Downloads/CSA%20in%20Sri%20Lanka.pdf (Accessed 30 November 2018)

Zubair,L., Ralapanawe,V., Tennakoon,U., Yahiya,Z. and R.Perera (Undated) Natural Disaster Risks in Sri Lanka: Mapping Hazards and Risk Hotspots.

## LOSSARY OF KEY TERMS

**Climate change:**
Climate change refers to 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, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes (IPCC, 2014).

**Impacts:**
Effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts (IPCC, 2014).

**Exposure:**
The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC, 2014).

**Resilience:**
The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC, 2014)

**Vulnerability:**
The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

**Adaptation:**

The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2014).

**Adaptive Capacity:**

The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2014).