INVESTIGATING COMMUNITY RESILIENCE TO CLIMATE CHANGE: APPLICATION OF ECONOMIC MODELS

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Thesis submitted in partial fulfilment of the requirements for the degree Master of Science (Major Component of Research)

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DECLARATION OF THE CANDIDATE AND SUPERVISOR

I declare that this is my own work, and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

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(Nadeetharu B. K. M.)

The above candidate has carried out research for the Master's thesis under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of the Supervisor: Prof. Udayangani Kulatunga

Signature: UOM Verified Signature Date: 30.09.2023

To my loving mother…

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ABSTRACT

Climate change is a significant issue in the present which impacts the economic status of communities by affecting their livelihoods. To investigate the problems of climate change on communities, economic models of climate change can be regarded as a suitable application, as they provide the parameters and climatic conditions to be considered. Thus, this study aimed to contribute to enhancing the community's resilience to the economic impacts of climate change in Sri Lanka through the application of economic models. Five climatic conditions, seven firsthand influences of climate change, and 25 parameters under four categories to determine economic impacts have been identified through a systematic literature review. This research adopts interpretivism philosophy and pace through a qualitative research approach to derive an abductive conclusion. Data collection has been conducted in four stages; preliminary interviews, focus group discussions, key informant interviews and expert interviews respectively. Stages 01 and 04 of data collection followed the survey strategy while Stages 02 and 03 aligned with case studies within low country wet zone tea and paddy industries. The findings were analysed using content analysis, and cross-case analysis. Finally, two causal loop diagrams (CLDs) have been developed for two cases. The findings revealed temperature and rainfall as the two main climatic conditions varying in Sri Lanka, while low country wet zone mainly suffers from rainfall variations. Despite the benefit of lowering the irrigation cost, climate change poses common and unique challenges for both tea and paddy growers. Six and four strategies for building resilience have been identified for tea and paddy growers respectively. Seven and six closed loops have been identified within the CLDs for tea and paddy respectively. The findings provide an influential understanding for decision makers to derive policies and the developed CLDs can be benchmarked in system dynamic models.

Keywords: Climate change, Economic impacts, Livelihoods, Causal loop diagrams (CLDs), Systematic Literature Review (SLR)

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LIST OF ABBREVIATIONS

ADB	:	Asian Development Bank
CLD	:	Causal Loop Diagram
EPA	:	Environmental Protection Agency
GDP	:	Gross Domestic Product
IPCC	:	Intergovernmental Panel on Climate Change
PICO	:	Problem Intervention Comparator Outcome
PRISMA	:	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
R&D	:	Research and development
RRDI	:	Rice Research and Development Institute
SLR	:	Systematic Literature Review
UN	:	United Nations
WMO	:	World Meteorological Organization

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1 CHAPTER ONE- INTRODUCTION

1.1 Background

Climate change is a significant issue in the present world (Han & Ahn, 2020; Mikhaylov et al., 2020) that challenges the survival of humanity (Hoegh-Guldberg et al., 2019). According to Evans (2019), climate change refers to "a dynamic, multidimensional system of changes in environmental conditions that will likely influence human behaviour" (p.2). The United Nations Environmental Protection Agency (EPA) (2022) has identified the causes of climate change under the two main categories of natural and human made. According to Nwankwoala (2015) variations in the atmospheric carbon dioxide level, variations in the orbital characteristics of the earth, volcanic eruptions, solar output variations, and thermohaline circulation have been caused the occurrence of climate change. Although the geological impact is significant, the influence of human activities has become the key contributor to climate change in the past century (Abbass et al., 2022; Swim et al., 2011). Furthermore, the European Commission (2022) elaborates that global warming is the key cause behind climate change that occurs because of several man-made activities, including deforestation, burning of fossil fuels, increased livestock farming, and emission of fluorinated gases.

Climate change is a key threatening issue for mankind (Nguyen & Tenhunen, 2015). It negatively influences human existence (Nwankwoala, 2015) due to the remarkable implications it has on biodiversity, water, agriculture, cities and the built environment, and health (Ziervogel et al., 2014). Further, Carleton and Hsiang (2016) highlight several negative implications of climate change such as health issues, impacts on trade and agriculture, and disturbance to the population structure and growth. Additionally, Feulner (2017) identifies climate change as a global issue with cross-repercussions on many sectors, including agriculture, energy, infrastructure, health, production, and international security. According to Porter et al. (2015), irrespective of other impacts of climate change, temperature and precipitation changes can together increase the global food prices from 30%-84% by 2050. Overall, climate change affects society as a whole by impacting various sectors of the economy, including agriculture, coastal

resources, energy, timber, fisheries, aesthetics, human health, and ecosystems (Fevero et al., 2021; Mendelsohn et al., 2004).

Climate change as a concern was firstly declared at the United Nations (UN) scientific conference, held in Stockholm in 1972, which highlighted the importance of controlling the activities that were causing it (Jackson, 2007). Since then, scientists as well as other experts have studied climate change and its impacts which are more widespread and affect the environment, economy, society, technology, and governance. Furthermore, as argued by Sadoff and Muller (2009), the effects of climate change – in addition to their physical impact - are compounded by other implications including the way they transcend into social and economic spheres. However, climate change influences the welfare of people and its impacts on the economy have been underestimated (Rao & Mustapa, 2021). For example, the poor community especially are disproportionately affected by climate change (despite barely contributing to it) and the climatic impacts their livelihoods in significant, but not well investigated (Anser et al., 2023; Shemsanga et al., 2010). Further, according to Dietz and Maddison (2009), since economy and welfare of community is frequently affected by climate change, it is important to identify the economic impacts and the possible actions and measures to curtail them.

Climate change is directly associated with population and economic growth (Chen et al., 2016; Messono & Homere, 2023; Tanner & Allouche, 2011). Low-income developing countries face considerable difficulties in managing socio-economic conditions associated with climate change (Biesbroek et al., 2013). Further, the authors emphasise poverty as a main constraint in processing adaptive measures to manage the economics of climate change. In addition, climate change results in economic losses which worsen the living conditions of the population and thereby intensifies social issues (Gasper et al., 2011). Moreover, despite the initial influence on the growth of some economic sectors, the economic impact of climate change indicates negative connotations in the long run (Alemzero et al., 2021; Wade & Jennings, 2016).

The net impact of climate change on people and the economy depends on a variety of factors including the sector that is impacted, the location impacted by climate change, and the period of the impact (Tol, 2018). Accordingly, addressing the consequences of

the economic aspects of climate change is challenged by to these multidimensional impacts (MacGregor et al., 2018) including environmental, social, economic, political, and cultural impacts. Furthermore, speedy actions to manage the economic impacts of climate change and implications on society are difficult to implement. For example, immediate actions to reduce carbon dioxide emissions consequently create substantial costs for many reasons including the difficulty of stabilising the emissions, a limited time frame to adapt to changes, and the difficulty in predicting impacts (Mendelsohn et al., 2004). Thus, economic challenges of climate change are inevitable. Targeted actions to determine the economic impacts of climate change in a limited time frame and to predict the results have continuously taken attention of researchers.

Modelling has increasingly used as a methodology to determine and predict economy, as it is beneficial in regulating frequent changes in economy, with response to a large number of forces (Debelle, 2019). Subsequently economic modelling is a procedure of using structured methodology to study and forecast the behaviour of the economy and economic relationships, with the focus on simplifying real world economic systems and providing predictions of the future status to assist decision making (Ouliaris, 2011). The application of this procedure to the focus on climate change and to analyse economic impacts can be identified as economic modelling of climate change.

Accordingly, the economic modelling of climate change can be used to promptly address socio-economic impacts of climate change, as it helps to determine costs and benefits of climate change and guide the decision-making process in the economy (Rising et al., 2022). Since, the economic assessment of the impacts of climate change is required to be comprehensive and must include all the physical effects and costs associated with markets and non-markets, the greatest challenge lies in the vulnerability of the poor and the challenges of adaptation (Xie et al., 2020). Climate economic modelling can be identified as an assessment mechanism which involves the process of identifying costs, benefits, and potential trade-offs of climate risks and climate change adaptation on the economy (Dekens & Hammill, 2021).

Economic models of climate change use different climatic and economic conditions to model and quantify the impact of climate change on community livelihoods (Auffhammer, 2018). Accordingly, the indicators represented within the economic

models denote the climatic conditions impacting the modelled country, and the key features which can be used to identify the impacts, which are referred to as parameters. As stated by Khabbazan (2022) economic models can input highly accurate and relatable data which can be used to obtain transparent results (Yalew et al., 2018). Thus, the parameters used within the economic models are a good representation of the livelihood impacts and this can be used as a structured framework for decision making (Gawith et al, 2020; Nadeetharu et al., 2023). Further, economic models of climate change indicate the potential economic performance of different livelihoods using multiple indicators (Gurgel et al., 2021; Navarro & Tapiador, 2019). Accordingly, the economic models of climate change can be adopted as a reliable methodology to identify the climatic conditions, their different economic impacts on livelihoods and the parameters used to determine them.

The method used in economic models of climate change is vital as it directly impacts the prediction of results (Van Meijl et al., 2018). Further, it helps to capture the factors/criteria considered in economic models to determine the economic impacts. As conveyed by Gurgel et al. (2021), economic models possess a variety of matrices to smoothen the decision-making process and help to determine the potential economic importance to derive practical management actions. Therefore, economic models of climatic change are a good cross representation of the status of livelihoods of communities and how their economy is impacted by climate induced problems.

1.2 Problem Statement

The economic impacts of climate change have continued to remain for centuries. Accordingly, investigating the impacts of climate events tied to societies and economies has become a recent trend as climate change creates significant impacts on past and present societies, whilst simultaneously affecting with the future society and economy (Carleton & Hsiang, 2016). Falco et al. (2018), predicts that climate change will create substantial negative impacts on the global economy specially in developing countries and damages will be apparent sectors like agriculture. The ability of the global community to respond to climate change has become more challenging and consequently this has created unexpected economic and/or social changes (Lotstein, 2013). The economic information associated with climate change is vital to formulate

climate actions in South Asia (Ahmed & Suphachalasai, 2014). However, there are no proper actions interlinking physical impacts and economic processes of climate change, which can be used to formulate resilient actions (Hein et al., 2009). Therefore, a careful understanding of how economies and societies are affected by climate change is important to develop effective responses to climate change (Dell et al., 2014; Lam et al., 2020).

Climate change creates a variety of implications in Sri Lanka including environmental, economic, health, and social phenomena (Baba, 2010; Narmilan et al., 2022). An increase in temperature, exposure to extreme climate events, and unique and complex hydrological movements place Sri Lanka at risk of climate change (Asian Development Bank [ADB], 2023). Further, the current anthropogenic climate change contributes to increase global warming and rising sea levels which further aggravate the problem. (Nianthi & Shaw, 2015). Additionally, Sri Lanka being a developing country, portrays a deficiency in action formulation to manage the environmental and economic implications of climate change. Climate change creates damaging impacts on the economy of the country by affecting different sectors of the economy such as agriculture, industries, and energy consumption (Dasandara et al., 2021).

The overall economic impact of climate change shows significant differences between countries and regions (Wang et al., 2021). There is a crucial necessity to address the impacts of climate change on livelihoods especially in the context of developing countries, as it is highly influential to the entire economic system of the country (Yalew et al., 2018). Moreover, due to the impacts of climate change (such as floods, temperature etc.), the livelihoods of communities in developing countries are badly affected and worsens poverty levels (Birkmann et al., 2022; Hoque et al, 2019). Risks caused by climate change impacts are clearly seen in Sri Lankan communities and these make the country highly vulnerable to climate change (Kottawa-Arachchi & Wijeratne, 2017). Thus, Sri Lanka requires adaptation measures to address the economic impacts of climate change and enhance the resilience of the industries affected by different climatic conditions (Aryal et al., 2020).

Since the need for climate resilience has soared creating severe impacts on modern and future society (Carleton & Hsiang, 2016), it is important to propose strategies to

build up resilience to climate change. Considering the vulnerability of the Sri Lanka agricultural industry to climate change and the deficiency of necessary information to develop proper resilience, this study has conducted to investigate the economic aspects of climate change impacts in building up resilience of the communities in Sri Lanka.

1.3 Aim and Objectives

1.3.1 Aim

This study aims to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models.

1.3.2 Objectives

The following objectives have been established to accomplish the research aim.

1. Review economic models of climate change, and the different climatic conditions and economic parameters used in economic models of climate change.
2. Identify the economic impacts of climate change conveyed in economic models.
3. Investigate the different climatic conditions and economic parameters applicable to Sri Lankan context.
4. Investigate the economic impacts of different climate conditions on livelihoods of communities in Sri Lanka.
5. Provide recommendations to increase community resilience against economic impacts of climate change on the livelihoods.

1.4 Research Scope and Limitations

This study has been conducted in the Sri Lanka context to investigate the economic impacts of climate change on the livelihoods and thereby contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through

the application of economic models. Thus, the scope of the study has been limited to agricultural sector to investigate the problems faced by agricultural communities.

Agriculture and climate change are interconnected, as climate change creates direct impacts on agriculture (Masud et al., 2017). Furthermore, these impacts are more substantial in developing nations than in developed nations and farmers are suffer greatly due to the pressure enforced by climate change (Nguyen et al., 2023). Actions to counteract the impacts of climate change on livelihoods of individuals are inadequate (Masud et al., 2017). More specifically, the information available on climate change is limited to developed countries and adaptation actions to resilience to climate change are mostly not investigated (Agrawala et al., 2011). Furthermore, during the past decade Sri Lanka has displayed significant negative outcomes from climate change and climate induced disasters (Weerasekara et al., 2021). Among the different livelihoods prevailing in Sri Lanka, agriculture, manufacturing, and services rank amongst the top three (03) contributors to the Gross Domestic Product (GDP) of Sri Lanka (Central Bank Report 2022). Further, from agricultural, industrial, and service sectors and subsectors, agriculture is the most vulnerable sector to climate change despite different subsectors showing different degrees of vulnerability (Weerasekara et al., 2021). Additionally, Abeysekara et al. (2023), highlight that the vulnerability of the Sri Lankan agriculture to climate change is increasing and identifies the importance of scientific research on proposing strategies to adapt to climate change. Thus, the scope of this study is specifically located around build up resilience of agricultural communities through the recommendation of strategies to overcome climatic impacts.

Case studies were adopted as the research strategy (refer to subsection 2.3.6.2) and the number of cases were limited to two considering time constraints. Accordingly, among the different sectors of agriculture, Tea and Paddy were selected as the two livelihoods this research will look at (refer to justification of selected livelihoods in subsection 2.3.6.2). Moreover, as per the findings of the study of Wickramasinghe et al. (2021), an assessment mapping of the vulnerability of divisional secretariat levels in Sri Lanka to climate change identified that the Southwestern part of the wet zone is more vulnerable to climate change, specially to floods. Considering the climate vulnerability, and the significance of the agricultural industry as a major livelihood

with different crop species cultivation, this study has been limited to cases from the low country wet zone of Sri Lanka.

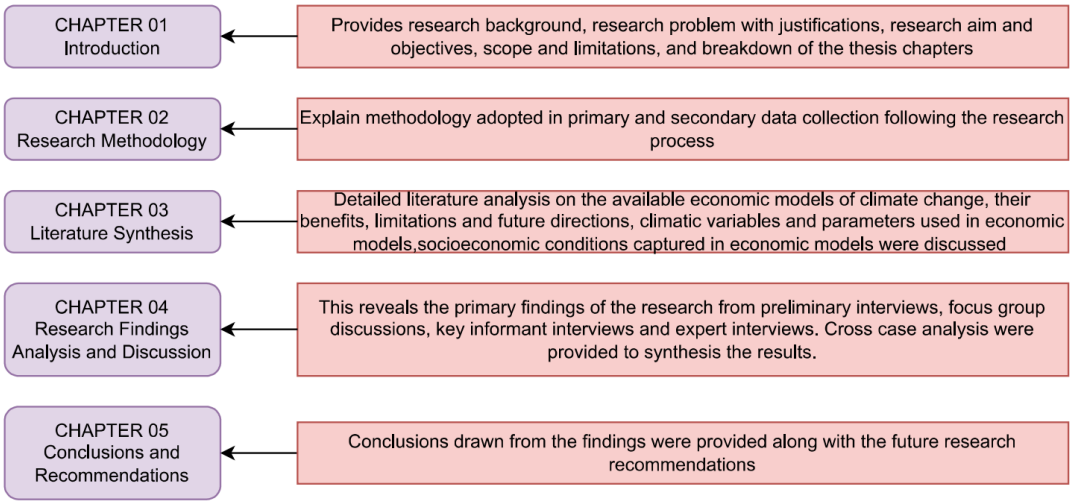
1.5 Research Methodology

This study aims to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models. Accordingly, a qualitative research approach was followed to accomplish the research aim. A systematic literature review (SLR) was conducted to review economic models of climate change, different climatic conditions, the parameters used in economic models of climate change (Objective 01) and the economic impacts of climate change conveyed in the economic models (Objective 02). The primary data collection was extended in four stages. The Stage 01-Preliminary interviews focused to investigate the different climatic conditions and economic parameters applicable in the Sri Lankan context which is Objective 03. The next rounds of data collection followed the two strategies of case study and survey. Cases of two different livelihoods were investigated using the data collection techniques of focus group discussions (Stage 02) and key informant interviews (Stage 03). Accordingly, set of livelihood impacts of climate change were identified (Objective 04) for tea and paddy industries and these provided the base for the next stage of data collection: Stage 04-Expert interviews. Expert interviews were conducted to provide solutions for the identified causes (Objective 05). Finally causal loop diagrams (CLDs) were developed following the identified causes and effects.

1.6 Chapter Breakdown

Figure 1.1 portrays the structure of the research with a brief description of each chapter. Accordingly, Chapter 01 introduces the study. The processes followed in progressing the research have been discussed in Chapter 02- Research methodology. Existing literature findings related to the study are presented in Chapter 03- Literature review, while the primary data findings have been analysed and presented in Chapter 04- Data analysis, findings, and discussion. Finally, Chapter 05 provides the conclusions drawn from the study.

Figure 1.1: Chapter breakdown of the research



1.7 Chapter Summary

This chapter describes the background study and arrives at a problem statement. Further, aims and objectives were highlighted with a brief discussion on methodology. The identified scope of the research along with the research limitations were stated. To summarise, the chapter breakdown of the thesis was indicated with a brief description of the content.

2 CHAPTER TWO- RESEARCH METHODOLOGY

2.1 Introduction

This chapter discloses the methodology followed in this study for secondary and primary data collection. Accordingly, the SLR was explained as the secondary data collection method, while the primary data collection methods were emphasized following the research onion model.

2.2 Methodology for Literature Review

This study incorporates a SLR as the research method since it can be recognized as a positive trend in recent literature reviews (Sadeghi, 2022). It provides a structured process for selecting literature sources than utilising a random search. To accomplish this process, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used as the research method, as it is an internationally recognized, evidence based, transparent review method for published papers (Monash University, 2023). The latest version of PRISMA (PRISMA 2020) was used to increase the reliability of the findings. As stated by Geekiyanage and Fernando (2021), PRISMA guidelines reveal a three (03) phased process consisting of (i) identification, (ii) screening, and (iii) inclusion.

2.2.1 Search Tool

There are q variety of search tools which can be used to perform SLRs. Among them, the PICO search allows results with high sensitivity (Methley et al., 2014) and can be used to extract qualitative data. It includes four (04) elements these are **P**roblem, **I**ntervention, **C**omparator, and **O**utcome. Accordingly, the initial research question was formulated as "What are the characteristics, benefits and limitations of the economic models used to manage the economic impacts of climate change". Following the research question, "sectors of economy" was identified as the population, "economic models" as the intervention, "climate change" as the comparator and "characteristics, benefits and barriers" as the outcomes.

The elements identified in the PICO tool are required to be entered as search terms to generate results. Accordingly, a search string was formulated concerning the following rationales. The "sectors of economy" is a term, rarely used in articles where sectors are described; instead, articles use the sector name. This particular term was therefore removed from the search string. Moreover, the word "change" under the comparator "climate change" was removed as it unnecessarily narrowed the results and could potentially exclude appropriate articles. For example, articles which address the intended research question can use the word "climate economic models" instead of "climate change" and the use of the term "change" can cause the exclusion of the article. However, no converse effect will be made on the search string as all articles with the phrase "climate change" are always included with the keyword of "climate". Emphasising the requirement of a comprehensive search string to have versatile results, possible alternative words conveying similar meanings were incorporated into the search string and Table 2.1 illustrates the logic grid developed in this study.

Table 2.1: Logic grid for the systematic literature review (SLR)

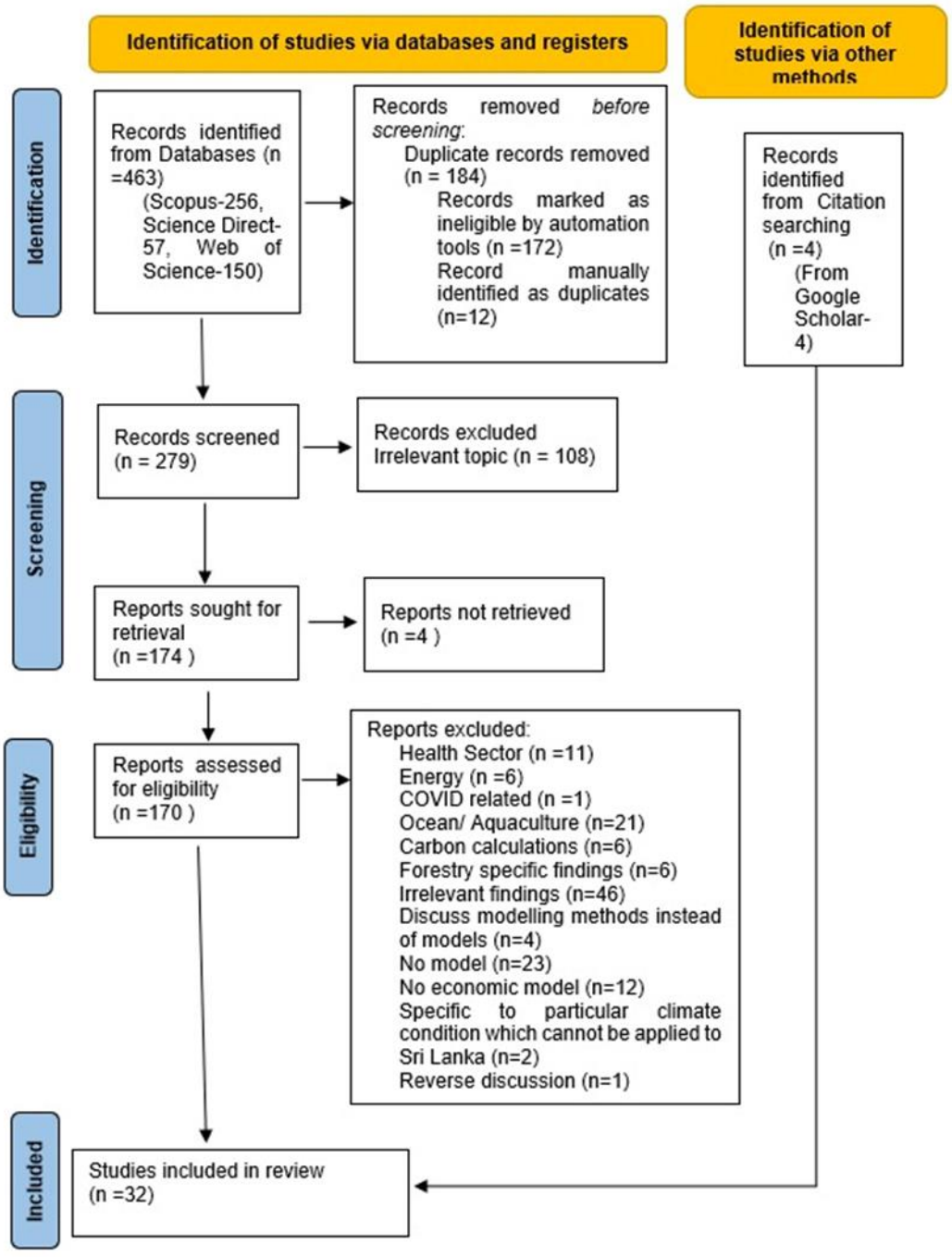
Population	**Intervention**	**Comparator**	**Outcome**
Global Context (**Sectors of economy**)	**Economic models**	**Climate change**	**Characteristics** **Benefits** **Limitations**
	Econom* W/0 model*	Climat*	Econom* W/0 value*
			Character*
			Feature
			Benefi*
			Barrier*
			Advantage*
			Disadvantage*
			Limitation
			challenge

The search string was developed based on the keywords in Table 2.1 and adjusted to suit the selected databases (wildcards etc.). Further, as the search scope, the paper title, abstract and keywords were included in the search. However, the comparator of the search string deviates from its general search criteria and was explored only in "title". This was consequent to the abundancy of the term "climate" in general articles wherein the content has no relation to climate change.

2.2.2 Study Database Selection

To accomplish the purpose of a SLR and obtain a versatile set of structured results three databases ranked as the top databases of the relevant fields were used. Accordingly, “Scopus”, “Web of Science”, and “Science Direct” are the three (03) databases used. These articles were filtered based on “English” as the written medium and the publication year was set from “2013 to 2022”. The selection process involved an initial screening and the subsequent reductions in the chosen articles for further consideration were based on a developed criterion. The selection process in this instance followed a 3-step framework as identified in Figure 2.1. Accordingly, the initial screening identified 463 records across the three databases (as mentioned earlier). After a careful analysis carried out in three phases, a further search of Google Scholar was conducted which resulted in the addition of four extra articles from the journals.

Figure 2.1: Identification of studies in the systematic literature review (SLR)

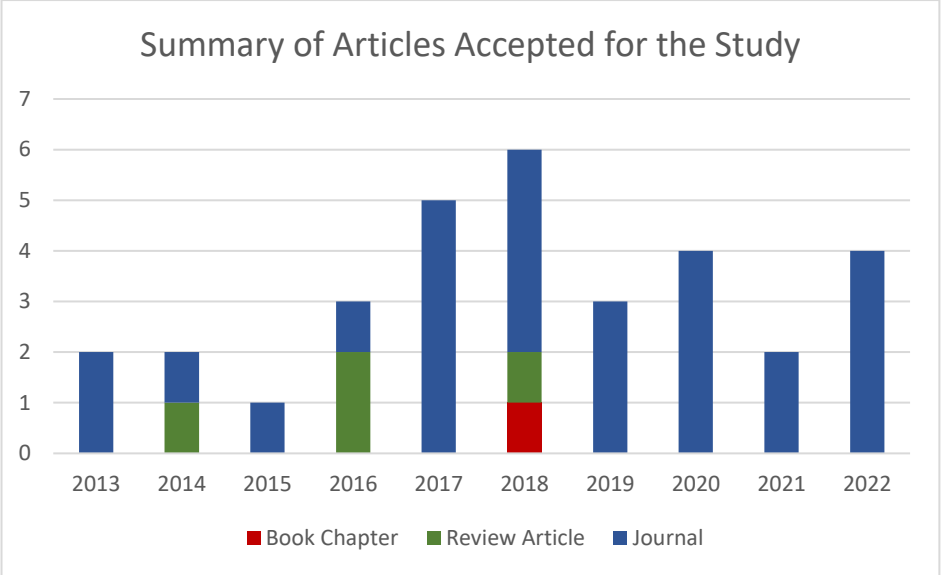


According to Figure 2.1, an initial record of 463 articles were found after the keyword search in three databases - Web of Science, Scopus, and Science Direct. A record of 279 (articles after removing duplicates) were subjected to a screening process. 170 articles were assessed for eligibility, and following the criteria mentioned in Figure 2.1, 32 articles were selected to further investigate the economic models of climate

change in accordance with the criteria mentioned above. One book chapter, four review papers and 27 journal articles were identified.

The 32 articles accepted for the study depict the background information as shown in Figure 2.2 in terms of article type and the year of publication.

Figure 2.2: Classification of the accepted reports



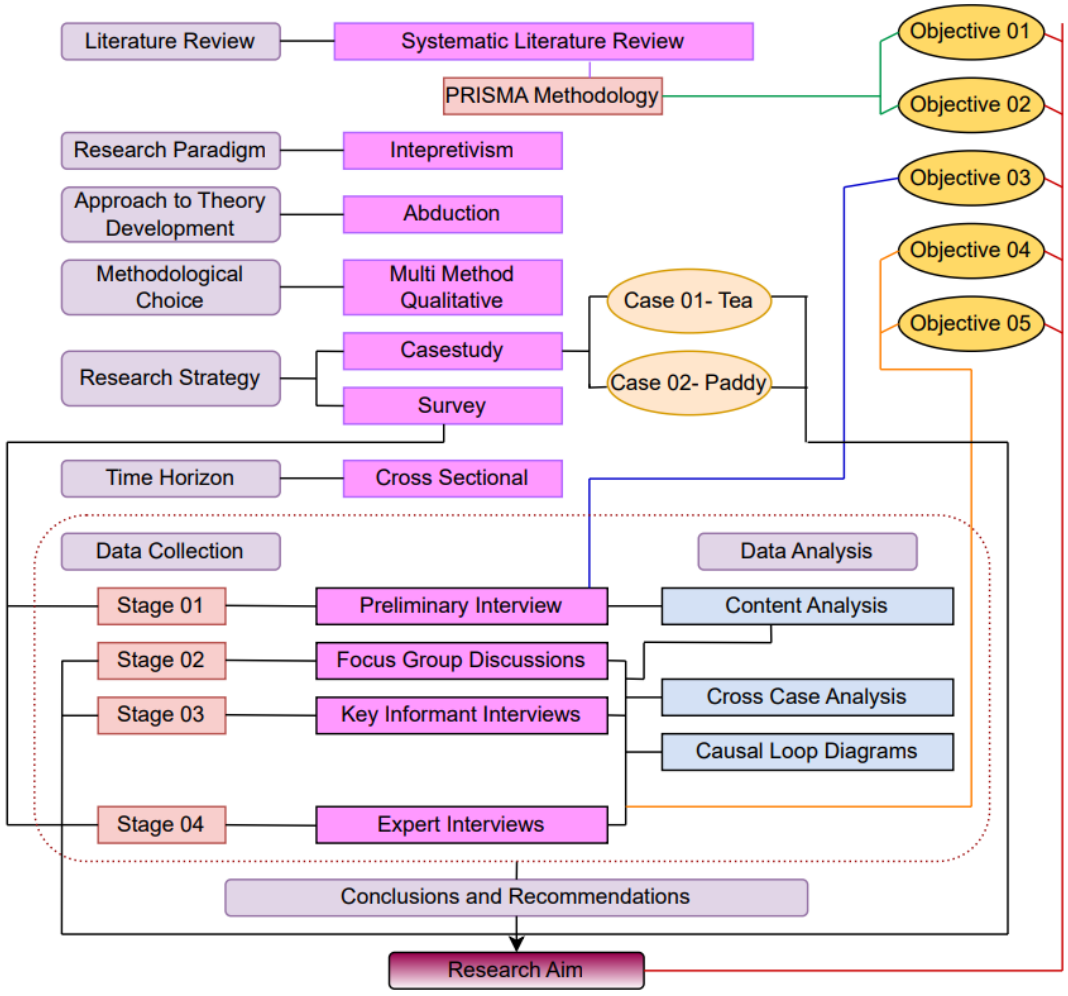
According to Figure 2.2, studies on economic models of climate change related to agriculture peaked in 2017 and 2018. This is supported by reports of the World Meteorological Organization [WMO] (2020), which indicates that in 2017, severe droughts prevailed in many parts of the world which may have caused this peak. Moreover, in 2018 there was some common understanding that there was an acceleration in climatic events and a lot of studies were undertaken in line with Intergovernmental Panel on Climate Change (IPCC) reports which may be the reason for the 2018 increase. A slight increase can be observed in 2020, which may be a result of inputting climatic information into the IPCC report of 2021. In addition, it can be argued that the Covid-19 pandemic in 2020, caused the reduction of the number of articles in 2021, where the necessity for investigation is less consequent to the reduced air traffic.

2.3 Methodology for Primary Data Collection

2.3.1 Research Process

The research process refers to the plan of structuring a research problem to arrive at conclusions (either implicit or explicit) which can be explained as the logical framework (Yin, 2013). Accordingly, Figure 2.3 explains the graphical framework of the research process adhered to in this study.

Figure 2.3: Research process



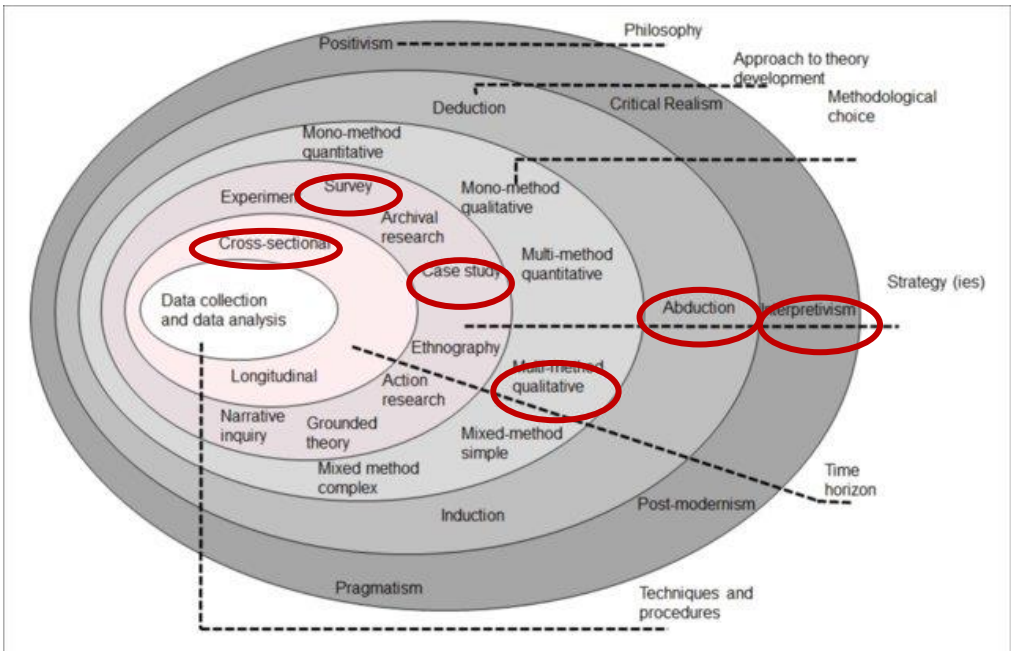
As the initial stage of the study, the background literature was examined to identify and develop the research problem. Following this, a comprehensive literature review was conducted adhering to the SLR research methodology, to identify and review the literature using a structured approach. This helps in accomplishing the first three objectives of the research study. Primary data collection directed to cover the last two

objectives of the research study and data collection was conducted in four stages using two research strategies of survey and case study. Initially Stage 01- preliminary interviews were conducted with two experts in the academia, who are aware of and working on climatic-related studies and community research to identify the parameters applicable to the Sri Lankan context. Following that, two case studies from the low country wet zone were selected for the next two stages of data collection: Stage 02 includes- focus group discussions and Stage 03 involves key informant interviews. Finally, Stage 04- expert interviews were conducted to accomplish the last objective of the study. Manual content analysis (Stage 01-04), cross case analysis (Stage 02-03) and CLDs (Stage 02-04) were used to analyze the data and thereby contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models, the research aim. Finally, conclusions and further research recommendations were made from the primary findings of the study.

2.3.2 Research Methodological Design

The research methodology includes a set of values and philosophical viewpoints that form the position for addressing the research problem (Melnikovas, 2018). Furthermore, according to Jonker and Pennik (2010), the research methodology is one that outlines the most logical, transparent, and explicit route the researcher desires to follow to address the study problem, including ideas for the origination of research, its direction, and action plan, as well as the most appropriate methods for data collecting and analysis. This study adopted the research onion model proposed by Saunders et al. (2019), as it is a recent and frequently practiced research design to establish the methodological design. Accordingly, Figure 2.4 presents the research onion model with remarks on the choices made in this study.

Figure 2.4: Research onion model



Source: Saunders et al. (2019)

The upcoming sections describe the layers of the research onion with reference to the methodology used in this study.

2.3.3 Research Philosophy

The way in which data is gathered, analyzed, and interpreted in research is determined by the researcher's philosophical perspective (Walliman, 2021). In order to arrive at the notion that conducting research is necessary, Holden and Lynch (2000) provide the research paradigm as a collection of beliefs based on the author's perspective on society and human beliefs. Ontology, epistemology, methodology, and methodologies are thus included in the philosophical components of the research philosophy (Rehman & Alharthi, 2016). The research onion by Saunders et al. (2019), identifies five research philosophies and the conclusion was that this study suits the philosophy of interpretivism.

Interpretivism is based on the assumption that there is no universal truth (Dudovskiy, 2022), and reality can be perceived through subjective measures depending on the context. Thus, interpretivism is applicable in instances where human involvement and interpretations add value to complex and multifaceted topics. Interpretivists argue that

humans cannot be separated from the knowledge which is created (Saunders et al., 2019) and provide researchers with the ability to be a part of the research, where the findings are value laden.

In this study, the researchers focused to identify the economic impacts of climate change on communities, where the communities cannot be separated from what is being found and different views and perspectives of human beings, provide rich insights into the research problem. Further, providing recommendations to problems identified within the context of the industries requires views of the most knowledgeable people on the problem and are not predefined theories, but are those emerging from the context. Therefore, this study promotes subjective-values and data created from the affected society. Thus, the interpretivism research philosophy was identified as the most suitable philosophy in this context.

2.3.4 Approach to Theory Development

As indicated in the second layer of the research onion, three approaches to theory development can be identified; these are, induction, deduction, and abduction. Furthermore, to Saunders et al. (2019), the deductive approach has to do with testing the existing theories while the inductive approach is to produce or generate new theories. The abductive research approach facilitates a combination of both inductive and deductive approaches. Creswell (2014) reveals the characteristics of the three research approaches mentioned above, which have been summarized in Table 2.2.

Table 2.2: Features of different approaches to theory development

	Inductive	**Deductive**	**Abductive**
Research Problem	Incipient	Predetermined	Combination of both
Nature of Questions	Majorly open ended	Majorly close ended	Can be Both
Types of Data	Interview data, Document data, Audio and visual data, Observation data	Performance data, Attitude data, Observational data and Census data	Combination of both
Data Analysis	Text and image analysis	Statistical analysis	Combination of both

Data Interpretation	Themes and Patterns	Statistical figures	Combination of both

The aim of this study is to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models. This aligns with the generation of knowledge, and testing or verifying the existing economic parameters from the global context. It is context specific and economic impacts are required to be generated from the context simultaneously with the use of parameters that were identified from the literature review. Thus, the abductive research approach can be justified as the most suitable research approach for this study.

2.3.5 Methodological Choice

The next layer of the Saunders et al. (2019) research onion refers to the methodological choice, which can be identified in three main choices as qualitative, quantitative, and mixed method. According to Walliman (2021), the questions in terms of "how much", "how many", "what", "who", and "where" were used for quantitative research methods. In contrast qualitative research methods study the textual data gathered through views, experiences, attitudes, and beliefs of human and therefore generally follow the question types of "how" and "why" (Fellows & Liu, 2015). The mixed method as suggested by its name is a combination of both qualitative and quantitative methods (Doyle et al., 2009).

This study deals with the research question of "How the resilience of different livelihoods of communities in Sri Lanka can be built up against climate change", which provides textual evidence. This requires input from varieties of community groups, including the people whose livelihoods are affected, authorities who are currently connected to handle the impacts on livelihoods and academic or theoretical feasible strategies to be implemented through expert groups. Following the two above requirements, this study incorporates the "multi-method qualitative" methodological choice.

2.3.6 Research Strategy

The research strategy refers to a general plan, which structures the path to conducting research (Yin, 2014). Furthermore, it helps to identify the research problem in detail and develop accurate solutions to it (Mohajan, 2017). As per Saunders et al. (2019), research strategies suitable for a particular study are determined based on the selected research approach and Yin (2014) identifies the available research strategies as survey, case study, experiment, archival analysis, and history. Further to the author, there is no extant strategy or set of strategies for a research problem that can be investigated through multiple appropriate possibilities based on reliable arguments and structure. Following that, this study uses two different research strategies of survey which is for Stage 01 (preliminary interviews) and Stage 04 (expert interviews), and case studies for Stage 02 (focus group discussions) and Stage 03 (key informant interviews) of data collection. The next subsections described the rationale for adhering to particular research strategies.

2.3.6.1 Survey Research Strategy

A survey is a research strategy suitable for both qualitative and quantitative data collection in a study (Cherry, 2020) to collect data from a population or a sample using a systematic procedure (Mathiyazhagan et al., 2010). Furthermore, it is appropriate for answering the questions which involved "who", "what", "where", "when", "how many" and "how much" (Fellows & Liu, 2015). As the preliminary interviews of this study focused on identifying "the parameters and climatic conditions derived from the economic models are prevailing in Sri Lanka", carrying out a survey was considered as the most appropriate strategy for Stage 01-preliminary interviews data collection. Moreover, for the identification of a set of strategies to build up community resilience against climate change, a survey strategy was identified as suitable, as it focuses on the question of "how community resilience to climate change is ensured in tea and paddy industries?".

2.3.6.2 Case Study Research Strategy

Case study refers to *"an empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between the phenomenon*

and context are not clearly evident and in which multiple sources of evidence are used" (Yin, 1984, p.23). According to Yin (2014), case studies can be identified as the most suitable research strategy for research problems comprising of "why" or "how" questions as they provide an in-depth investigation to answer the research question. As this study required in-depth empirical investigations to identify the economic issues experienced by the community consequent to climate change, case studies were selected as the suitable strategy for that. Accordingly, Objective 04 utilized the data collection methods followed by case studies.

Design of case studies

There are two case study designs as revealed by Yin (2009) as single case study design or multiple case study design. Single case study design is used in situations where we study a common case, longitudinal case, critical case, unusual case, or revelatory case (Yin, 2014). Since this study focuses on investigating the economic impacts of climate change on the livelihoods of communities in Sri Lanka evidence from multiple case studies were deemed appropriate.

Selection of cases

The selection criteria of cases of the case study depend on the parameters of judgement, convenience, and time and cost limitations (Yin, 2014). The selection is based on the "replication" which is two types; theoretical replication and literal replication (Saunders et al., 2019). Literal replication forecasts similar results from the multiple cases whereas theoretical replication predicts contrasting results in the multiple cases due to predicted reasons (Yin, 2018). This study selected theoretical replication as the appropriate replication logic because of the expectation to see different results in the multiple case studies. A study conducted in Kerala, India regarding the impacts of climate change on different cropping systems stated that climate change, tend to similarly impact on both paddy and tea cultivation and act as a cause to reduce harvest (Rao et al., 2008). Another study in Eastern Africa also conveyed similar view and stated that climate change cause in reduction of the output in both tea and paddy cultivation (Adhikari et al., 2015). Following that, this study uses literal replication in selecting cases. However, this study aims to investigate multiple impacts of climate change on the two agricultural crops, tea and paddy in addition to the reduction of

output. Henceforth, the findings are predicted to be different following the nature of the industry. Thus, literal replication was based as replication logic.

Since, Sri Lanka displays different climatic patterns across different regions which are differently affected by climatic impacts, this research selected the low country wet zone as the region for investigation based on the findings of Wickramashinghe et al. (2021), which identified the low country wet zone as a highly vulnerable area to climate change, especially the southwestern part of it. Since the research aim was to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models, within the context of agriculture, different livelihoods under agriculture were selected as the case study boundary. Hence, this study investigates the phenomenon of economic impacts of climate change within the context of livelihoods. Following time constraints, the number of cases were limited to two. The rationale for the selection of two different livelihoods from agriculture is mentioned below.

Justification of Selected Livelihoods

As revealed in the records of the Ministry of Agriculture Sri Lanka (2023) on the crop distribution and suitable crop types for selected regions tea, rubber, paddy, cinnamon, and pepper were identified as the main crops cultivated in the low country wet zone of Sri Lanka. Among these, paddy is the primary food crop of Sri Lanka, while tea can be identified as the major source of foreign exchange (International Trade Administration, 2022). Furthermore, tea and paddy were determined to be the two most vulnerable industries in Sri Lanka, by the end of 2022 following several reasons including weather challenges (Chandrasiri et al., 2023). Accordingly, “tea” and “paddy” were selected as two livelihoods for the case studies.

Justification of the Selection of Particular Case from Each Livelihood

This is based on the judgement of the researcher followed by convenience and accessibility to data. Accordingly, cases were judged based on the frequency of damages to cases during the last five years, followed by the inclusion of any extreme events.

Case Study Selection Criteria

The selection of cases was based on the criteria including, 1). Cases should be based on low country wet zone, 2). Industry (tea or paddy as per the case) should be the main source of income of the participants, 3). Should undergo challenges consequent to at least one of the main climatic conditions identified, 4). Should have at least 12 farming families who suffer from difficulty of continuing their livelihood mainly due to climatic barriers, and 5). Accessibility to community, officers, and documents (if required). Accordingly, one case from each livelihood (one from tea and one from paddy) was selected. Participants for the focus group within the case were selected based on the criteria specified in Table 2.3 used to determine the nature of participants and status of impact by climate change.

Table 2.3: Focus group member selection criteria

Mandatory Criteria	Optional Criteria
Should be an owner or worker of a particular crop (tea or paddy as per the case) land	To have mix of participants from all plot sizes (small, medium, large)
Income from this agricultural industry should be the primary income	Better to have mix of participants to mix all age groups.
Should suffer from at least one climatic condition from the two main conditions identified.	Better to have mix of participants who have received/ not received compensations for climatic damages to their industry.
Minimum of 4 members per each focus group	

Based on Table 2.3 focus group members of two cases were selected from each industry of tea and paddy, and in both studies, communities who belong to only employee category was difficult to found and therefore, the focus group discussions were conducted with owners and people who work as both owners and workers.

Defining the Unit of Analysis

The selection of unit of analysis in a case study is directly related to the research question being investigated (Yin, 2014), which are the economic impacts of climate change on different livelihoods in this research study. Accordingly, holistic cases refer to cases with single unit of analysis while embedded cases follow multiple units of analysis (Rowley, 2002). In this case the data is collected on the economic impacts based on different livelihoods as the boundary. The unit of analysis has determined as

the “economic impacts of climate change” in these two cases which follows holistic case study design with single unit of analysis.

2.3.7 Time Horizon

The next layer of the research onion proposed by Saunders et al. (2019) is the time horizon, which is identified under the cross-sectional and longitudinal categories. Cross-sectional refers to studies where data is collected at a particular time, while longitudinal conveys periodical studies in which data collection occurs over a period of time. Thus, this study falls into the category of cross-sectional approach where the study is conducted in the prevailing context.

2.3.8 Data Collection Techniques

Data collection is the inner most layer of Saunders et al. (2019) research onion. Data used in this study falls under the two main categories of primary data and secondary data. Secondary data was collected through the literature review, based on the methodology specified in subsection 2.2. Primary data collection of this study aligned in four stages within the two research strategies. The structuring of data collection under each stage is described in Table 2.4.

Table 2.4:Structure of data collection stages

Stage	**Research Strategy**	**Data Collection Tool**	**Sampling Method**	**Sample Size**	**Selection Criteria of Sample**
Stage 01	Survey	Preliminary Interviews	Convenience Sampling	02	Experts with the knowledge and research experience on climate and community research and with more than 20 years of academic experience
Stage 02	Case study	Focus Group Discussions	Judgmental Sampling	03 groups 05 member each in each case	Both owners and workers, Both Female and Male, With and without other crops and other employments, Covering range of educational levels

Stage 03	Case study	Key Informant Interviews	Judgmental Sampling	04 experts from each case	Officers who are directly involved and communicated with on disaster related issues regarding livelihoods of the selected case
Stage 04	Survey	Expert Interviews	Judgmental Sampling	06 per each livelihood	Experts in the relevant industry with theoretical and practical knowledge on particular livelihoods

All four stages of data collection were conducted physically (face-to-face). Language of data collection was English in Stage 01, Stage 03 and Stage 04. Stage 02 of data collection was conducted in Sinhala (native language in Sri Lanka) as the community are not familiar with English. The focus group members were selected following the criteria specified in the last column of Table 2.4. This criterion was established following the findings of the literature review (the parameters that emerged from the economic models of climate change) to cover a multiple range of demographics. Further, the groups were organized to capture data of different perspectives (refer to Table 4.3 and 4.7). This also helped in improving group dynamics where input from participants of different backgrounds stimulates the discussion.

The sample size was designed based on the following concerns.

- Stage 01- This sample size was determined based on the convenience and time frame. Since repetitive responses were obtained from both experts, the number was limited to two.
- Stage 02- Rabiee (2004) investigated the number of focus groups and number of participants in a focus group suitable for qualitative data collection methods. Accordingly, three to four focus groups have been identified as the ideal number of focus groups for a study. Furthermore, around six to eight has been identified as the manageable number of members for a focus group who are comfortable talking about the subject. Furthermore, Rabiee (2004) states that it depends on the context and emphasizes that small groups have the potential to yield highly focused results. Accordingly, this study used three focus group discussions consisting of five

members each. Further, data saturation was reached with two interviews and one additional interview was conducted to confirm the saturation of data.

- Stage 03- The key informants associated with each case were investigated and four of them were selected as being closely related from different authorial duties (refer to Table 4.4 and 4.8). These four participants were disclosed comprehensive views about the questions and considering the saturation of data, the number was limited to four.
- Stage 04- Data saturation was considered the main concern in determining the number of experts. Accordingly, six experts were interviewed, where the data saturation was reached, at the point of four members and two additional interviews were conducted to confirm the saturation point.

2.3.8.1 Data Collection Tools

Four distinct semi structured interview guidelines (refer to annexures 1-4) were used at each data collection stage where Stage 01 and Stage 02 guidelines were based on literature, Stage 03 guidelines were based on literature and findings of Stage 02 and Stage 04 guideline similarly follow literature and the findings of Stage 03. Stage 01 guideline developed based on section 3.6 and 3.7 of literature and additional questions were included to investigate the suitability of the two selected cases based on literature. Stage 02 focus group guideline was developed based on section 3.7 and 3.8 of the literature review following few background questions to determine the community awareness on climate variability (about recurrent and frequent events) and climatic impacts through observations. Digital recording and note taking with the permission of the interviewees were to ensure the credibility of the data.

2.3.9 Data Analysis Techniques

Since this study involves qualitative data, three qualitative data analysis techniques were selected for the analysis of data. Thus, the findings of Stage 01 were analyzed through content analysis as it is the most popular analysis method for text data, which encrypts data with clear codes (Hsieh & Shannon, 2005). Content analysis can be done with two main methods as manual content analysis and software-based content analysis. This study utilized manual content analysis considering the requirement of

the researcher to have in-depth investigation of the data and the capacity of the data to be handled manually.

The next three stages of data collection were followed by multiple methods of data analysis as manual content analysis, cross case analysis and CLDs in system thinking for all three stages. As stated by Rose et al. (2015), findings of the case studies are useful and rational if cross case analysis and tabular presentation is used. Thus, cross case analysis was conducted for the findings of two case studies. Further, since the researcher aimed to analysis the data using system thinking and CLDs (justification for using this approach is explained in subsection 2.3.9.1), questions were directed to have a detailed investigation on both causes and effects of climate variability and causes and consequences of change in the parameters identified under section 3.7. Accordingly, Chapter 04- Data Analysis and Discussion presents the findings on causes and effects of different climatic conditions and causes and impacts captured using identified parameters used to determine economic impacts.

2.3.9.1 System Thinking and Causal Loop Diagrams (CLDs)

System thinking refers to the process of providing a holistic view of a problem where the components associated with the problem are presented in a graphical way which emphasizes their relationships. This is helpful to determine the behavior of the components over time (Dhirasasna & Sahin, 2019). Further, it helps to develop a conceptual model of the parameters associated with a particular context by considering the context as a system and helps to visualize the relationships among them (Crielaard et al., 2022). CLDs is a conceptual model or structure, which links the relationships between a set of causes and effects (causalities) of a particular instance or problem (Haraldsson & Bonin, 2021). It follows system thinking and considers the instance/problem, and its causes and effects as a system (Groundstroem & Juhola, 2021). CLDs show a visual representation of relationships between the components of the system which produce the problem and the consequences of the problem (Crielaard et al., 2022).

Justification of Causal Loop Diagrams as a Data Analysis Technique

As explained by Dhirasasna and Sahin (2019), CLDs are suitable for complex problems which change over time. Climate change can be considered a complex problem, which changes over time (Evans, 2019) and creates concurrent impacts on the livelihoods of the community (Feulner, 2017). Accordingly, a visual representation of impacts of climate change on livelihoods as a holistic system helps to determine the causes and consequences of the impacts on livelihood, their relationships which will assist the users and decision makers to study the behaviors, predict actions and control the impacts. Thus, CLDs have been identified as an effective way of analyzing the identified parameters within the context of economic impacts of climate change on livelihoods. Moreover, CLDs provide reliable results when incorporating perspectives of multiple stakeholders (Dhirasasna & Sahin, 2019). As this study incorporates data collection from a wide range of respondents (focus groups of farmers, officers from administration and academic experts), the construction of reliable CLDs can be ensured.

2.3.9.2 Causal Loop Diagrams

Relationships in Causal Loop Diagrams

The relationship between two variables is denoted with an arrow where the arrowhead is towards the variable impacted by the previous variable. Figure 2.5 clarifies this where "Variable A" causes "Variable B".

Figure 2.5: Relationship of variables in a causal loop diagram (CLD)

Polarity in a Causal Loop Diagram

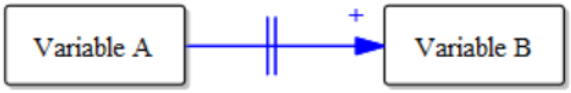
Polarity in a CLD refers to the nature of the relationship between the two variables. There are two main methods of denoting polarity as 1). + (Plus) or – (Minus) and 2). S or O polarity. Here the "Plus (+)" sign or "S" stands to show that the two variables

have a directly proportional relationship where if one variable increases so dose the other and vice versa. This means that both variables behave in the same direction. Conversely, “Minus (-)” sign or “O” stands to denote an inversely proportional relationship between two variables where an increase in one variable leads to a decrease in the other.

Delay Indication in a Causal Loop Diagrams

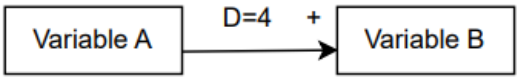
Despite the CLDs indicating the relationship between variables, there is an additional feature to indicate the time of impact which is known as “delay”. Delay implies that impact is not immediately visible and there is the involvement of a time lag. Figure 2.6 shows the method used to indicate a delay in a CLD.

Figure 2.6:Indication of delay in a causal loop diagram (CLD)



According to Figure 2.6, an increase in “Variable A” results in an increase of “Variable B” however the effect is not immediately apparent. Here, the duration which is being considered as delay is context specific and it can be seconds, minutes, hours or even years depending on the context of the study. There is an alternative way of indicating delays as “D=X” X here is a number which stands for delay period and definition of unit of delay that can be provided with the diagram. Figure 2.7 shows an example on how to indicate a delay period.

Figure 2.7: Indication of delay with time period



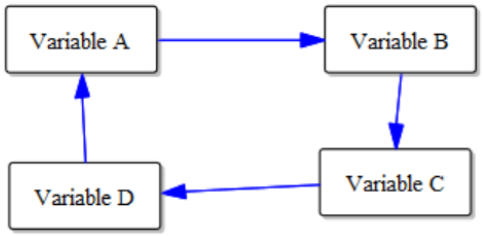
As per Figure 2.7 an increase/decrease in “Variable A” results increase/decrease (simultaneously) in “Variable B” However the impacts on “Variable B” is observable after 4 years of occurring “Variable A” (considering the delay is recorded in years).

This study used the first method to indicate the delays with two parallel lines on the arrow.

Loops in a Causal Loop Diagram

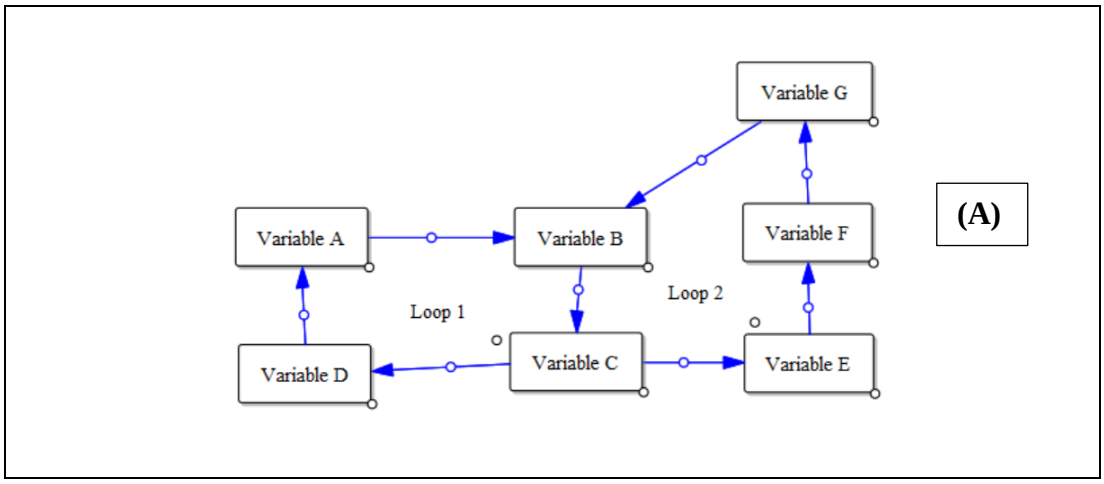
CLDs can have closed relationships which are referred to as loops. It is important to note that all the variables in the CLDs are not required to belong to a loop (Dhirasasna & Sahin, 2019) and loops indicate that the variable within the loops behaves circularly. Figure 2.8 indicates an explanation of the loop where “Variable A” impacts “Variable B”, “Variable B” impacts "Variable C”, “Variable C” impacts "Variable D” and “Variable D” impacts " Variable A”.

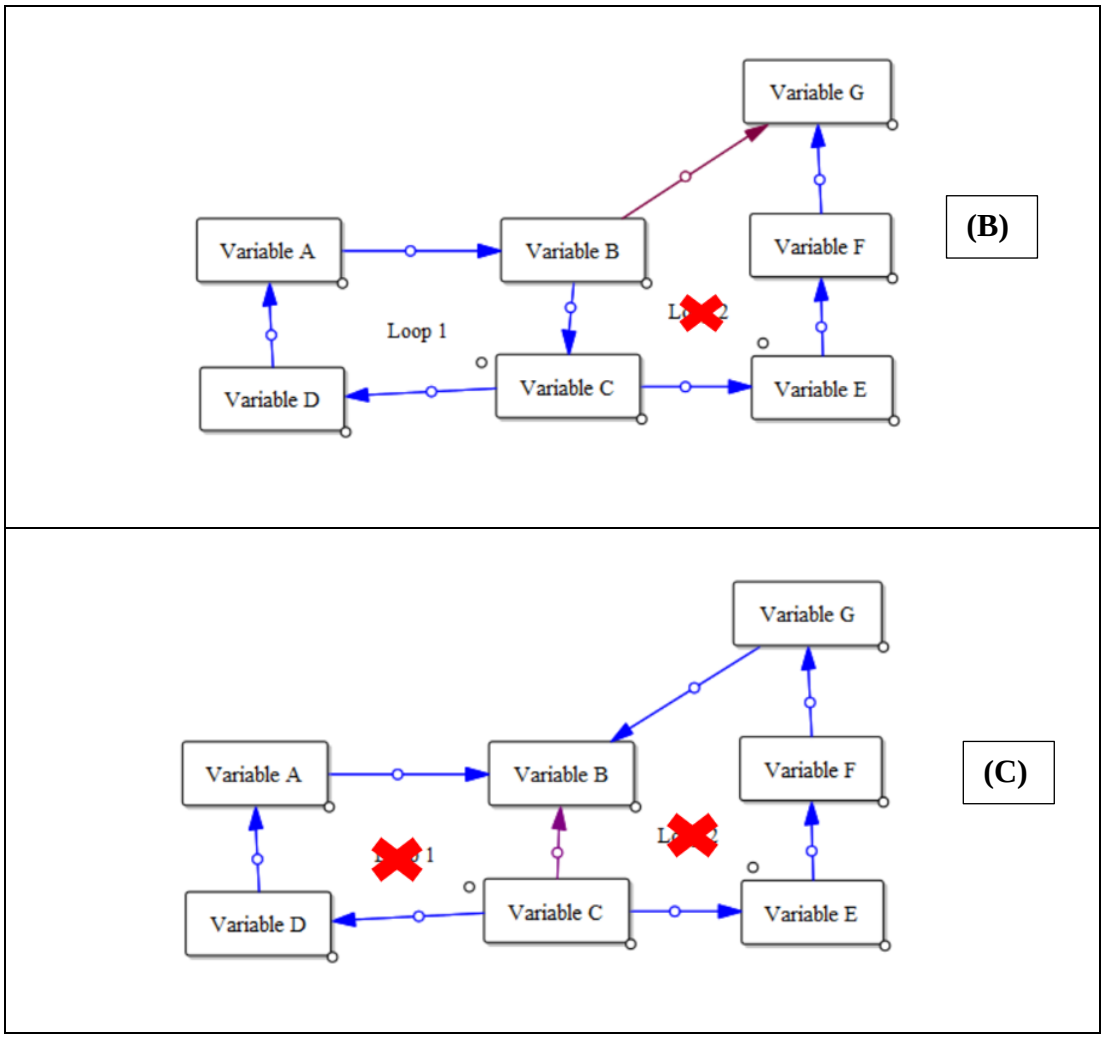
Figure 2.8: Loop in a causal loop diagram (CLD)



In this loop as indicated in Figure 2.8 - all the arrows are moving in the same direction which creates a closed loop. Figure 2.9 shows different CLDs with and without loops.

Figure 2.9: Different causal loop diagrams (CLD) with and without loops





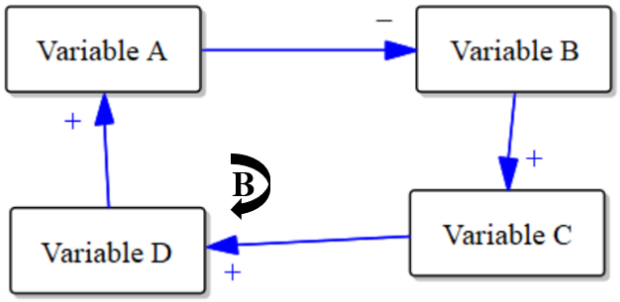
According to Figure 2.9 (B) and (C), the arrow with a different color has a different direction and it, therefore, does not form a loop. There is no significant number of variables for forming a loop and it can be any number more than two. The loops in a CLD can be identified under two main types as 1). Balancing loops and 2). Reinforcing Loops (Lannon, 2012).

Balancing Loops

Balancing Loops are generally indicated with the sign "B" with a circular arrow towards the direction of the arrows in the loop. A balancing loop stabilizes a system over time (Lane & Husemann, 2008) and when a particular variable increases and runs the system out of balance, it regulates the system and brings it back to the original state. It is same as the body temperature of a healthy man, which increases or decreases based on environmental conditions. Figure 2.10 shows a balancing loop where the

number of minus marks is odd (which is one in this case). Here the “B” with an arrow in the middle denotes the balancing loop symbol.

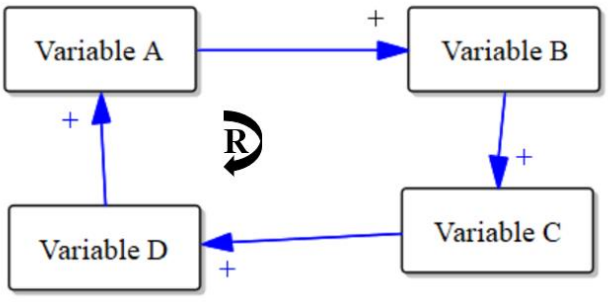
Figure 2.10: Balancing loop



Reinforcing Loop

Reinforcing loops are referred to with the letter “R” followed by a circular arrow in the direction of arrows in the loop. Reinforcing loops tend to produce exponential growth or decay in the system, if a Variable in the system changes (Lannon, 2012). In general terms, it is the same as compound interest where an increase in money increases the interest not proportionally but in a higher amount. Figure 2.11 denotes a reinforcing loop.

Figure 2.11:Reinforcing loop



As observed in Figure 2.11, it has zero minus signs. Accordingly, the reinforce loop possesses zero or an even number of minus signs within the loop.

The nature of the loop (whether it is balancing or reinforcing) can be easily determined with the number of minus (-) signs or “O” marks in the loop. Accordingly, loops with

zero or an even number of minus signs are reinforcing loops while the loops with an odd number of minus signs are balancing loops (Lannon, 2012).

Developing Causal Loop Diagrams

"Vensim PLE x64" has been used as the software for the graphical representation of CLDs. It provides a supportive platform for the development of CLDs with functions available to indicate relationship, polarity, and delay.

2.4 Validity of the Research

This study follows the approach of validation of data through the subsequent round of data collection. Thus, the findings of Stage 01 were further investigated to validate on Stage 02- focus group discussions, findings of Stage 02 were validated with key informants (Stage 03) and findings of Stage 03 were validated through experts (Stage 04). Accordingly, this study used multiple sources of evidence to validate case studies which is known as construct validity (Rowley, 2002).

2.4.1 Generalisability of the Research

Generalizability is limited in qualitative research as it focuses on developing content specific and theme development instead of obtaining generalised findings (Creswell & Creswell, 2018). Nevertheless, there is an ability of generalising the findings of the case studies, outside the immediate study. This can be more referred to as transferability than generalisability, as this fallows discussion of other situations, where the obtained findings might be relevant (Eamonn & David, 2013). This study uses two cases in low country wet zone, tea, and paddy industry, which can be relevant and transferable into other wet zone areas of the Sri Lanka. Moreover, the findings can be relevant and transferable to tea growers who are suffering from landslides, and to the paddy growers who are subjected to floods. Since climate change is a global issue, affecting the entire world community, the findings generated may be transferable to other industries of the tropical countries, which are subjected to similar climatic conditions and threats.

2.4.2 Reliability of the Research

The ability of a researcher to reach the same findings and conclusions by using the same methods as the original researcher is what constitutes a study's reliability (Yin,

2018). Henceforth, reliability aims to reduce the biases and inaccuracies of the research. Further to Yin (2018), proper and detailed documentation of information and procedures followed is important to derive a proper conclusion. Accordingly, the methodology chapter explains the detailed procedures followed in the four stages of data collection and analysis. Moreover, adhering to SLR also increased the reliability of the study. In terms of the CLDs developed, they were validated with pattern matching with the literature, internal validity, and construct validity.

2.5 Chapter Summary

This chapter explains the research methodology adhered to in this study. Accordingly, a SLR was used as the secondary data collection technique. Primary data collection followed four stages under a qualitative research approach, where surveys and case studies were used as research strategies. Manual content analysis, cross case analysis, and CLDs were described as data analysis techniques. Finally, the data validation process followed was described.

3 CHAPTER THREE- LITERATURE REVIEW

3.1 Introduction

This chapter focuses on providing extant, and comprehensive literature on the research field which helps to establish the background of the research problem. Accordingly, a SLR was conducted to identify the economic models of climate change, their benefits, limitations and future directions, climatic conditions and parameters used, and the economic impacts discussed.

3.2 Climate Change

Global climate change refers to a "dynamic, multidimensional system of changes in environmental conditions that will likely influence human behaviour" (Evans, 2019, p.2) which is a significant issue in the present world (Bobojonov & Aw-Hassan, 2014; Wang et al., 2021). It has become a major threat issue for mankind (Van Meijl et al., 2018) that challenges the survival of humanity (Hoegh-Guldberg et al., 2019). Moreover, climate change is directly associated with economic growth and the welfare of the people (Mulwa et al., 2016) and the socio-economic conditions of people are highly influenced by climate change (Biesbroek et al., 2013; Gasper et al., 2011). Henceforth, climate change can be acknowledged as a current concern, which disturbs the persistence of people by creating substantial direct and indirect impacts on them like health damages due to changes in heat stress, land losses due to sea level rises, changes in agricultural productivity and declining economic growth (Hof, 2015).

The impacts of climate change are pervasive from all aspects including from global, regional, national, and local perspectives and necessitate multi-level intervention (Ministry of Maheweli Development and Environment, 2016). Health issues, impacts on trade and agriculture, and disturbance to population structure and growth are the burning negative impacts of climate change at the global level (Carleton & Hsiang, 2016; Ziervogel et al., 2014). Moreover, climate change creates cross-repercussions on many sectors, including agriculture, energy, infrastructure, health, production, and international security (Feulner, 2017). All this means climate change affects the environment through changes in temperature and precipitation patterns, thereby damaging the economic wellbeing of people affecting their trade and food security and

change the overall balance of the society (Porter et al., 2015). Hence, climate change affects all the three pillars of sustainability (environmental, economic, social), creates negative impacts on livelihoods of people and has become a key cause of poverty (Intergovernmental Panel on Climate Change [IPCC], 2022).

3.3 Economic Impacts of Climate Change

Climate change impacts all the sectors of the economy and ultimately impacts on population. For the identification and definition of climate change in terms of economy, it is essential to consider a number of factors i.e. trend of climate change, frequency of climate change, assumptions on severity and longevity of climate change, current measures, and future plans from the economic sector to adapt to climate change, the physical impact of climate change and time frame of impacts (Debelle, 2019).

3.3.1 Measures to Identify Economic Impacts of Climate Change

The economic impacts of climate change is usually measured as the extent to which the climate of a given period affects social welfare in that period (Fankhauser & Tol, 2005). As stated by Yalew et al., (2018) the statistical results of economic impacts of climate change is vital, as they can use them as a source for planning and adaptation to be resilient in climate change. Economic modelling is a reliable Modelling the economics of climate change is challenging because, most of the already available models help predict impacts but do not help understand them. Therefore, the findings (outputs) of these models are lost in real world. But these models for understanding provide the knowledge on the available and sufficient assumptions to take actions on economics of climate change (Dietz & Maddison, 2009). Further, policy makers should not base the climate change mitigation policy on the estimated net economic impacts and the need to use actual models 18 (Rosen & Guenther, 2015).

3.4 Importance of Economic Tools on Climate Change Impacts

Consequent to the multidimensional impacts of climate change, it is important to investigate the economic tools (Eg: Cost benefit analysis, Formal modelling, Evaluation of damages) that could be used to immediately progress on managing the

impacts of climate change; for instance by policy formulation (Stern, 2008). Hence, a structured set of actions to prevent the generation of impacts with the economic factor, and to mitigate and adapt already experienced impacts are essentially beneficial. The economic assessment of the impacts of climate change is required to be comprehensive and include all the physical effects and costs associated with markets and non-markets (Xie et al., 2020). Further, as intensified by Xie et al. (2020) it is important to account and weight the vulnerability of the poor communities and the challenges of adaptation, in conducting economic assessments of climate change. Climate economic modelling can be identified as such assessment mechanisms involves the process of identifying costs, benefits, and potential trade-offs of climate risks and climate change adaptations on the economy (Dekens & Hammill, 2021).

3.5 Introduction to Economic Models of Climate Change

Economic modelling is a tool which can be identified as a structured procedure used to generate knowledge on climate change impacts and address the relationships between climatic conditions, and changes created on the economy consequent to climatic conditions (Pindyck, 2017). It is a procedure of using a structured methodology to study and forecast the behaviour of the economy and economic relationships, with the focus on simplifying real-world economic systems and providing predictions of the future status to assist decision-making (Ouliaris, 2011). The application of this procedure to the focus on climate change to analyse economic impacts can be identified as economic modelling of climate change. This can be prompted as a methodology to address the socio-economic impacts of climate change, as it helps to determine the costs and benefits of climate change and guide the decision-making process in the economy (Hashida & Lewis, 2022).

3.5.1 Economic Models of Climate Change Derived from Systematic Literature Review

The identified records from a SLR were reviewed to investigate the parameters which can be used to determine the livelihood status and the parameters were extracted from the models presented in Table 3.1.

Table 3.1: Models identified from the systematic literature review (SLR)

Category	**Model**	**Authors**
Land Based Models	The Discrete Choice Economic Model- Logit Model (DCEM)	(Hashida & Lewis, 2022)
	Ricardian Model (RM)	(Hossain et al., 2019), (Hashida & Lewis, 2022) (Falco et al., 2018)
	Hedonic Model (HM)	(Mu et al., 2017)
	Land Use Share Model (LUSM)	(Mu et al., 2017)
	Agro-Economic Model (AEM)	(Falco et al., 2018) (Antle & Stockle, 2017)
	Agent-Based Rural Land Use New Zealand Model (ARLUNZ)	(Gawith et al., 2020)
	Ethiopia's Economy-wide Multi-Market Model (EEMM)	(Zhang et al., 2020)
Integrated Assessment Models	Integrated Assessment Models (IAM)	(Rising et al., 2022) (Revesz et al., 2014) (Stern, 2016) (Rao et al., 2017) (Antle & Stockle, 2017) (Nikas et al., 2018) (Antle et al., 2018)
	Probabilistic Integrated Model of Climate and Economy (PRICE)	(Khabbazan, 2022)
Crop Models	Global Gridded Crop Model (GGCM)	(Gurgel et al., 2021)
	Bio Economic Farm Model (BEFM)	(Bobojonov & Aw-Hassan, 2014), (Schuler et al., 2020) (Sánchez, 2018)
	International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT)	(Islam et al., 2016), (Palazzo et al., 2017)
	Probabilistic Decision Model (PDM)	(Choi et al., 2015)
	Global Trade Analysis Project Model (GTAP)	(Moore et al., 2017) (Wang et al., 2021)
Computable General Equilibrium Models	Dynamic Computable General Equilibrium Model (DCGE)	(Breisinger et al., 2013)
	Computable General Equilibrium Model (CGEM)	(Matsumoto, 2019), (Yalew et al., 2018)
	Rural Socioeconomic Model (RUSEM)	(Navarro & Tapiador, 2019)

Models that consider Policy based outcomes as the main objective.	Global Biosphere Management Economic Model (GLOBIOM)	(Palazzo, et al., 2017) (Van Meijl et al., 2018)
	Time Series and Panel Model (TSPM)	(Falco et al., 2018)
	Probit Model (PM)	(Adego & Woldie, 2022) (Ogada et al., 2020)
	Trade Off Analysis and Multi-Dimensional Impact Assessment Tool (TAMIAT)	(Mulwa et al., 2016)

The combined study of these is beneficial in providing a versatile outcome in determining the economics of climate change. Accordingly, we have hereunder described the economic models of climate change, which have been categorized under four categories mentioned in Table 3.1.

3.5.1.1 Land Based Models

The DCEM model as identified by Hashida and Lewis (2022) is a land management model, which studies the different land plots, the climatic impacts on those land plots and behaviours of the landowners. Thereby, the model describes the nature of replantation activities to be undertaken to maximise profitability. Among the land value-based models in Table 2, the RM, which can be applied in the context of agriculture to evolve an appropriate scope of land management to adapt against climate change (Falco et al., 2018). It examines the relationship between the value of land or net revenue (based on the regressive nature of land values) and agro-climatic factors (Mendelsohn et al, 1994) and the most important advantage of the RM is its ability to incorporate private adaptations (eg: changing crop mix, planting and harvesting dates, and a host of agronomic practices (Deressa, 2007). HM derived the term “hedonic”, giving the meaning of implicit (observed) prices where both consumer and seller are kept at equilibrium (Rosen, 1974). It has been used by Mu et al (2017) to determine the impacts of weather changes on net production in agricultural fields.

As part of land-based models, it further incorporates other factors such as population density and irrigation data in line with land usage to provide accurate results (Mu et al., 2017). The incorporation of irrigation data provides further opportunities to incorporate adaptation action into the equation. LUSM is another model in this

category of land value-based models, which assumes that the land usage for the agricultural purposes is decided based on the expected market returns. AEM model is also considered within this category as it analyses the impacts of different climatic conditions on performance of agricultural lands (Antle & Stockle, 2017). They consider the environmental, social, and technological changes along with the changes in climatic conditions to determine climatic impacts on agricultural lands over the time. Agent-Based Rural Land Use New Zealand Model (ARLUNZ) is an agent-based model developed for New Zealand which provides insights on farmers adaptation measures to reduce vulnerability to climate change using farmer agents. Accordingly, farmer agents study the landscape features, changes in economy and climate, and social and economic background information of the farmers who cultivated on the lands to provide adaptation measures to sustain their lands amidst climate and economic changes. EEMM is another country-based model like ARLUNZ which predicts climatic conditions in a particular area and derive agricultural guidance for farmers and economic decisions for the country (Zhang et al., 2019).

3.5.1.2 Integrated Assessment Models

IAM are widely used in global context to determine the impacts of climate change on agricultural livelihoods. Revesz et al. (2014) have used IAMs to determine impacts of climatic conditions, particularly those that are going to impact in the future by incorporating future climate change scenarios. According to them, there are four main rationales which can be used to explain an above-normal increase in future costs consequent to climate change. Thus, i). increasing the vulnerability of societies and economies than the prediction of current models, ii). omission of important economic data (damage to labour productivity, productivity growth and the value of capital shocks) leading to underestimated figures, iii). an insensible assumption that value given to ecosystems by people will remain constant (Hashida & Lewis, 2022), and iv). use of wrong calculation figures like constant discount rate for years (Rising et al., 2022) prove that the world is at a more threat to climate change than the already visible impacts. Khabbazan (2022) incorporates risk assessment to identify the value of "climatic information" in preparing for climate change. Thus, the author uses PRICE which concerns the magnitude of climate sensitivity, to analyse cost and risks on agriculture and henceforth integrate climate and economy in assessment to make

decisions. It is beneficial in decision making processes to manage welfare cost of people.

3.5.1.3 Computable General Equilibrium Models

DCGE Models are used to assess global, national, and/or regional level economic impacts of climate change (Breisinger et al., 2013). It is used to determine long term impacts of climate change on a particular administrative unit (household, region, country, etc.). CGEM inputs future climatic scenarios and assumptions to determine socioeconomic and climate impacts to labour markets (Matsumoto, 2018). Based on the findings about the impact of climate change to labour, it analyses the economic loss from climate change on a particular region.

3.5.1.4 Crop Models

GGCM also can be used in simulating economic impacts of climate change on agricultural market. According to this model, crop yield is calculated by dividing the land into small grids and thereby predicting the economic impact of climate change according to the changes in soil conditions and different types of crops. BEFM is also used as a modelling tool to assess the impact of climate change on agriculture (Schuler et al., 2020). It uses household survey data, crop experiment data and long-term price and yield data to identify the changes in crop yields and the rationales for them (Bobojonov & Aw-Hassan, 2014). Islam et al. (2016) and Palazzo et al. (2017) in their studies provided information about IMPACT, which is also used to determine crop yields and thereby the economic decisions. It has incorporated both changes in climatic conditions and social trends to derive conclusions on crop productivity. Thus, it portrays how the technology, location of field, population and income affect the yields. PDM is a decision-making model, which analyse the value of information regarding climatic conditions in making decisions in agricultural industries. Accordingly, decisions on crop adjustments, market changes and resource consumption amidst climate change are provided based on the findings of the model (Choi et al., 2015). GTAP is used to determine the crop yield changes and thereby quantify the welfare impacts of climate change (Moore et al., 2017; Wang et al., 2021). It is used to determine how crop production, consumption, intermediate use of crops on other

products, and trade have been changed following the climatic impacts (Moore et al., 2017).

3.5.1.5 Models that Consider Policy Based Outcomes as the Main Objective

RUSEM is a mathematical model used to determine climate change and thereby derive policies (Navarro & Tapiador, 2019). It examines the impacts of climate change on social perspective and input the parameters such as the availability of public services, access to credit and labour to study on required policy changes for rural economy. GLOBIOM on the other hand can be applied to the contexts of agriculture, forestry, and bioenergy to determine agricultural productivity, land use, production prices, and emissions hence enabling policy making (Van Meijl et al., 2018). As per Falco et al. (2018), TSPM used crop yields and weather information to provide mathematical information regarding the relationship between climate change and migration. Here, they have studied the behaviour of crop yields and weather information (multiple parameters) over the time following the concept "time series". These models provide policies that support rural development and sustainable agriculture, to address the issue of migration.

According to Adego and Woldie (2022), PM determine the relationships or correlation between various adaptation strategies to climate change. Accordingly, the word "probit" has derived from the word "probability" and shows probability of impacting adaptation practices on each other. It uses different climatic conditions and economic factors as parameters to focus on adaptation strategies which can be input to policy design. PM are of two types: multivariate Probit models and ordered Probit models. In multivariate Probit models, a variety of adaptation strategies can be identified, and ordered Probit models can be used to rank them. Henceforth it is evident that the outcomes provided in the models are different even with the same set of data. Moreover, there are key factors that emerged because of climatic impact on communities which are difficult to capture in a mathematical sense through models, however, have been mentioned as requirements to be considered economic models of climate change (Stern, 2016). For example, evidence of local-level adaptation by communities themselves and migration activities can be mentioned (Adego & Woldie, 2022; Yalew et al., 2018). Status of climatic conditions on agricultural lands are

assessed using TAMIAT. Thus, net production in farms, per capita income and poverty levels are analyses to determine the household welfare amidst climate change (Mulwa et al., 2016).

Overall, these economic models have used different climatic conditions (subsection 3.6) and parameters (subsection 3.7) as inputs to determine the socioeconomic impacts of climate change (subsection 3.8) as the outputs of these economic models of climate change.

3.6 Climatic Conditions Input in Economic Models to Determine the Economic Impacts of Climate Change

The economic models in the identified articles used input from five (05) climatic conditions to determine economic impacts including, temperature changes, global radiation, wind speed, rainfall and precipitation, and humidity. Further, they have used seven (07) firsthand influences of climate change as inputs to the model; these include changes to carbon dioxide concentration, climate tipping points, extreme events of climate change, changes in environmental and natural resources, shocks of climate change, shared socioeconomic pathway (SSP) narratives and exogenous shocks. (SSPs referred to five scenarios which are used by climate researchers to initiate the future developments required to address the different ways the societies can change which will impact on climate change).

The five climatic conditions identified are mainly associated temperature, rain, and wind. According to the findings of the SLR, the majority of articles have incorporated “temperature changes” (12 out of 32) to determine the economic impacts of climate change on livelihoods. Accordingly, it can be stated that temperature changes have a significant impact on socio-economic systems as a climatic condition. Moreover, Mu et al. (2017) have specifically narrowed down the temperature to “temperature in growing days” to generate precise results. The articles have used the conditions associated with rainfall in economic models to determine the economic impacts of climate change. Accordingly, humidity is a climatic condition which determines the crop yield and the requirement of irrigation for a particular crop (Schuler et al., 2020). Hence it can be recognized as a climatic condition to determine the economic impacts

of climate change. In addition, six articles have identified precipitation level as a climatic parameter used to determine the impacts of climate change.

In addition to the two main climatic conditions of heat and rain, Schuler et al. (2020) have identified wind speed as a climatic parameter which impacts the economic activities of the people. Further, Rising et al. (2022) and Yalew et al. (2018) have identified that the sudden hazardous climatic events (climatic shocks) in any of these climatic conditions will impact the economic activities of the people. Moreover, another first-hand influence of climate change is shared economic pathways (SSP) which incorporated the trends in society and climatic conditions for mitigation and adaptation to determine economic impacts (Van Meijl et al., 2018). It describes five different scenarios of climatic conditions, which will affect atmospheric composition and sustainable development. Overall, climatic parameters are influential in determining the economic status of the community.

3.7 Parameters Used in Economic Models to Determine the Economic Impacts of Climate Change

Economic models of climate change have incorporated several other factors in addition to climatic conditions that have been identified as parameters. Table 3.2 presents these parameters which have been grouped under agricultural, demographic, economic, and social categories. We have ranked here the parameters based on the frequencies following the methodology of (Geekiyanage et al., 2020) which is conducted in a similar context of communities and disasters.

Table 3.2:Parameters used in economic models to determine the economic impacts of climate change.

Category	Parameter	Sources	Nr of citations	Rank
Agricultural	Changes in technologies used for production and cultivation/ method of harvesting	(1, 27, 12, 23)	4	4
	Crop waste and losses/ status of cultivation/ Productivity of output/ productivity	(6, 8, 10, 16, 12, 20, 21, 23, 24, 25, 28, 32)	12	1

	of land/ changes in yield			
	Irrigation nature	(2, 7, 14, 16, 28)	5	3
	Soil condition/ Nature of the land	(1, 12, 15, 16, 17, 23, 26, 28)	8	2
	Number of cultivation crop types in a particular land/ alternative crops	(1, 10, 16)	3	5
Demographic	Population growth/ density	(5, 31, 11, 28, 27, 24, 18, 13, 12)	9	1
	Personal characteristics of a person	(2, 10, 15, 18, 20, 23)	6	2
	Social background of family	(2, 10, 15,17)	4	4
	Size of the family	(2, 5, 10, 15, 17)	5	3
Economic	Reshaping policies	(3, 4, 23, 29)	4	6
	Access to credit	(2, 15, 17)	3	8
	Changes in economic lifestyle overtime / other expenses/ availability of safe and healthy food	(5, 7, 11, 14, 16, 23, 25, 27, 30)	9	2
	Cost of production	(5, 10, 16, 23)	4	6
	Wage (income)	(3, 8, 10, 11, 12, 18, 20, 21, 24, 25, 27, 28, 30)	13	1
	Gross Domestic Product (GDP)	(11, 12, 14, 19, 21, 27)	6	4
	Consideration of alternate modes of employment	(8)	1	9
	Changes in income generating opportunities	(10, 16, 20, 23, 25, 30)	6	4
	Product prices	(6, 8, 10, 13, 21, 23, 26, 31)	8	3
Social	Poverty	(7, 10, 14, 18, 22, 24, 25, 26)	8	1
	Migration	(11, 22, 30)	3	4
	Level of Risk and damages	(4, 7)	2	6
	Access to public services and advisors	(2, 12, 14, 15, 18, 20)	6	2
	Vulnerability to hazard	(8, 12)	2	6
	Willingness to adapt	(2, 9, 22)	3	4

	Changes in labour/ machine intensity	(18, 19, 20, 21, 25)	5	3

Sources: [1-(Revesz et al., 2014), 2-(Falco et al., 2018), 3-(Stern, 2013), 4-(Mu et al., 2017), 5-(Palazzo et al., 2017), 6-(Antle & Stockle, 2017), 7-(Rao et al., 2017), 8-(Van Meijl et al., 2018), 9-(Antle et al., 2018), 10-(Nikas et al., 2018),11-(Yalew et al., 2018), 12-(Sánchez, 2018), 13-(Matsumoto, 2019),14-(Navarro and Tapiador, 2019), 15-(Hossain et al., 2019), 16-(Schuler et al., 2020), 17-(Ogada et al., 2020), 18-(Zhang et al., 2020), 19-(Gawith et al., 2020), 20-(Islam et al., 2016), 21-(Stern, 2016), 22-(Mulwa et al., 2016), 23-(Choi et al., 2015), 24-(Breisinger et al., 2013), 25-(Bobojonov and Aw-Hassan, 2014), 26-(Wang et al., 2021), 27-(Gurgel et al., 2021), 28-(Khabbazan, 2022), 29-(Rising et al., 2022), 30-(Adego and Woldie, 2022), 31-(Hashida and Lewis, 2022), 32-(Moore et al., 2017)]

As stated in Table 3, we have ranked the parameters based on the frequencies following the methodology of (Geekiyanage et al., 2020) which is conducted in a similar context of communities and disasters. Accordingly, this provides a quantitative analysis of identified parameters which helps to identify the frequency of use of above parameters for economic modelling of climate change in the global context. The four categories were derived after an extensive review of the identified variables with internal validation and pattern matching.

Productivity of the output was the key parameter captured in the majority of models in the context of agriculture. Similarly, population growth, income and poverty have appeared as highly applied parameters in the contexts of demographic, economic, and social respectively. This provides insights on critical information (parameters) which have considered in determining socioeconomic impacts of climate change and parameters with limited use on economic models of climate change. Accordingly, these limited use parameters can be investigated in detail to determine the reason for limited incorporation of them (whether they are less reflective on economic impacts of climate change or whether there are any barriers to capture and model them so on.) For example, consideration of alternative modes of employment is an important economic parameter to determine the socioeconomic impacts of climate change because the diversification of income sources increases the adaptation capacity of communities. Henceforth, the ranking of the variables underlay several benefits for policymakers, economists and authorities focusing on socioeconomic development of the agricultural communities to initiate hotspots for decision making.

3.7.1 'Agricultural' Category

The articles have disclosed the conditions which can vary with climate change, and which will create impacts on the economic status of the people. Accordingly, agricultural parameters directly influence the economic status of communities as they are closely associated with livelihood. As identified by Gurgel et al. (2021), the status of cultivated land is directly associated with income and is an important factor in determining the economic impacts of climate change. According to the authors, the status of cultivated land is referred to as crop distribution in the land. For example, whether the land has only been utilized for main crops or cultivates both major and minor crops is an influential factor in income and thereby affects the economic status of the community. A similar view has been expressed by Hashida and Lewis (2022) and Mulwa et al. (2016) who identify the number of cultivated crops in a land as a parameter to determine economic impacts. Moreover, the condition of the land including the status of the soil, productivity, and nature of irrigation requirements are also conditions used in economic models of climate change to determine economic impacts.

3.7.2 'Demographic' Category

'Demographic' refers to community characteristics such as age, gender, family sizes and educational level etc., that count as input in the economic models. These characteristics shape the economic impacts as outcomes for decision-making. Accordingly, the 'demographic' inputs into the models were population growth (Antle & Stockle, 2017), educational levels (Hossain et al., 2019b) and gender (Sánchez, 2018a); these are aspects that are influential in determining economic impacts as outcomes. These impacts or outputs show variations in relation to 'demographic' parameters like the gender of the household head and number of members in the family (Hossain et al., 2020; Schuler et al., 2020). Trade-off analysis and the multi-dimensional impact assessment model (TOA-MD) have mainly incorporated demographic parameters to determine the impacts and identify how the demographic conditions impact the decision-making ability of the community (Navarro & Tapiador, 2019). For example, changes in climatic conditions have been similarly recognized by similar age categories and differences in the level of understanding has been noted in

different age categories. This helps to execute reactions to changing climatic conditions (Mulwa et al., 2016). Consequently, the economic impacts of climate change on the community vary with demographic features.

3.7.3 'Economic' Category

'Economic' includes policies, interest rates, access to credit, investments, wages, per capita income, GDP, opportunity costs, cost of production, prices, demand, off-farm income and expenses all of which are directly impacted by climate change (Adego & Woldie, 2021; Antle et al., 2018). The key parameter identified in the 'economic' category within the articles is the GDP (Matsumoto, 2019b; Palazzo et al., 2017; Zhang et al., 2020). It is a macroeconomic parameter which impacts the entire community (Stern, 2013; Zhang et al., 2020). Further, there are microeconomic conditions including wage (Breisinger et al., 2013b; Islam et al., 2016; Rising et al., 2022a) and cost of production (Antle & Stockle, 2017; Mulwa et al., 2016), where variations in these conditions create diversified impacts on the community.

3.7.4 'Social' Category

Social parameters are characteristics of a society or community which are influential to determine the economic impacts of the community. Accordingly, the economic models of climate change have identified a variety of social conditions including poverty (Zhang et al., 2020), level of risks and damages by climatic conditions (Bobojonov & Aw-Hassan, 2014), conflicts consequent to migration (Stern, 2016), location of the house (Islam et al., 2016) and access to public services (Navarro & Tapiador, 2019) as social parameters which have been disclosed in economic models. Hence, the social conditions revealed in economic models of climate change behave as parameters in determining economic impacts. Since agriculture is a labour-intensive industry, changes in the productivity of labours and the evolution of the labour market create variations in the economic impacts on people can and consequently be recognized as parameters. According to, the Computable General Equilibrium Model climate change creates negative implications on economic activities as changes in climatic conditions limit labour productivity (Matsumoto, 2019; Yalew et al., 2018). The Rural Economic Model (RUSEM) also disclosed that climatic change creates changes in the labour market as the employment rate of rural communities depends on

climatic conditions. Further, the willingness of labours to engage in a particular service also limits climatic variations (Navarro & Tapiador, 2019). As explained in the study of Islam et al. (2016), the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) has incorporated conditions of labour and determined that changes in labour activities create diversified economic impacts. Overall, labour-related parameters are indicative of (and are impacted by) climatic conditions, which are required to be considered in determining the economic impacts of climate change.

Next section of this study provides the outcomes or socioeconomic impacts derived in economic models of climate change after using above climatic conditions and parameters as the variables.

3.8 Economic Impacts of Climate Change Conveyed in Economic Models

The 32 selected articles which were subjected to a SLR have disclosed the following economic impacts of climate change through the economic models of climate change.

The *welfare of the community* is a key finding articulated in many studies (Breisinger et al., 2013a; Gurgel et al., 2021; Hashida & Lewis, 2022b; Khabbazan, 2022). The economic models attempted to develop methodologies to determine the *welfare impacts of climate change* on communities like *reduction of income of people* (Breisinger et al., 2013a), *changes in consumption patterns* (Nikas et al., 2018). The DCEM of land management uses population growth and product prices as parameters to convey the negative impacts of climate change on land-owners consequent to the reduction in land value, rental income, and damages to commercially valuable crop species by climate change (Hashida & Lewis, 2022). Similarly, Khabbazan (2022), has integrated crop waste and losses, nature of the land, irrigation nature (agricultural parameters), population growth (demographic parameters) and income (economic parameters) to derive welfare conclusions. Accordingly, PRICE model has also been utilized to develop a methodology to determine *welfare costs* and incorporated a cost risk analysis scenario for the particular purpose. Moreover, the *measurement of welfare changes* was identified and incorporated to convey the impacts of climate

change on the household economy (Gurgel et al., 2021; Wang et al., 2021). Accordingly, economic models of climate change have revealed the importance of identifying the *welfare impacts* as a socioeconomic condition of the community.

The *change in the economy* is also a significant impact articulated by authors through the economic models of climate change. Economic losses are inevitable in situations of changes in climate and it impacts all global and rural household groups creating more significant impacts on the poorest (Breisinger et al., 2013). Climate change reduces economic output, and consumer and producer prices which create overall impacts on the national economic welfare (Wang et al., 2021b). According to Breisinger et al. (2013) and Gurgel et al. (2021), productivity of output, population growth, wage, poverty (in DCGE) and method of harvesting, population growth, income and expenses, GDP (in GGCM) have used as parameters to portray that changes in climatic conditions increased the resource requirement for continuing agricultural activities, which reduces the household budget for food and other essential needs. Another piece of evidence to explain the impacts of climate change on the economy is that it reduces GDP in all sectors of the economy when combining the local and global climatic impacts (Breisinger et al., 2013b). However, the authors further state that there can be a positive impact on some crop growers, consequent to high food prices but it creates negative implications for the majority of the community.

Adaptation is another popular concept revealed in articles which incorporated economic models of climate change. Current economic models of climate change have identified measures to adopt climate change impacts in the field of agriculture. Thus, Gawith et al. (2020) have identified the adaptive constraints of changing climatic conditions using parameters like GDP and changes in labour intensity. Moreover, the impact of irrigation on adaptation measures have described with economic model of BEFM conveyed that farmers with irrigation facilities are required more adaptation to climate change and farmers depend on rainfed agriculture have already adopted (Bobojonov & Aw-Hassan, 2014; Schuler *et al.* 2020). Furthermore, Adego and Woldie (2022) in PM use income and expenses, changes in income generating opportunities and migration to reveal adaptation measures. Accordingly, they have proposed to maintain the quality of the output including the delaying of harvesting time, improved diversification of seeds, and improve irrigation methods. Moreover,

the authors emphasized that variability of climatic conditions inversely impacts adaptation and higher variability decreases the adaptive capacity (Adego & Woldie, 2022; Gawith et al., 2020; Islam et al, 2016). Another important finding conveyed through the studies is that, even in the optimum adaptation situation, climate change creates negative impacts on timber land owners (Hashida & Lewis, 2022a).

Migration has been developed as an adaptation method to face climate change resiliently; this is beneficial in circumstances where aren't any other adaptation option and the migrant can bear the migration costs (Falco et al., 2018). Conversely, it is a prominent consequence of climate change (Stern, 2013). However, it creates negative impacts on the economy of the particular area and immediate solutions are therefore required to tackle migration in response to climate change. Sustainable agriculture and rural development can be identified as two such methods to address the migrations that occur due to climate change (Falco et al., 2018). Moreover, it acts as a cause of conflict between and among the countries (Stern, 2013). Economic models of climate change generally omit the impacts of migration which create unreliable results (Stern, 2013). A different interpretation of migration is captured by Yalew *et al.*, (2018) who identifies as a movement of people between occupations. Mitigating the impacts of climate change on livelihoods of the communities is another important finding conveyed in the studies. Thus, Wang et al. (2021b) proposed trade as a mitigation measure to address the consequences of declining national economic welfare and to increase agricultural production at country level.

Mitigating the impacts of climate change on the livelihoods of the communities is another important finding conveyed in the studies. Thus, Wang et al. (2021) analysed nature of land, product prices and poverty as parameters to proposed trade as a mitigation measure to address the consequences of declining national economic welfare and to increase agricultural production at the country level. Moreover, shared socioeconomic pathways have been identified as a concept which discloses the mitigation of social and economic challenges of different climatic conditions (Van Meijl et al., 2018). Thus, the importance of mitigation is also another socioeconomic impact conveyed in economic models of climate change.

3.9 Economic Impacts of Climate Conditions on Livelihoods of Communities in Sri Lanka

Despite the dearth in Sri Lankan literature focusing on using economic models of climate change as a methodology to identify the parameters which can be influenced on agricultural livelihoods, there are studies which have identified some parameters which impacts on adaptation actions of farmers to climate change. As per the study of Menike and Keeragala Arachchi (2016), household size, education status, income, location of land, cultivated crop types, access to loans, distance to input markets, availability of climatic information has identified as variables impacting on adaptation decisions by farmers.

As revealed in subsection 1.2, Sri Lanka is increasingly vulnerable to climate change which requires adaptation strategies (Abeysekara et al., 2023). Furthermore, Tsuchida and Takeda (2021) identify a low resilience to climate change in Sri Lanka consequent to low awareness and emphasize it as an emerging area. Moreover, the requirement of adaptation tools and frameworks to climate change has been identified as an area which requires immediate attention (Wickramasinghe et al., 2021). Amidst all this, the studies less conveyed the economic impacts of climate change on agricultural livelihoods. Moreover, the comparison of economic impacts on different livelihoods has not been considered in past literature. Accordingly, this study intends to contribute to this literature pool by identifying impacts of climate change on different livelihoods using the parameters captured from economic models of climate change. Further, this study aims to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models.

3.10 Current Strategies to Increase Community Resilience against Economic Impacts of Climate Change on Livelihoods of Sri Lanka

There are few studies in Sri Lanka, which have been conducted in divisional level to identify the adaptation measures to climate change in agricultural industry. Accordingly, Esham and Garforth (2013) which focus on intermediate zone of Sri Lanka, have identified several adaptation actions including changing crop variety, soil

conservation techniques, increased use of supplementary irrigation and off-farm employment as adaptation measures for farming community. However, most of the studies are within the context of paddy and have focused on different zones of Sri Lanka. There is dearth of studies in the context of low country wet zone to identify the measures to overcome climatic impacts. Moreover, despite the adaptation measures, there is lack of climate resilience strategies for the agricultural industry in Sri Lanka. According to a recent study of Chandrasiri et al. (2023), which focused on identifying impacts of climate change on paddy industry in different climatic zones in Sri Lanka, emphasizes the need of an insurance schemes, and upgrading irrigation facilities as measures to minimize impacts of climate change on paddy growers. Further to Suresh et al. (2021) requirement of policy improvements, enhancing farmers access to credit, expansion of infrastructure and technical support have been identified as adaptation measures to climate change impacts on paddy growers. Moreover, Gunathilaka et al. (2018) state expansion of knowledge sharing and governmental support as key adaptation actions for perennial crop growers including tea growers.

However, there are very few studies focus on providing climate resilience strategies for agricultural livelihoods and there are studies specified to dry zone of Sri Lanka by Costa (2020), which identified the importance of increasing tree cover in farmlands, optimizing planting times, and soil moisture conservation as resilient measures for cropping systems. Accordingly, this study attempts to identify set of strategies for climate resilience of different livelihoods in low country wet zone, which is still lacking in Sri Lankan context.

3.11 Chapter Summary

This chapter describes the secondary data available on the topic which were gathered through a SLR. Accordingly, economic models of climate change, their benefits, limitations, and future directions, climatic conditions used in developing economic models, parameters used to determine economic aspects, economic aspects discovered and measures to address current economic conditions have been stated as well.

4 CHAPTER FOUR- DATA ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter provides the analysis and discussion of data collected through the methodology specified in Chapter 02 to achieve Objectives 03, 04, and 05. Accordingly, the findings of focus group discussions and key informant interviews under the case studies and findings of the expert interviews under the survey have been evaluated and presented. This helps in the identification of economic impacts of climate change on tea and paddy industries and possible adaptation measures to increase resilience. Finally, CLDs have been developed with the findings.

4.2 Preliminary Interviews

Before structuring the background for primary data collection, two preliminary interviews were conducted to structure the applicability of identified parameters to the Sri Lankan context and to confirm the suitability of planned case studies to the Sri Lankan context. Accordingly, Table 4.1 shows the details of the respondents selected based on convenient sampling as per the criteria specified in sub section 2.3.8.

Table 4.1: Profile of respondents- Preliminary interviews

Code	Position	Experience in field of climatic research
PE1	Senior Lecturer Grade I	25 years
PE2	Professor	27 years

4.2.1 Climatic Conditions in Sri Lanka

PE1 disclosed three main facts about the climate condition in Sri Lanka and referred to it to as *"climate variability"* and not *"climate change"*. This idea was confirmed by PE2 who mention that *"Sri Lanka is undergoing a climate variability. However, intensity of this variability is different in different agricultural zones".*

Accordingly, climate variability can be referred to as short term natural fluctuations in climate system, which can be irregular but recurrent. This can be distinguished from climate change, which occurs as a result of long-term alterations, which may be like decades and centuries. Moreover, both experts agreed that *"changes in temperature"*

and *"rainfall changes"* are the two main conditions experienced by Sri Lankan communities. Accordingly, Table 4.2 shows the results obtained on the identified climatic conditions in the literature review (refer to subsection 3.6).

Table 4.2: Climatic conditions prevailing in Sri Lanka

Climatic Condition/ Firsthand influences of climate change	**PE1**	**PE2**
Temperature changes	✔	✔
Global radiation	✘	✘
Wind speed	✘	✘
Rainfall and precipitation	✔	✔
Humidity	✘	✘
Changes to carbon dioxide concentration	✘	✘
Climate tipping points	✘	✘
Extreme events of climate change	✘	✘
Changes in environmental and natural resources	✔	✔
Shocks of climate change	✘	✘
Shared socioeconomic pathway narratives	✘	✘
Exogenous shocks	✘	✘

This can be further supported with the data available in Department of Meteorology, Sri Lanka (2023) that Sri Lanka is undergoing temperature and rainfall fluctuations with a highest record of 35°C in temperature and over 5000mm of annual rainfall. Further according to National Building Research Organisation (NBRO) (2023), there is an increase of 1°C of temperature in Sri Lanka over last 50 years and expecting a further rise. However, there were lack of reliable comparative data available for Sri Lanka considering the changes of rainfall and temperature over years, with detail attention to the changes occurred in months of the year (eg: delaying or hastening of monsoons).

Based on the aim of the study, which is to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models.in Sri Lanka, preliminary experts identified the conditions impacting the economic status of communities in Sri Lanka. Accordingly, they confirmed that the temperature and rainfall variations are drastically affecting Sri Lanka while the other three key climatic conditions are less observed. Moreover, PE2 mentioned that "*there are variations in zones itself and Sri Lanka being a tropical country shows different status of tropical climate in different parts of the country"* and

therefore it is required to adhere into a particular climate zone for better results. Accordingly, the low country wet zone was selected based on the availability of multiple economic crops. Moreover, when considering the firsthand influences of climatic conditions, both experts confirmed that extreme events of climate change, exogenous shocks and climate tipping points are not experienced in the Sri Lankan context at all. However, they agreed that there is a loss of natural resources which can be observed consequent to these climatic conditions. Following that, PE1 stated that, there is a scarcity in natural resources created due to climate change like reduction of number of cultivated lands due to landslides and increase of barren paddy fields. Also, PE2 stated that there is a scarcity of water observed in some parts of Sri Lanka due to drought conditions. As a result, the depletion of natural resources can be looked at as well science these scenarios are studied along with climatic conditions.

4.2.2 Parameters Used to Determine Economic Impacts- Applicable Parameters to the Sri Lankan Context

The SLR identified a set of parameters used in the global context in economic models of climate change to determine economic impacts (refer Table 3.4). However, consequent to unique climatic conditions prevailing in Sri Lanka, all the identified parameters from different climatic backgrounds are not suitable for Sri Lanka. Accordingly, the preliminary survey focused on refining the parameters applicable to the Sri Lankan context. Experts were questioned about the parameters in Table 3.4 (refer to subsection 3.10) and both experts confirmed the applicability of all parameters to Sri Lankan context to have further investigation. Accordingly, the interview guidelines were developed incorporating all the parameters derived from the economic models.

4.2.3 Suitability of Tea and Paddy for Case Studies in Sri Lanka

Two experts of the preliminary interviews were questioned about the suitability of the selected livelihoods as case studies. Accordingly, both experts agreed that tea and paddy are two industries vulnerable to both climate change and/or variability. Furthermore, PE1 confirmed that *"both tea and paddy contribute to make significant percentage of GDP of Sri Lanka and provide lots of job opportunities for a wide range of people"*. Moreover, they recognized both tea and paddy as two crops vulnerable to

climate change. Henceforth, experts justified the suitability of the selected two case studies to study the impacts of climate change on different livelihoods.

4.3 Case 01- Case of Tea Industry

4.3.1 Profile of Respondents- Focus Group Interviews

As the first round of case study data collection, focus group discussions were conducted and accordingly 15 respondents selected on purposive sampling have been identified under three focus groups with five member each. As mentioned in subsection 2.3.8 of the methodology, the participants were selected to cover different age groups, genders, educational level, involvement to the industry, and weight of income on tea industry to have views from different perspectives. Table 4.3 shows the profile of the respondents participated in the focus group discussions.

Table 4.3: Profile of respondents- Case 01 focus groups

Code	Demographic Background	Average educational Status	Other Crops or Employment	Involvement (Owner/ Labour)
C1FG1	5 Male	A/L	Both	Both
C1FG2	2 Male 3 Female	O/L	Only one	Owner
C1FG3	4 Male 1 Female	Grade 8	No	Both

4.3.2 Profile of Respondents- Key Informant Interviews

Key informants were identified from the selected case to verify the views provided by the focus groups and to collect the facts about impacts of climate change on communities, community responses to climate change and measures to address the impacts. Accordingly, key informants were selected from the administrative hierarchy who are directly communicated with the communities. Based on the rational mentioned in subsection 2.3.8, Grama Niladari Officer, Disaster Management Officer, Economic Development Officer, and Tea Board Officer have selected as the suitable key informants. Table 4.4 shows the background information of the parties participated in the study.

Table 4.4:Profile of respondents- Case 01 key informant interviews

Code	Profession	Experience in the industry	Experience in particular case	Key job responsibilities
C1GN	Grama Niladari Officer	17	6	Involve in managing disasters and threats undergone by communities as a primary source of reporting to the people.
C1ED	Economic Development Officer	10	6	Advise the people on expanding their economic activities and increasing income.
C1TB	Tea Board Officer	28	10	Involve in issues related with tea crop cultivation and advise on continuing and expanding tea industry
C1DM	Disaster Management Officer	14	14	Involve in disaster related consequences to people and work on ensuring their betterment against disasters.

4.3.3 Profile of Respondents- Expert Interviews

Round 03 of the data collection was the expert interviews which is focused to validate the findings collected from first two rounds of data collection and to identify the impacts of the climate change on the tea industry along with the adaptation measures to overcome the identified problems. Accordingly, professionals contributing to the Research and Development (R&D) of the field have selected as experts (please see subsection 2.3.8 for detailed criteria) and Table 4.5 shows the details of the experts participated in the study.

Table 4.5: Profile of respondents-Case 01 expert interviews

Code	Profession	Experience
C1E1	Senior lecturer	25 years
C1E2	Researcher at tea research institute	05 years
C1E3	Field officer	06 years
C1E4	Senior lecturer (Professor)	27 years
C1E5	Officer- Tea Board	13 years
C1E6	Senior lecturer	15 years

4.3.4 Case Background

Economics of tea has been identified as a priority research area by Tea Research Institute (TRI) (2020), as tea is contributing about 14% to the national export earnings. Moreover, growing deviations in rainfall in Sri Lanka, tend to impact the agriculture and crop industries which are highly contributed to the GDP of the county. Further, as conveyed by the past researchers (Wickramasingha et al., 2021) wet zone of Sri Lanka is vulnerable to climate change and communities undergo many threats. Accordingly, particular case has been selected from low country wet zone of Sri Lanka to examine the threats faced by the tea growers.

4.3.4.1 Climate Variation Influences on Tea Industry

As revealed in the literature and as per the views of preliminary respondents, tea industry is highly influenced by climatic conditions. Being an agricultural country, which depends on cultivations as the main source of income variations in climatic conditions directly affects the general patterns of the tea crops and thereby reduce the productivity. C1FG3 stated that the *"rain is the favourable condition for general tea growth, but our plants do not show any improvements in productivity or growth".* This can be validated with the view of C1E1 who has claimed that the overall rainfall in Sri Lanka have not changed.

In determining the tea industry as a suitable livelihood, community claim that tea industry itself only has the capacity to provide substantial income for the growers and *"have used to do so. In past 30-40 years, tea growers belong to the group of wealthy families in the country".* This view of C1FG1 agreed the views of other two focus groups as well. They also collectively mentioned that tea industry gets declined consequent to several reasons and changes in climatic conditions and climate induced disasters also a key responsible reason.

4.3.5 Impacts of Features of the Cultivated and Nearby Area on Climate Impacts to Livelihoods

According to the view of the respondents of focus group, variations in the climate, deviate the natural environmental conditions. Concurrently, status of natural environment too has an impact on the economic impacts of climate change on the

people. As per the findings of the SLR, the environment features have incorporated into models as parameters. Similarly, responses of focus group members and key informants identified the below mentioned environment conditions as catalysts which accelerate the economic impacts of climate change.

4.3.5.1 Impact of Location

As highlighted by C1DM location itself accelerate the impacts of climate change on livelihood and explained that people actions on selecting location for cultivation, make them suffered at present. He claimed that the *"people have cleaned and used top of the mountains for cultivations, which has a high impact on damaging their plantation by landslides"*. Moreover, C1FG2, C1GN, and C1ED confirmed that tea itself a landslides prone crop as the tea roots contribute to losing the soil. Yet, experts confirmed the impacts of location on accelerating landslides but on a different perspective. As per C1E4 and C1E6, tea plants explicit a healthy growth in lands with a gradient and thereby it tends to be highly responsive to climate variability consequences. Accordingly, "slope in the land" has been identified as a cause for both "soil wash off" and "growth of the plant" as shown in Figure 4.2. In addition, location next to a rain forest, reservoir or waterbody can accelerate the impacts (C1E2). Overall, as the conditions required for the tea industry preferred slopy lands there is an inevitable impact of location on the sequel of the cultivations.

4.3.5.2 Impact of Soil Condition

Soil condition, combined with the topology of the area creates damages on planted lands. As per C1TB, sandy and loamy soils with acidic to neutral pH value is generally prefer for tea cultivation and intermittent rains prevailing in the area contribute to keep the soil loose (C1DM). Moreover, C1FG2 and C1FG3 mentioned the requirement of soil stabilised crops to reduce the soil sedimentation and erosion (refer to Loop 02 of Figure 4.2). Moreover, this soil condition impacts on manure requirement and thereby affects the growth of the plant as shown under Loop 03 (reinforcing loop) in Figure 4.2. Overall, soil types which supports healthy tea growth are generally loose which can be identified as a factor which accelerate landslides.

4.3.5.3 Impact of Irrigation

All the three focus groups have stated that they are depending on the rainwater to fulfil irrigation requirements. Further, C1FG3 mentioned that *"we are undergoing the problem of excess water here and actually the supply of water is not an issue at all".* Moreover, C1FG1 and C1FG2 confirmed that they have accessible water bodies to supply water to their lands if required. However, C1TB claimed that there are problems in the drainage system within the land, which can be further improved and community not willing to do. C1GN also agreed that the drainage system within the land must be more expanded and simultaneously highlighted the financial barriers faced by the communities which limited the improvement of drainage system. Accordingly, requirement of improving drainage systems have been highlighted as a cause of landslides in Figure 4.2. Moreover, C1ED explained the initiation of economic expansion opportunities besides the drainage channels including cultivation of crops like pineapple. Further, C1FG2 members highlighted the barriers for improving drainage lines including frequent landslides events which *"wash off the lands making all effort of drainage in vain".*

Overall, irrigation network in the surrounded area of the cultivation is a catalyst of climatic impacts on tea growers.

4.3.6 Impact of Demographic Factors of the Communities on Climate Impacts to Livelihoods

Despite the available economic models of climate change captured the demographic parameters to determine economic impacts of climate change, it was less influential in context of Sri Lanka for the tea industry as identified by the Focus groups. However, they made indirect statements which can be explained as demographic factors and have explained in the later paragraphs of this section. Moreover, experts unveiled that they are key indirect contributors for the occurrence of economic impacts.

Growth of population impacted on division of lands (C1E3, C1E5) and C1FGs also confirmed that they are heiring the lands from their parents, which has been divided among their siblings. A respondent in C1FG2 mentioned that, only his land is affected by landslides and lands of his siblings are safe. Furthermore, development of

infrastructure facilities was emphasized by the C1FG2, C1GN and C1DM as a threat for accelerating landslides and C1ED mentioned it because of urbanisation, where the demand for infrastructure increases. Accordingly, it is a reinforcing condition to landslides as shown in Loop 01 of Figure 4.2. Moreover, according to C1FG1 and C1GN, communities tend to clear vegetation, and their already cultivated lands to fulfil the housing needs of the growing population (refer Figure 4.2). Hence, there are land use changes which is observable in tea growing communities, which is also expressed in views of C1E3, C1E4 and C1E5 as an impact of population growth on economic impacts of climate change.

Despite gender of the worker/landowner and age of the worker/landowner have been identified as two parameters in economic models of climate change from the SLR, those portrayed less influential creating economic impacts on communities, consequent to climate change. C1ED and C1TB mentioned that *"there may be difficulties in the comfort level for working based on the changes in climatic conditions and however, there is no such severe cases reporting here".* Accordingly, this has been identified as a variable with reinforcing effect as shown in Loop 05 of Figure 4.2. Moreover, C1E4 mentioned that age and gender have impact on working, in high temperature conditions and such influence may be observed in a dry zone.

Education level and experience in the industry, were identified as two main parameters, which impact on economic impacts of climate change on tea growers. Accordingly, C1E5 mentioned that *"based on their educational level, they have the capacity to grab new technologies and measures to endure the variations".* Also, C1TB mentioned that it is convenient to distribute the technical measures to an educated community and high implementation of technology can be expected from them (C1ED, C1DM) (refer to Loop 10 of Figure 4.2). For example, a selected sample of people was provided with a rain gauge to record the rainfall and C1DM and C1GN have experienced that only the people with a sound educational background, captured the importance of recording rainfall on their cultivation and others have ignored the task. In contrast, to proceed with the traditional techniques of cultivating and harvesting experienced community is more beneficial since *"they have high patience, prediction capacity and familiar with the life of a tea tree"* (C1TB). Also, experience can be directly linked to adaptation strategies as the communities with more experience

can share the limitations of already practiced adaptation strategies and can contribute to develop more sustaining adaptation strategies.

However, both well-educated and experienced people as tea growers are currently low in the tea sector as with the education, people tend to move for more formal and professional jobs. Overall, population growth, education level and experience are influential in climate variation induced economic impacts, while age and gender show less relation.

4.3.7 Climatic Conditions Undergone by the Communities

Based on the preliminary findings wet and dry climate have identified as the two main prevailing climate conditions in Sri Lanka. Accordingly, temperature and rain were the two main prevailing climatic conditions. Both focus groups and key informants were questioned about their experience regarding the climatic conditions prevailing in the area.

4.3.7.1 Variations in Temperature

Two contradictory views were recorded regarding the temperature. Accordingly, C1FG2 and C1FG3 stated that they are experiencing an increase in temperature while C1FG1 stated that there is no significant variability. According to C1FG1 *"we have shifted our working hours to noon to evening, which is earlier the morning to late noon. This causes for feeling of increase in temperature and else, there is no temperature rise as it is frequently raining".* Therefore, they stated that the feeling of temperature change because of shifting the work hours, not the climatic condition. However, according to the other focus groups, despite changing the working hours and they are experiencing an increase in temperature, which makes difficult to work. Further, C1FG3 stated that even in the times of *"less sunny and cloudy days, the temperature rise can be felt, and it makes us uncomfortable for working".* However, this condition has been explained as a cause of humidity by C1E1, C1E3, and C1E4. They have explained that the moisture content in the atmosphere as the reason for the feeling of temperature changes. Further as per C1E4, increase of temperature can be an outcome of three main reasons: temperature rise, humidity rise, change of wind direction and wind speed. Moreover, all the three groups confirmed that this variations

in temperature have not create unfavourable environmental conditions to growth of the tea plant and however according to C1FG2 and C1FG3, it affects the productivity of workers.

Key informants validated the focus group member opinions regarding the temperature. According to C1GN and C1ED there is no significant change in temperature and mention that there were no complains or cases made by the communities regarding the temperature variations. Further, they stated that however, there are fluctuations in the temperature conditions in terms of severity and period. Moreover, C1DM and C1TB stated that temperature intensity of the area has increased. Further C1DM claimed that *"the temperature has increased but it is not a huge increase. However, if there is a huge increase, it impacts the output of the tea products".* In addition, all the key informants claimed that there is a record of fluctuations in temperature as reported in the climatic and weather records available in the Divisional Secretariat offices and by the research made by NBRO. According to the selected case study undergoes slight fluctuations in temperature and affected the labour productivity. Moreover, even it is not evidenced through this case study, the key informants confirmed that the temperature variations affect the product output in other areas of as well.

4.3.7.2 Variations in Rainfall

Rainfall is another important parameter identified from the literature review and confirmed from the preliminary interview as a condition applicable to Sri Lanka.

All the focus groups agreed that they are experiencing frequent rainy events in the recent years than the past. Moreover, all the key informants similarly conveyed that the frequent rain as a climatic condition experienced by the tea growers in wet zone. As stated by C1FG3, *"it is raining here in the present, at the times which are previously not"* which "*become a key difficulty to punctual harvesting, to replant the vacated areas, to supply manure and for weeding and clear the area"* (refer to Figure 4.2). C1FG2 had a similar opinion and stated that rain contributes as a factor for delaying the usual activities of the tea lands. C1ED stated that there are *"frequent quick rains throughout the day*" which cause difficulties for all agriculture and related communities to continue their livelihoods. Accordingly, number of rainy days and intermittent rainy events have increased.

Further, both C1GN and C1DM expressed that this frequent rainfall creates *"extreme events"* in the area where rainfall intensity is higher than the previous years. This view has confirmed by the C1FG1 and stated that the rainfall is severe when it compared to the past. One member of the group stated that he is using a rain gauge to measure the rainfall and there are getting record of 100 mm of rainfall even within 15 minutes. Moreover, C1TB mentioned that these severe events of rain are currently experiencing by the communities of low country wet zone, and this can be confirmed through the records of NBRO and Meteorological department of Sri Lanka.

In terms of period of rain, all the respondents collectively stated that the period of rain has shifted. Moreover, C1TB stated that *"period of rain has extended as that the commencing of Southwest Monsoons is prior than February and the end is later than September".* Further, the C1FG2 also evidenced this view and mentioned that *"our replantation works take place generally in late January but now it is extremely raining from the beginning of the year, which makes difficult to execute our planned routines".* Other two focus groups also confirmed the disturbance to their livelihood activity through non-predictable rainy events. Moreover, C1ED also stated that there is a difficulty of continuing planned agricultural routines consequent to the period fluctuations of rainy events. Overall, three main trends of rainfall changes can be identified as the conditions affected to the growth of tea: period, frequency, and severity of rain.

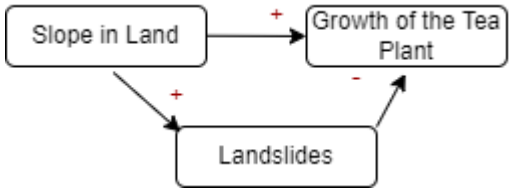
4.3.8 Effects of Climate Variation

4.3.8.1 Identification of Effects of Climate Variation

Low country wet zone undergoes several disasters consequent to the changes in climatic conditions. All the respondents highlighted landslides as the key disaster event of climatic variability which create huge implications on the tea industry. C1FG1 *"floods also difficult but manageable however the landslides are a total disruption, with no recovery".* Moreover, C1DM stated also confirmed landslides as the key threat to tea growers and mentioned *"topology itself affects the landslides to be a major disaster event for tea growers".* As per the view of C1TB, tea cultivations prefer the slopy lands and therefore, it faces the threat of climatic variations than the other

industries, especially in case of landslides. Accordingly, Figure 4.1 shows the relationship among slope of the land, growth of the plant, and landslides.

Figure 4.1: Relationship among slope, landslides, and plant growth



According to Figure 4.1, slope in land shows a positive relationship with both the landslides and growth of the tea plants a proportional relationship. Further, landslides and growth of the tea plants depict an inverse relationship where, increase in landslides decreases the growth.

Despite landslides, waterlogging is the next threat to tea cultivator's consequent to climate variations. Accordingly, member of C1FG1 shared his experience and mentioned that his land is situated adjacent to water body, which results in retaining water for longer periods than other lands does, consequent to its location. Henceforth, following the rainy events, waterlogging is observed in these lands which damages the roots of the tea plant (C1GN, C1TB). Moreover, C1ED mentioned that tea is a long-term crop with a lifespan of about 10-20years. Consequently, with the damages of waterlogging replantation must be propagated which incurs **additional unplanned cost**. Further, this results in loss of income from crop for a considerable period of about 12-18 months.

Since the low country wet zone tea growers mainly undergoes rain related climatic parameter conditions, flood is another disaster prevailing in the area. The three focus groups have key contravention views on impacts of flood on tea. According to C1FG1, flood is negatively impacted on tea growers, as it makes them difficult to continue daily operations related with the tea plant. It causes, delaying the plucking time and disrupt transportation of harvests to factories. Moreover, *"being punctual with harvesting is essential, as if it delayed for even a single day, the quality declined rapidly and make harvest to be refused by buyers"*. Further, floods become a cause of destroying roots of tea trees consequent to excess water content. However, C1FG2 and

considered flood as a blessing for tea growers compared other disasters, as floods "*in general do not retain water in the land for longer periods"* and consequently flood provide nutrients to the soil which accelerate the growth of tea plants. In addition to these views, all the key informants considered flood as a threat or a disaster for community which produce both long term and short-term consequences by affecting the health of the crop (C1TB), by disrupting daily livelihood activities (C1ED), and by reducing the income (C1GN).

Apart from the above main concerns, there are some specific indirect impacts of rainfall changes on tea plants. This includes the growth of a bacteria on tea leaves, which has been observed recently but still have not identified any potential solution (refer to Figure 4.2). This view has brought forward by focus groups mentioning, *"tea leaves tend to have spots on them, which is refused by buyers. We complain this to tea board officers, and they presume it is consequent to excess rain".* Moreover, C1TB confirmed this opinion and stated that there are signs of a disease consequent to moisture levels and tea research institute is currently working on that. Further, C1FG2 and C1FG3 stated that extreme lightning events can be observed compared to past and this creates difficulties on workers to continue their daily activities since they are outdoor works.

Overall, floods, waterlogging and landslides have identified as the constant direct disasters of climate variations while there are some contemporary pest and insect damages arising from rainfall and temperature changes.

4.3.8.2 Frequency of Effects of Climate Variation

According to the views expressed by the communities and the key informants of the case, frequency of disasters has been increased over last 5-10 years. C1FG1 has identified that the activities undertaken to expansion of road network of the area, including "*vibrations and clearance of surrounded lands"* as a cause for increasing severity of landslides as it contributes to lose the soil. Moreover, deforestation activities are frequent in the area which was also contributed to change the natural water cycle.

As mentioned by C1FG3 they are facing frequent waterlogging events, then the past which results in delaying their harvesting periods. Also, even though they have not experienced frequently, there is the threat of damaging the tea roots and thereby reduce the tea harvest consequent to the retaining of water in land. Moreover, C1DM mentioned that *"the records evidenced an upward trend in disasters which is not favourable at all"* and according to C1TB this can be further evidenced by the complaints of the communities on reducing the harvest regarding the loss of harvest consequent to improper harvesting patterns posed by rainfall variations than the past.

Further, C1GN and the C1FG1 mentioned about the warnings given by NBRO to abandon the lands consequent to the frequent signs of landslides. This accelerates the problem of loss of livelihoods and thereby create multiple consequences on the families including migration issues, establishment problems to a new livelihood or the same livelihood in a different area, impacts on education of the children etc. As C1ED and C1GN evidenced the reporting of climatic impacts very frequently, this also confirmed that the disasters have evolved at a higher frequency compared to the past.

4.3.8.3 Severity of Effects of Climate Variation

Members of the focus groups and key informants have shared their experience on the severity of climatic events. C1FG1 stated that "*now the water retained for more than 24 hours, sometimes 2-3 days"* which explains that the same rainfall behaves differently on the people. This can be supported with the views of the experts regarding the variability of climatic events which become hazardous to the community. However, tea growers in low country wet zone have faced less damages consequent to the droughts, which is result of increase of temperature or absence of rainfall. According to C1DM, a major drought event was experienced in 2014, there after so such severe cases were reported.

Overall, it was founded that the climate impacted on the livelihoods of the tea community basically by accelerating the disasters as the primary consequence and the impacts have grown more frequent and severe over the period of past decade (C1TB).

4.3.9 Climate Induced Causes Which Challenge the Livelihoods of Communities

As per the findings of the literature, causes behind the changes in climatic patterns which is often refer to as climate variations can be categorised under two main categories of natural and manmade causes. However, as explained by the focus group members, key informants and experts, Sri Lanka is mostly subjected to climate variations consequent to the manmade issues.

As explained by C1FG1 and C1FG3, construction activities undergone on the reservoir project near the case study area increases rainy events on the area. Furthermore, C1FG2, C1GN, and C1DM identified increase in vibrations due to road construction activities increases landslides. This view has been validated by C1E4 and C1E6 mentioning that *"any kind of vibration loosen the soil and thereby accelerate the landslides".* Further, C1DM confirmed that these vibrations were a direct cause for 2017 landslide event occurred in the area.

Reduction of nutrient rich top forest cover in the mountains (Deforestation) consequent to human settlement is another manmade cause, which accelerate landslides as well cause in reduction of output get reduced due to human settlements. The relationship between unauthorised human settlements and landslides have been shown in Figure 4.2 as a cause-and-effect relationship. Moreover, C1DM has expressed that the air pollution in the area has increased. This view was further validated by C1E2 and C1E5 and identified the contribution of human to air pollution by the dramatic increase of carbon dioxide generation. C1E2 mentioned that *"polluted air mixing up with the clouds and when it rain, that rain is toxic to the plants".* An important concern explained by C1E3 is that, though the rural community suffering most from the change of required nutrients for their crops, they are the least contributors for the cause. Accordingly, there is a global cause for climate change, which impacts the communities, and it is required to address as a holistic approach.

The focus groups expressed unpredictable weather patterns as a challenge to continue their livelihood. C1E4 also confirmed this as a cause affecting the community and mention the reason behind the cause as, "*predictable weather is an ecosystem service, so unpredictable weather is the distortion of ecosystem service people are getting, that*

is why it is a problem". Henceforth, this is also an issue associated with climate change which challenges the community.

Another prominent cause, which challenges the livelihood of the communities is expansion of human settlements (C1TB, C1ED, C1E1, C1E2, C1E6). C1E6 described this issue as,

> *"so… the early generation of the tea industry, they were settled within the factory itself. Now they are celebrating more than 200 years of commencement and now they are literary on the fourth or fifth generation. Now most of them do not have sufficient space, so they gradually getting into the other parts of the mountain slopes and mostly they are clearing the forest patches. Some forest patches belong to government, some belong to the estate itself.*

Overall, it is evident that, human-induced causes are directly and indirectly contributed to disrupting the livelihoods of people. Accordingly, some of the activities need to be eliminated (non-eco-friendly human settlements) while some of the activities can be reduced while the only option for some causes is to adapt (expansion of human settlements).

4.3.10 Climate Induced Opportunities to Livelihoods of Communities

Despite all the negatives, the focus groups highlighted some positives of climate variability to their livelihood, tea plantation. Accordingly, all the three focus groups agreed that the soil moisture is saturated following the frequent rainy events. Thus, it led to reduction of irrigation costs which have been expressed by C1ED, C1GN and C1TB as a benefit of climate variability. C1FG2 also confirmed that *"we are not facing difficulties of watering at all and there is an easy irrigation, already set by the nature".* Therefore, cost efficiency irrigation with saturated soil moisture can be identified as benefits of the climate variability on tea growers.

Diversifying tea flavours is another positive impact of climate variability on tea growers, which has been highlighted by C1E2 and C1E6 as a benefit. According to them, variations in rainfall frequencies are affected by natural wind movements and therefore, it adds variety of flavours to tea leaves. This is a benefit in selling the

product, as the demand for tea in particular area increases. For example, as explained by C1E1,

"You know, there is a Turpentine yard near the tea lands towards the upper area, and the tea growers believe that the rain coming with the wind has the fragrance touch of Turpentine. Therefore, they believe that their tea leaves absorb the particular smell and flavoured it in the tea leaves. So, they are very keen on maintaining the Turpentine yard, in parallel to their tea lands".

Accordingly, this has been identified as a cause of diversifying tea flavours and increase demand as shown in Figure 4.2. Thus, despite the low number, there are benefits of climate variability on tea growing communities.

4.3.11 Climate Induced Challenges to Livelihoods of Communities

The focus groups have identified key challenges that are undergone consequent to the changes in climatic conditions, which were verified by key informants and experts. Table 4.6 provides an overview of challenges undergone by the communities which has been categorized as harvest related challenges, labour related challenges, land related challenges and other challenges.

Table 4.6: Challenges undergone by tea community.

		C1FG1	C1FG2	C1FG3	C1GN	C1DM	C1ED	C1TB
1	**Harvest Related**							
1.1	Difficulty to practice current method of harvesting consequent to the unpredictability of weather events.	✔	✔	✔	✔	✔	✔	✔
1.2	Harvest per acre reduced	✔	✔	✔	✔		✔	✔
1.3	Quality of harvest reduced consequent to difficulty of timely plucking	✔	✔					✔
2	**Labour Related**							
2.1	Difficulty to find workers	✔		✔	✔		✔	✔
2.2	Labourers are migrated as casual workers	✔			✔			✔
3	**Land Related**							
3.1	Area of cultivated land get reduced	✔	✔	✔	✔	✔	✔	✔

3.2	Changes to the natural topology of land which increases requirement of soil stabilisation techniques	✔	✔	✔				✔
4	**Other**							
4.1	Threat of losing seasonal jobs like clearing lands	✔	✔			✔	✔	✔
4.2	Infrastructure damages through landslides which provide access difficulties		✔		✔	✔		✔

All the focus groups emphasised that they are facing the harvesting issue with inability to harvest on the planned time (refer to Loop 04 of Figure 4.2). This is confirmed by all the focus group members and mentioned that unpredictable rainy events with short gaps are frequent in the area, and C1TB further insisted that this affects the quality of the tea leaves and thereby results in price reductions. Furthermore, C1ED mentioned that when analysing the tea leaves production of the area, the declination can be observed in harvest per acre, *"which is not solely due to the climate variability, but it also a key cause".*

Labour related challenges are another issue faced by communities and C1GN stated that *"current workers are connected to manpower agencies and go for jobs outside the area for casual work".* Furthermore, C1FG1 stated that initially people from different regions of the country, especially upcountry have migrated to their area, set up temporary accommodation and used to work as labourers for plucking tea. However, in the current context, following the landslides threat, absence of regular plucking jobs consequent rainfall variability and less availability of lands for temporary accommodation consequent to landslides and expansion of human settlements. Accordingly, these labour related variables like "labour migration", and "labour shortage" have identified as variables in Figure 4.2 under Loop 04.

Damages and changes to lands following rainy and landslides events is another concern arising from the communities, which is confirmed by all the key informants. Moreover, C1TB disclosed the costs aspects of this and mentioned that it increase the requirement of soil stabilization crops or techniques, where the community have to bear an additional cost. Despite above, threats of losing seasonal jobs like clearing the lands etc. can be noticed in the area following the excess rainfall. C1TB explained that initially, seasonal activities were available *"eight to ten days a month but difficult to*

do such works due to extreme events of rain and intermittent rain". This has a reinforcing impact on labour migration as shown in Loop 04 of Figure 4.2. Moreover, C1GN mentioned that some families are struggle on access roads to their lands, as those get interrupted by the soil movements of landslide events.

4.3.12 Current Actions Taken to address Climate Induced Challenges on Community Livelihoods

4.3.12.1 Actions Taken by the Communities

Favourable Responsive Actions

Communities have initiated actions to build up their resilience amidst the climatic impacts and accordingly, C1FG3 mentioned that earlier they were "*maintaining a turpentine forest which reduce soil erosion, decelerate landslides, reserves water. and when wind flows through the turpentine forest and when they pluck the tea leaves the tea leaves have a different better taste. Now those are being clearing as well* to resist the space availability problem. In the present context, most popular resilient action was the collaboration and farmers associations which is the key to share their knowledge, to discuss their problems and to help each other during a damage to livelihood (refer to Figure 4.2 where collaboration and farmer associations have identified as a variable which leads to increase ability to use technologies). Key informants confirmed that there are active farmer associations which focus on developing their economic status.

Harmful Responsive Actions

In responses to the challenges faced by communities, there are taking harmful responses which have long term consequences. According to C1GN and C1ED, the highly noticeable issue was abandoned of lands, following the landslides event mainly consequent to difficulties of recovering the land as a suitable space for cultivation. This increase of barren lands impacts on the entire economy of the country and ecosystem services. This is in contrast with the findings of Campbell et al. (2008), which identifies abandoned lands as a solution for climate mitigation in United States of America (USA), which is a developed country. However, in the context of Sri Lanka, increase of abandoned lands disrupt economy and therefore not encouraged.

Figure 4.2 identified abandoned lands as a cause to reduction of income as harvest quantity get reduced.

Migration for new opportunities to new areas is another responsive action taken often by communities which has a reinforcing effect on punctual harvesting, quality of harvest and thereby the income (refer to Loop 04 of Figure 4.2). According to C1GN and C1ED they reported the instances where people migrated to different areas and struggle to adapt and survive mainly consequent to financial barriers. Moreover, C1FG2 and C1FG3 mentioned that they are willing to migrate and however, have the difficulty to settle in a new location, adapt to a new livelihood, and find opportunities in a strange area. Further, C1DM, C1E3 and C1E5 mentioned the possibility of conflicts followed by climate change and migration. Thus, they highlight that it affects the wellbeing of the people. This is aligned with the empirical evidence of the review study by Kaczan and Orgill-Meyer (2019), which identified migration as a community action to resist disasters induced by climate change. However, this study less revealed on landslides as a cause for migration, which is derived from primary findings of this study.

4.3.12.2 Actions Taken by the Authorities

C1DM, C1E1, C1E4, C1E5, and C1E6 claimed that Sri Lanka possess a sound set of policies which are substantially developed for managing the climatic impacts. Accordingly they have highlighted some available policies including National Disaster Management Plan (NDMP) (C1DM, C1GN, C1E4, C1E6), National Climate Change Policy of Sri Lanka (NCCP) (C1TB, C1E3, C1E5), Climate Risk and Adaptation Country Profile Sri Lanka (CRACP) (C1E2, C1E3, C1E4, C1E6), National Adaptation Plan for Climate Change Impacts in Sri Lanka (NAPCCI) (C1E1, C1E2), and National Policy and Strategy on Sustainable Development (NPSSD) (C1ED, C1E5). However, C1E2 mentioned that there are no policies solely developed for the climate resilience of tea industry and he also agreed that the available policies are sound and manageable to improve climate resilience of tea industry (refer to Figure 4.2). However, all the experts agreed and commented on a close monitoring and investigation on policy implementation, as it is not properly practiced in Sri Lanka. This is clarified by C1E4 and mentioned that *"policy implementation is at infant level and have long journey*

ahead, to maintain the balance of policy formation and implementation". Accordingly, policy formulation is currently practicing in Sri Lanka, and however policy implementation needs to be improved.

R&D is another current action highlighted by communities to enhance the economic status of communities amidst climate variability (refer to Loop 09 of Figure 4.2). Accordingly, C1TB and C1E1 explicated that National Tea Research Institute (TRI) in Thalawakele, Sri Lanka is working on developing climate resilient tea species, which are resistant to pest and different soil conditions. Moreover, C1TB explained that *"these are not assertive to landslides"* and reflected the importance of landslide resistance species and mention the regional centres of TRI in Kottawa, Ratnapura, and Kalutara (low country wet zone) need to prioritize this action as centres in landslide prone areas.

Use of technology is practicing in Sri Lanka and to detect variability events like use of GIS, Seismometers, and Satellite images (C1E2, C1E5). However, the interpretation of the data needs to be expanded to provide reliable figures which can be directing to communities. This led to increase the "quality of harvest" as shown in Figure 4.2 (Loop 10).

In addition to above mechanisms, there are some other activities taken by authorities to enhance the climate resilience of tea growers. Accordingly, C1E2 explained that National Building Research Organisation (NBRO) works on developing early warning systems to detect climatic impacts where people can plan for drainage systems in the area, and vegetation cover to reduce the severity of the impacts. However, C1E5 expressed that early warning systems will not very efficient for long term crops like tea as it is difficult to stop the landslide to protect the cultivated land. Henceforth, C1E4 mentioned prevention as the best mechanism for resilience of tea growers amidst climate variations as other strategies will not properly work to eliminate from the loss. Moreover, all the key informants and experts express that there are awareness programs implementing to educate the communities about the threats from climate variations and basic actions to be taken.

4.3.13 Limitations for Implementing the Identified Actions

The next question was focused on identifying the barriers of current actions to increase the climate resilience of tea growing communities. The main identified barrier was the absence of sufficient funds to continue R&D activities. This is further explained in Loop 09 (reinforcing loop) of Figure 4.2, where R&D activities help to ensure the quality of the harvest. Moreover, C1E6 stated that "*the fund allocation for policy implementation is not sufficient and need to budget again"* considering the priorities. Further, absence of enough funding schemes in Sri Lanka can be observed (C1GN, C1E2) which may be due to the view of funding organisations that the value for their money is not ensured (C1E1). Moreover, low funding on R&D is from the government as convincing of the final outcome to the authorities to secure funding is challenging (C1E3, C1E5). To sum up, financial barriers are prevailing in Sri Lanka for climatic resilient action implementation.

Despite the technologies are used in Sri Lankan context; the interpretation and communication of results need substantial improvements (C1E5). C1E2 expressed communication as *"the sizable, but easily manageable barrier for climate resilience in Sri Lanka, regardless of the economic sector".* Accordingly, C1E4 explained the importance of widening both horizontal and vertical communication channels to ensure that the information are transparent, and accurate.

Knowledge barriers arise from communities is another limitation to implement identified actions against climatic variability issues and C1E4 explained that the tea growers are less exposed to the data on rainfall and moisture content of soul. Simultaneously, their capacity to interpret the data is also low which reduces their willingness to take actions. This was explained by C1DM with an example of *"we have distributed some rain gauges to landslide hotspots, however the community is not actively engaged in monitoring and reporting them, which makes our effort in vain".* Furthermore, most of the communities involved in tea industry are less educated to frequently update their activities with the changes (C1E6), which also limits the implementation of identified actions.

All the experts confirmed social resistance is a key and central issue which limits the implementation of identified actions. According to C1E1 *"most of the farmers*

maintain status quo and their traditional ideas, strongly disagreeing with use of new cultivation techniques". Further, they tend to less rely on the institution's consequent to their past experience with institutions, which made difficult to convince to have practical implementation (C1E4). In addition, market volatility is also caused to this social resistance, which generate the fear of exploring new things (C1E3, C1E5, C1E6).

Finally, geographical vulnerability is also identified as a limitation to implement resilient actions to damages to tea plants consequent to climate change. Accordingly, tea plants prefer slopy areas for better growth and therefore, the ideas initiated at the institutions are practically difficult to implement (C1E3).

4.3.14 Causes for Limitations of Implementing the Identified Actions

Awareness was identified as the key reason behind the above-mentioned (refer to subsection 4.3.13) limitations of financial, communication, knowledge, and social resistance. Accordingly, next subsections described the awareness of communities and authorities on climatic impacts.

4.3.14.1 Awareness of Communities on Effects of Climate Variability Induced Challenges

The primary data collection focused on identifying the knowledge and awareness of communities regarding the consequences of climate change, which is useful in providing resilient strategies. Accordingly, all the three focus groups ascertained that they are less aware on technology related to disaster identification and responding. This is confirmed by the view of C1FG3 that "*we are participating in the awareness sessions by all the organisations. But we sort of required for practical understanding of methods than the explanations"* which intensify the importance of practical sessions on detection methods and responding ways. However, C1FG1 had the basic knowledge on climate variation detection mechanisms like use of rainwater gauge. Further under the suggestions for improvement in their economy resilient to climate change, all the three focus groups acknowledge the requirement of new technologies for climate detection and responding. However, they do not aware of the technologies.

Regarding the alternative planting technologies, tea varieties resist to climate change, C1FG1 and C1FG2 stated that the introduced new tea varieties are difficult to grow in their lands and *"they only suit lab conditions, not the real life".* Accordingly, they acknowledge on the requirement of the species suitable for climate variations.

Despite the less technical knowledge, people had sound response to environmental changes which is also confirmed by C1DM and C1TB. The communities are currently managing their actions observing and responding the weather changes. However, *"they only respond to basic weather changes like, rain and wind. Beyond that, they do not take any measures to reduce the acceleration of landslides and keep continuing clearance of forest patches and unauthorized constructions"* (C1ED).

When concerning the future economy of the communities, they are less educated on the problem and planning to *"something"* to their economic declinations, which is not a clear focus. Accordingly, it is important to define *"these somethings"* communities and focus on increasing their economic development by economic resilience.

4.3.14.2 Awareness of Authorities on Effects of Climate Variability Induced Challenges

Despite the focus groups condemning the authorities for not taking actions to improve their economic wellbeing, key informants and experts argue that they are aware on the long-term consequences of climate change. Moreover, C1E3, C1E4 and C1E6 explained that Sri Lanka has sound policies for the implementation of climatic actions. Furthermore, C1E4 stated that *"Sri Lankan authorities are sound on the problem, especially the regional institutes, but the problems I guess here… are the miscommunication on administration channels, and willingness to succeed only on documentation, not on practical scenarios"* which was confirmed by C1E2 mentioning that Sri Lankan authorities need to prioritise the attention components concerning on implementation procedures.

Moreover, key informants explained the severity of the challenges undergone by the low country wet zone tea growers and the problem of *"vulnerable lands to landslides",* which is developing the outcome of financial struggles. Furthermore, C1GN and C1ED mentioned that at the regional level, there are maintaining a log called *"resource*

profile" to record the conditions undertaken by communities and which is used in decision making. Overall, the authorities have the knowledge and awareness on climatic conditions undergone by the communities and however, it is required to deepen the communication channels for sound implementation of actions.

4.3.15 Suggestions for Building up Climate Resilience of Livelihoods of Communities

This section presents a collection of views of focus groups, which were validated by key informant interviews, the suggestions of key informants, which were confirmed by experts and the views of experts. Accordingly, measures have been identified under following categories.

Alternative Means of Agriculture

As per the views of focus group members, the location of the tea land and nearby area have an influence on deciding the feasible alternative crops. As identified by C1FG2 there are knowledgeable about the alternative crops suitable for the area and however have the threats from animals. Further C1FG3 stated that *"as our lands are next to Sinharaja rain forest, it is very difficult at least to do home gardening and the peacocks, pigs, are always destroying them".* However, C1TB and C1ED mentioned that farmers are used to mention alternative cultivation crops in general including cinnamon for land boundaries, pineapple for the slopy areas and besides the access roads. Moreover C1E2, C1E4 and C1E5 mentioned that community can themselves move to some crops, which prevent soil erosion in this case and decelerate landslides. Cultivation on the boundary lines of the field was encouraged by C1DM and C1ED. Overall, alternative means of agriculture provides great support for economic resilience amidst climate change and thereby have identified as a variable in Figure 4.2.

Other Alternative Means of Income (Alternative livelihoods)

C1E4 elicited the importance of identifying alternative livelihood development programs for people within the area to minimise migration on casual works. C1E5 also claimed a similar view on this and argued that *"if it is holistic, it is feasible to develop alternative means of income for people, it can be whatever, not common for all, but*

set of distinct income sources, is possible". For example, C1E1 suggested to introduce any labour-intensive product and mentioned that *"we do not have to necessarily cultivate it there"* and can encourage the production part in the particular area, which expand the job network for communities. Moreover, C1E3 mentioned that *"if we can identify some alternative livelihood development programs, in order to engage them and trained them to do a productive work, I think that is going to be the best solution".* Thus, sesame (C1E1), weaving (C1E2), and coir (C1E4) are some alternative industries identified as suitable for the particular context. Overall, alternative livelihoods have identified as measure to enhance economic status of people amidst climate variability.

Trained labourers for productive works

All the six experts identified "training" as an important step to building up resilience of communities to climate variability (refer to Loop 11 in Figure 4.2). Accordingly, C1E3 mentioned the requirement of training communities for alternative livelihoods, to increase the efficiency. A similar view was explained by C1E2 and mentioned the possibility to couple up some handy craft industries associated with the tea industry, depending on the other locally available natural resources for example: weaving. According to him (C1E2), "*most of the people, who do traditionally weaving, they need lots of patience. Most of the ladies in weaving industry, they are old now. They have the patience and the talent, but they do not have enough physical power to operate the handloom machine".* In such instances, combination of these old women with women works in tea industry, the combination could make a successful work and output. Another example is related with sesame industry and C1E1 explains that seasonal women workers in these climates prone area can go for blending sesame with mortar and pestle because they have energy to do it and it is providing them with an income and a skill. For the coir industry, basic steps like extracting coir, blending them have identified as alternative training skills for tea growers in low country wet zone (C1E4). Hence, it is important to identify the possibilities and couple it up.

Institutional Measures

To reduce the acceleration of climate change collaborative contribution from entire community is required. According to C1E5, *"it is not only the one suffers, we all have*

to do that starting from a national policy, we do have "national climate change action plan but it needs to be strategically implemented". Moreover, C1E1 stated the importance of expanding the national level action plans to regional level programs, to directly capture and involved affected communities in policy formulations. This idea was confirmed by C1E6 and mentioned the importance of *"scenario-based analysis"* in policy formulation. A similar view was expressed by C1E3 and mentioned that *"the available policies are quite alright. There is no major change required in the policies, the only thing is that regional planning policies are not adequately incorporated to minimise harmful contributions to climate".* Overall, rearrangement of policies are important targeting more regional levels vulnerable to climate.

Importance of planning was another concern expressed by experts for the improvement of economic status of tea growing communities. It is vital that *"airsheds", "watersheds"* are operated as regions not isolated towns or cities (C1E3). As per C1E6, regional planning and urban development are the areas where improvements are required to develop a community to better cope with climate change. Moreover, C1E4 and C1E5 have highlighted the importance of conducting background studies on environment and social background of these people to propose suitable alternative means of living. According to C1E4, *"we need to know about their environment because they are not well educated, and what they can do, and they have is good body power. Most of the cases they are not intelligent"*. Therefore, it is important to have background planning before the development of plan and proposals.

C1E2, C1E3, C1E6 emphasised the importance of actions targeting the causes of climate variability. Accordingly, C1E6 stated that *"we are globally connected as one biosphere, so not only our actions global actions are required".* Similarly, C1E3 identified the importance of offsetting the climatic damage a particular group of people made and stated to expand the regulations targeting the emitters to compensate for their emissions. Following that C1E1 mentioned that *"it is vital to expand the national level action plans to regional level programs, and target not only the affected communities, but the main emitters"*.

In addition, the experts intensified the importance of regulations, as policies itself does not work without proper regulatory system. As per C1E4, it is important to impose

regulations to mitigate the causes of climate variability. For example, making composting plants a mandatory requirement of tea lands help to maintaining the soil quality, provide fertiliser for lands and simultaneously reduce the washing off soil (refer Loop 06 of Figure 4.2).

In addition, financial institutions can introduce insurance schemes which helps the community to recover from climatic impacts (C1E1, C1E2, C1E5). According to C1E2 this helps to develop the mindset of the people, making them self-responsible with increase accountability of them for the threats to them. This has been identified as a cause which led to cover preparation costs in the instances where the land get damaged by climatic variations (refer to Figure 4.2).

Overall, these institutional aspects can be identified as the suitable measures for communities to withstand climate variability and work for the betterment of their economic conditions.

Technology Measures

Technical measures to climate resilience range in a wide variety from soil preservation technologies, tea cultivation technologies, tea land maintenance technologies and harvesting technologies (refer to Figure 4.2). According to C1E2, since most of the tea lands are in slopy areas, there are natural mechanisms, which can be used to increase the soil fertility and preventing the runoff of nutrients. C1E2 explained that *"there is a nutrient rich runoff which comes from top mountains. Therefore, try to make top part of the hill a forest to increase soil fertility. Then the nutrient rich soil is mixing with the surface runoff"*. In addition, experts have highlighted the techniques like use bio sludge, harvesting waste, kitchen waste, crop waste and sewerage to generate composting (C1E1, C1E2). Further, C1E2 insisted that make the people familiar with those technologies will be beneficial in their current livelihood, helps to mitigate climate variations and will create positive impacts on absence of livelihoods, as alternative livelihoods. Moreover, C1E1 mentioned that people can get municipal waste and generate compost, which is also climate friendly, new business opportunity.

C1E3, C1E4 and C1E5 emphasised the importance of technical studies focusing on microclimate variations, for example: wind movement simulations, which can be used

in climate sensitive built environment design which assists the natural environment with less disruptions. Further, C1E5 stated that this technology can be used to identify wind corridors, road and building layouts in new constructions which helps to minimise harmful impacts of construction on landslides. Moreover, C1E2 mentioned that plan for microclimatic regions within the affected areas will bring more uniform and certain climate conditions, which helps to minimize the hazardous climate events.

Moreover, all the focus groups members mentioned the problem of difficulty of harvesting on time and maintaining the expected quality of the output, which results in declination of the value day obtained for the output. C1E3 and C1E4 have stated a suggestion which assist this problem which is to expand tea processing technologies to communities to deal with problems of tea plucking (refer to Loop 10 of Figure 4.2). For example, C1E4 mentioned that *"if the tea leaves are too wet, go for blow drying instead of sun drying and if the wind is also not available go for mechanical ventilation".* In addition, C1E2 and C1E5 highlighted the importance of changing the tea plucking time (Loop 04 of Figure 4.2), to suit with current climatic conditions and mention that *"people have to move outside their status quo to survive".* Further, C1E1 explained that it is important to study the crop calendar and identify deviations of it, try to incorporate those variations into calendar.

Financial Measures

Since financial management has highlighted as a key issue in the context of the change it is important to provide strategies to manage financial aspect to increase the economic aspects of people amidst climate variability. Accordingly, C1E5 highlighted that the tea industry must bear the cost they incurred which damage the social status of people. Hence it is the owners' responsibility to bear the costs of landslides (C1E2) and implement landslides reduction measures and climate impact reduction plans (C1E4). Thus, Large size estate owners are mostly doing that, and the problem is with the small-scale owners as *"small estate owners, they have 01-acre, 02-acre small areas of lands, so they are not able to invest on".* Henceforth some mechanism should be developed to compensate for their impacts like trade off fund or compensation raised from buyers which is charged over the period from tea growers. Moreover, C1E3 explained that small increment in salaries to attract estate labourers will be beneficial than the use of

local labour for their plantations. Moreover, C1E2, C1E4 and C1E6 identified the importance of proper low-cost soil preservation techniques since tea plants accelerate landslides (refer to Figure 4.2) or go for an alternative crop.

4.4 Case 02- Case of Paddy Industry

4.4.1 Profile of Respondents- Focus Group Interviews

Farmers in the selected case study area were selected as the possible members for focus group discussions. Table 4.7 shows the background details of the farmers selected based on the selection criteria explained in subsection 2.3.8.

Table 4.7: Profile of respondents- Case 02 focus groups

Code	Demographic Background	Average Educational Status	Other Crops or Employment	Involvement (Owner/ Labour)
C2FG1	5 Male	A/L	Both	Owner
C2FG2	4 Male 1 Female	O/L	Only one	Both
C2FG3	4 Male 1 Female	O/L	No	Both

4.4.2 Profile of Respondents- Key Informant Interviews

Key informants of the case study 02 also have selected based on the criteria adopted in case study 01 (refer subsection 2.3.8). In addition, agricultural officer was identified as the closely communicating party related to the paddy industry, similar to the tea board officer in tea industry. Table 4.8 discloses the details of the key informants participated for case study 02.

Table 4.8: Profile of respondents- Case 02 key informant interviews

Code	Profession	Experience in the industry	Experience in particular case	Key job responsibilities
C2GN	Grama Niladari Officer	24 years	6 years	Handle all the key community activities and record keeping on the demographic backgrounds of the communities and their economic activities.

C2ED	Economic Development Officer	12 years	6 years	Work on developing the economy of the people, attending to their problems, and explaining further directions.
C2AG	Agricultural Officer	18 years	5 years	Connect the communities with authorities to address their problems and reporting the status of paddy cultivation.
C2DM	Disaster Management Officer	7 years	4 years	Plan, communicate and work to keep the people informed of the disaster events in the area and work on recovery activities for damages to people as required.

4.4.3 Profile of Respondents- Expert Interviews

Similar to the case study-01, expert interviews were used to validate the findings of focus groups and key informant interviews and to produce adaptation strategies. The criteria for the definition of experts were followed as mentioned in subsection 2.3.8. Accordingly, combination of experts involved in research at Universities, Rice Research and Development Institute (RRDI) and Sri Lankan Agricultural Service have selected as experts. Details of the respondents are summarised in Table 4.9.

Table 4.9: Profile of Respondents- Case 02 expert interviews

Code	**Profession**	**Experience**
C2E1	Professor	27 years
C2E2	Senior Lecturer	15 years
C2E3	Researcher at RRDI	05 years
C2E4	Senior Lecturer	12 years
C2E5	Senior Lecturer	25 years
C2E6	Agricultural officer	05 years

4.4.4 Case Background

Economics and planning center of Department of Agriculture Sri Lanka (2023) has established the requirement of focusing on ensuring the economic and social development of farmers simultaneously with other stakeholders. Being an agricultural crop sensitive to changes in climatic conditions, paddy growers faced the risks on their livelihoods associated with climate variations. Despite the minor differences in the

problems faced by the paddy growers in the different areas of the country, the study selected low country wet zone paddy growers who depicted the highest tendency to uncultivated the lands consequent to climatic problems.

4.4.4.1 Climate Variation Influences on Paddy Industry

Paddy is considered as the main agricultural crop in Sri Lanka, which has extended to entire geographical area, providing livelihood opportunities for a substantial community and made an enormous contribution to GDP of the country. All the respondents from all multiple data collection methods agreed that climate change and variations made a direct and huge contribution on livelihood of farmers and thereby affect their economic wellbeing. The study adopted low country wet zone paddy as a case study to provide a fair comparison basis for two livelihoods. According to C2DM low country wet zone agriculture mainly depend on rainfall and *"since it is rain-fed it is obvious that rainfall changes affect the paddy industry".* Moreover, C2FG2 mention the continuous loss of their harvest (refer Figure 4.3 Loop 01) due to rainy events prevailing in the area. Specifically, C2AG highlighted that percentage of fallow lands (refer Figure 4.3 Loop 01,03) in the area increased in the recent past. *"We worked with community on identifying the cause behind it and it was basically the flood events in the area"* C2AG mentioned. This evident that there is an impact of climate on livelihoods of paddy growing community in Sri Lanka.

Despite being an agricultural country, wet zone paddy industry is currently and continuously subjected to climatic barriers. As per the view of C2GN, *"the cases reported are scattered though the entire Grama Niladari Division and we are even finding it challenging to visit them all immediately".* Hence it is clear that despite the location, entire community find it challenging to continue their livelihoods. However, this is because the land areas of paddy growers are mainly centralised to waterbodies, where probability of flooding is high (refer to CLD paddy which is mentioned that the location near water body impacts on floods). This view has ascertained by C2ED, and he further mentioned that *"we are reported with cases of bulk damages to multiple families, as paddy fields of different owners are located vey nearby"*.

In addition, experts also confirmed that climate and paddy industry as two interrelated fields and wet zone paddy growers faced circumstances to continue their livelihoods

consequent to extreme rainy events. Further, as per C2E2, *soil is also a catalyst which accelerate the impacts of variations in climate*" which results in producing more visible impacts in the area. This can be clarified in Figure 4.3, where soil moisture belongs to Loop 3; a reinforcing loop (change in this condition, magnifies the impacts) and boggy soil and waterlogging connected with plus (+) sign which implies boggy soil accelerates waterlogging and impacts on harvest quality. Henceforth, these variations in climate change affect the economic status of communities.

4.4.5 Impacts of Features of the Cultivated and Nearby Area on Climate Impacts to Livelihoods

4.4.5.1 Impact of Location

As most of the time, paddy fields are near a waterbody in these areas, obvious floods are observable (C2GN). Moreover, C2FG2 confirmed that their fields are located besides the river and marshy lands. In addition, C2AG and C2ED mentioned that most of the paddy fields in low country wet zone are located on river basins, constructed reservoir areas, peri-urban areas, near canals and ditches, and on marshy lands. Accordingly, it is evident that location of the cultivated area, which is almost nearby a water body magnifies the impacts of climate variability on paddy growers. This has been identified as a cause of flood as well as soil moisture as stated in Figure 4.3.

4.4.5.2 Impact of Soil Condition

As revealed by C2AG, the fields bear a boggy soil with high water retention ability, which hastens the negative impacts of rain on crops. This view has confirmed by C2E1 and mentioned that *"low country wet zone bears BHP soil, that mean boggy and half boggy soil, which made the problem of waterlogging severe".* In addition, C2FG2 and C2FG3 also expressed this view and mentioned that soil is always over saturated with water, which results to dead of the paddy plants at the very early stage. Overall, it can be stated that the soil condition impacted on changes of the economics of communities, consequent to climate change. This has been expressed in Figure 4.3, where boggy soil acts as a cause for waterlogging and soil moisture acts as a cause to determine irrigation requirements (Loop 03).

4.4.5.3 Impact of Irrigation

There are two main irrigation methods used in low country wet zone paddy cultivation system as rainfed and river fed. C2AG stated that the recent deviations in climate conditions impacted on both farmers and waterlogging is the key issue for rain fed farmer groups while floods impacted the river fed farmers. Moreover, the focus groups comprised of farmers of combination of both, and they stated that irrespective of the irrigation method, they are suffering from the climatic problems. Further, C2GN and C2DM mentioned that low country wet zone rarely faced the challenge of absence of water, and it was recorded before 2014 for the last time. Further, C2AG mentioned that nature of irrigation has a high impact on the agriculture of dry zones, which is needed to be considered when assessing the economic impacts and decision making. "Irrigation requirement" and "irrigation cost" have identified as the two variables on CLD (refer to Figure 4.3) which impacts on increasing fallow lands and thereby affect the income.

4.4.6 Impact of Demographic Factors of the Communities on Climate Impacts to Livelihoods

The focus groups were questioned to determine the impact of demographic factors amidst climate change on their economy and accordingly, they did not find it much influential. All the three focus groups believe that they are work on share labour basis in all lands and therefore, their age or gender have not impacted on making them vulnerable. However, in terms of education level C2FG1 explained that the people with *"sound education background have the knowledge on the most responsive behaviour in forecasting and taking actions to hazardous climate impacts on their business".* Moreover, C2FG2 and C2GN, C2AG mentioned that paddy industry always progressed with collective thinking, where protecting only the individual land is difficult and not practical. Accordingly, farmers related to the entire field act as a group in flood or any hazardous event. Overall, in the context of low country paddy growers in Sri Lanka it can be concluded that the demographic factors have insignificant influence in their economic status related to climate variability.

4.4.7 Climatic Conditions Undergone by the Communities

4.4.7.1 Variations in Temperature

Since paddy is a seasonal crop and planned according to the weather conditions, changes in climate affected the expected yield of the crop. According to the view of C2FG2 and C2FG3 temperature in the area has reduced consequent to the frequent rainfall received. Further, as per C2FG1 *"temperature is not a threat to us as paddy is mainly caught to floods and from about ten years, we have not faced a severe drought however the slights signs of droughts were in 2020".* Moreover, C2DM and C2AG mentioned similar ideas and depict that paddy cultivation of their area was less disruptive due to temperature variations in the area. However, they further stated that, despite this situation in particular area, paddy cultivation is generally threatened by temperature changes, especially droughts and high intensity of temperature. Henceforth, temperature was not emerged as a cause in CLDs.

4.4.7.2 Variations in Rainfall

All the respondents agreed that the rainfall has changed over the recent past and it negatively impacted on agriculture in the context of paddy. According to C2DM *"low country wet zone mostly practices rainfed agriculture and henceforth, mostly suffers from rain".* Furthermore, he has mentioned the extension of rainy period prior to May and beyond September for the "Yala" season as disruptive. Accordingly, this was identified as a cause for harvest to be caught by water, waterlogging, and floods as presented in Figure 4.3. Moreover, C2FGs mentioned the impacts of the frequent floods on their livelihood. According to C2FG3 at least one season of paddy cultivation (Most of the time "Yala" season) got disrupted due to rain and there are times where entire land is abandoned if it rained in the early stage of paddy plants and most of the time, harvest is substantially reduced *"ending up with a loss which even difficult to recover the money spent"* (C2FG2) (Early harvesting also identified as a cause for enough maturing of harvest and harvest catch by rain as shown in Figure 4.3). Further, this results in reducing the time available for land preparation works prior to a season (refer to Figure 4.3 where time for preparation work has identified as a cause for determine labour cost).

Further, experts witness the changes of rainfall patterns in the Sri Lanka, which are highly observable in selected case area at southwest monsoon periods. C2E3 and C2E6 mentioned the frequent extreme events of rainfall, which tend to happen in the two farming seasons. In addition, C2AG mentioned that "*there are frequent rains to the area throughout the day for two-three continuous days, which ended up with floods".*

Another key rainfall related highlighted by C2E1 and C2E4 is that the low country wet zone suffered from the rain directly received to their area as well as from the rainfall received by up countries. This is also a cause of waterlogging and flood as stated in Figure 4.3 and this cause in magnifying the water content in the water bodies, which obstruct the general cultivation practices of the communities. Overall, the paddy growers of low country wet zone faced the problems in continuing their livelihoods consequent to changes in rainfall patterns.

4.4.8 Effects of Climate Variation

4.4.8.1 Identification of Effects of Climate Variation

Floods and water logging were revealed as the two concurrent disasters faced by the paddy growers in the selected case study area (refer Figure 4.3). This idea was confirmed by C2FGs and C2KIs and stated that since the paddy lands are in lowlands plains, low threat of landslides is observed (C2GN). Moreover, most of the time the paddy fields are not surrounded by a hilly area nor at a bottom of a mountain and therefore have the less threat of landslides (C2FG2). Henceforth, changes in the climatic conditions itself create disasters and they are accelerated by the conditions prevailing in the area.

C2FG3 mentioned water logging as the main difficulty faced by them to continue their livelihood as *"all the plants get died due to excess water content and this is worse when it happened at the very early stage of the plant where the water tolerance is very low"* (refer to Loop 01 in Figure 4.3). Similarly, C2E1 and C2E2 have identified water logging as a disaster event consequent to excess rainfall prevailing in the area. They further highlighted that being in the low country is another reason for waterlogging as water flowing from the hilly areas are too retained in the downlands. However, they further intensified this as a condition which can be managed properly and not an

unpredictable disaster. In contrast, floods have been identified as an unpredictable event which is impacted on the paddy fields as most paddy fields are situated beside the river. However, focus groups were less concerned on lightning and mentioned that it has not become a disruption to continue their activities.

Overall, floods and water logging are the two disasters undergone by the tea growers in low country wet zone.

4.4.8.2 Frequency of Effects of Climate Variation

The frequency of damages of climate variability has increased over the past years which can be supported with the opinions of the focus groups and key informants. Thus, C2GN explained that the "*number of flooding events per year has increased and the number of days a flood continued in a single flooding event also has increased"* over the past years. Moreover, C2ED mentioned that from about 10-15 years back, floods used to be benefitted to the farmers which enrich the soil fertility and nutrients (refer Figure 4.3- Loop 03). However, it has evolved negatively in the present context with high frequency, damaging the crops (C2FG3). Overall, evolution of floods moves towards negative impacts on the paddy growers.

4.4.8.3 Severity of Effects of Climate Variation

All the three focus groups agreed that the severity of the disasters have increased over the past 10-12 years. Further, C2FG1 mentioned that manmade causes like sand mining, unnecessary increase of height of roads as a solution to floods than focusing on proper drainage methods as key reasons for increasing the frequency and severity of floods (Refer Figure 4.3 which used these as causes of floods). Rather C2FG3 and C2ED focused on natural causes for increasing the severity of floods and highlighted those frequent and extreme rainy events beyond the monsoons magnified the water quantity and the impacts. Besides, C2GN and C2DM stated that the time to recover from the flood has been extended during the past few years. In addition, as explained by C2FG3 *"now there is an obvious flood of about 3-4 inches on the fields at least one or twice a year"* and this is future evidenced by C2FG1 *"in earlier time, it is once in 2-3 years and water retained only for few hours"*. Overall, the severity of the floods and water logging has been increased over the past years.

4.4.9 Climate Induced Causes Which Challenge the Livelihoods of Communities

Similar to Case 01, the causes associated with climate variability are manmade and have the possibility of reducing. Accordingly, three main causes were identified from the interviews, which challenges the community as continuous river mining in the nearest area (C2FG1, C2AG, C2ED, C2GN), heightening the roads (C2FG1, C2FG2, C2FG3, C2ED, C2DM) and altering natural canals (C2DM, C2AG, C2GN). Experts, C2E2 and C2E4 further validated that the altering natural river channels can increase the frequency of flood. Moreover, C2E6 explained that soil movements near riverbanks for construction or cultivations increases the damage from climate variability, making it rain even in a little rainfall as *"when, riverbanks get to collapse rapidly, it increases the threat of the flood".* These have been linked with floods as a cause of flood (refer Figure 4.3). Overall, these are the human induced causes, which increases the damage of climate variability, and which can be controlled to control the impacts.

4.4.10 Climate Induced Opportunities to Livelihoods of Communities

Despite the negative consequences, the focus groups, key informants, and experts explained some pros of climate variability on low country wet zone paddy industry. According to C2FG2, C2FG3, C2AG, C2DM, C2E3, and C2E6 low country wet zone paddy industry is a mix of rainfed, and irrigation-fed most of the time as the *"Southwest monsoon in 'Yala' season, where farmers used rain and for 'Maha', they use water from the nearby canals, which has changed now"* and the farmers received enough water throughout the year in most cases to their paddy lands. Intermittent rains help the healthy growth of the paddy tree (C2E4). Hence, "intermittent rains" have identified as a cause for increasing soil moisture and mentioned in Figure 4.3. Accordingly, the cost of irrigation reduced which is positive economic impact on them (C2ED, C2AG, C2E1). Furthermore, C2FG1, C2AG, C2E1, and C2E2 explained that retaining soil moisture by intermittent rains is beneficial for the healthy growth of the tree. Accordingly, intermittent rains have identified as a positive cause to soil moisture as present in Figure 4.3. Overall, sufficient water from rain to accomplish the water requirement of the paddy lands is a benefit for farmers caused by climate variability.

Though the focus group members have not disclosed any benefit of waterlogging, C2AG, C2E2, and C2E5 identified that it the overflow of water and water logging for periods are beneficial as it helps to absorb the nutrients to the soil and contribute to soil fertility. This argument was extended by C2E2 and mentioned that *"it is highly subjective, depends on the stage it happens, what if it just happened day prior to the harvesting…, no point at all and totally a disaster"*. Overall, waterlogging following by climate variability can be identified as a positive impact based on the time it happened.

4.4.11 Climate Induced Challenges to Livelihoods of Communities

Focus groups explain the challenges they are facing consequent to excessive rain and flooding events which can be mainly categorised under the two areas of 1. Harvest or output related challenges and 2. Financial Challenges.

According to all the focus groups, C2AG and C2ED, if the field caught by a flood, it reduces the quality of harvest, as the paddy seeds get wet (this has been identified as a cause for post-harvest damages as shown in Figure 4.3), and if the difficulty of drying continued due to rain, they get to planted which cannot be consumed as food and must throw away. C2E2 further insisted that, *"if it is gone, it is gone. We have to wait until the next season. But our hopes!! All get vanished and we are mentally down and clueless of next season".* Accordingly, the quality of harvest reduced following climate variability impacts (refer Figure 4.3). Another concern raised was the difficulty of following harvesting methods (C2GN, C2DM, C2E3). Accordingly, if it is continued rain for days near the harvesting period, it is difficult to harvest by hand and, also use harvesting machines (C2E4). Henceforth rapid fluctuation of output can be observed in climate variability events (C2AG, C2E4, C2E6), which will lead to food crisis in some situations as the paddy is the main food crop of Sri Lanka (C2E2). Moreover, C2E3 explained that despite paddy fields but the entire paddy industry is vulnerable to climate variability as though the harvesting done before any disasters climatic event, *"it does not mean that we passed the hurdle, because post harvesting activities are highly affected by climate variability, especially the rain"* (C2ED). Accordingly, low

country wet zone communities undergo variety of challenges following the climate (rainfall) variability.

In addition to the harvest related challenges, there are financial challenges undergone by the communities, consequent to climate variability. Accordingly, in an event of flooding or waterlogging they have to bear substantial financial losses by destroying entire cultivation (C2FG1, C2FG3, C2GN, C2E2, C2E6). Furthermore, rapid recovery in particular scenarios is difficult as the output is followed by series of investments, specially made as loans (C2GN, C2E1). Thus, the challenges are tricky and incurs long term suffering and difficult to recover.

4.4.12 Current Actions Taken to address Climate Induced Challenges on Community Livelihoods

4.4.12.1 Actions Taken by the Communities

Favourable Responsive Actions

Experts mentioned some current practices to withstand the climate change. Accordingly, C2AG and C2E4 highlighted the concept of *"Sthira Kotu"* as a current practice, which is mostly used for leaks and vegetables. This has been identified as a cause for increasing income by alternative food crop cultivation as shown in Figure 4.3. In there, the part of the land is used for cultivation of vegetables which are resistant to climate variability and use as an additional source of income. Accordingly, "alternative food crops" have been identified as a cause for increasing income as shown in Figure 4.3. Furthermore, some farmers tend to separate part of the land just to retain water in floods and fill up the other area and use for the cultivation (C2DM, C2E3). This is also identified as a cause to reduce waterlogging as shown in Figure 4.3.

Moreover, farmers used to have farmers associations to discuss their problems, including climate related issues, their temporary actions to face excess rainfall issues like, delaying or hastening planting time, and harvesting time (C2FG1, C2FG2, C2FG3, C2AG). This is also identified as a cause in CLDs, which impact to worked on shared labour basis (refer Figure 4.3).

Harmful Responsive Actions

Increasing number of fallow lands is a growing problem identified specific to the low country wet zone (C2E4, C2E6). This is consequent to the abandoned of lands by farmers following the climatic impacts (C2GN, C2AG). Moreover, there is a trend of farmers to engage in paddy cultivation for single season, instead of two seasons, used to depend on that harvest for entire year and invest the money for next season some alternative income (C2ED, C2AG). This is not a positive practice in the case of paddy, as it is the main food crop of the country. Accordingly, increase of number of fallow lands (Loop 01) and cultivate only on single season (Loop 02) have identified in Figure 4.3 as activities with balancing and reinforcing effects respectively.

4.4.12.2 Actions Taken by the Authorities

According to C2AG and C2E4, authorities and research institutions are working on developing resistant varieties of rice along with the support from universities (refer Loop 04 and 04 of Figure 4.3). As stated by C2E5 *"initiations have been launched to introduce tolerable varieties, but their success rate is not good as expected".* He has highlighted the reason for this as the difficulty of providing actual environmental conditions at the research labs, which failed the product in field. Also, some cross pollinations of two varieties have to be continuous which results in incurring additional costs. However, the efforts are still in progress to develop tolerable varieties which can survive in water.

Moreover, there are fund raising and compensation programs practicing for the people of whom the agricultural lands have damaged consequent to the climate change (C2GN, C2ED, C2E1). This has identified as a cause which increase ability to recover money spend in Figure 4.3. Further, the authorities are providing the ability to report communities' disaster related issues even to the highest administration level to solve them effectively (C2DM). Furthermore, the authorities at the local level maintaining weather profiles, which can be used to successfully predict the climatic conditions (C2DM).

Experts highlighted the availability of policies and mentioned the adequacy of policy documents and emphasised the loopholes in implementation of policies. Moreover,

there are programs to educate the communities on climate variability, their consequences, current actions taken by authorities, and the support required from communities (C2AG, C2GN, C2E2, C2E6). However, C2E4 argued that these programs do not serve the purpose and require improvements. These have been identified as variables in CLD under Figure 4.3 which ultimately led to determine believes of communities on technologies.

4.4.13 Limitations for Implementing the Identified Actions

Financial Barriers

Sri Lanka undergoes financial barriers which affect almost all activities of the entire country. Accordingly, investments on R&D projects to identify new rice varieties, investments to recover from immediate climatic impacts and startup compensations have become problematic (C2E3, C2E5, C2E6). Moreover, C2DM and C2E2 mentioned that there are funding barriers for knowledge sharing programs, *"especially the programs which requires live models to make it acceptable to the community"*. Henceforth, this placed the communities limited to the traditional agricultural frame (C2E4). Overall, financial barriers to improve climate resilience are observable in Sri Lanka which have been identified under Loop 04 of Figure 4.3.

Technology Barriers

In terms of technology, there are advanced technologies, which are required to develop new rice varieties consequently and to test them for field efficiency (C2E2). However, this technology is dearth in Sri Lanka, where quality control activities are difficult to implement (refer to Loop 06 in Figure 4.3). Moreover, technology to produce large-scale production of successful rice varieties under controlled conditions are challenging in Sri Lanka (C2E4, C2E6). For example, C2E4 explained that *"the technology transfer extensions and networks are extremely poor in our country"*, genetic engineering (refer to Figure 4.3) needs further improvements to breed climate resilient *"specially the flood resilient varieties"* (C2E1) (refer to Loop 03 of Figure 4.3), with the ability to implement pest controlling techniques (C2E3, C2E6). Moreover, C2E1 mentioned that *"our human resources are ideal, but the background*

to well employ them needs sweeping improvements". Overall, it can be observed that there are technical barriers prevailing the implementation of identified actions.

Social Resistance

As mentioned by C2E4 and C2E6, community does not willing to accept new species they find it threatful and risky. Moreover, C2E1 conveyed that it is difficult to convey to the entire farmers gang and accept them for a change. However, it is vital for collaborative approach, which is accepted by all the parties, as *"unless accepted by all, it is difficult to implement any technology or cultivation method to a single land of paddy".* Further, C2E1, C2E2, and C2E6 conveyed that this social resistance is highly observable in the present context as the farmers reluctant to believe on institutions. Further, C2E4 emphasised that there are popular technologies in other countries for paddy cultivation. However, according to C2E5 *"these are very popular in other countries. But in Sri Lanka, these are not very popular due to cultural issues and social issues".* Further, C2E3 stated that *"these are yet not popular in Sri Lanka due to attitudes of the people and resistance to change".* Further, economy and willingness of the farmers have identified as two other issues, for the less popularity of these systems in Sri Lanka (C2E1, C2E5). These have been identified as causes in Figure 4.3, which were referred to as "community belief on technology" and "funding ability".

Institutional Barriers

As per the view of C2E3 and C2E6, institutional support from Sri Lanka is average. There are some programs already launching (C2E2). However, sometimes the effectiveness of those is very low and not up to the required level (C2E1, C2E2). Because the "*programs should be tailor made to suit farmers and therefore less effective"* (C2E1). A similar view was expressed by C2E4 and conveyed that the already implemented programs are not *"community friendly"* and idle action and policy development can be observed in Sri Lanka. Further to C2E4, *"these are not a problem of officers themselves, but the pioneers of the institutes".* Accordingly, farmers tend to rely less on institutions, based on past behaviors, our weather forecast is less accurate in most cases, *so the farmers feel lost.*

Poor policies on insurance and poor insurance schemes are another institutional barrier to recovering from climate induced damage and maintain economic wellbeing. C2E4 stated that *"government provide compensations to each and everything, where people always encouraged to be dependents of the government".* Moreover, C2E1 stated the importance of self-accountability of people towards their actions and developing independence, which ensures rapid recovery.

4.4.14 Causes for Limitations of Implementing the Identified Actions

4.4.14.1 Awareness of Communities on Effects of Climate Variability Induced Challenges

Similar to the tea growers, paddy growers also depict less awareness on responsive mechanisms for disaster induced consequent to climate variability. C2FG1 mentioned that *"we know that our lands are highly risky to floods, but what can we do, we cannot stop cultivation in particular season forecasting there will be a flood, we need to know what we have to do to overcome flood impacts"* and C2FG2 also confirmed that they are less aware on the coping mechanisms. Furthermore, all the three focus groups agreed that there are sessions conducted by agricultural officers advising to early the harvesting time before significant rainy events and so on. However, these are difficult to practice as the growth of the plant is not sufficient for harvesting (C2FG1). However, as identified by C2AG and C2GN, communities are less likely to believe on technologies as they are time and money consuming. Moreover, they rely less on flood tolerant varieties of paddy, as their harvest is comparatively low. Overall, communities are aware on the consequences of climate change, however, there is still a dearth of knowledge in coping mechanisms.

4.4.14.2 Awareness of Authorities on Effects of Climate Variability Induced Challenges

As identified by C2E1, C2E2, and C2E4 authorities are acknowledge on climate impacts on agriculture and already developing policies to address them. Moreover, there are R&D activities taking place to develop climate resilient paddy varieties, which are being challenged by the fund issues (C2E3, C2E6). Furthermore, there are

programmes conducting at regional level to collect data of affected families and impact on output to develop strategies to be resilient to climate variability (C2AG, C2E4).

4.4.15 Suggestions for Building up Climate Resilience of Livelihoods of Communities

According to C2E4 *"paddy industry in Sri Lanka can develop in many ways to be more climate resilience, however, consequent to the idling of parties, strategies are less implemented".* Accordingly, varieties of measures have been unveiled from the case studies and from the expert interviews. The identified measures have been categorised under technical measures, institutional measures, alternative means of agriculture, and financial measures.

Institutional Measures

Institutional measures have been identified as a key concern of the experts which ensure the resilience of the paddy growing community in Sri Lanka. Accordingly, collaboration with the private sector is identified as a key concern to overcome the theory and practice gaps (gaps of implementation) (C2E1, C2E3, C2E6). As mentioned by C2E3, *"inputs from private sector bridges the financial and social gaps with substantial funding and marketing".* Furthermore, C2E4 mentioned that farmers rely more on private sector and therefore it will see to introduce the concepts to the communities with the private sector collaboration.

Develop live working models of farmlands to motivate farmers is another strategy proposed by C2E4, C2E5, and C2E6. C2E5 explained this as *"the best solution for social resistance, because people believe what they see".* Furthermore, C2E2 explained that there is an already practicing project in "Bombuwela" area, which needs to expand further to other regions as well. Simultaneously, it is important to encourage field visits of farmers (Figure 4.3), to explore these models (C2E4) and C2E2 mentioned that it can be initiated with the leaders of the farmers' associations and later expand to farmers.

Another institutional measure suggested by C2E1 and C2E5 is to expand institutional support to establish market networks and expand and value addition to available networks (C2E4). This is also identified as a reinforcing cause in Loop 05 of Figure

4.3. Accordingly, C2E5 mentioned that *"there are varieties, which as not extremely endangered to floods. However, their harvest is comparatively low, with no significant difference in market price. So… farmers do not plant them".* Hence, it is important to encourage farmers to cultivate flood resistant varieties by providing a good market value for the harvest. Similarly, C2E5 explained the challenge behind this experimental varieties to field and mention the importance of all farmers in the field planting that as otherwise harvest will not be sustained. However, it is difficult to convince entire group of farmers about the benefits of an experimental variety, and therefore it is important to have live models (C2E2).

Despite experts agreeing on the availability of sound policies for promoting climate resilience in paddy cultivation, C2E1 and C2E5 explained the improvements required in policies to promote community participation and empowerment. Moreover, institutes like Agricultural Department, Irrigation Department, and Department of Agrarian Development required to promote integrated interventions to review the exact problems of climate variations and implement actions.

Moreover, C2E1 and C2E5 identified the requirement of willingness of farmers from entire field land as otherwise, single farmer cannot do the thing. However, they further insisted that convincing many farmers for a change is difficult. Accordingly, they mentioned the requirement of collective approach where awareness and guidance are made by institutions (C2E3).

Alternative Means of Agriculture

Experts encourage alternative means of income through agriculture and identify the importance of flood tolerant ways of agriculture (C2E1, C2E2, C2E5). Accordingly, prawn cultivation has identified as a good source of alternative income (C2E2). C2E3 further insisted that, as farmers tend to abandon potion of their land as low land for flood and make the cultivated area in the rest of the heightened land, it is better to use such land also for an effective mode of income. Thus, prawn cultivation will be beneficial in this context. In addition, Leaks can be used as a possible alternative crop to even low country wet zone, as they are resistant to water (C2E6). These have been identified as causes which led to increase income as shown in Figure 4.3.

Moreover, it is important to highlight that experts provide less interest on other alternative means of income and emphasise the importance of protecting the farmers and expanding the agriculture.

Technology Measures

C2E4 emphasised the importance of practicing cultivation technologies which are popular in global context to mitigate the harmful effects of climate change. Accordingly, "Sojan Cultivation" (refer to Figure 4.3) was mentioned as a suitable practice for Sri Lanka, which is a technology popular in Malysia, Indonesia and Thailand, however less practiced in Sri Lanka (C2E1). Moreover, C2E3, C2E4 and C2E6 mentioned on the "Ridge and Furrow cultivation" as a suitable technique for low country wet zone paddy lands, as they are often affected by floods. Here, *"the ridge can be used for rice and other upland crops"* (C2E4). However, the furrow is the area which is difficult to grow crops and can be utilised for fish integration, fish and rice integration (C2E3), aquatic plants, and multiple crop integration (C2E6).

Adhering to new cropping systems is another suggestion mentioned by C2E1, C2E4 and C2E5. According to C2E5 *"Cropping system of Sri Lanka is not very much diverted"* and it is basically the monocropping where a single crop is cultivated in the particular land (C2E4). Instead of that, "rice based" or "rice integrated" cropping systems must be promoted in Sri Lanka (C2E1). This is also resulted in increasing income and henceforth identified as a cause of income in Figure 4.3. Here, rice is cultivating as the main crop and other crops are cultivated in the times rice is not cultivated or simultaneously with rice. This also supported the idea of ridge and furrow cultivation where in the non-flooding areas, rice cultivation is used while for flooding areas other crop or fish cultivation can be used (C2E4). Overall diversification and diversion are required in available cropping systems (C2E5).

Development of new rice varieties was identified as another technical measure where flood tolerant rice varieties should be introduced to the field (C2E3, C2E6). These rice varieties should be developed to increase length, respond to water levels and thereby prevent the plant catching the flood (C2E6). This is explained by C2E3 as *"even in a water logging situation of two three weeks, if the plant can retain alive in the water, it is the status required to us"*. However, current crops are flood susceptible. Moreover,

C2E1 mentioned the development of rice varieties tolerant to iron as a resilient strategy following a waterlogging. As explained by him, waterlogging is a situation where soil become oxygen reduced and which impacted on general rice varieties to reduce growth and the yield. However, iron tolerant varieties can continue growth in these conditions which is favourable to continue the expected growth and yield.

Use diversification of rice as an alternative crop is another strategy mentioned by experts and C2E2 explained it as follows.

"In wet zone low country harvest per acre is comparatively low compared to other areas of rice cultivations in Sri Lanka. Therefore, farmers can go for unique varieties, which can be sell to a rich market. There are traditional varieties, tolerant to these climatic conditions. So even though with less harvest, farmers can get a good price margin. By these method market competition for crop can be reduced". Henceforth, it is important to encourage the plantation of new varieties by farmers through awareness programs and policies.

Financial Measures

Managing the financial wellbeing of farmers is also important in ensuring the resilience to climate change and accordingly introduction of new insurance schemes targeting farmers is beneficial as it aids in financial challenges (C2E1, C2E5). Thus, C2E6 mentioned that insurance should be encouraged as a mandatory component of farming. Accordingly, this is acting as a cause for increasing "ability to recover the money spent" (Figure 4.3). Overall, above mentioned strategies can be identified as actions to promote climate resilience of the low country wet zone farmers.

4.5 Cross Case Analysis

Paddy is a seasonal (short-term) crop while tea plants have a lifespan of about 10 to 20 years generally (long term crop) Following this key difference and other unique features, two industries undergo several similarities and differences amidst the climate variability which impacted the livelihoods communities. This section explains the findings through the cross-case analysis of two cases: tea and paddy.

4.5.1 Impacts of Features of the Cultivated and Nearby Area on Climate Impacts to Livelihoods

Each crop encourage cultivation within their unique environmental conditions and accordingly, the two industries show similarities and differences in this context. Thus, the similarities and differences of environmental conditions have been expressed in Table 4.10 under the areas of nature of the crop, location, soil conditions and irrigation nature.

Table 4.10: Comparison of environmental features of the two cases

Feature	Case 01 - Tea	Case 02 - Paddy
Nature of the Crop	Landslide accelerating crop as roots contribute to loosening of the soil	Does not act as an accelerator of climate induced disasters
Location	Slopy Lands with substantial gradient. If they are located next to a waterbody, reservoir, or rainforest, impacts are accelerated.	Near a waterbody (besides marshy lands, river, constructed reservoir, peri-urban areas)
Soil Status	Sandy and loamy soil with a pH value ranging from acidic to neutral. Soil sedimentation and soil erosion can be seen as common problems	Boggy soil with high water retention (soil is saturated with water)
Irrigation Nature	Face no challenge due to absence or scarcity of water	
	Rainfed irrigation Improper drainage systems can be observed.	Both rainfed and river fed irrigation

As per Table 4.10, in both contexts, the absence of water for agriculture is not seen as a problem. However, they suffer from the issue of excess water. In Case 01- Tea, it accelerates landslides and in Case 02-Paddy, rainfed farmers suffered from waterlogging while river fed farmers suffering from floods. Moreover, even though tea is identified as a disaster (landslides) accelerating crop, paddy is not seen as a catalyst for disaster.

4.5.2 Impact of Demographic Factors of the Communities on Climate Impacts to Livelihoods

The demographic factors identified through the literature were applied to the context of tea and paddy industries. Table 4.11 shows the cross-analysis of the findings from the two areas.

Table 4.11: Impacts of demographic factors in the two cases

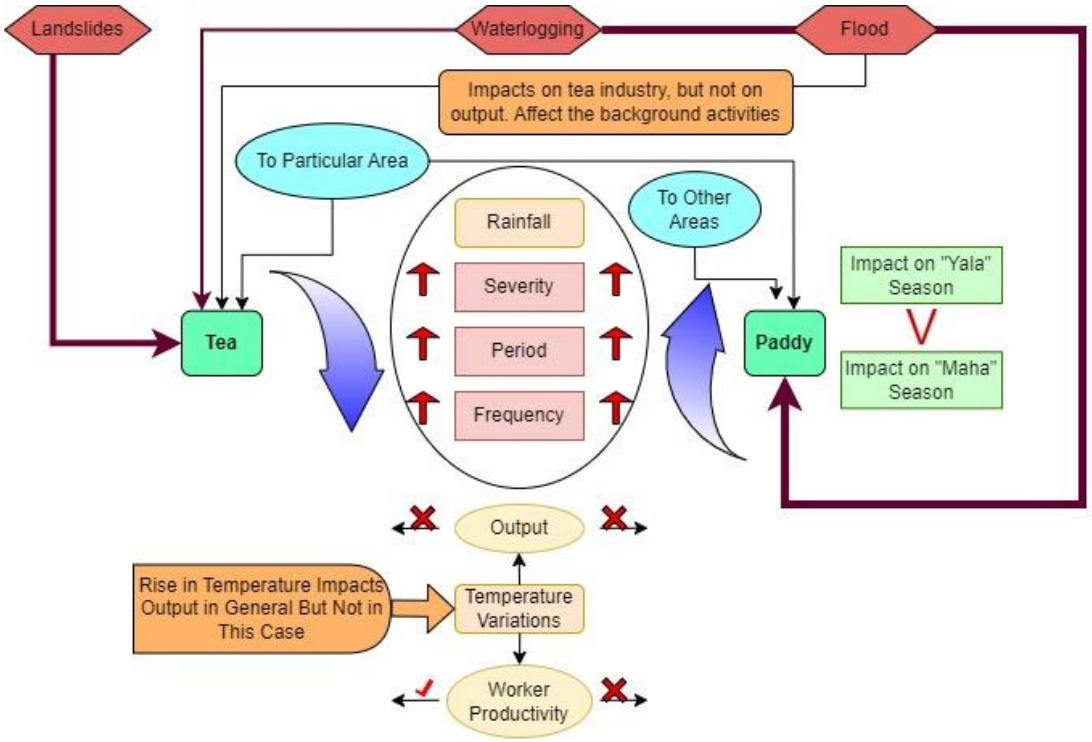
Demographic Factor	Case 01-Tea	Case 02-Paddy
Population Growth	✔	✘
Age	✘	✘
Gender	✘	✘
Educational Status	✔	✔
Experience	✔	✔

Accordingly, in both contexts, gender and age has not made them vulnerable in continuing their livelihoods consequent to climatic variability. In both cases, educational status and experience have been identified as factors with positive impacts on the livelihood. Population growth provides contravention impacts in the two cases as population growth acts as a direct cause for landslides in the area, consequent to urbanisation and expansion of human settlements in cultivated lands. However, such trends have still not impacted paddy growers of the low country wet zone.

4.5.3 Climatic Conditions Undergone by the Communities and Effects of Climate Variation

Through the cross-case analysis of the identified data, the nature of climatic conditions undergone by tea and paddy industries of low country wet zone were analysed. Figure 4.2 shows the findings of the similarities and differences of the impacts of climatic conditions in two areas.

Figure 4.2: Climate conditions and disasters on the two industries



As shown in Figure 4.2, both industries experience an increase in the severity of rainfall, the period of rain and intermittent rainy events (frequency of rain). However, an inverse effect is seen in all three conditions as the severity of rainfall created the highest damage on the paddy industry while the frequency of rainfall is a minor impact (as shown by the blue arrow, the size of the arrow indicates the severity). Conversely, the frequency of rain acts as the key cause for the increase in landslides of the tea growing areas, as the moisture content of the soil is always saturated. Although the rise in temperature damage the cultivation, this tendency deviates in low country tea and paddy industries, as they do not observe drastic changes in temperature. However, it affects the productivity of tea growing workers.

The analysis of two cases identifies three main disasters: landslides, waterlogging and flooding. Landslides have highly destructive impact on the tea plantation while the minor impacts of waterlogging can be observed (size of the arrow indicates the severity of the disaster in a particular cultivation). Floods also portrayed the impacts on the tea industry (not on the plant but in the access facilities to land). In contrast, both floods and waterlogging are severe disasters in the context of paddy cultivation and landslides have not incurred any damages so far. Finally, the low country tea industry is affected

by rain variability in a particular area, while low country paddy cultivation suffers from rain variability as in other regions of the country as well.

Climate Induced Causes Which Challenge the Livelihoods of Communities Both industries are basically suffering from human induced causes to climate variability which can be identified as a common trend in both industries. However, the specific activities contributing to accelerate climate variability in each case varies as mentioned in Table 4.12.

Table 4.12: Comparison of causes contributing to accelerate climate variability in tea and paddy.

Case 01- Tea	**Case 02-Paddy**
Vibrations due to road construction	River mining
Initiation of a new reservoir project	Altering natural river channels
Expansion of human settlements	Heightening the roads
Deforestation	Soil movements near the riverbanks

The causes mentioned in Table 4.12 are the main contributors to climate variability in each case. Among them, deforestation, and river mining can be identified as activities to be eliminated while other activities are difficult to eliminate but can control to reduce the impacts on climate.

4.5.4 Climate Induced Opportunities to Two Livelihoods of Communities

There are common as well as unique benefits of climate variability on the two livelihoods of tea (Case01) and paddy (Case 02). In both cases, they are not facing the drought conditions consequent to absence or scarcity of water. Hence the cost of irrigation is reduced. In terms of the unique benefits in each industry, it can be identified that intermittent rains caused increase and diversifying favours of tea leaves, which results in increasing the demand for the tea harvest. Conversely, despite waterlogging is a disaster condition on paddy, it creates some beneficial instances in terms of soil fertility as retaining water in the soil helps to absorb nutrients to the soil. However, this is impacted by time of occurring as if the waterlogging occurs amidst plantation, it is destructive and if it occurs between end of one season to beginning of another season, it is beneficial.

4.5.5 Climate Induced Challenges to Two Livelihoods of Communities

Both industries undergo challenges following the climate variability and there are some similarities and differences of challenges can be identified. Accordingly, difficulties of practicing current harvest method, declination of harvest quality have been highlighted as harvest related issues in both Case 01 and Case 02. Similarly, reduction of output has been intensified in both cases, but it is comparatively low in case of tea followed by rainy events and if it is a landslide, entire disruption for long period. In paddy, reduction of output is seasonal and independent from the previous season. In addition, Case 02-Paddy highted the post-harvest issues like blowing and drying difficulties which affects the quality of the output.

In terms of financial challenges, Case 02-Paddy highlighted loss of entire investments and loss of income for around half years if the harvest gets entirely disrupted by floods. However, Case 01-Tea highlighted reduction in output which leads to reduction in income and have not mentioned about the impacts of entire landslides, as it is occasional, not frequent. Additionally, Case 01-Tea emphasised labour related challenges, reduction of cultivation area, loss of seasonal jobs and access road damages, which are not emerged in Case 02-Paddy.

4.5.6 Current Actions Taken to address Climate Induced Challenges on Community Livelihoods

Responses made by the communities to climate variability demonstrate both similarities and differences in the two cases. Thus, abandoned of lands (Tea) or fallow lands (Paddy) can be identified as an unfavourable responsive action taken by communities to climate variability. Further, trend of migration can be observed in the case of tea industry (Case 01), and the paddy growers tend to cultivate only in one season which is harmfully impacted on the economy of the country, as paddy is the main food crop in Sri Lanka.

4.5.7 Limitations for Implementing the Identified Actions

In terms of the limitation for implementing the identified actions, communication, knowledge, geographical vulnerability are some unique barriers for tea growing communities, while technological and institutional barriers are prevailed as unique

barriers for paddy growers. Both industries undergo financial barriers and social resistance as common hurdles to implement the identified actions for climate variability.

4.5.8 Causes for Limitations of Implementing the Identified Actions

With related to awareness of communities on consequences of climate change, both communities are aware on the harmful impacts, however, do not have sufficient technical knowledge and understanding on coping mechanisms to overcome climate impacts. Moreover, there is a trend that Case 01-Tea respondents are willing to adapt to new technologies and Case 02-Paddy communities are still not towards it. Further, communities in both group of industries shows, less reliability on resistant varieties of plants. However, they have different reasons behind the resistance as in Case 01-Tea, they believe that the resistant varieties test in special and controlled conditions in laboratories, which are not resilient with the actual land conditions. In Case 02-Paddy, community believes that those climate resistant varieties produce less harvest and therefore reluctant to adopt them.

Moreover, both Case 01-Tea and case 02-Paddy shows substantial awareness by authorities on the impacts of climate change on their industry and policy formulation. Furthermore, they are focusing on developing databases of affected communities and conducting regional level programs to educate the community. However, in both cases, there is a dearth of matching the community knowledge of understanding and the actions implemented.

The next two sections portray the summary of findings of the Stage 02,03, and 04 of data collection presented as two separate CLDs for two industries.

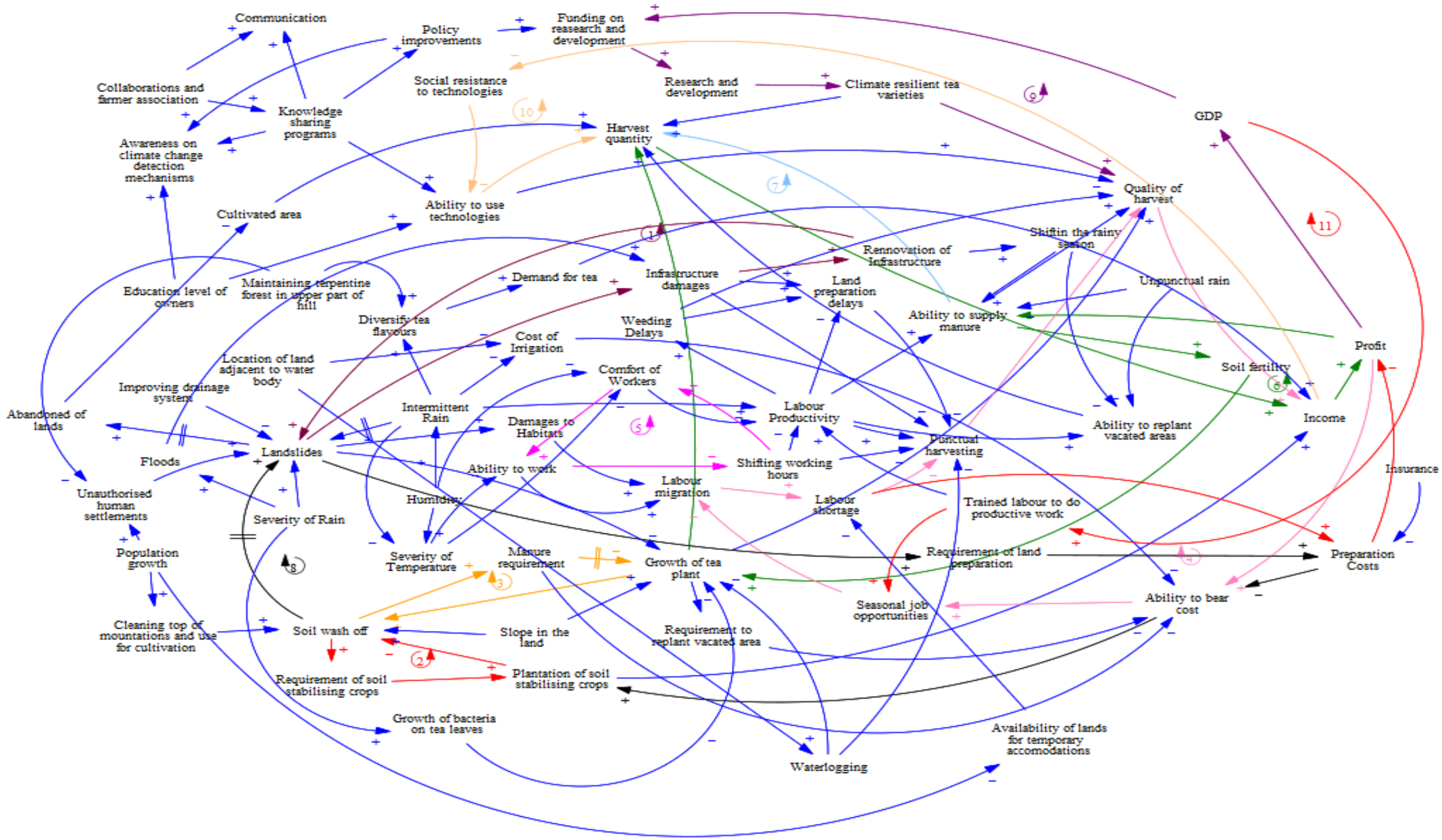
4.6 Causal Loop Diagrams- Tea Industry

Considering the identified parameters from the Case 01- Tea industry, a CLD has been developed to identify the causal relationships between and among the parameters. Accordingly, Figure 4.3 explains the CLD developed with 66 parameters derived for the tea industry through primary data collection. Blue colour arrows shown in Figure 4.3 refer to the relationship between the variables, which are not captured into any

closed loop. The parameters used expressed in Figure 4.3 cover some parameters emerged from the secondary data collection (eg: GDP, population growth, cultivated land area, technologies, quality of harvest, income, etc.) while there are some unique parameters emerged specific to the case (eg: Insurance, communication, research and development, weeding delays, etc.). Moreover, primary data collection has highlighted the detailed parameters, where the parameters appeared on the economic models of climate change were split into sub-parameters. For instance, intermittent rains, severity of rains, and period of rain can be identified as sub-parameters of the parameter "rain".

Moreover, time delay is presence between several sets of two parameters (eg: Intermittent rain and landslides, manure requirement and growth of tea plant) which has been stated with the delay sign. That means, the immediate effect of the first parameter is not visible on the second parameter. For example, degrowth of tea plant is not immediately observed in situations of lack of manure.

Figure 4.3: Causal loop diagram for tea industry



According to Figure 4.3, 11 closed loops have been identified which are indicated in different colors and numbered from 1 to 11. Table 4.13 depicts the descriptions of identified loops with their type and the parameters involved.

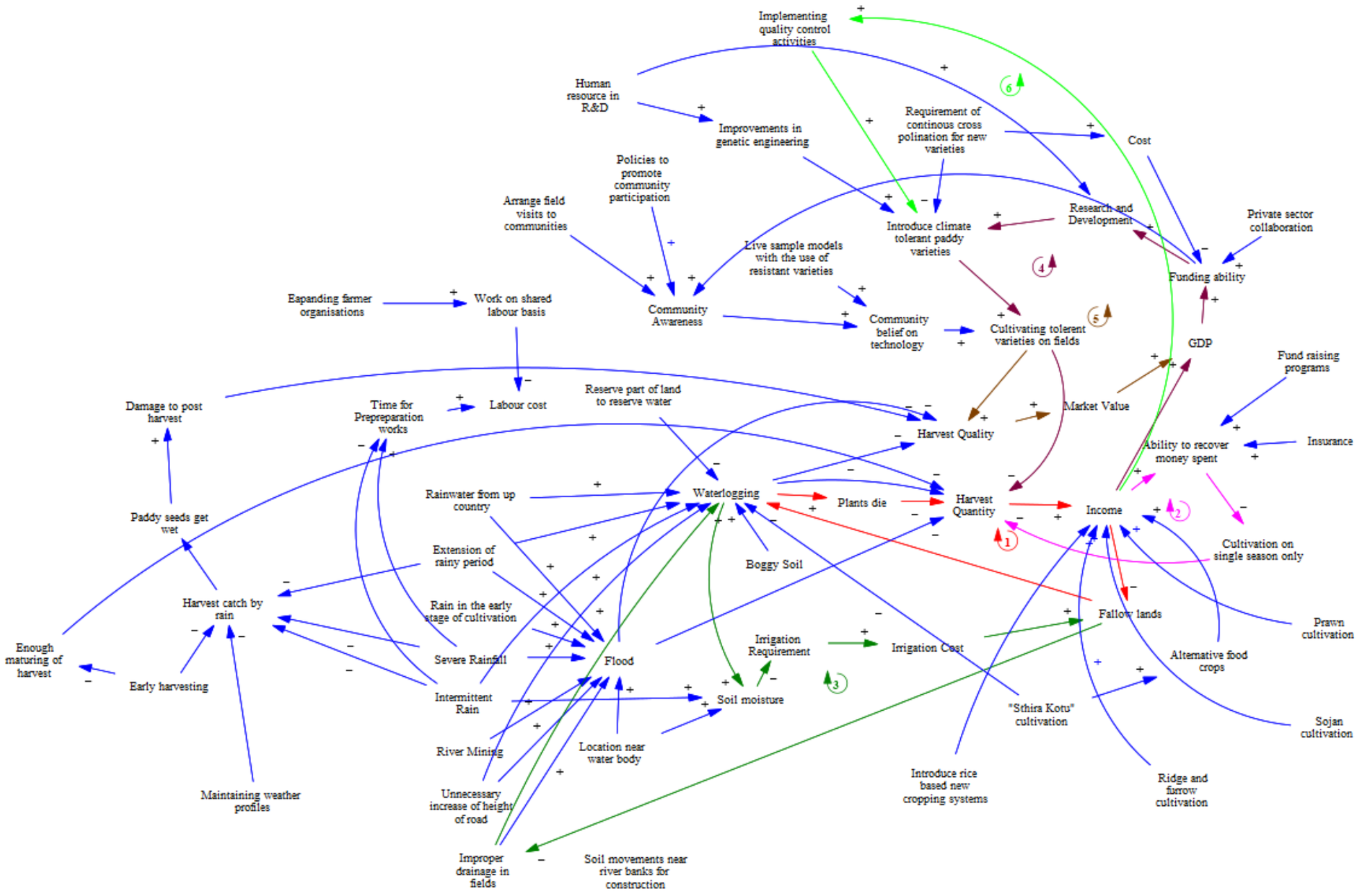
Table 4.13: Loops determined from causal loop diagrams (CLDs) - Case 01 tea industry.

Loop Number	**Loop Type**	**Parameters Involved**
1	Reinforcing	Landslides, Infrastructure Damages, Renovation of Infrastructure
2	Balancing	Soil Wash-off, Requirement of Soil Stabilization Crops, Plantation of Stabilization Crops
3	Balancing	Soil Wash-off, Manure Requirement, Growth of Plant
4	Reinforcing	Ability to Bear Costs by Owners, Seasonal Job Opportunities, Labor Migration, Labor Shortage, Punctual Harvesting, Quality of Harvest, Income, Profit
5	Reinforcing	Comfort of Workers, Ability to Work, Shifting Working Hours
6	Reinforcing	Ability to Supply Manure, Soil Fertility, Growth of Plant, Harvest Quantity, Income, Profit
7	Reinforcing	Ability to Supply Manure, Harvest Quantity, Income, Profit
8	Reinforcing	Landslides, requirement of land preparation, preparation cost, ability to bear cost, plantation of soil stabilizing crops, soil wash off
9	Reinforcing	Profit, GDP, Funding on R&D, R&D development, climate resilient tea varieties, quality of harvest, Income
10	Reinforcing	Social resistance to technology, ability to use technology, harvest quantity, income
11	Reinforcing	Trained labour to do productive work, seasonal job opportunities, labour migration, labour shortage, preparation costs, profit, GDP

4.7 Causal Loop Diagrams- Paddy Industry

Considering the parameters identified from the economic models of climate change which have been further investigated through the primary data collection for the paddy industry, causes, effects and relationships on the parameters have been identified and presented in Figure 4.4 as a CLD. Similar to the CLD for tea industry, blue arrows indicate the relationship between the parameters which do not belong to any loop. Accordingly, 59 parameters have been identified which are applicable to low country wet zone paddy industry.

Figure 4.3: Causal loop diagram for paddy industry



Accordingly, six closed loops have been identified which have numbered from 1 to 6. Table 4.14 describes the closed loops identified in CLDs.

Table 4.14: Loops determined from causal loop diagrams (CLDs) - Case 02 paddy industry.

Loop Number	Loop Type	Parameters Involved
1	Balancing	Waterlogging, Plants die, Harvest quantity, Income, Fallow lands
2	Reinforcing	Harvest quantity, Income, Ability to recover money spent, Cultivation on single season only
3	Reinforcing	Waterlogging, Soil moisture, Irrigation requirement, Irrigation cost, Fallow lands, Improper drainage in field
4	Balancing	R&D, introduce climate tolerant paddy varieties, Cultivating tolerant varieties on fields, Harvest quality, Market value, GDP, Funding ability
5	Reinforcing	R&D, introduce climate tolerant paddy varieties, Cultivating tolerant varieties on fields, Harvest quantity, Income, GDP, Funding ability
6	Balancing	Implementing quality control activities, Introduce climate tolerant paddy varieties, Cultivation of tolerant varieties on fields, Harvest quantity, Income

So as indicated in Table 4.14 and Figure 4.4, Loop 01 represents the balancing effect of waterlogging and fallow lands. An increase in waterlogging, causes increase in plant death, which reduce harvest quantity, and income, which cause in abandoning lands which increases number of fallow lands. Conversely, Loop 03 depicts a reinforcing loop, where waterlogging is accelerated by improper drainage in a field.

4.8 Discussions

This study has conveyed similar findings with studies of Antle & Stockle (2017), Schuler et al. (2020) and Khabbazan, (2022) who have emphasised the importance of identifying changes in yield as a key measure to determine the economic impacts of climate change. Further, this study similarly articulates changes in technologies (Gurgel et al., 2021), and soil condition (Hossain et al., 2019) also as determinants of climate impacts on tea and paddy livelihoods in low country wet zone. However, this study uniquely reveals the finding that based on the nature of the climatic conditions impact on the two industries, irrigation nature has not act as a determinant for tea growers. In contrast, irrigation nature (rain-fed or irrigation-

fed) can be considered as an economic impact determinant in paddy industry, which aligns with the findings of Navarro and Tapiador (2019).

As per the empirical findings, the demographic parameters input in economic models of climate change to determine the economic impacts on livelihoods are less indicative to these two industries. This contrast with the findings of Falco et al. (2018), Nikas et al. (2018), and Hossain et al. (2019) who have identified personal characteristics of a person, social background of family and size of family are indicative on determining climatic impacts on livelihoods. Further, empirical evidence stated that population growth can be identified as a cause associated with determining climatic impacts on livelihoods as population growth increases the expansion of human settlements. Though the existing studies also have identified population growth as a highly used parameter in economic models of climate change, their argument extended that population growth increases consumption and thereby impacts on livelihoods. Accordingly, empirical findings have provided another interpretation for the same parameter.

Regarding the economic parameters input in the economic models, empirical findings differently convey the findings of Stern (2013), and Mu et al. (2017) mention policy changes are rather an outcome of economic impacts than an input. However, this study similarly argues with Nikas et al. (2018) and mention changes in income generating opportunities, cost of production, wages, and product prices as determinants of economic impacts. Further this study diverges the findings of Ogada et al. (2020) and mention that access to credit does not an influential parameter in low country wet zone context for two industries. However, access to insurance or availability/requirement of insurance schemes have identified as a parameter to determine ability to recover, which is currently not practiced in these ind. Accordingly, empirical findings uniquely convey the importance of developing proper insurance schemes and make them mandatory.

Economic models of climate change as per the literature have conveyed welfare of the community, changes in economy, adaptation, migration, and mitigation of impacts of climate change on livelihoods as the main outcomes to be addressed to enhance community resilience to climate change. However, there were very limited discussions on “how” to do this. As per the studies of Abeysekara et al. (2023) and Wickramasinghe et al. (2021), requirement of adaptation actions has highly taken the attention of researchers. Empirical studies convey similar views with the study of Esham and Garforth (2013) who has identified off-farm employment, soil conservation techniques, and changing crop varieties are feasible measures to address economic impacts of climate change on communities. However, this study has identified some unique adaptation actions in these areas

including alternative means of agriculture like “pineapple” for tea growers and “prawn cultivation” for paddy growers. Further, this is the first study to introduce possible alternative means of income for the tea industry including “weaving, coir, and sesame”. In addition, this study compares with the findings of Tsuchida and Takeda (2021) and has identified low awareness of communities as a limitation to implement resilient actions. However, the authorities have required awareness on technologies and the gap is on implementation with the proper interpretation of findings from the use of technologies. Moreover, empirical evidence identifies the importance of protecting the upper hill area and provide a feasible suggestion which enhance economic value like “plantation of turpentine forest”.

4.9 Chapter Summary

This chapter presented the analyses of the primary data findings of this study. Accordingly, data collected from the four stages of data collection was analysed using manual content analysis, cross case analysis and CLDs. Thus, main climatic conditions undergone in Sri Lanka, and the parameters which can be used to analyse the economic impacts have derived from manual content analysis of the findings of Stage 01- Preliminary interviews. Disasters faced by low country wet zone agricultural livelihoods, benefits and limitations undergone by them consequent to different climatic conditions, current actions taken by authorities to improve resilience, limitations of identified actions and recommendations to overcome the limitations have been analysed and presented. Moreover, CLDs have been developed which can be used as a basis in decision making and studying the dynamism of the two industries to climate change.

5 CHAPTER FIVE CONCLUSIONS AND FURTHER RESEARCH RECOMMENDATIONS

5.1 Introduction

Chapter 05 of this thesis describes the achievement of the objectives of this study based on the research findings. Further, this chapter presents the contribution of this study to knowledge and practice whilst simultaneously providing recommendations for practitioners and future researchers in the field of community resilience and climate change. The limitations of the study have been explained as well. The research study's conclusion is then drafted reflecting the entire research procedure.

5.2 Achievement of Research Objectives

The research aim, which is to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models was achieved through the systematic accomplishment of the objectives as follows.

5.2.1 Objective 01: Review Economic Models of Climate Change, and the Different Climatic Conditions and Economic Parameters Used in Economic Models of Climate Change.

Objective 01 of this study was to review economic models of climate change and the different climatic conditions and economic parameters used in economic models of climate change within the scope of agriculture. This objective was accomplished through the SLR using economic models. Accordingly, there were five main climatic conditions incorporated in economic models including temperature changes, global radiation, wind speed, rainfall, and humidity. In addition, there were seven firsthand influences of climate change which have been discussed in economic models. Among these climatic conditions, temperature was an integral part of modelling which stated that temperature has a significant impact on livelihoods and the economy in the global context (Refer to subsection 3.6). The parameters used in economic models to determine climatic conditions were identified under agricultural, demographic, economic and social categories. Crop productivity, population growth, wage, and

poverty were cited frequently in each category respectively while the number of crop types on land, social background of the family, consideration for alternative employments, and level of risk and vulnerability to hazards were occasionally accounted for in economic models (Refer to subsection 3.7). Thus, Objective 01 of the study has been accomplished.

5.2.2 Objective 02: Identify the Economic Impacts of Climate Change Conveyed in Economic Models

The second objective of the study was to identify the economic impacts described in the economic models of climate change. Hence climatic impacts were identified under the four areas of community welfare, changes in economy, adaptation, and migration. Furthermore, no articles were found from the SLR from the Sri Lankan context regarding the economic models of climate change that have used to determine the economic conditions of people. Therefore, a comprehensive literature search was conducted to identify the status of the economic impacts of climate change on agricultural livelihoods. Accordingly, it was found that even though they have not adopted economic models to identify the parameters impacts on community livelihoods, some of the parameters like household income, accessibility to information, location of the land, etc. (refer to subsection 3.9) were identified as important information in adaptation to climate change. Accordingly, a limited number of strategies were identified for the Sri Lankan agriculture industry including a few resilient strategies.

5.2.3 Objective 03: Investigate the Different Climatic Conditions and Economic Parameters Applicable to the Sri Lankan Context

Objective 03 of this study was to investigate the different climatic conditions and economic parameters applicable to the Sri Lankan context which was achieved through the primary data collection Stage 01-Preliminary Interviews. Accordingly, climatic conditions and economic parameters obtained from SLR were based for interview guideline from preliminary experts and the main climatic conditions of temperature changes, rainfall changes and changes in environmental and natural resources were observed in the context of Sri Lanka. Moreover, regarding the parameters used in the economic models, preliminary experts confirmed the applicability of all the parameters

in the Sri Lankan context. Another significant finding, derived from Stage 01-Preliminary interviews was that Sri Lanka is facing climate variability but not climate change. Accordingly, Objective 03 of the study was attained.

5.2.4 Objective 04: Investigate the Economic Impacts of Different Climate Conditions on Livelihoods of Communities

Objective 04 of this study was based on secondary literature findings, and data was collected through two methods of primary data collection: Stage 02-Focus group discussions and Stage 03-Key informant interviews. This follows the strategy of case studies in the two livelihoods of tea and paddy within the context of the low country wet zone. Thus, this study identified that low country wet zone paddy and tea growers are impacted mainly by rainfall variations. Three focus group interviews from five members each were conducted per each case, following four key informant interviews per each case. The major findings related to Objective 04 are discussed hereafter.

In Case 01-Tea, their lands were vulnerable to landslides, where the area of cultivation was reduced with time, the quality of the output was affected, faced the difficulty of labour supply, and thereby faced financial difficulties. Despite the available strategies to address the impacts of climate variability, there were financial, communication, knowledge, social resistance, and natural barriers to developing the community's resilience to climate change. Concerning, Case 02-Paddy, communities were mainly suffering from floods, and harvest was reduced or entirely destroyed in most of the seasons, consequent to rain. Moreover, they faced post-harvest difficulties, which did not emerge from Case 01-Tea. Further, the quality of the harvest is also affected by the rainfall variabilities prevailing in the area thereby creating financial losses. In both cases, communities tend to abandon their lands following the difficulty of continuing their livelihoods.

Moreover, CLDs from the causes and impacts of climate variability were developed for two cases, which provide an overview of the economic impacts of climate variability and their relationships. The loops identified in each CLD diagram can be used as decision making tool and to acknowledge on the behaviour of different causes and consequences of climate variability. Thus, Objective 04 of this study was accomplished with the abovementioned findings.

5.2.5 Objective 05: Provide Recommendations to Increase Community Resilience Against Economic Impacts of Climate Change on the Livelihoods

The last objective of this study, which was to provide recommendations to increase community resilience against economic impacts of climate change on the livelihoods was achieved through survey strategy under the data collection in Stage 04-Expert interviews. Accordingly, six expert interviews were conducted for each industry to identify the suggestions to build up climate resilience in communities.

Recommendations were provided from alternative means of agriculture, other alternative livelihoods, labour training, institutional, technology and financial measures for Case 01-Tea and institutional measures, alternative means of agriculture, financial measures and technology measures were provided for Case 02-Paddy. Accordingly, Objective 05 of this study was accomplished.

5.3 Research Conclusions

Climate change is a significant growing issue in the present context, which impacts on communities and hinders the successful continuation of their livelihoods by damaging their social and economic status. Economic models of climate change used different climatic conditions and parameters to determine the impacts of climate change in agriculture. Though there were few global literatures on economic models of climate change for paddy industry, economic models for tea industry are dearth in literature. Despite economic models of climate change can be considered as a reliable source for capturing climatic conditions and economic parameters impacted on communities, adhering to climatic conditions and parameters from a single model will limit the reliability of results. Most of the economic models of climate change have captured impacts of climate change through quantitative approach and trying to quantify, few have provided qualitative implications and suggestions in the global context. Economic impacts of climate change on different livelihoods have not investigated in Sri Lankan context by using economic models of climate change as the theoretical approach. There are few studies which investigated the economic impacts of climate change on different sectors of agriculture, however the strategies for resilience are lacking.

Sri Lanka undergoes “climate variability” not the climate change. Despite the higher number of climatic conditions modelled in the global literature, temperature and rainfall are the two main climatic conditions impacted on Sri Lanka, which creates changes to environment and natural resources as the firsthand influence. All the parameters identified in economic models of climate change can be applied to and investigated in Sri Lankan context. However, the visibility of impacts from parameters are case specific. For example, population growth, which is identified in the highest number of literature sources as an economic parameter of climatic impacts, has not impacted on paddy industry and however affected the tea industry due to land use changes and urbanization. Moreover, within the same climatic condition, impacts on industries are different on different sub parameters of the climate condition (rainfall severity, intermittent rains and period of rain differently impacted on the two industries). Demographic factors like education and experience are impacted on climatic impacts of the community livelihoods, however, age does not show any significant impact on these two industries in low country wet zone Sri Lanka.

Despite the low number, there are benefits of climate variability in these two industries, mainly including the cost savings followed by the natural irrigation. Man made causes have made higher contribution to climate variability and to amplify the impacts of disaster on communities. Harvest related, labour related, land related, infrastructure related and loss of seasonal occupations are the main challenges undergone by the tea community, while harvest and financial challenges are more emerged in paddy growers. Abandoned lands, migration is observed within tea communities as negative responsive actions to climate change while increase of fallow lands is noticed in paddy industry.

5.4 Contribution to Knowledge

Climate change is a global issue which impacts on livelihoods of the communities and the impacted are portrayed through sectors like agriculture. Despite there are studies to investigate the impact of climate change on different crop types, studies on climatic impacts on livelihoods are dearth in the context of Sri Lanka. The studies which investigate the climate change impacts on multiple livelihoods and provide resilient measures are further limited. Therefore, this research can be recognized as an

investigation on climatic impacts on different livelihoods, using two main agricultural livelihoods in Sri Lanka: Tea and Paddy.

This study used economic models of climate change as the basis for identifying climatic conditions and parameters, which is novel in this context. Hence future researchers in this context will have a comprehensive set of parameters to be used to determine economic impacts of climate change, which have been obtained through systematically reviewed economic models of climate change. Since the economic models of climate change incorporated limited number of parameters for the models, the provided list of parameters can be benchmarked by economists, modelers, and decision makers, in developing new models, decision making and formulating economic policies.

Cross case analysis provided in this study, will help to distinguish the unique impacts of rainfall variability on two livelihoods of tea and paddy which will assist for research institutes to apply to similar context and use as a benchmark for researching in another regions of Sri Lanka as well as in global context.

The CLDs developed for the two industries made a novel contribution to knowledge as it helped to determine the relationships between and among causes of climate variability, and their economic impacts. The developed CLDs can assist in testing the change of the identified parameters over the time and will be helpful in decision making and successful implementation of climate resilient actions with a holistic view on the causes and impacts of the actions.

The identified limitations of implementing current strategies for climate resilience will be helpful in future proceedings of decision making to identify the loopholes in existing ideas. Recommendations made for the two industries will assist the economic development of Sri Lanka, as the two industries of tea and paddy make significant contribution to GDP of the country. Moreover, it can be used as a basis for expanding livelihood opportunities in Sri Lanka.

5.5 Recommendations to Practitioners

In essence, this study has identified economic impacts of climate change on tea and paddy industries of low country wet zone in Sri Lanka and provide strategies to improve community resilience. Following that, policymakers of the country are recommended to formulate separate policies to tackle the specific climatic conditions, which create diversified impacts on the same industry. Research and development institutes should focus more on the practicability of the identified strategies and develop convincible strategies and actions for communities to enhance implementation. Moreover, immediate institutional officers to the community like Grama Niladari Officers, Disaster Management Officers, Economic Development Officers, and Agricultural Officers should initiate actions to encourage community participation in decision making. In addition, they should initiate actions to educate the community about available policies and actions regarding climate resilience. Economists are recommended to develop economic models of climate change to address the impacts of climate change on agricultural communities in the Sri Lankan context collaboratively with agricultural and climatic researchers. Further, community have a key role to perform in this context and therefore, communities are recommended to actively engage in reporting about actual problems they are undergoing, supporting research and development authorities to initiate new varieties (be flexible with adapting them and sharing results), and actively participate in promoting collaborative efforts with other industries to promote alternative methods of agriculture. Overall, all responsible stakeholders in decision making regarding the economic development of communities to be resilient in climate change and affected communities from climatic impacts to their livelihoods, can use the identified impacts, developed CLDs and mentioned recommendations to develop policies encountering practical barriers, and implement actions.

5.6 Further Research Areas

This study has initiated basis for investigating economic impacts of climate variability on tea and paddy industries of low country wet zone in Sri Lanka and contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models, which is a new methodology for

this context. Therefore, this study can be extended for more aspects to be addressed through separate studies. Accordingly, the following recommendations are made for future researchers.

- A similar study can be conducted for another climatic zone of Sri Lanka and examine how the changes are being occurred.
- Since agricultural industry in Sri Lanka is extended to variety of subsectors, impact on another agricultural related livelihood(s) can be investigated and modelled using CLDs.
- The data obtained from this study can be compared against mixed livelihoods and identify the benefits and limitations of engaging in a mixed livelihood to be resilient to climate change.
- Economic impacts of climate change on livelihoods of communities- Comparison of agriculture Vs another livelihood and express the behavior of the two livelihoods through system thinking approach.
- Identified CLDs can be tested for time and include delay values into the relationship between parameters.

5.7 Limitations

This study is subjected to the limitations mentioned hereunder. This study used a single case from each livelihood considering time limitation. The number of key informants was limited to four and have been selected only from the immediate administration level to the communities following the time limit.

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7 APPENDICES

Annexure 01- Stage 01 Preliminary Interview Guideline

……..

Dear Madam/ Sir,

Request to Participate in a Focus Group Discussion- Data Collection for Research Dissertation Master of Science with Major Component of Research

I am a postgraduate student at the University of Moratuwa following the Degree program of Master of Science with Major Component of Research. I am conducting research titled "An economic model to assess the impact of climate change on sectors of economy associated with the built environment". This research is being conducted under the supervision of Prof. Udayangani Kulatunga, of the Department of Building Economics, University of Moratuwa and Prof. Bingunath Ingirige of University of Salford.

I am currently at the stage of data collection through preliminary interviews, which focuses to refine the identified data in the Sri Lankan Context. The research aims to investigate the economic impacts of climate change on the livelihoods of communities in Sri Lanka.

Accordingly, this discussion aims to identify the climatic conditions prevailing in Sri Lanka from the identified set of variables from economic models in the global context, and to determine the variables derived from economic models, regarding economic impacts, which can be applied to the Sri Lankan context. Further, it focuses to validate the suitability of selected livelihoods in the Sri Lankan context.

Kindly consider helping me to collect the data mentioned above by participating interview of about 40 minutes. Digital recording and note taking will be used to record data while interviewing to maintain the accuracy of data (with permission of the interviewee). To maintain confidentiality, the personnel information of the interviewees and the names of the organisations will not be revealed in the report or any other documents relating to this study.

Thank You!

Yours faithfully,

Nadeetharu B.K.M.

Research Scholar,
Department of Building Economics,
University of Moratuwa.
Email: malshanadeetharu@gmail.com

Research Title: An economic model to assess the impact of climate change on sectors of economy associated with the built environment

Research Aim: The study aim is to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models.

Objectives Covered under this interview: Investigate the different climatic conditions and economic parameters applicable to Sri Lankan context.

Section 01- Background Information

1. Position:
2. Experience in the field of climatic research:

Section 02- Climatic Conditions Applicable to Sri Lanka

3. Explain whether following climatic conditions are applicable to Sri Lankan context.

Climatic Condition/ Firsthand influences of climate change	**A or N/A**
Temperature changes	
Global radiation	
Wind speed	
Rainfall and precipitation	
Humidity	
Changes to carbon dioxide concentration	
Climate tipping points	
Extreme events of climate change	
Changes in environmental and natural resources	
Shocks of climate change	
Shared socioeconomic pathway narratives	
Exogenous shocks	

Section 03- Variables Derived from Economic Models Applicable to Sri Lanka

4. Explain whether following variables can be applied to Sri Lankan context when determining economic impacts of climate change.

Category	Variable	A or N/A
Agricultural	Changes in technologies used for production and cultivation/ method of harvesting	
	Crop waste and losses/ status of cultivation/ Productivity of output/ productivity of land/ changes in yield	
	Irrigation nature	
	Soil condition/ Nature of the land	
	Number of cultivation crop types in a particular land/ alternative crops	
Demographic	Population growth/ density	
	Personal characteristics of a person	
	Social background of family	
	Size of the family	
Economic	Reshaping policies	
	Access to credit	
	Changes in economic lifestyle overtime / other expenses/ availability of safe and healthy food	
	Cost of production	
	Wage (income)	
	GDP	
	Consideration of alternate modes of employment	
	Changes in income generating opportunities	
	Product prices	
Social	Poverty	
	Migration	
	Level of Risk and damages	
	Access to public services and advisors	
	Vulnerability to hazard	
	Willingness to adapt	
	Changes in labour/ machine intensity	

Section 04: Suitable Livelihoods to be Selected as Case Studies

5. Comment on the suitability of tea industry as a case study to examine economic impacts of climate change on livelihoods of the communities.
6. Comment on the suitability of paddy industry as a case study to examine economic impacts of climate change on livelihoods of the communities.

***** Thank You! *****

Annexure 02- Stage 02 Focus Group Discussion Guideline

……..

……..

Dear Madam/ Sir,

Request to Participate in a Focus Group Discussion- Data Collection for Research Dissertation Master of Science with Major Component of Research

I am a postgraduate student at the University of Moratuwa following the Degree program of Master of Science with Major Component of Research. I am conducting research titled "An economic model to assess the impact of climate change on sectors of economy associated with the built environment". This research is being conducted under the supervision of Prof. Udayangani Kulatunga, of the Department of Building Economics, University of Moratuwa and Prof. Bingunath Ingirige of University of Salford.

I am currently at the stage of data collection through focus group discussion under the case studies. The research aims to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models.

Accordingly, this discussion aims to identify the economic influences of different climatic conditions on livelihoods of communities, which will be used to proceed with the next step of data collection, identification of adaptation strategies.

Kindly consider helping me to collect the data mentioned above by participating interview of about 1 hour. Digital recording and note taking will be used to record data while interviewing to maintain the accuracy of data (with permission of the interviewee). To maintain confidentiality, the personnel information of the interviewees and the names of the organisations will not be revealed in the report or any other documents relating to this study.

Thank You!

Yours faithfully,

Nadeetharu B.K.M.

Research Scholar,

Department of Building Economics,

University of Moratuwa.

Email: malshanadeetharu@gmail.com

Research Title: An economic model to assess the impact of climate change on sectors of economy associated with the built environment

Research Aim: This study aims to to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models.

Objectives Covered under the Case Study: Investigate the economic impacts of different climate conditions on livelihoods of communities.

Section 01- Background of Focus Groups

1. Industry:
2. Involvement Type: Owner/ Labour/ Both
3. Years of involvement in this industry:
4.
    a) Did you involve in any other employment previously?
    b) If yes, why did you shift to this job?

Section 02- Observations on Climatic Conditions

5. How the temperature of your area changed during the last 10 years (Since 2014)
6. How the Rainfall of your area changed during the recent 10 years period (Since 2014)?
7. How about the condition of the air changed during last 10 years period (Since 2014), have you experiencing frequent mists, heavy airs compared to past?

How the physical comfort of workers changed during last 10 years period (Since 2014)?

8. What are the main disasters affected to your area?
9. How the frequency of above disasters changed over the time?
10. How the severity of above disasters changed over the time?

Section 03- Environmental Features of the Area

11. How about the geographical location of cultivated lands in your area?

12. How about the soil condition of cultivated land in your area?
13. What are the irrigation techniques currently using to supply water required for the plantation?
14. Have climatic conditions caused evolution of irrigation techniques and how?
15. Any other things you want to describe about the lands in your area?

Section 04: Demographic Factors of the Area

16. How the population growth in the area takes place in terms of accommodations for next generations, employment? (touch division of lands)
17. Do you consider that the growth of population accelerated the climate change? State reasons for your answer.
18.
    a) Do you consider that women headed families faced more difficulties in continuing livelihood amidst climatic damages?
    b) State the reasons for your answer.
    c) What are the measures taken by women headed families to continue their livelihoods amidst the climatic barriers?
19.
    a) Do you consider that old workers faced more difficulties in continuing livelihood amidst climatic damages?
    b) State the reasons for your answer.
    c) What are the measures taken by old workers to continue their livelihoods amidst the climatic barriers?
20. How the educational level of the owner affects the continuation of livelihood amidst climatic barriers?
21. Do you consider that the experience in the field of agriculture helps to resist climatic impacts? Explain the reasons.
22.
    a) How many members are in your family?
    b) Do you consider increasing number of members in a family is challenging in this area under this income source? State the reasons for your answer.

Section 05: Workforce Changes Associated with Climate Change

23. Do you have sufficient labour to continue the works?
24. What are the problems faced by labours consequent to the climatic conditions?
25. What are the actions taken to address the labour related problems consequent to the climate change?
26. What are the strategies to be taken by authorities to address the labour related problems consequent to climate change?

Section 06: Changes to Output

27. How does climatic conditions impact on harvest quantity of a tree over last 10 years?
28. How does climatic conditions impact on harvest output per acre over last 10 years?
29. Have you experienced any crop losses over the last 10 years due to climatic issues?
30. What are the actions taken to recover the crop losses?
31. What are the barriers for implementing those actions?

Section 07: Changes to Income and Costs Associated with Climate Change

32. Do climatic conditions cause any increase/reduction of income in last 10 years? Explain?
33. Are you satisfied with your living conditions and why?
34. What are the changes in lifestyle you have undergone during past 10 years?
35. How does the climatic events affect your income? Why?
36. What are the additional expenses in cultivation you have to undergone consequent to climatic impacts (Cost of Production)?
37. What are the additional expenses in lives you have to undergone consequent to climatic impacts?
38. Do you think that climatic conditions affect the market price? Why and How?

Section 08: Awareness on Damages

39. Do you aware of risk level of your current cultivated plot?

40. From where you get the relevant information?
41. Have you experienced significant damages from climatic variations?
42. Do you aware about the significance of damage it can be caused by climate change in your area?
43.
    a) What are the information required for you to be aware of climatic conditions?
    b) Do you currently receive this information sufficiently?
    c) What are the sources of information available to you?
    d) What are the improvements required in information receiving?

Section 09: Impact of Policies on Climate Resilience

44. Do you aware of available economic policies on your industry? What are they?
45. Do you aware of available climatic policies on your industry? What are they?
46. How about the financial support for recovering damages of climatic conditions?
47. Do you have access to loan facilities?
48. Are interest rates of loans fair?
49. What are the policy changes required to better cope with climate change?

Section 10: Support from Authorities

50. Do you have relevant public services to support your livelihood?
51. What are the relevant public services?
52. What are the consultancy options available to get information on climatic related damages and employment opportunities?
53. Who are the responsible people for advising and how about their availability?
54. What are the other advises you required to sustain in climate conditions?
55. What are the already proposed adaptation options?
56. Do you follow those adaptation option?
57. What are the improvements required in adaptation options?

Section 11: Adaptation through Technology Measures

58.

a) What are the methods of harvesting used in your land?
b) Do you aware of other methods of harvesting which can be used? What are they?
c) What are the convenient methods of harvesting amidst these climatic conditions?

59.

a) What are the technologies used for plantation?
b) Do you aware of alternative technologies for plantation? What are they?
c) What are the preferable technologies for plantation amidst these climatic conditions?

60. What are your suggestions to improve application of technology to improve climate resilience of the crop lands?

Section 12: Adaptation through Alternative Means of Agriculture

61.

a) Do you like to move to alternative crops?
b) What kind of alternative crops are preferred for you?
c) Are there any alternative crops available in your cultivated land?
d) What are the already available alternative crops in your area?
e) What are the barriers to move to alternative crops?
f) What are the additional supports required to introduce alternative crops to your land?

Section 13: Adaptation through Other Alternative Means of Income

62.

a) Do you like to move to an alternative income?
b) What kind of alternative incomes are preferred for you?
c) What are the already available alternative income methods in your area?
d) What are the newly created investments opportunities consequent to climatic variations?

e) What are the barriers to move to alternative incomes?

f) What are the additional supports required to move to alternative incomes?

63. What are the challenges occurred in already invested opportunities consequent to climatic variations?
64. Do you like to migrate to new area? why?
65. Are there already migrated families in your area? What are their current livelihoods?
66. What are your key considerations when you are moving to an alternative income?

***** Thank You! *****

Annexure 03- Stage 03 Key Informant Interview Guideline

……..

……..

Dear Madam/ Sir,

Request to Participate in a Key Informant Interview- Data Collection for Research Dissertation Master of Science with Major Component of Research

I am a postgraduate student at the University of Moratuwa following the Degree program of Master of Science with Major Component of Research. I am conducting research titled "An economic model to assess the impact of climate change on sectors of economy associated with the built environment". This research is being conducted under the supervision of Prof. Udayangani Kulatunga, of the Department of Building Economics, University of Moratuwa and Prof. Bingunath Ingirige of University of Salford.

I am currently at the stage of data collection through key informant interviews under the case studies. The research aims to investigate the economic aspects of climate change impacts in building up resilience of Sri Lanka against climate change.

Accordingly, this discussion aims to identify the economic influences of different climatic conditions on livelihoods of communities and adaptation strategies required to be resilient in climate change.

Kindly consider helping me to collect the data mentioned above by participating interview of about 40 minutes. Digital recording and note taking will be used to record data while interviewing to maintain the accuracy of data (with permission of the interviewee). To maintain confidentiality, the personnel information of the interviewees and the names of the organisations will not be revealed in the report or any other documents relating to this study.

Thank You!

Yours faithfully,

Nadeetharu B.K.M.

Research Scholar,

Department of Building Economics,

University of Moratuwa.

Email: malshanadeetharu@gmail.com

Research Title: An economic model to assess the impact of climate change on sectors of economy associated with the built environment

Research Aim: This study aims to to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models.

Objectives Covered under the Case Study: Investigate the economic impacts of different climate conditions on livelihoods of communities.

Section 01- Background Information

1. Industry/ Case:
2. Profession:
3. Experience in particular field:
4. Experience in this division:
5. Key job responsibilities associated with community livelihood:

Section 02- Observations on Climatic Conditions

6. How the temperature of your area changed during the last 10 years (Since 2014)
7. How the Rainfall of your area changed during the recent 10 years period (Since 2014)?
8. How the humidity changed during last 10 years period (Since 2014)?
9. What are the main disasters affected to your area?
10. How the frequency of above disasters changed over the time?
11. How the severity of above disasters changed over the time?
12. Current Measures to Detect Climate Change/variability:
13. What are the ways of sharing the information prior to the hazards with people?

Section 03- Impacts of Climate Change

14. What are the problems undergone by particular crop grower's consequent to the above climatic impacts?
15. What are the long-term consequences of climatic damages on crop growers?

16. What are the disruptions caused to services provided by authorities/ public services consequent to climate change?
17. According to the available data, explain the severity of the above impacts on the livelihoods with reasons?

Section 04- Community Responses to Impacts of Climate Change

18. What are the actions taken by communities to recover from climatic damages?
    a) Short term actions
    b) Long term actions
19.
    a) Have the following incidents recorded due to climatic damages?
        Abandoned of lands
        Conflicts/ Protests
        Migration
    b) If yes, mention the frequency and things happen thereafter?

Section 05- Measures to Address Impacts of Climate Change

Section 04.1: Preparation to mitigate the damage

20. Explain the process of diagnosing the impacts of climate change on community?
21. What are the actions taken to reduce the damages to the livelihoods of the people consequent to climatic events?
22. What are the future suggestions for actions to be taken to reduce livelihood impacts?
23. What are the barriers to take/ implement actions to resist in climate change?
24. What are the suggestions to address the identified barriers?

Section 04.2: Actions during a climatic damage on livelihood

25.
    a) What is the organizational procedure to handle the damages due to climatic conditions?

b) Do you consider it is effective to recover economic damages to the community?
c) What are the limitations of the current procedure of handling climatic damages?

26. What are your suggestions to rebuild the economic status of the people amidst climate change?

Section 04.3: Policy improvements

27.

a) Do you aware of the policies available to address the impacts of climate change on livelihood of communities in Sri Lanka?
b) What are they?
c) According to your opinion, what are the areas to be concerned to improve the policies available to enhance economic status of communities?

28. What are the actions can be taken to improve the regional officers' involvement in building up community resilience to climate change?

***** Thank You! *****

Annexure 04- Stage 04 Expert Interviews

……..

……..

Dear Madam/ Sir,

Request to Participate in an Expert Interview- Data Collection for Research Dissertation Master of Science with Major Component of Research

I am a postgraduate student at the University of Moratuwa following the Degree program of Master of Science with Major Component of Research. I am conducting research titled "An economic model to assess the impact of climate change on sectors of economy associated with the built environment". This research is being conducted under the supervision of Prof. Udayangani Kulatunga, of the Department of Building Economics, University of Moratuwa and Prof. Bingunath Ingirige of University of Salford.

The research aims to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models. I am currently at the final stage of data collection, to identify the adaptation strategies required for communities to uplift their economic status and be resilient in climate change. This data will be collected through expert interviews and I have identified you as one of the potential experts in this regard.

Kindly consider helping me to collect the data mentioned above by participating interview of about 45 minutes. Digital recording and note taking will be used to record data while interviewing to maintain the accuracy of data (with permission of the interviewee). To maintain confidentiality, the personnel information of the interviewees and the names of the organisations will not be revealed in the report or any other documents relating to this study.

Thank You!

Yours faithfully,

Nadeetharu B.K.M.
Research Scholar,
Department of Building Economics,
University of Moratuwa.
Email: malshanadeetharu@gmail.com

Research Title: An economic model to assess the impact of climate change on sectors of economy associated with the built environment

Research Aim: This study aims to contribute to enhancing community resilience to the economic impacts of climate change in Sri Lanka through the application of economic models.

Objectives Covered: Provide recommendations to increase community resilience against economic impacts of climate change on the livelihoods.

Section 01- Background Information

1. Profession:
2. Educational Background:
3. Experience:
4. Knowledge on climate change: (any research?)

Section 02- Changes of Climate in Sri Lanka

5. Explain the behaviour of following climatic conditions in Sri Lanka and mention how it changes overtime.

	Frequency of experience	Severity	Changes in climatic patterns
Rain			
Temperature			

Section 03- Impacts of Climate Change on the Tea Industry

6.
    a) Do you consider that tea industry itself contributes to increase the damages of climatic conditions? State the reasons for your answer?
    b) What are the possible actions to reduce the acceleration of climatic damages to tea industry through tea industry?
7. According to your opinion, do Sri Lankan tea cultivators undergo these problems?

- Period of rain is high (compared to past few years), therefore the people work on daily wage difficult to continue the livelihood
- Days where there is no rain, temperature is high which affects the optimal growing conditions of tea.
- Since the excess rain is also not the required condition for tea planters, harvest hasn't increase, but decreases (reduction of output)
- Since the same crop is continued in the area for years, quality of the output has reduced, and the land topography and the area does not support alternative cultivations.
- Soil washing off can be observed, which reduce the nutrients of the soil- affect the quality of the tea leaves.
- Number of tea trees reduced in an event of landslide and replantation of trees incurs substantial costs.
- Unpredictable weather patterns delay harvesting.
- Sources of supplying water to cultivated lands are blocked by landslides.
- Lack of accommodation for migrant labours consequent to the severe threat of landslides

8. What are the other problems faced by tea growers, consequent to climate change?

Section D- Measures to Address Impacts of Climate Change on Tea Industry

9. Suggest feasible solutions to address the following problems faced by tea growers?
    - Period of rain is high (compared to past few years), therefore the people work on daily wage difficult to continue the livelihood
    - Days where there is no rain, temperature is high which affects the optimal growing conditions of tea.
    - Uncertainty of employment of daily workers
    - Since the excess rain is also not the required condition for tea planters, harvest hasn't increase, but decreases (reduction of output)
    - Since the same crop is continued in the area for years, quality of the output has reduced, and the land topography and the area does not support alternative cultivations

- Soil washing off can be observed, which reduce the nutrients of the soil- affect the quality of the tea leaves.
- Number of tea trees reduced in an event of landslide and replantation of trees incurs substantial costs.
- Unpredictable weather patterns delay harvesting.
- Sources of supplying water to cultivated lands are blocked by landslides.
- Lack of accommodation for migrant labours consequent to the severe threat of landslides
- Unawareness of technologies to take precautions to climatic impacts.
- Financial difficulties to take precautionary measures to climatic damages.
- Risk of migration to another areas

10. What are the actions taken by authorities to address impacts of climate variability?
11. What are the key areas that the attention to be made to withstand the climate change?
12. What are the improvements required on available policies to address the impacts of climate change on communities?
13. What are the possible measures to overcome the following barriers on community?
14. What are you overall recommendation to improve economic conditions of people?

*****Thank You! *****

Annexure 05- Interview Transcript Sample

I: Hi good morning, sir, thank you so much for participating today, shall we start?

PE2: Hi Malsha, yeah sure!

I: So, this is the preliminary interview of my study and if I introduce about my study, before we are proceeding, it is like, I am investigating on the impact of climate change on different livelihoods in agricultural industry and try to provide strategies to improve their resilience,

PE2: Oh that's great!

I: and what I expected from you is the support to refine and organise my literature findings to further proceed as I planned to do some focus groups and interviews in next rounds.

PE2: Yeah??

I: So we have used economic models of climate change as the methodology to gather data and review the available economic models and found the climatic conditions used by them and the variables they have used in their models. Soo… my first question to you is some background checks... where, I want to know you are a professor and your experience in the academia as a researcher is…

PE2: Yes, 27 years…

I: Okay, first question is associated with the table you have in the section 02…

PE2: Okay, I'll have a look!!

I: and I want to know whether the Sri Lanka is facing changes in these climatic conditions… and suffered??

PE2: Okay, temperature changes, yes, it is obviously there, anddd… radiation, I think it is not and wind speed, yes! There are changes, but…. People are not suffering still…, Rainfall and precipitation, Obviously Yes, it has changed and keep changing!!!,

Humidity, there may be changes! But I think it is not unsafe on people. Okay! (Mumbling and keep silently reading),

I think these are not climate conditions……...???

I: Yes yes sir, these are the first hand influences of climate change, sorry I forgot to mention that, but mention it in the question sir.

PE2: Okay okay no worries, Yes, I think these influences are not affecting Sri Lanka, except the changes in environmental and natural resources. I think exogenous shocks, and climate tipping points are hardly observed…. May be not at all…. And shared economic pathway narratives, I think its bit complex, yes regarding SSP1, climate change impacts on sustainability, and the other SSPs are not a result of climate change. Soooo…. it is not influential in Sri Lankan context.

I: Okay, you said that changes in environmental and natural resources are an influence, how is that, can you explain?

PE2: Yes, if I explain it with an example, it means that Sri Lanka being known for agriculture, has sustained ecosystem balance in the previous times, with sufficient resources for agriculture, now the water is very limited for dry zone, as well the rain is. So, droughts invaded agriculture. Likewise, there are changes in natural resources as there are variations in zones itself and Sri Lanka being a tropical country shows different status of tropical climate in different parts of the country. So… hope it is clear.

I: Yes, sir. Sooo... you have mentioned temperature changes and rainfall changes are damaging the Sri Lankan community?

PE2: Yes, it is varying and oh! I forgot to say before, it is good to use the word climate variability as Sri Lanka is undergoing a climate variability and the temperature, rainfall varies in Sri Lanka, impacting the communities, yes it makes farmers suffer, However, intensity of this variability is different in different agricultural zones and so, suffering levels are different. I guess you are specifying this to any agricultural type. Otherwise, it is too broad, I think.

I: Yes sir, I have included questions regarding that in the later section and was planning to get your opinion regarding the suitability of the studies we have planned.

PE2: Okay okay then!

I: Okay sir, since you asked, let's discuss that before moving to the next section, so I have selected the two industries of tea and paddy to investigate the economic impacts of climate change on tea and paddy growers using the case study approach, So do you think those two industries are good way of proceeding?

PE2: Yes yes, it is exactly so…. As you say, you are investigating economic impacts, isn't it?

I: yes sir, impacts of climate change on their livelihoods and thereby how it affects their economic status.

PE2: Okay, these two industries are good points of moving because they cover a substantial portion of people. I mean those two are the two main industries in Sri Lanka, so the output of your study is obviously helpful in uplifting Sri Lankan economy, if it provides strategies for these two sets of industries. Yes, it is a good move!

I: Happy to hear that sir and hope it is okay to move to the next section now?

PE2: Yes, please

I: Okay sir, there is a table in section 03 of this guideline,

PE2: Let me see!

I: Sure sir, meanwhile, it is a set of parameters or conditions which have been used in economic models to investigate the impacts of climate change on agriculture related livelihoods, so what I want to know is, whether can we consider these variables as livelihood parameters in the Sri Lankan context?

PE2: Okay, let's see!

<Expert mention Yes and No in this Variables, so it is input to table in italics>

Category	Variable	A or N/A
Agricultural	Changes in technologies used for production and cultivation/ method of harvesting	*Yes*
	Crop waste and losses/ status of cultivation/ Productivity of output/ productivity of land/ changes in yield	*Yes*
	Irrigation nature	*Yes*
	Soil condition/ Nature of the land	*Yes*
	Number of cultivation crop types in a particular land/ alternative crops	*Yes*
Demographic	Population growth/ density	*Yes*
	Personal characteristics of a person	*Yes*
	Social background of family	*Yes*
	Size of the family	*Yes*
Economic	Reshaping policies	*Yes*
	Access to credit	*Yes*
	Changes in economic lifestyle overtime / other expenses/ availability of safe and healthy food	*Yes*
	Cost of production	*Yes*
	Wage (income)	*Yes*
	GDP	*Yes*
	Consideration of alternate modes of employment	*Yes*
	Changes in income generating opportunities	*Yes*
	Product prices	*Yes*
Social	Poverty	*Yes*
	Migration	*Yes*
	Level of Risk and damages	*Yes*
	Access to public services and advisors	*Yes*
	Vulnerability to hazard	*Yes*
	Willingness to adapt	*Yes*
	Changes in labour/ machine intensity	*Yes*

I: Okay, do you have any further comments on the variables,

PE2: No, I think all good and those can be investigated in the Sri Lankan context and Sri Lanka is undergoing them all. But I want to highlight that if you are considering the vulnerability to hazard and also, in general as well, it is good to be specific to some area of Sri Lanka, because different areas behave differently and climate hits differently on different areas, so it is good if you can select some good area. Also, it is your intention to investigate impacts of climate on different livelihoods.

I: Yes sir,

PE2: So, in that case I guess you can structure it based on zones as well and see how different industries in different zones get impacts, or else, see how different the impacts are within the same zone for two industries…

I: Yes sir, we are planning on that already as well. Thank you so much for the constructive comment!

PE2: Sure, anything else you want to know.

I: No sir, this is the scope I expected from preliminary interviews and thank you so much for participating today. Have a good day!

PE2: My pleasure and if you want any help on this at any point, please do not hesitate to contact me, Okay? See you then!

I: Yes, thank you sir, see you!

Annexure 06- Systematic Literature Review Screening Process Samples

Nr	Year	Paper Type	Article Name	Model Type	Model Name	country	Screening Criteria	Status	Sector	Remarks	Characteristics
1	2022	Journal	pollution control and climate change mitigation strategies				Irrelavant Topic	Reject		Irrelavant Topic No sector	
2	2022	Journal	impacts of climate change using a discrete-choice	Adaptation Model	Choice Economic model	USA	Accepted	Accept	Forestry management / Land Value		
3	2022	Journal	Impacts for Economic Models of Climate Change A				Health sector	Reject		Vice versa Discussion Irrelevant sector	
4	2022	Journal	and determinants of adoption of climate change adaptation	Adaptation Model	and ordered econometric models		Accepted	Accept	Agriculture	Discusses factors affecting adaptation decisions	X
5	2022	Journal	climate policy projections: A scoping review of				Irrelavant Topic	Reject	Energy		
6	2022	Journal	the Cost-Effective Governance Mode for Biodiversity				Irrelavant findings	Reject	bio diversity	Findings are on how to protect crops	
7	2022	Book	Bottom-Up Approach for Climate Change		x		aquaculture and associate	Reject	Water		
8	2022	Journal	assessment and multi-objective optimization of a geothermal-based tri-				Irrelavant Topic	Reject		No sector	
9	2022	Journal	and the Social Cost of Carbon: Addressing				Carbon calculations and output	Reject		No sector	
10	2022	Journal	hydrological, power system and economic modelling of climate				Irrelavant Topic	Reject	Electricity	Irrelavant sector	

11	2022	Journal	benefits of China's Climate mitigation Policy				Irrelavant Topic	Reject	Health	Irrelavant Topic	
12	2022	Journal	Seaweed: A potential climate change solution				aquaculture and associate	Reject			
13	2022	Journal	climate change on urban resilience in the Beijing-Tianjin-				Irrelavant Topic	Reject	Urban resillience	Not a sector of economy	
14	2022	Journal	innovations in the economic evaluation of the risks of	Integrated Assessment models	Integrated Climate Economy		Accepted	Accept		Content some good facts about socio economic costs and implications	
15	2022	Journal	of food export restrictions under climate change on				Irrelavant Topic	Reject	Food exports	Irrelavant findings (Food export management under the climate change have discussed)	
16	2022	Journal	Term Commitments to Replace Electricity				Irrelavant Topic	Reject	Nuclear	Irrelavant Sector	
17	2022	Journal	War, Pandemic, Climate Crises and Global Dis-				Irrelavant Topic	Reject		Out of scope	
18	2022	Journal	Reconsidered—Valu e of Information on the Climate	Integrated Assessment models	PRICE		Accepted	Accept		Can identify limitations of economic models due to unavailability of information NOT on any sector and highlights	
19	2022	Journal	Agglomeration Dynamics in Face of Climate-Driven				Irrelavant findings	Reject	Transport	Irrelavant Sector	
20	2022	Journal	optimization of solar park design under climatic uncertainty				Irrelavant Topic	Reject		Out of scope No model	
21	2022	Book	Model with Endogenous Carbon Intensity				Irrelavant Topic	Reject		No sector	
22	2022	Journal	Integrated Assessment Modeling of Climate	Integrated Assessment models			not retreived	Accept		Have data with characteristics of IAMs. But not belong to any sector, generally discusses	

23	2021	Journal	approach for the design of robust and cost effective				Irrelavant Topic	Reject	Grasshopper conservation	Irrelevant sector	
24	2021	Journal	modelling of ground and air source heat pumps in a hot and				Irrelavant Topic	Reject	Air conditioning	Out of scope No sector of ecoomy	
25	2021	Journal	climate resilient, net-zero health system: Transforming supply				Health sector	Reject	Health	No model Out of scope	
26	2021	Journal	leakage under regionally differentiated climate				Irrelavant Topic	Reject		No sector	
27	2021	Conferenc	Response to Climate Change Impacts on Rural Agricultural				No model	Reject	Agriculture	No model	
28	2021	Journal	simulating economic effects of climate change on global	Adaptation Model	Prediction and Policy Analysis		Accepted	Accept	Agriculture		
29	2021	Book Sect	policies and resource abundance: The case of Russia				No model	Reject		No model	
30	2021	Journal	financial stability and policy coordination in the				Irrelavant Topic	Reject			
31	2021	Journal	Farmers' varietal innovation adoption in a context of				No model	Reject	Agriculture	No model	
32	2021	Journal	change on capacity expansion decisions of an electricity				Irrelavant Topic	Reject	Electricity		
33	2021	Web artic	Challenges and Opportunities in Climate Economics				Carbon calculations and output	Reject		Web articles will be excluded No sector	
34	2021	Journal	relationship between climate change-related research				Irrelavant Topic	Reject		No model No sector	

35	2021	Journal	software-based DSS for the climate change adaptation of				aquaculture and associate	Reject	Aqua culture		
36	2021	Conferenc	Energy Efficiency under Different Technological				Irrelavant Topic	Reject	Energy	Out of scope	
37	2021	Journal	Climate Change as Contained in Economic Models				Health sector	Reject	Health sector	Irrelavant Sector	
38	2021	Journal	Climate Stressors in a Multiuser River Basin Setting: Who		x		aquaculture and associate	Reject	Agricultura l and urban household		
39	2021	Research Article	term interactions of climate change and timber markets on				Carbon calculations and output	Reject	forestry	Irrelvant findings	
40	2021	Journal	Dwellings in Delta Region to Enhance Climate Change				Irrelavant Topic	Reject			
41	2021	Journal	climate change on housing market analytics in				Irrelavant Topic	Reject		Out of scope	
42	2021	Journal	of tropical forests in meeting global climate stabilization				Forestry specific findings	Reject	Forestry	No characteristics, benefits or drawbacks of a model	
43	2021	Conferenc	carbon adaptation model to climate change in rural				Irrelavant Topic	Reject	Agriculture		
44	2021	Journal	technological innovation in global climate policy				Irrelavant findings	Reject		No sector (status and importance of Research and development to create climate policies)	
45	2021	Book	and the environmental crisis: The link between				No model	Reject		No model	
46	2021	Journal	on COVID-19 prevalence rates: An application of a				COVID	Reject		No sector	

47	2021	Journal	benchmarks for emissions and pledges promote				Irrelavant Topic	Reject		No sector No model	
48	2021	Journal	work: Time allocated to work under varying climate and				No model	Reject		No model	
49	2021	Journal	comprehensive and comprehensible multi-model energy				Irrelavant Topic	Reject		No sector	
50	2021	Journal	of national energy, water and air pollution nexus in				Irrelavant Topic	Reject		No sector	
51	2021	Research	assessing climate control trade-offs and responding to				Irrelavant findings	Reject		Actions and policies can be taken to manage GHG emissions have identified	
52	2021	Book	Ten new insights in climate science 2020-a horizon scan				No model	Reject		No model No Sector	
53	2021	Conferenc	Modelling climate smart agriculture with ontology				Irrelavant findings	Reject	Agriculture	Discusses on a computational technology, to prepare models no model	
54	2021	Journal	economic and mitigation benefits of climate-smart				Forestry specific findings	Reject	agriculture		
55	2021	online arti	of rural population from a climate perspective:				Irrelavant findings	Reject		Analyse population distribution based on climate conditions of a particular region No socio-economic implications	
56	2021	Journal	perceptions, goals and characteristics of wine growers on				aquaculture and associate	Reject	Wine growing	have discussed. Instead of that, what are the ideas of wine growers to manage water in	
57	2021	Journal	food security: The impact of some key variables on wheat				No economic model	Reject	Agriculture	No economic model	
58	2021	Journal	climate-induced crop yield changes: Evidence from agri-	Adaptation Model	Computable General Equilibrium		Accepted	Accept	Agriculture	Impact of temperature changes on crop yielding	