ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH

Final Technical Report
CAF2016-RR10CMY-MARAMBE

Building Climate Resilience in Farming Systems in Sloping Lands of South Asia

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1. Contents

Project Overview

Project Duration	**:**	July 2015-June 2017
Funding Awarded	**:**	US$ 60,000 for Year 1; US$ 25,000 for Year 2
Key organisations involved	**:**	Faculty of Agriculture, University of Peradeniya, Sri Lanka Postgraduate Institute of Agriculture (PGIA), University of Peradeniya, Sri Lanka Faculty of Science, University of Colombo, Sri Lanka Department of Agriculture, Peradeniya, Sri Lanka Department of Meteorology, Colombo, Sri Lanka Bangabandhu SMR Agric. University, Bangladesh Tribhuvan University, Nepal SmallEarth, Nepal

Project Summary

The study revealed that the farming systems (FS) in hilly areas in Chittagong (Bangladesh) Jhikhu Khola (Nepal) and Hatton and Welimada (Sri Lanka) differ in their size (extent), composition, resource utilization, and sustainable management practices adopted by the farmers. The resilience of the faming systems in hilly areas (slopy lands) in three countries were assessed using five indices namely climate vulnerability index (CVI), social vulnerability index (SVI), food nutrition and health Vulnerability Index (SNH), adaptability index (AI) and the climate resilient index (CRI). The CVI was estimated by using exposure (represented by 3 parameters), sensitivity (represented by 11 parameters) and adaptive capacity (represented by 18 parameters). The FNH vulnerability score was calculated using 18 parameters, SVI 23 parameters, AI 28 parameters, and CRI 31 parameters (by aggregating absorptive capacity, adaptive capacity and transformative capacity).

FS in Chittagong as the most vulnerable to climate change, having the highest CRI and CVI, lowest FNH score and AI and CRI. FS in Hatton was the least vulnerable to climate change, least social vulnerable, and had the highest AI and CRI among the study sites. The CVI is the best index among five indices used to assess the farming systems under changing climate.

Keywords: *Farming systems. Hilly areas in south Asia, Climate Vulnerability Index (CRI), Food, Nutrition and Health (FNH) Score, Climate Change*

Project outputs and outcomes

Project outputs:

- Output A: Indicators on level of resilience of Farming Systems (FS) in hilly areas in South Asia (SA) to changing and variable climate
- Output B: Climate vulnerability maps based on exposure, sensitivity and adaptive capacity,
- Output C: Inventory report on types of FS in hilly areas of SA and their productivity.
- Output D: Status report on food and nutrition security of faming systems in hilly areas of SA under changing and variable climate – *Combined with Output C*
- Output E: A policy brief with recommendation of suitable climate resilient FS for practical implementation in project sites and mainstream project outcomes - *currently nearing completion and will be submitted by 30 June 2020*

Project outcomes:

- Outcome A: Improved understanding on the homegarden farming systems in the hilly areas in SA , their dynamics, and climate resilience in different countries
- Outcome B: Improved capacity in developing climate resilient indicator maps using latest technologies and globally accepted indicators
- Outcome C: Strengthening partnership and collaboration among institutes within and among partner countries
- Outcome D: Strengthening evidence-based policy making of countries in relation to climate change impacts in farming systems with special focus on hilly areas

Key facts/figures

- Detailed description of farming systems in the hilly areas on three different countries in SA
- Estimation of Climate Vulnerability Index (CVI), Food, Nutrition and Health (FNH) score, Social Vulnerability Index (SVI), Adaptation Index (AI), and Climate Resilient Index (CRI) focusing on farming systems in hilly areas of three south Asian Countries
- Identification of CRI has the best index out of the five indices selected and identification of 31 parameters to assess CRI to estimate the performance of farming systems in the hilly areas (slopy land) in the south Asian regions.
- Climate vulnerability maps developed focussing on 4 study sites identified in Sri Lanka (2), Bangladesh (1) and Nepal (1) based on globally accepted indices
- Trained a young scientists at the PhD level on climate resilience of farming systems in the hilly area.

Potential for further work

The project can have vertical and lateral expansion on educating the policy makers on the vulnerability of farming systems in hilly areas with a special focus on home gardens. Hence, the project will lead to a capacity building exercise across countries, media coverage on the climate vulnerability drawing urgent attention of the respective government in the region of the project outcomes. Climate resilient mapping and food and nutrition and health security mapping should be carried out for different farming systems at the lowest administrative level to assess the level of present resilience.

Publications

Currently under preparation

Awards and honours

None to-date

Pull quote

Quote by Professor CMB Dematawewa, Director of the Postgraduate Institute of Agriculture (PGIA), University of Peradeniya (mdematawewa@gmail.com):

> "*Coping with the impacts of inevitable climate change is a challenge unavoidable for future agriculturists. The degree of commonality among countries in the south Asian region with respect to the consequences of climate change on Agriculture is substantial, which warrants regional collaborative research projects on the field crops. In that light, the current*

collaborative project on Building Climate Resilience in Farming Systems in Sloping Lands of South Asia funded by the Asia Pacific Network (APN) for Global Change on Research encompassing three key countries is of utmost importance and the Postgraduate Institute of Agriculture is privileged to be a partner of the project and a contributor to high standards of postgraduate training."

Acknowledgements

The Project Team would like to acknowledge the services rendered by the Research Assistants from Sri Lanka, Bangladesh and Nepal whose activities immensely supported in achieving the project goals. The project team also thank the service and support extended by the staff of Department of Meteorology (Sri Lanka), Natural Resource Management Centre of the Department of Agriculture (Sri Lanka), Faculty of Agriculture and the Agriculture Education Unit (AEU) of University of Peradeniya (Sri Lanka), Bangabandhu SMR Agric. University (Bangladesh), Tribhuvan University (Nepal) and SmallEarth-Nepal, the farming community in the study sites in three countries who willingly cooperated in providing required information, and the staff of Asia Pacific Network (APN) for Global Change Research.

The financial assistance provided by the APN through the grant CAF2016-RR10CMY-MARAMBE is gratefully acknowledged.

1. Introduction

This section should include background information, scientific significance, objectives, and other relevant information leading to the development and justification of the current project.

South Asia (SA), is home to around one fourth of the world's population (Worldometers, 2020) and is the most densely populated geographical region in the world (Pandey, 2015). The region is also comprised a variety of geographical features such as glaciers, deserts, valleys, rainforests, and grasslands (Pandey *et al*. 2015). The majority of land (more than 260 million ha) in SA is used for agriculture contributing to about 15% of the total Gross Domestic Production (GDP) and employing more than 50% of the population in the region (Khatri-Chhetri and Aggarwal, 2017).

A considerable number of people in the SA region suffer from hunger and malnutrition. Recent estimates indicate that 14.9 % of the people in the region suffer from hunger or undernourishment. Further, there is a continued high incidence of malnutrition (FAO, 2019). Food production sector of SA strives to keep pace with growing population and rising demand for food. However, it is anticipated that SA countries are likely to face severe food crisis by 2050, due to adverse impact of climate change, fast and unplanned urbanization, reduction in arable land, declining average farm size, low productivity as a result of land degradation and low investment on R & D, slow process of structural transformations and poor institutions (Ahmad *et al*., 2015).

Growth in the agriculture sector to enhance food security has led to resource degradation under a changing and variable climate, with adverse impacts on its sustainability, especially in diverse farming systems in sloping lands of hilly areas. In agro-ecological terms, 20% of the land in SA region consists of steeply sloping hills and mountains (FAO, 2001). Hilly areas in Asia, have considerable global importance as the source of most of the major rivers of Asia, sustain billions of small holder faming systems, provide area for urban expansion, and part of Global Biodiversity Hotspots and rich cultural diversity.

Agriculture in SA is vulnerable to climate change and adaptation measures are required to sustain agricultural productivity, to reduce vulnerability, and to enhance the resilience of the agricultural system to climate change (Aryal *et al.* 2019). As climate is a primary determinant of agricultural productivity, any changes will influence crop growth and yield, hydrologic balances, supplies of inputs and other components of managing agricultural systems (Berhane, 2018). Moreover, climate change may affect food systems in several ways ranging from direct effects on crop production (e.g. changes in precipitation leading to floods or droughts, warmer or cooler temperatures affects in changes in the length of the growing season), to changes in food prices, markets and supply chain infrastructure (Gregory *et al*,2005).

The hill and mountain areas differ with the plains in topography, elevation, diversity of habitats for flora and fauna and etc. In general hills provide vast scope for cultivators with diverse mix of crops and livestock production (Fatima *et al*. 2012). Small land holdings, sloping marginal land and rainfall dependent farming are the dominant features of the hill farming in SA (Fatima et al. 2012). Widespread land degradation augmented by climate change (CC) has seriously eroded the production capacity of hilly areas across countries leading to food and nutrition insecurity. Though climate vulnerability of SA countries and their major agro-ecological regions has been assessed to a greater extent, there is a paucity of information on integrated analysis of the vulnerability of farming systems in hilly areas to climate change.

Though the assessments of such impacts have been done in some parts of SA, there are serious deficits in information on the status of hilly areas with respect to the resource utilization and building resilience in farming systems (FS) within SA as the issue has been addressed in isolation, through best farming practices. Information on systematic and holistic approaches to reduce vulnerability of this agro-ecosystem to CC, land degradation and loss of biodiversity are meagre thus, hindering the provision of responding to a key policy question on "what best farming practices could be recommended for hilly areas to minimize resource degradation and to ensure environmental sustainability while enhancing food security and climate resilience?". Therefore, identification of the best farming practices which could be recommended for hilly areas of SA to minimize resource degradation and to ensure environmental sustainability, while enhancing food security and resilience is a vital and urgent requirement. This study was thus, intended to use concepts of successful farming models reported from other Asian countries, and address this key policy question and support informed-decision making, by providing the much needed scientifically validated information on resource degradation and environmental sustainability, best practice FS for higher level resilience, and well-being of farming communities in sloping lands, while ensuring food and nutrition security of farm households and at national and regional levels.

Main objective:
The main objective of the research was to assess resilience and characterization of diverse FS in hilly areas in SA based on their adaptation capacities, with special emphasis on food and nutrition security.

Specific objectives:
The specific objectives were to (1) identify, characterize (species and genetic variation of species - crops, livestock, natural and indicator species and their productivity, socio-economic opportunities and limitations, level of integration and nutrient recycling) and document FS and land use patterns in hilly areas of SA in detail, (2) assess the technologically important strategies and the resource utilization that lead to sustainability and stability of the FS in the study areas, (3) map the climate vulnerability, and food and nutrition and health security of different FS at the lowest administrative level, to ascertain the level of present resilience in the study sites, and (4) develop a Climate Resilient Index (CRI) to estimate the climate resilience of FS in the study sites, a Social Vulnerability Index (SVI), and Adaptation Index (AI) in line with Global Adaptation Index (GAIN) to capture the degree of food, nutrition and health insecurity of Farming households. The project includes two activities *i.e.* (1) Identification, characterization and documentation of FS and land use patterns in hilly areas of SA in detail to identify the differences among them in terms of resource utilization, and sustainable management and (2) Climate vulnerability mapping, food and nutrition and health security mapping of different FS at the lowest administrative level to assess the level of present resilience.

2. METHODOLOGY

2.1 Site Selection

Sites selection criteria was based on expert consultation carried out at the beginning of the project, to ensure uniformity in site selection among different countries. The project partners and Sri Lankan expertise involved in agriculture research in hilly areas in Sri Lanka took part in the exercise. The criteria agreed upon and used for this study are shown in Table 2.1.

Table 2.1 Site selection criteria

Criteria	Specification
Slope in the Hilly land	>30%
Representative elevation	300 – 1800 m amsl
Availability of historical information on disasters (at administrative offices, web sites, newspapers, etc.)	Minimum of recent 10 years
Availability of climate data	Minimum of recent 20 years
Farming systems	Different systems having on broad components of crops, farm animals, forest, and fish)
Access	Easy access to study sites to collect information
Community	Willingness of the farming community to support project activity

Based on the criteria listed in Table 2.1, sites were selected to characterize various FS with extreme climatic conditions and other common criteria in three countries and to enable within and between site comparisons. Accordingly, two sites namely, Welimada and Hatton were selected from Sri Lanka, whereas one each from Bangladesh and Nepal, namely Chittagong and Jhikhu Khola, respectively were selected (Figure 2.1). Stratified sampling technique was used to select the samples and 100 farm families were selected to represent a minimum of 30% of the population in each sample site.

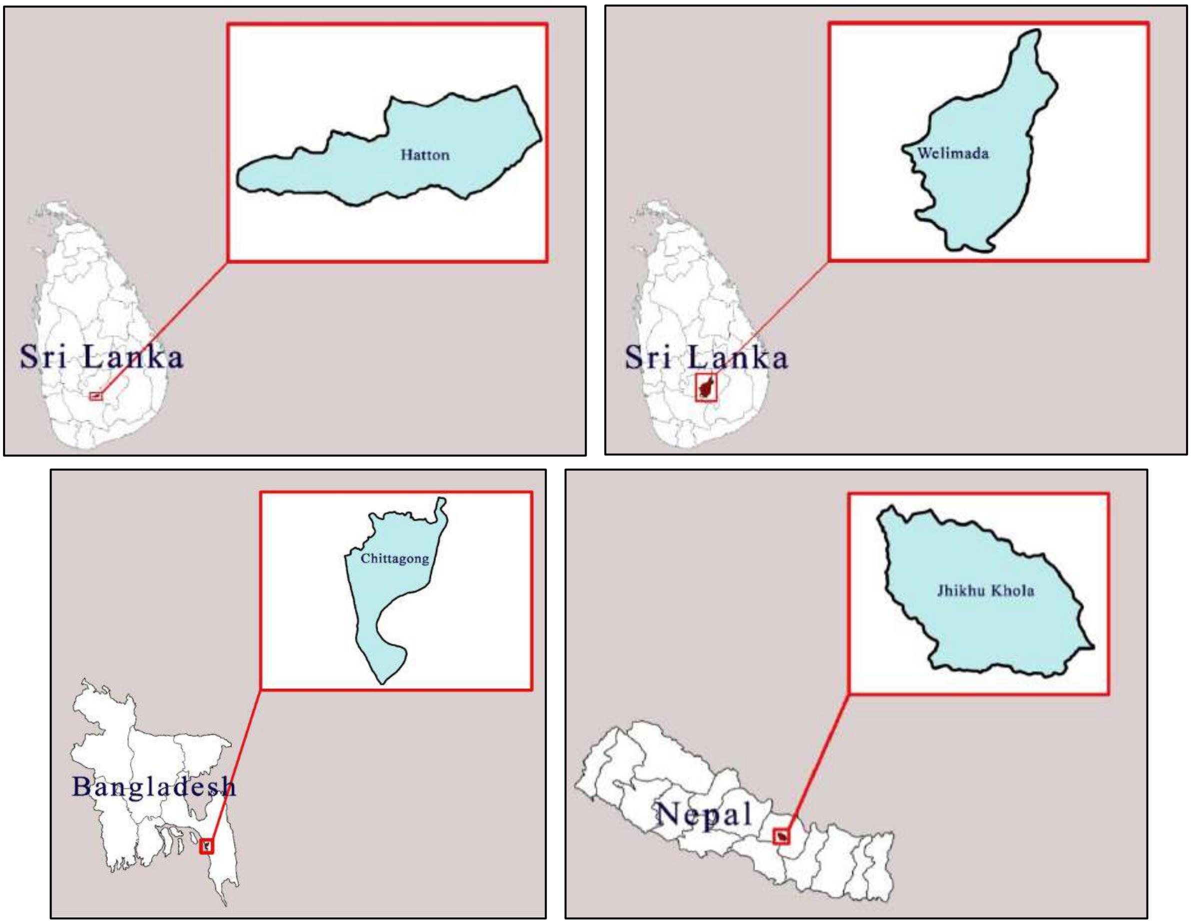

Figure 2.1. Study sites selected from three countries based on the criteria listed in Table 2.1

The study site of Chittagong in Bangladesh located between 22°07’20” N to 22º09'30" N latitude and 92°12’40” E to 92°13’43” E longitude, Jhikhu Khola in Nepal located between 27°35’0” N to 27°55’0” N latitude and 85°18’0” E to 85°48’0” E longitude, Hatton in Sri Lanka located between 06˚46'25" N to 06˚47'10" N latitude and 80°42’20” E to 80°43’45” E longitude and Welimada in Sri Lanka located between 06˚56'0" N to 06˚57'10" N latitude and 80°51’0” E to 80°53’0” E longitude.

2.2 Data Collection

Primary data were collected by a survey using a pre-tested questionnaire and a database was constructed based on survey results. The survey questionnaire (Annex 1) consisted of ten broad sections: Basic information, socio-economic characteristics, plant and animal inventory in the farming system, water and soil conservation strategies and crop management adopted in farming system, land use patterns in the farming system, climate change adaptation strategies in the farming system, food consumption pattern, income and expenditure in household, market and enumerator’s observation.

Secondary data on productivity and soil erosion, soil fertility status, land degradation status, system changes, meteorological data, occurrence of natural disasters, human-health related issues, pest outbreak in crop and animal species, etc., were collected from relevant local and national administrative services.

2.3 Analytical framework

Secondary data sources and the results of the survey were used to develop a database on the type of existing FS and their socio-economic, demographic and agronomic characteristics, technological adaptations, combination of crop, tree and animal components and their genetic variation in main cropping seasons.

Adaptation strategies used by farmers to climate change shocks, historical information on changes of crops, trees and animals genetic resources of the sites and descriptive information, such as, farmer's perspective on the possible reasons for the above changes were recorded.

A system change over the past decade was recorded from the survey and published and unpublished sources, especially from land use maps. Indicator species for various aspects were identified and characterized against existing limitations in different farming systems. Human-health related issues, pest outbreak in crop and animal species during last 20 years was identified through questionnaire and focus group discussions at sites.

Secondary data on production and soil erosion was collected from local and national administrative services. Prevailing soil fertility status of each farming system was assessed and agro-ecosystems was determined using standard soil fertility parameters such as soil bulk density, Organic matter content, Cation Exchange Capacity (CEC), Total N, P and K along with other important micro nutrients.

The degree of land degradation in each agro ecosystem was assessed with the assistance of the department responsible for Natural Resource Management in each country and expert opinions by comparing the situation with an undisturbed land with same topographical features of the area.

Meteorological data (rainfall, temperature, RH, mist) obtained from the meteorology departments of respective countries were used to analyse location specific climate trends, patterns of change in the past and make forecasts for future. Variability, extreme events and changes during the last 20 years was analysed. In this study, NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) of 6 General Circulation Models (GCMs) namely CanESM2, CNRMCM5, CSIRO-MK3-6-0, GFDL-CM3, MRI-CGCM3 and NCAR-CCSM4 with 25km grid spacing were selected to develop future climate projections. Climate projections were made for changes in number of precipitation extremes from 2011 to 2100 with a significance level of 5% using those 6 GCM models for both Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios and discussion was made based on the ensemble mean of 6 GCM models of RCP 4.5 scenario.

2.4 The indicator approach

The indicator approach is one of the methods of quantification of vulnerability/ resilience. In this study a numerical composite indexes were calculated for Climate Vulnerability, Climate Adaptability, Food Nutrition and Health Vulnerability, Social Vulnerability and Climate Resilience. These indexes were calculated household wise and those enable comparisons among households as well as locations. The composite indexes were designed to be between 0 and 1.

2.4.1. Normalization of Parameters

Parameters used in the study are measured in different scales and units. Therefore, normalization of indices was carried out to obtain figures are free from units and comparable following the methodology used in Human Development Index (HDI) (UNDP, 2006). Parameters were normalized to obtain values ranging between 0 and 1. Before the values are normalized, it was important to identify the two possible types of functional relationship between the parameters and the vulnerability, adaptability or resilience. With this it is ensured that the index values are always in positive correlation with vulnerability, adaptability or resilience and that higher value means higher vulnerability, adaptability or resilience and vice versa. Functional relationship between the parameters and the vulnerability, adaptability or resilience were determined from the previous studies or based on the theoretical assumptions.

If vulnerability increases with an increase in the value of the parameter (positive correlation), and therefore has a positive functional relationship with vulnerability. Then normalization was carried out .by using Equation 1.

$$\mathbf{X}_{ij} = (\mathbf{X_i} - \mathbf{Min}\ \{\mathbf{X}_j\}) / (\mathbf{Max}\ \{\mathbf{X}_j\} - \mathbf{Min}\ \{\mathbf{X}_j\}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, X_{ij} is the normalized value of parameter (j) with respect to household (i), Xi is the actual value of the parameter with respect to household (i), and Min $\{X_j\}$ and Max $\{X_j\}$ are the minimum and maximum values, respectively, of parameter (j) among all the households.

If the functional relationship with vulnerability was negative, i.e., if vulnerability decreases with an increase in the value of the parameter (negative correlation), the normalized score was computed using Equation 2.

$$\mathbf{X}_{ij} = (\mathbf{Max}\ \{\mathbf{X}_j\} - \mathbf{X_i}) / \mathbf{Max}\ \{\mathbf{X}_j\} - \mathbf{Min}\ \{\mathbf{X}_j\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

2.4.1.1. Climate Vulnerability Index

In this study Climate Vulnerability Index (CVI) was developed based on the definition provided by IPCC where vulnerability is defined as: "The degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes". Since the definition stated that, vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity, vulnerability was assessed by the mathematical expression proposed by McCarthy *et al.* (2001):

Vulnerability = f (Exposure, Sensitivity, Adaptive capacity)

The relevant parameters to represent exposure, sensitivity and adaptive capacity were selected based on the literature with similar issues as well as expert opinion. In this study, exposure is represented by 3 parameters, sensitivity is represented by 11 parameters and adaptive capacity is represented by 18 parameters. Parameters selected for each component is presented in Table 2.2 with the hypothesized relationship to climate vulnerability.

Table 2.2 Parameters selected for Climate Vulnerability with their hypothesized relationship to climate vulnerability

Components of Vulnerability	Sub-components of Vulnerability	Parameters selected for analysis	Description of indicators	Hypothesized relationship between indicator and vulnerability
Exposure to Climate Change	Extreme Climate related Hazards	Occurrence of droughts	No. of Drought events recorded during 2009 - 2018	Higher No. of Drought events, higher the vulnerability
		Occurrence of Floods	No. of Flood events recorded during 2009 - 2018	Higher No. of Flood events, higher the vulnerability
		Occurrence of Landslides	No. of Landslides recorded during 2009 - 2018	Higher No. of Landslides, higher the vulnerability
Sensitivity to Climate Change	Agriculture	Diversity of crops	No. of crops cultivated	Having cultivated more than three crops, Lower the vulnerability

		Cropping System	Whether cultivated as sole crop or mixed cropping	Cultivated as sole crop, higher the vulnerability
		Cultivated variety	Cultivated variety	Cultivated hybrid varieties, higher the vulnerability
		Fertilizer management	Type of fertilizers used in the cultivation	Using organic fertilizers, lower the vulnerability
		Hired labor	No. of hired labors used in farming activities	Use of hired labor, higher the vulnerability
	Irrigation Potential	Cultivation under irrigation	Sources of water for agricultural activities	No potential to irrigation, higher the vulnerability
	Storage	Availability of storage facilities	Whether households have storage facilities	Having storage facilities, lower the vulnerability
Sensitivity to Climate Change	Ecological Stability	Presence of naturally grown plants	No. of naturally grown plants available	Presence of naturally grown plants, lower the vulnerability
		Presence of woody trees	No. of woody trees available	Presence of woody trees, lower the vulnerability
		Soil and water conservation	Practicing of soil and water conservation methods	Practicing of soil and water conservation methods, lower the vulnerability
		Slope of the land	Whether the land is flat, undulating, moderate slope or steep slope	Higher the slope, higher the vulnerability
Adaptive capacity to climate change	Socio-Demography	Gender of the household head	Whether the household is a male or female	Households with female head, higher the vulnerability
		Dependent household head	Household heads who older than 65 years	Households with dependent Household head, higher the vulnerability
		Condition of the house	Based on the construction materials of the walls, roof and the floor	Poorly constructed houses, higher the vulnerability
	Education	Educational level	Whether the household head has completed the primary education, secondary education or post-secondary education	Household heads with no formal education, higher the vulnerability
Adaptive capacity to climate change	Economy	Property regime	Availability of own lands	Households that do not own a private land, higher the vulnerability
		Income sources	Diversified income sources	Having more than one income source, lower the vulnerability
		Household employment	Whether the members of households are employed or not	Any member of household is not employed, higher the vulnerability
		Savings	Ratio of income and expenditure	Households with little or no savings, higher the vulnerability
		Dependence on agriculture	Percentage of agriculture base income	Households that depend on agriculture as major source of Income, higher the vulnerability

	Animal Husbandry	Practicing of animal husbandry	Whether the household is practicing animal husbandry	Practicing of animal husbandry, lower the vulnerability
		Diversity of Species	No. of animal species	Have more than one species, lower the vulnerability
		Animal breed	Whether animals are hybrid, cross bread or indigenous	Have hybrid breeds, higher the vulnerability
		System of animal rearing	Whether animals are rearing as extensive, intensive or semi-intensive system	Practicing of extensive system for animal rearing, higher the vulnerability
		Feeding method	Whether animals are feed with concentrate, cut and fed, free grazing or other	Feeding animals with concentrate feeds, lower the vulnerability
Adaptive capacity to climate change	Awareness	Farming knowledge	Years of experience in farming	Higher the farming experience, lower the vulnerability
		awareness about the area	Living period in the area in years	Higher the living period, lower the vulnerability
		Climate change	Noticed the changes in climate	Having notice the changes in climate, lower the vulnerability
		Changes in farming system	Noticed the changes in farming system	Having notice the changes in farming system, lower the vulnerability
	Food	food from own cultivation	Whether households consume food from animal husbandry	Consuming food from own cultivation, lower the vulnerability
		food from animal husbandry	Whether households consume food from their cultivations	Consuming food from animal husbandry, lower the vulnerability
	Sanitation	Improved toilets	Type o toilet	Having improved toilets, lower the vulnerability

Here Composite indexes were developed for each component, namely, exposure, sensitivity and adaptive capacity. Variables were normalized prior to calculations and equal weight was assigned to each parameter to make simple in approach and interpretation. Exposure (E), sensitivity (S) and adaptive capacity (AC) was computed using Equations 3, 4 and 5, respectively.

$$\mathbf{E}\boldsymbol{i} = \sum (\mathbf{E}\boldsymbol{ij}) / \mathbf{N_E} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, Ei is the value for exposure with respect to household (i), Eij is the value of the j^{th} parameter of exposure with respect to i^{th} household and N_E is the number of parameters in exposure component.

$$\mathbf{S}\boldsymbol{i} = \sum (\mathbf{S}\boldsymbol{ij}) / \mathbf{N_S} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where, Si is the value for sensitivity with respect to household (i), Sij is the value of the j^{th} parameter of sensitivity with respect to i^{th} household and N_S is the number of parameters in sensitivity component.

$$\mathbf{AC}_{\boldsymbol{i}} = \sum (\mathbf{AC}_{\boldsymbol{ij}}) / \mathbf{N_{AC}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where, AC_i is the value for adaptive capacity with respect to household (i), AC_{ij} is the value of the j^{th} parameter of adaptive capacity with respect to i^{th} household and N_{AC} is the number of parameters in adaptive capacity component.

The degree of climate vulnerability (CV) of each household in each location was computed using Equation 6.

$$\mathbf{CV}_{\boldsymbol{i}} = \mathbf{E}_{\boldsymbol{i}} + \mathbf{S}_{\boldsymbol{i}} - \mathbf{AC}_{\boldsymbol{i}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where, CV_i is the value for climate vulnerability, E_i is the value of exposure, S_i is the value of sensitivity and AC_i is the value of adaptive capacity with respect to i^{th} household.

2.4.3 Food Nutrition and Health Vulnerability Score

Since Climate change affects food security through its four dimensions, food production and availability, stability of food supplies, access to food and food utilization (Hossain *et al*. 2014) and human health is affected by climate change either directly or indirectly through various mechanisms, Food Nutrition and Health Vulnerability (FNH) score was developed to assess the food nutrition and health insecurity in the farming systems.

The relevant parameters were selected based on the literature with similar issues as well as expert opinion. In this study, 18 parameters were used to compute food nutrition and health vulnerability score and Table 2.3 shows the parameters selected for the FNH index with their hypothesized relationship with food nutrition and health vulnerability. To make simple in approach equal weight was assigned for each parameter and food nutrition and health vulnerability score was computed using Equation 7 for each household and the variables were normalized prior to computation.

$$\mathbf{FNH}_{\boldsymbol{i}} = \sum (\mathbf{FNH})_{\boldsymbol{ij}} / \mathbf{N_{FNH}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Where, FNH_i is the food nutrition and health vulnerability score for i^{th} household, $(FNH)_{ij}$ is the value of the j^{th} parameter of food nutrition and health vulnerability index with respect to i^{th} household and N_{FNH} is the number of parameters in food nutrition and health vulnerability index.

Table 2.3 Parameters selected for Food Nutrition and Health Vulnerability with their hypothesized relationship to Food Nutrition and Health Vulnerability

Dimension	Parameters selected for analysis	Description of parameters	Hypothesized relationship between indicator and Food Nutrition and Health Vulnerability
Socio-demographic	Gender of the household head	Whether the household is a male or female	Households with female head, higher the vulnerability
	Educational level	Whether the household head has completed the primary education, secondary education or post-secondary education	Household heads with no formal education, higher the vulnerability
	Property regime	Availability of own lands	Households that do not own a private land, higher the vulnerability

Economic	Income sources	Diversified income sources	Having more than one income source, lower the vulnerability
	Household employment	Whether the members of households are employed or not	Any member of household is not employed, higher the vulnerability
	Availability of storage facilities	Whether households have storage facilities	Having storage facilities, lower the vulnerability
	Savings	Ratio of income and expenditure	Households with little or no savings, higher the vulnerability
	Dependence on agriculture	Percentage of agriculture base income	Households that depend on agriculture as major source of Income, higher the vulnerability
Agriculture	Diversity of crops	No. of crops cultivated	Having cultivated more than three crops, lower the vulnerability
	Cultivated variety	Cultivated variety	Cultivated hybrid varieties, higher the vulnerability
	Cropping System	Whether cultivated as sole crop or mixed cropping	Cultivated as sole crop, higher the vulnerability
	Fertilizer management	Type of fertilizers used in the cultivation	Using organic fertilizers, lower the vulnerability
Animal husbandry	Practicing of animal husbandry	Whether the household is practicing animal husbandry	Practicing of animal husbandry, lower the vulnerability
	Diversity of Species	No. of animal species	Have more than one species, lower the vulnerability
	Animal breed	Whether animals are hybrid, cross bread or indigenous	Have hybrid breeds, higher the vulnerability
Food	food from own cultivation	Whether households consume food from animal husbandry	Consuming food from own cultivation, lower the vulnerability
	food from animal husbandry	Whether households consume food from their cultivations	Consuming food from animal husbandry, lower the vulnerability
Sanitation	Improved toilets	Type o toilet	Having improved toilets, lower the vulnerability
Ecological stability	Presence of naturally grown plants	No. of naturally grown plants available	Presence of naturally grown plants, lower the vulnerability

2.4.4 Social Vulnerability Index

Social vulnerability is the characteristics of a person or group and their situation that influence their ability to expect, overcome, resist and recover from the impact of a natural hazard. (Lynn *et.al*. 2011). As stated by Lynn *et.al*. (2011), levels of income, unemployment, pension contributions, illiteracy and malnutrition among children, livelihood resilience, self -protection, societal protection, social capital, class or income group, gender, ethnicity, type of state, civil society, and science and technology can be suggested as indicators for measuring and understanding vulnerability. In this study, 22 parameters were selected to cover those indicators based on the available literature and the expert opinion.

The parameters selected for the Social Vulnerability Index (SVI) with their hypothesized relationship to social vulnerability are expressed in Table 2.4. Social vulnerability score was computed using Equation 8 for each household. To make simple in approach equal weight was assigned for each parameter. Normalized values were used for the computation.

$$\mathbf{SVI}_{\boldsymbol{i}} = \sum (\mathbf{SVI})_{\boldsymbol{ij}} / \mathbf{N}_{\mathbf{SVI}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

Where, SVIi is the social vulnerability score for i^{th} household, (SVI)ij is the value of the jth parameter of social vulnerability index with respect to i^{th} household and N_{SVI} is the number of parameters in social vulnerability index.

Table 2.4 Parameters selected for Social Vulnerability with their hypothesized relationship to Social Vulnerability

Dimension	Parameters selected for analysis	Description of parameters	Hypothesized relationship between indicator and Social Vulnerability
Socio-demographic	Gender of the household head	Whether the household is a male or female	Households with female head, higher the vulnerability
	Dependent household head	Household heads who older than 65 years	Households with dependent Household head, higher the vulnerability
	Educational level	Whether the household head has completed the primary education, secondary education or post-secondary education	Household heads with no formal education, higher the vulnerability
Economic	Property regime	Availability of own lands	Households that do not own a private land, higher the vulnerability
	Income sources	Diversified income sources	Having more than one income source, lower the vulnerability
	Household employment	Whether the members of households are employed or not	Any member of household is not employed, higher the vulnerability
	Access to basic public services	Distance to market	Higher the distance to market, lower the resilience
	Presence of middleman	Presence of middleman when marketing their products	Presence of middleman, lower the resilience
	Availability of storage facilities	Whether households have storage facilities	Having storage facilities, lower the vulnerability
	Savings	Ratio of income and expenditure	Households with little or no savings, higher the vulnerability
	Dependence on agriculture	Percentage of agriculture base income	Households that depend on agriculture as major source of Income, higher the vulnerability
	Condition of the house	Based on the construction materials of the walls, roof and the floor	Poorly constructed houses, higher the vulnerability
Agriculture	Hired labor	No. of hired labors used in farming activities	Use of hired labor, higher the vulnerability
	Diversity of crops	No. of crops cultivated	Having cultivated more than three crops, Lower the vulnerability
	Cultivated variety	Cultivated variety	Cultivated hybrid varieties, higher the vulnerability
	Cropping System	Whether cultivated as sole crop or mixed cropping	Cultivated as sole crop, higher the vulnerability

Animal husbandry	Practicing of animal husbandry	Whether the household is practicing animal husbandry	Practicing of animal husbandry, lower the vulnerability
Food	food from own cultivation	Whether households consume food from animal husbandry	Consuming food from own cultivation, lower the vulnerability
	food from animal husbandry	Whether households consume food from their cultivations	Consuming food from animal husbandry, lower the vulnerability
Sanitation	Improved toilets	Type o toilet	Having improved toilets, lower the vulnerability
Awareness	Presence of woody trees	No. of woody trees available	Presence of woody trees, lower the vulnerability
	Awareness about the area	Living period in the area in years	Higher the living period, lower the vulnerability

2.4.5 Climate Change Adaptability Index

Adaptability can be expressed as "adjustments in ecological socioeconomic systems in response to existing or expected climatic stimuli and their effects" and "adjustments in a system's behaviour and characteristics that increase its ability to withstand the external stress" (Smit and Wandel, 2006). To assess the adaptability of the households to climate change, Climate Adaptability Index (AI) was developed.

In this study 28 parameters were selected to compute the adaptability score and those parameters are expressed in Table 2.5 with their hypothesized relationship to climate adaptability.

Table 2.5 Parameters selected for Climate Adaptability with their hypothesized relationship to Climate Adaptability

Dimension	Parameters selected for analysis	Description of parameters	Hypothesized relationship between indicator and adaptability
Socio-demographic	Gender of the household head	Whether the household is a male or female	Households with female head, lower the adaptability
	Dependent household head	Household heads who older than 65 years	Households with dependent Household head, lower the adaptability
	Educational level	Whether the household head has completed the primary education, secondary education or post-secondary education	Household heads with no formal education, lower the adaptability
	Property regime	Availability of own lands	Households that do not own a private land, lower the adaptability
Economic	Income sources	Diversified income sources	Having more than one income source, higher the adaptability
	Household employment	Whether the members of households are employed or not	Any member of household is not employed, lower the adaptability
Economic	Access to basic public services	Distance to market	Higher the distance to market, lower the adaptability
	Presence of middleman	Presence of middleman when marketing their products	Presence of middleman, lower the adaptability
	Availability of storage facilities	Whether households have storage facilities	Having storage facilities, higher the adaptability
	Savings	Ratio of income and expenditure	Households with little or no savings, lower the adaptability

	Dependence on agriculture	Percentage of agriculture base income	Households that depend on agriculture as major source of Income, lower the adaptability
	Condition of the house	Based on the construction materials of the walls, roof and the floor	Poorly constructed houses, lower the adaptability
Agriculture	Hired labor	No. of hired labors used in farming activities	Use of hired labor, lower the adaptability
	Diversity of crops	No. of crops cultivated	Having cultivated more than three crops, higher the adaptability
	Cultivated variety	Cultivated variety	Cultivated hybrid varieties, lower the adaptability
	Cropping System	Whether cultivated as sole crop or mixed cropping	Cultivated as sole crop, lower the adaptability
	Cultivation under irrigation	Sources of water for agricultural activities	No potential to irrigation, lower the adaptability
	Fertilizer management	Type of fertilizers used in the cultivation	Using organic fertilizers, higher the adaptability
Animal husbandry	Practicing of animal husbandry	Whether the household is practicing animal husbandry	Practicing of animal husbandry, higher the adaptability
	Diversity of Species	No. of animal species	Have more than one species, higher the adaptability
	Animal breed	Whether animals are hybrid, cross bread or indigenous	Have hybrid breeds, lower the adaptability
	System of animal rearing	Whether animals are rearing as extensive, intensive or semi-intensive system	Practicing of extensive system for animal rearing, lower the adaptability
	Feeding method	Whether animals are feed with concentrate, cut and fed, free grazing or other	Feeding animals with concentrate feeds, higher the adaptability
Ecological stability	Slope of the land	Whether the land is flat, undulating, moderate slope or steep slope	Lower the slope, higher the adaptability
	Presence of naturally grown plants	No. of naturally grown plants available	Presence of naturally grown plants, higher the adaptability
	Presence of woody trees	No. of woody trees available	Presence of woody trees, higher the adaptability
	Soil and water conservation	Practicing of soil and water conservation methods	Practicing of soil and water conservation methods, higher the adaptability
Awareness	Awareness about the area	Living period in the area in years	Lower the living period, lower the adaptability
	Farming knowledge	Years of experience in farming	Lower the farming experience, lower the adaptability
	Climate change	Noticed the changes in climate	Having notice the changes in climate, higher the adaptability
	Changes in farming system	Noticed the changes in farming system	Having notice the changes in farming system, higher the adaptability

For each household climate adaptability score was computed using Equation 9, In order to make it simple in approach, equal weight was assigned for each parameter and the variables were normalized prior to computation.

$$\mathbf{AI}\boldsymbol{i} = \sum \mathbf{(AI)}\boldsymbol{ij} \,/\, \mathbf{N_{AI}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(9)}$$

Where, AI*i* is the climate adaptability score for i^{th} household, (AI)*ij* is the value of the j^{th} parameter of climate adaptability index with respect to i^{th} household and N_{AI} is the number of parameters in climate adaptability index.

2.4.6 Climate Resilience Index

As defined by the Intergovernmental Panel on Climate Change (IPCC), climate resilience is the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the ability of self-organization, and the capacity to adapt to stress and changes. Keeping in line with this definition, a Climate Resilient Index (CRI) was developed to assess the capacity of the community to reach and maintain an acceptable level of functioning with ongoing climate change and variability.

In order to better understand resilience, the parameters selected for Climate Resilience Index (CRI) were aggregated into three resilience capacities: absorptive capacity, adaptive capacity and transformative capacity. There are 31 parameters to represent CRI and the description about the parameters and their hypothesized relationship with the climate resilience are expressed in Table 2.6.

Normalized parameters were aggregated into respective resilience capacities to generate the CRI using Equation 10.

$$\mathbf{CRI}\boldsymbol{i} = \quad \mathbf{(ADC}\boldsymbol{i} + \mathbf{ABC}\boldsymbol{i} + \mathbf{TC}\boldsymbol{i}\mathbf{)} \,/\, \mathbf{(N_{ADC} + N_{ABC} + N_{TC})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(10)}$$

Where, CRI*i* is the climate resilience score, ADC*i* is the value of adaptive capacity, ABC*i* is the value of absorptive capacity and TC*i* is the value of transformative capacity with respect to i^{th} household. N_{ADC}, N_{ABC} and N_{TC} are the number of parameters in adaptive capacity, absorptive capacity and transformative components respectively.

Values for adaptive capacity (ADC), absorptive capacity (ABC) and absorptive capacity (TC) were calculated using Equations 11, 12 and 13, respectively). Equal weight was assigned for each parameter to make it simple in approach and interpretation.

$$\mathbf{ADC}\boldsymbol{i} = \sum \mathbf{(ADC)}\boldsymbol{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(11)}$$

Where, ADC*i* is the value for adaptive capacity with respect to household (*i*) and ADC*ij* is the value of the j^{th} parameter of adaptive capacity with respect to i^{th} household.

$$\mathbf{ABC}\boldsymbol{i} = \sum \mathbf{(ABC)}\boldsymbol{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(12)}$$

Where, ABC*i* is the value for absorptive capacity with respect to household (*i*) and ABC*ij* is the value of the j^{th} parameter of absorptive capacity with respect to i^{th} household.

$$\mathbf{TC}\boldsymbol{i} = \sum \mathbf{(TC)}\boldsymbol{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(13)}$$

Where, TC_i is the value for transformative capacity with respect to household (i) and TC_{ij} is the value of the j^{th} parameter of transformative capacity with respect to i^{th} household.

Table 2.6 Parameters selected for Climate Resilience Index with their hypothesized relationship to Climate Resilience

Capacity	Components of climate resilience	Parameters selected for analysis	Description of parameters	Hypothesized relationship between parameter and climate resilience
Adaptive capacity	Socio-Demography	Gender of the household head	Whether the household is a male or female	Households with female head, lower the resilience
		Dependent household head	Household heads who older than 65 years	Households with dependent Household head, lower the resilience
		Condition of the house	Based on the construction materials of the walls, roof and the floor	Poorly constructed houses, lower the resilience
	Education	Educational level	Whether the household head has completed the primary education, secondary education or post-secondary education	Household heads with no formal education, lower the resilience
	Economy	Property regime	Availability of own lands	Households that do not own a private land, lower the resilience
		Income sources	Diversified income sources	Having more than one income source, higher the resilience
		Household employment	Whether the members of households are employed or not	Any member of household is not employed, lower the resilience
		Savings	Ratio of income and expenditure	Households with little or no savings, lower the resilience
		Dependence on agriculture	Percentage of agriculture base income	Households that depend on agriculture as major source of Income, lower the resilience
Adaptive capacity	Animal Husbandry	Practicing of animal husbandry	Whether the household is practicing animal husbandry	Practicing of animal husbandry, higher the resilience
		Diversity of Species	No. of animal species	Have more than one species, higher the resilience
		Animal breed	Whether animals are hybrid, cross bread or indigenous	Have hybrid breeds, lower the resilience
		System of animal rearing	Whether animals are rearing as extensive, intensive or semi-intensive system	Practicing of extensive system for animal rearing, lower the resilience
		Feeding method	Whether animals are feed with concentrate, cut and fed, free grazing or other	Feeding animals with concentrate feeds, higher the resilience
	Awareness	Farming knowledge	Years of experience in farming	lower the farming experience, lower the resilience
		awareness about the area	Living period in the area in years	lower the living period, lower the resilience
		Climate change	Noticed the changes in climate	Having notice the changes in climate, higher the resilience

		Changes in farming system	Noticed the changes in farming system	Having notice the changes in farming system, higher the resilience
	Food	food from own cultivation	Whether households consume food from animal husbandry	Consuming food from own cultivation, higher the resilience
		food from animal husbandry	Whether households consume food from their cultivations	Consuming food from animal husbandry, higher the resilience
	Sanitation	Improved toilets	Type o toilet	Having improved toilets, higher the resilience
Absorptive Capacity	Technology utilization	Diversity of crops	No. of crops cultivated	Having cultivated more than three crops, higher the resilience
		Cropping System	Whether cultivated as sole crop or mixed cropping	Cultivated as sole crop, lower the resilience
		Cultivated variety	Cultivated variety	Cultivated hybrid varieties, lower the resilience
		Fertilizer management	Type of fertilizers used in the cultivation	Using organic fertilizers, higher the resilience
	Irrigation Potential	Cultivation under irrigation	Sources of water for agricultural activities	No potential to irrigation, lower the resilience
	Ecological Stability	Presence of naturally grown plants	No. of naturally grown plants available	Presence of naturally grown plants, higher the resilience
		Presence of woody trees	No. of woody trees available	Presence of woody trees, higher the resilience
		Soil and water conservation	Practicing of soil and water conservation methods	Practicing of soil and water conservation methods, higher the resilience
		Slope of the land	Whether the land is flat, undulating, moderate slope or steep slope	lower the slope, higher the resilience
Transformative Capacity	Infrastructure	Availability of storage facilities	Whether households have storage facilities	Having storage facilities, higher the resilience
		Access to basic public services	Distance to market	Higher the distance to market, lower the resilience
	Social capital	Presence of middleman	Presence of middleman when marketing their products	Presence of middleman, lower the resilience
		Hired labour	No. of hired labour used in farming activities	Use of hired labour, lower the resilience

2.5 Data analysis and presentation

Descriptive statistics such as percentages and frequencies were used in the data analysis and the results were used to assess the status of climate vulnerability, food nutrition and health vulnerability, social vulnerability, climate adaptability and climate resilience and to characterize the diverse farming systems in hilly areas.

Based on the maximum and minimum values of climate vulnerability, food nutrition and health vulnerability, social vulnerability, climate adaptability and climate resilience indexes, households were categorized into five categories namely lesser, less, moderately, high and higher for each index separately. Equal Interval Classification method was used to determine the cut-off points. Percentage of households in each category was computed and those details were used in within site and between sites comparisons.

In order to spatially represent the results of the indices project areas were mapped for climate vulnerability, food nutrition and health vulnerability, social vulnerability, climate adaptability and climate resilience based on the values obtained by the households for each index using Inverse Distance Weighted (IDW) interpolation technique of Geographic Information Systems (GIS).

3. RESULTS & DISCUSSION

3.1. Description of Study sites:

3.1.1. Hatton in Sri Lanka

Hatton is a city in the Nuwara Eliya District of Central Province, Sri Lanka and a major center of the Sri Lankan tea industry. It is located approximately 112 km southeast of Colombo and 72 km south of Kandy, at an elevation of 1,271 m (4,170 ft) above sea level. Hatton serves as a gateway to Adam's Peak (Sri Pada) and Sinharaja Forest Reserve, but is better known for its Ceylon tea plantations. As it is the central point for most upcountry tea growing regions, such as Maskeliya, Talawakelle, Bogawantalawa and Dickoya, Hatton is one of the busiest cities in the hill country of Sri Lanka.

Hatton has a tropical climate and the annual rainfall is 2834 mm. The driest month is February, with 85 mm of rainfall and the most precipitation falls in June with an average of 346 mm. The average annual temperature in Hatton is 19.9 °C. The warmest month of the year is May, with an average temperature of 21.1 °C and with an average temperature of 18.6 °C, January has the lowest average temperature of the year. The difference in precipitation between the driest month and the wettest month is 261 mm. During the year, the average temperatures vary by 2.5 °C. Significant land area is covered with tea and vegetable cultivation is mainly limited to home gardens.

3.1.2. Welimada in Sri Lanka

Welimada is located at about 204 km east of Colombo, and is a part of the Uma Oya catchment. Since the average elevation in the area is 1017 MAMSL, Welimada is belongs to upcountry. It is situated along the boundary of two climatic zones namely; intermediate (east portion) and wet zones (west portion). Most of it, however, belongs to the intermediate zone, including the Grama Niladhari (GN) Divisions of Palugama Ella, Idamegama and Kebillegama (Rivas *et al.* 2005).

As stated by Rivas *et al*. (2005), Welimada has a tropical climate. The average annual rainfall is around 1300 mm and the temperature ranges from 12°C in December to 32°C in August. As other parts of the country, Welimada also has two seasons; the *Maha* (rainy) and *Yala* (dry) seasons. *Maha* usually starts in late September or early October and ends in early January, and *Yala* season starts from March and ends in August. The slope of the area is vary from undulating to steep slopes. The typical hill slope in the area is divided into two, namely; upland (rainfed) and lowland (irrigated).

There are two major growing seasons in Sri Lanka namely *Yala* season (mid-March to mid-September) and *Maha* season (mid-September to mid-March) and the seasons are distinguished only by means of the timing of the two monsoons. The transitional periods which separate the monsoons called inter-monsoon seasons. The Southwest monsoon is from May to September and the Northeast monsoon from December to February. The inter-monsoon periods are from March to April and from October to November (Herath and Jayawardena 2017).

3.1.3. Chittagong in Bangladesh

Chittagong, officially known as Chattogram, is located on the banks of the Karnaphuli River between the Chittagong Hill Tracts and the Bay of Bengal. It is the second largest city in the country with a population of more than 2.6 million (2019 Revision of World Population Prospects) in the city and more than one million in the metropolitan area (Mia *et al*. 2015). Chittagong is rich in biodiversity, its hills and jungles are laden with waterfalls, fast flowing river streams and elephant reserves. Bandarban, Rangamati, and Khagrachari located in the east, are the three hill districts which are the highest mountains in Bangladesh.

Chittagong has a tropical monsoon climate with a heavy rainfall varies between 1500 mm and 4300 mm annually, falling mainly during the summer monsoons and the area is vulnerable to North Indian Ocean tropical cyclones (Alamgir *et al*. 2019). Karnaphuli, Feni, Halda, Sangu, and Matamuhari are the major rivers in the area. The higher parts of the hills are covered with forests while the lower parts are covered with brushwood.

The crop-growing period in Bangladesh is divided into two main seasons namely *Kharif* and *Rabi*. *Kharif*/*Kharif* II season starts in May and ends in October while *Rabi*/Winter season starts November and ends in April which covers the months having no or very little rainfall. It starts at the end of the humid period and lasts up to the pre-monsoon season. In addition to these two main seasons, another transition season called Pre-*Kharif*/*Kharif* I can be identified. Pre-*Kharif* season (March to May) is characterized by unreliable rainfall that varies in time, frequency, and intensity from year to year, and provides only an intermittent supply of moisture for crops (Alamgir *et al*. 2015).

3.1.4. Jikhu Khola in Nepal

Jikhu Khola is located 35 km east of Kathmandu in the Middle Mountains of Nepal. In 1996, the population in the watershed was 48,728 and had been increasing at a rate of 2.6 % per year. The region has a complex geology which result complex spatial patterns of topography, soils, and vegetation

Jikhu Khola has humid subtropical climate grading to warm temperate above 2000 MAMSL with around 1500 mm of mean annual rainfall at mid elevations (1560 MAMSL) (Ghimire *et al*. 2013). The main seasons are, respectively, the monsoon (June to September), the post monsoon period (October to November), winter (December to February), and the pre-monsoon period (March to May). The rainy season brings about 80% of the total annual precipitation (Ghimire *et al*. 2013). Air temperatures range from 3 to 40 °C in the lower watershed, and decrease by around 3ºC at higher elevations.

As stated by Ghimire *et al*. (2013), the vegetation at elevations between 1000 and 2000 m amsl consists of a largely evergreen mixed broadleaved forest. Due to the prevailing population pressure, much of the original species-rich forest has disappeared and most of the remaining forest are also either occurring on slopes that are too steep for agricultural activity or being in various stages of degradation because of continued disturbance. Since the watershed elevation ranges from 790 to 2,200 m amsl, Steep side slopes result in a high erosive potential, while the flat valley bottom acts as a sediment depository. Vegetation cover in the Jikhu Khola consists of 30% forest (both natural and planted), 7% shrubland, and 6% grassland, with the remaining 57% largely under agriculture (Ghimire *et al*. 2013). Paddy, maize, wheat, millets, and barley are the most important food crops.

There are four seasons in Nepal, namely, pre-monsoon (March–May), monsoon (June–September), post-monsoon (October–November) and winter (December–February). Pre-monsoon season is characterized by localized precipitation with hot, dry and westerly windy weather, the monsoon is characterized by moist southeasterly monsoonal winds coming from the Bay of Bengal and sometimes from the Arabian Sea with widespread precipitation while post-monsoon is a dry season with sunny days featuring a driest month, November and the winter is a cold season with precipitation in the form of snow in high-altitude mountainous regions. (Karki *et al*. 2017).

3.2. Descriptive analysis

Primary data collected from the survey were used to develop a database on the type of existing farming systems (FS) and their socio-economic, demographic and agronomic characteristics, technological adaptations, combination of crop, tree and animal components and their genetic variation in main cropping seasons. Details in the database were initially analyzed to check the differences among four locations, to identify the characters of different farming systems and to identify the technologically important strategies used in different farming systems such as use of crop varieties and animal breed, resource utilization, irrigation methods, integrated farming practices, fertilizer usage, cropping pattern, pest and disease management, integrated farming practices etc.

3.2.1 Age of the Household Head

Distribution of the age of the household heads in years in each location is expressed in Figure 3.1. Results of one-way ANOVA revealed a significant difference in age distribution among four locations ($P<0.001$). The average age of the household heads in each location is shown in Table 3.1.

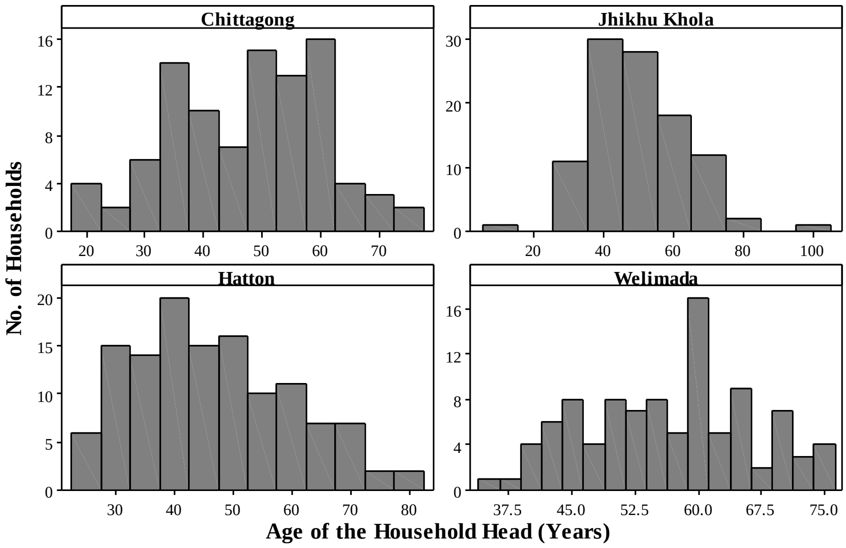

Figure 3.1: Distribution of Age of the Household Head of Chittagong in Bangladesh, Jhikhu Khola in Nepal, Hatton and Welimada in Sri Lanka

Table 3.1: **Average Age of the Household head in Years of each location**

Study sites		**Average age (Years)**
Bangladesh	Chittagong	47.50 ± 13.08b
Nepal	Jhikhu Khola	48.73 ± 14.20b
Sri Lanka	Hatton	46.70 ± 13.39b
	Welimada	56.495 ± 9.742a

Within the column, means with the same letters are not significantly different at $p = 0.05$

Elderly household heads were observed in Welimada (56.495 ± 9.74) followed by Jhikhu Khola (48.73 ± 14.20), Chittagong (47.50 ± 13.08) and Hatton (46.70 ± 13.39). In Hatton more than 60% of household heads were below 50 years and this may due to their early marriages and having their own homesteads moving away from the parents, compared to the other sites.

3.2.2. Gender of the household head

Percentage of male household heads and female household heads among study sample in each location are illustrated in Figure 3.2. Chi-square test revealed that there is an association between location and the gender of the household head ($P<0.001$). In all locations majority of the household heads were males. Among the four locations, Hatton had the highest percentage of female household heads as there were more widows while percentages of male households and female household heads in other three locations were similar.

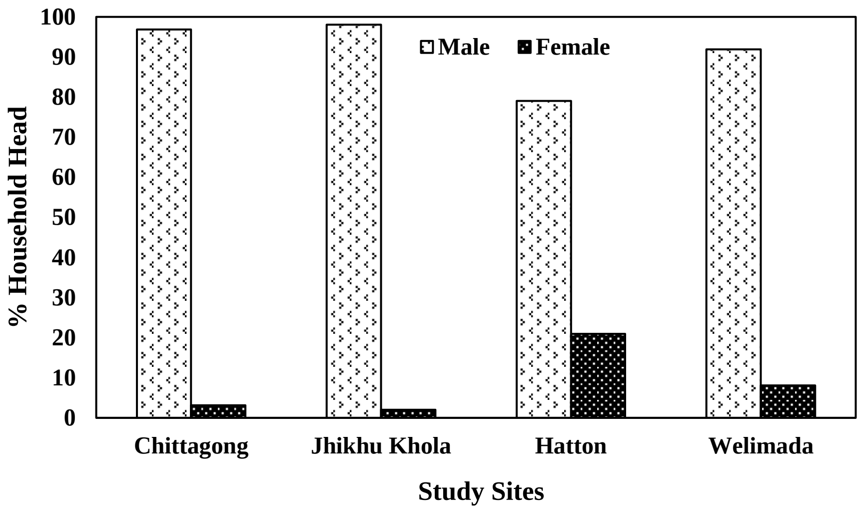

Figure 3.2: **Percentages of male households and female households of Chittagong in Bangladesh, Jhikhu Khola in Nepal, Hatton and Welimada in Sri Lanka**

3.2.3 Education Level of the Household Head

Households were categorized into three education categories as no schooling, primary education and secondary education & above. Education level of the household head was taken into account and summary of the education levels in four locations is expressed in Figure 3.3.

Chi-square test revealed that there is an association between location and the education level ($P<0.001$). In Chittagong, the proportion of no schooling was higher and in other three locations proportion of primary education was higher. Jhikhu Khola had the highest proportion of household heads in the category of having Secondary education or above.

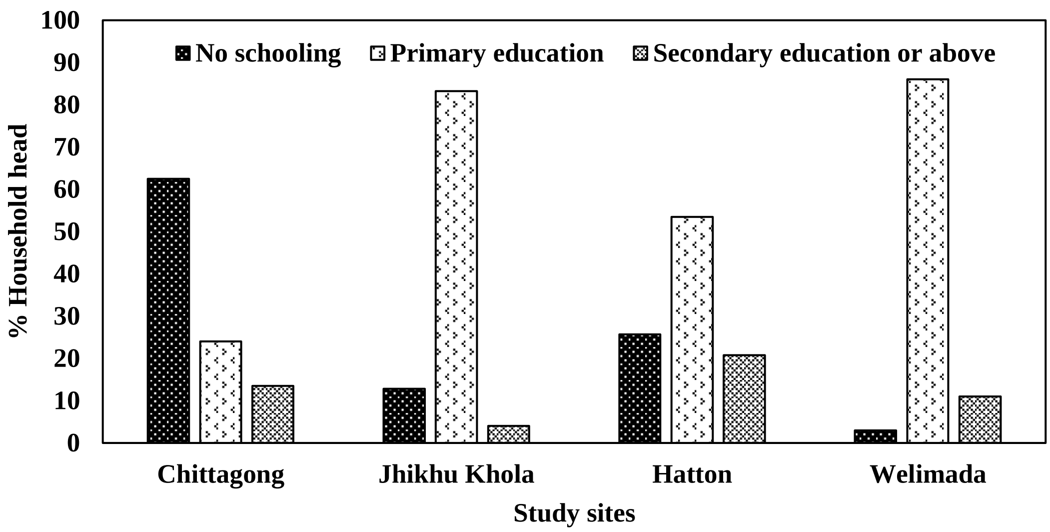

Figure 3.3: **Percentages of household heads in each education category of Chittagong (Bangladesh), Jhikhu Khola (Nepal), and Hatton and Welimada (Sri Lanka)**

3.2.4 Main occupation of the Household Head

The main occupation of household head was expressed as the percentage of households among the study sample in each occupation category for each location (Table 3.2).

Table 3.2: **Main occupation of the household head**

Study sites		**Occupation**					
		Government Employee	**Farmer**	**Estate Worker**	**Retired estate worker**	**Mason**	**Driver**
Bangladesh	Chittagong	2	98	-	-	-	-
Nepal	Jhikhu Khola	-	100	-	-	-	-
Sri Lanka	Hatton	1	6	63	26	2	1
	Welimada	1	97	-	-	-	-

All the household heads in Jhikhu Khola, and the majority of in Chittagong and Welimada were farmers while the majority of the household heads in Hatton were Estate workers (mainly tea).

3.2.5. Period of living in the Village

Variation observed in the period of living (years) of the household heads in each location is expressed in Figure 3.4. Welimada had the highest average living period among the four locations (56.430 ± 9.87 years) while lowest average living period can be seen in Chittagong (30.81 ± 17.87 years), due to recent settlement (Table 3.3). There was a significant difference in living period among the four locations and (P<0.001).

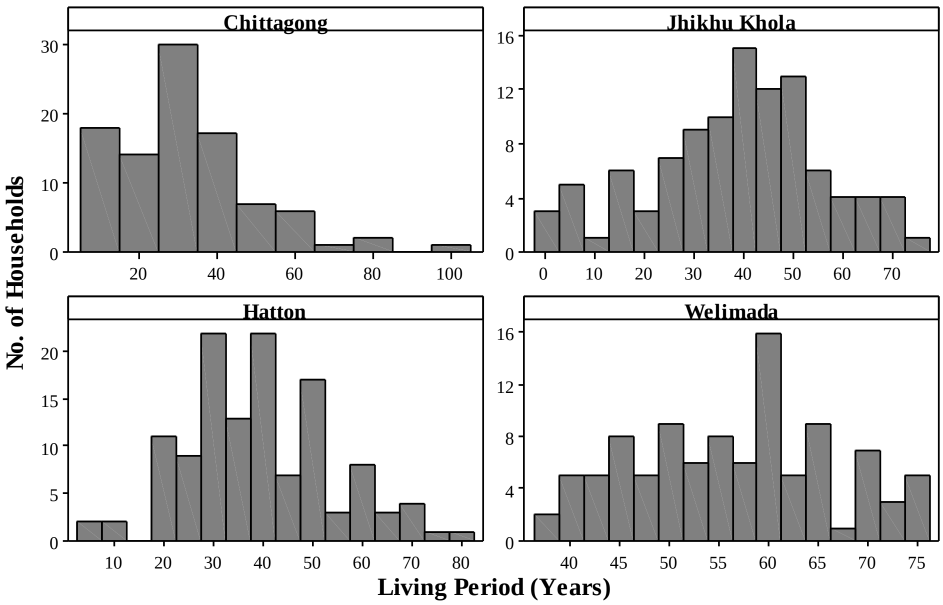

Figure 3.4: Distribution of the living period of Chittagong in Bangladesh, Jhikhu Khola in Nepal, Hatton and Welimada in Sri Lanka

Table 3.3: **The average living period of each location**

Location		**Average Living period (Years)**
Bangladesh	Chittagong	30.81 ± 17.87c
Nepal	Jhikhu Khola	38.39 ± 17.64 b
Sri Lanka	Hatton	39.31 ± 14.76b
	Welimada	56.43 ± 9.87a

Within a column, means followed by the same letters are not significantly different at p = 0.05

3.2.6. Farming Experience of Household Head

The variation on the farming experience of the household heads in years in each location is illustrated in Figure 3.5., and the average years of farming experience is expressed in Table 3.4.

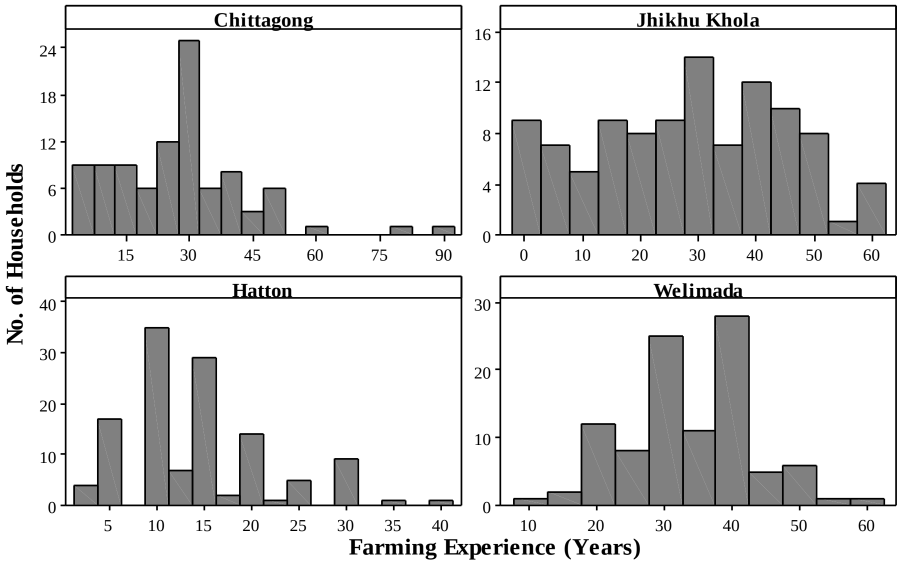

Figure. 3.5. Distribution of Farming Experience of Chittagong (Bangladesh), Jhikhu Khola (Nepal), and Hatton and Welimada (Sri Lanka)

Table 3.4: **Average Farming experience in Years of each location**

Location		**Average Farming experience (Years)**
Bangladesh	Chittagong	27.56 ± 15.22b
Nepal	Jhikhu Khola	28.16 ± 16.64b
Sri Lanka	Hatton	14.160 ± 7.60c
	Welimada	33.810 ± 9.337a

Within a column, means followed by the same letters are not significantly different at $p = 0.05$

The highest farming experience was found with the respondents in Jhikhu Khola as they have started cultivations at their early stages of life. The lowest farming experience is in Hatton as they have started farming recently.

3.2.7 Time Allocation for Farming

The summary of time allocation during different cultivating seasons in all four locations is illustrated in Figure 3.6. In Chittagong, approx. 96 % of respondents cultivated crops only in the *Kharif* season and all were full time farmers. Further, 96 % of the respondents in the Welimada area were full time farmers. A higher proportion of respondents in the Hatton (Sri Lanka) and Jhikhu Khola (Nepal) were part time farmers.

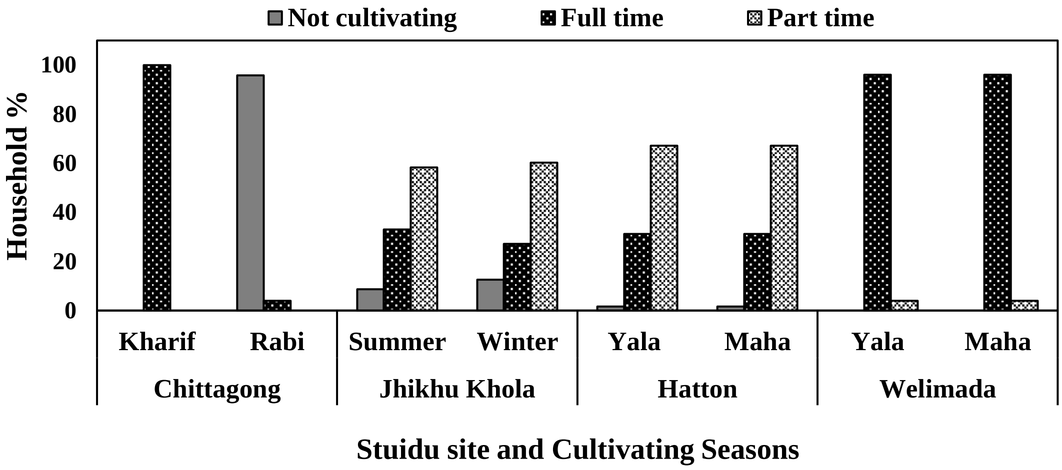

Figure 3.6: Percentages of full-time and part-time farmers of Chittagong in Bangladesh, Jhikhu Khola in Nepal, Hatton and Welimada in Sri Lanka

3.2.8 Land ownership

Land availability and ownership summary of home garden, lowland and upland in all four locations is calculated as a percentage of the study sample. As illustrated in Figure 3.7, all the respondents in Chittagong and Hatton did not have lowlands and all respondents in Chittagong had and owned home gardens and uplands. Further, all respondents in Welimada, had home gardens but 4% of them were not the owners of that land. In Jhikhu Khola, 35 % of respondents did not have home gardens while 40.8 % of respondents in Hatton also did not have home gardens. Hatton had the highest proportion of respondents who did not have uplands and home gardens. As majority of the households in Hatton were estate workers, they were living in line rooms provided by the estate, where the residents did not have the ownership of the land.

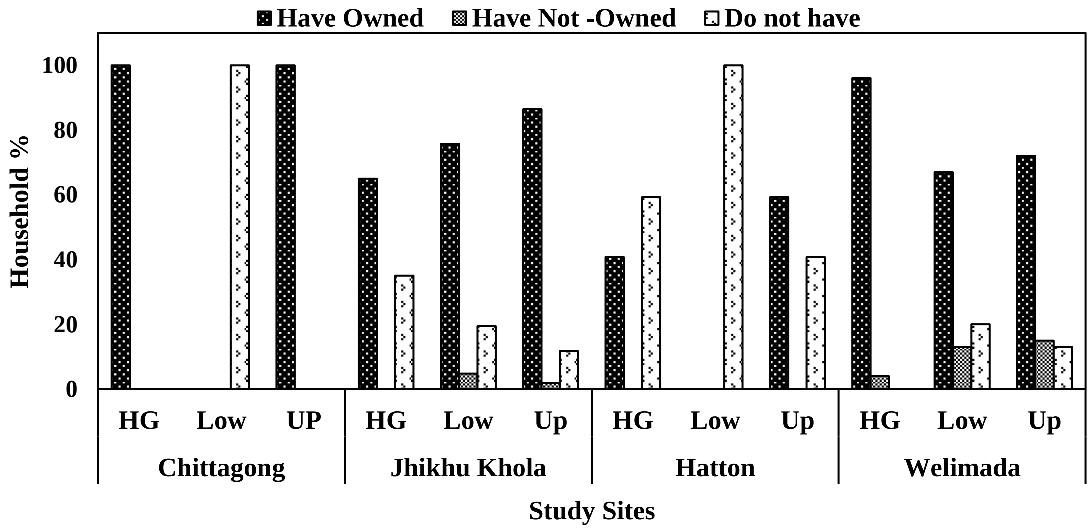

Figure 3.7: Ownership of farming land by the responding farmers in Chittagong (Bangladesh), Jhikhu Khola (Nepal) and Hatton and Welimada (Sri Lanka)

3.2.9 Cultivated by self

Percentages of respondents who do their own cultivation among those who have lands in each study site are illustrated Figure 3.8.

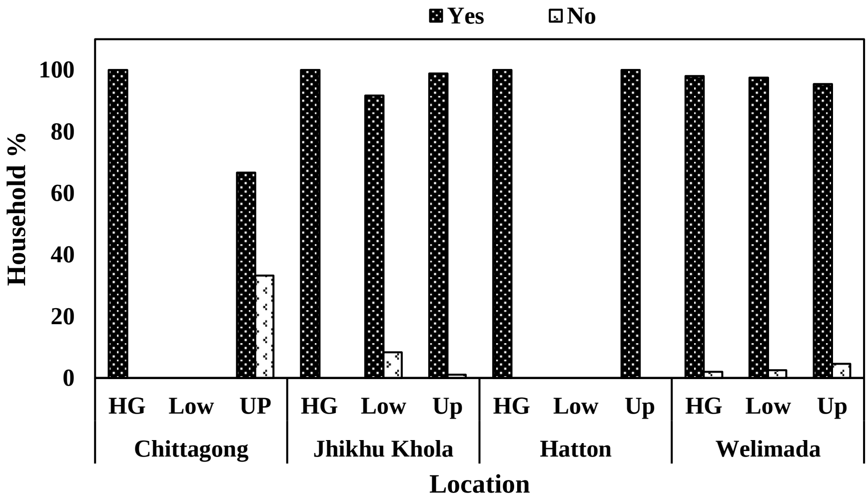

Figure 3.8: **Percentages of respondents who carry out self-cultivation of homegardnes (HG), lowland (Low) and upland (UP) in Chittagong (Bangladesh), Jhikhu Khola (Nepal), and Hatton and Welimada (Sri Lanka)**

Many of the respondents in each location cultivated their land by their own. A significant number of respondents in Chittagong did not cultivate their uplands on their own. Respondents in Hatton and Chittagong did not have lowlands to cultivate.

3.2.10 Use of Hired Labor

All respondents in Chittagong use household labour for their home gardens while all used hired labour for their upland cultivations. All respondents in Hatton did not use hired labour for their home gardens as well as upland cultivations. Further, all interviewees in Chittagong and Hatton did not have lowlands. Respondents in Jhikhu Khola and Welimada used hired labour and those from households (Figure 3.9 and Table 3.5).

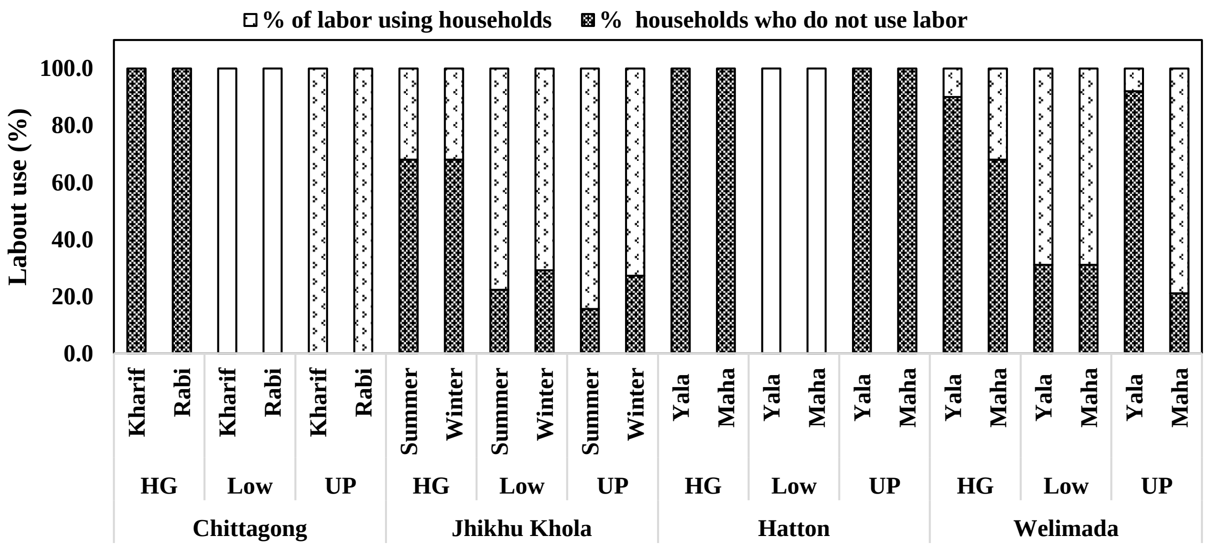

Figure 3.9: **Labour usage in *Kharif* and *Rabi* seasons of Chittagong in Bangladesh, Summer and Winter seasons of Jhikhu Khola in Nepal, *Yala* ans *Maha* seasons of Hatton and Welimada in Sri Lanka**

Table 3.5: **Percentage Households used Hired Labor**

Parameter	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
% households who do not use hired labour	0	8.7	100	8
% of households using hired labour	100	91.3	0	92

All respondent households in Chittagong using hired labour in at least one of the cultivation (home garden and upland) and at least in one season while all respondents in Hatton do not use hired labour in any type of cultivation evaluated in any given season. As the cultivated extent in Hatton is lower, they did not require hired labour and could manage using family labour. Majority of the households in Welimada and Jhikhu Khola used hired labour.

3.2.11 Average hired labour usage

Statistical analysis revealed that there the use of hired labour significantly differed between four locations with respect to average hired labour usage ($P<0.001$). The average hired labour usage was highest in Chittagong (173.2 hired labour days per household per year) and the lowest in Hatton (zero hired labour days per household per year). The average hired labour usage was high in Chittagong for upland cultivations. Respondents in Jhikhu Khola and Welimada have used hired labours in a similar manner. Chittagong farmers did not use hired labour in their home gardens and they do not have lowland cultivation. Further, respondents in Hatton did not have lowland cultivations and they did not use hired labour in their home gardens and uplands. The average labour usage in each location is expressed in Figure 3.10.

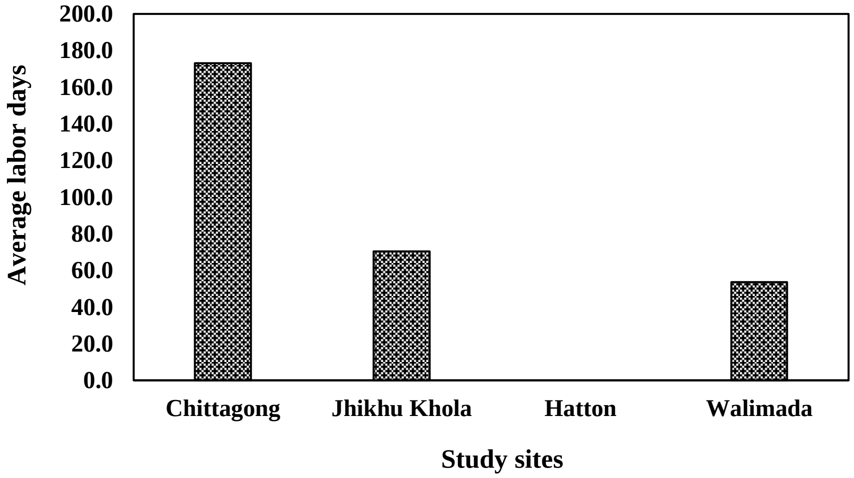

Figure 3.10: **Average labor usage of Chittagong in Bangladesh, Jhikhu Khola in Nepal, Hatton and Welimada in Sri Lanka**

3.2.12. Plant and Animal Inventory in the farming System

3.2.12.1. Cultivated extent

Statistical analysis revealed that there is a significant difference in cultivated extent among locations ($P<0.001$). Chittagong has the highest cultivation extent while the lowest cultivated extent is in Hatton. Average cultivated extent of each location is given in Table 3.6.

Table 3.1: **Average Cultivated Extent of Each Location**

Location		Cultivated Extent (m^2)
Bangladesh	Chittagong	20,084 ± 15,148[a]
Nepal	Jhikhu Khola	3,021 ± 1,656[c]
Sri Lanka	Hatton	89.8 ± 76[c]
	Welimada	16,530 ± 9.461[b]

Within a column Means with the same letters are not significantly different at p=0.05

3.2.12.2 Cropping system

Percentages of households who were cultivating sole crops and mixed crops among the respondents are illustrated in Figure 3.11.

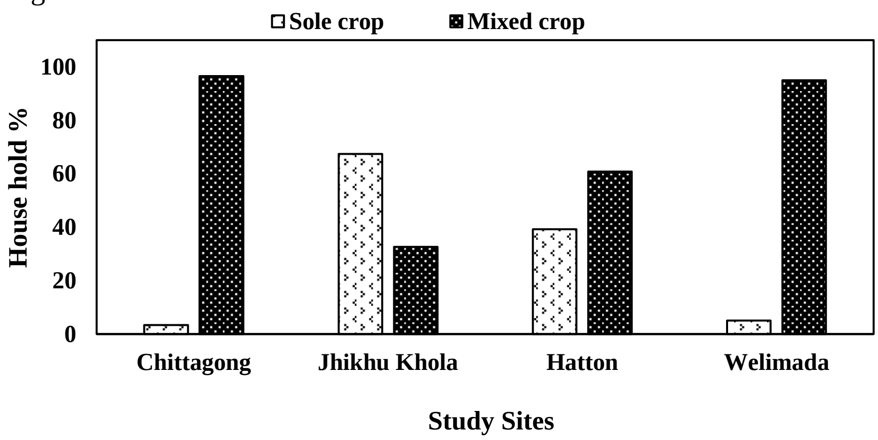

Figure 3.11: **Percentage farmers of the study sample using different cropping systems**

In Chittagong, 96.5 % of the respondent households have cultivated a mixed crop and only 3.4 % was cultivating sole crops. In Jhikhu Khola, a higher proportion of the farmers have cultivated sole crops while a higher proportion at Hatton were cultivating a mixed crop. Ninety five percent of respondents at Welimada have cultivated a mixed crop while only five percent have done sole crops.

3.2.12.3 Presence of Naturally Grown Plants

Percentage of households who have at least 3 naturally grown plants in their lands in each location is given in Figure 3.12. All the households in Jhikhu Khola have naturally grown plants in their lands. Lowest percentage can be seen in Chittagong while considerable number of households in Hatton and Welimada have naturally grown plants in their lands.

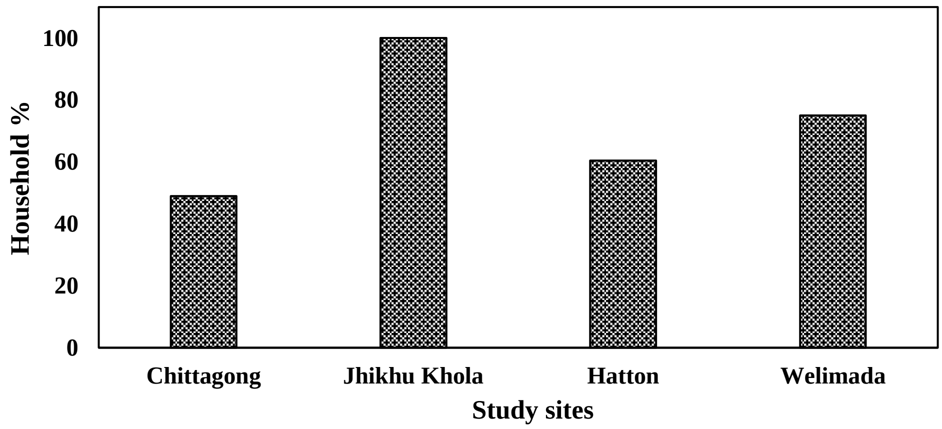

Figure 3.12: **Percentage of Households who have naturally grown plants in their lands**

3.2.12.4 Presence of Woody Trees

Percentage of household who have at least 3 woody trees in their lands in each location is given in Figure 3.13. All households in Chittagong and Hatton, 60% of Jhikhu Khola households and 81 % of Welimada households among interviewed households have at least 3 woody trees in their lands. Tree diversity of lands in Chittagong and Hatton sites are comparatively higher than 2 other locations.

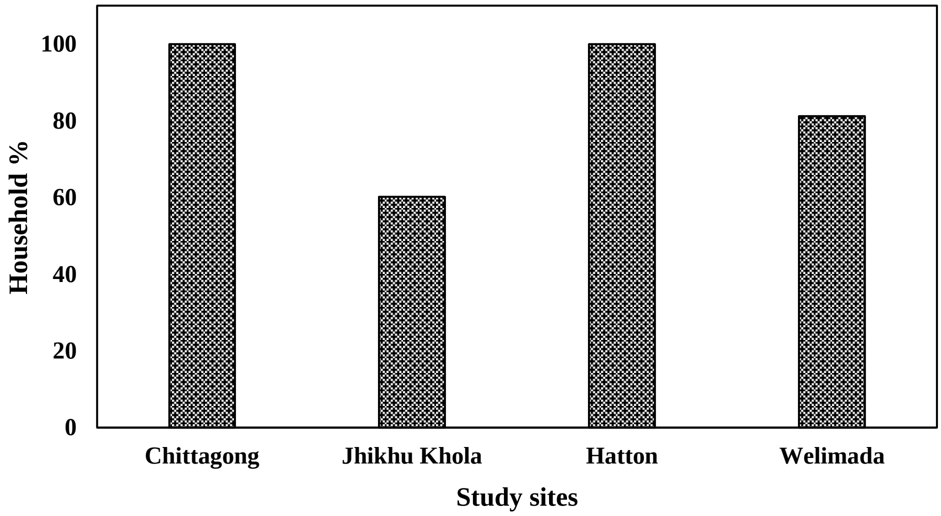

Figure 3.13: **Percentage of Households who have woody trees in their lands**

3.2.12.5 Animal Husbandry

Percentages of animal rearing households among interviewed households are expressed in Table 3.7. In Jhikhu Khola 98 % of the interviewed households are rearing animals while only 24% of interviewed households in Welimada are rearing animals recording the lowest among four locations due to more concentration on cultivations and depend on family labours.

Table 3.2: Percentage of Animal rearing households

Paramter	Bangladesh	Nepal	Sri Lanka	
	Chittagong	**Jhikhu Khola**	**Hatton**	**Welimada**
Household %	62.5	98.06	38.4	24

3.2.12.6 Animal species Diversification

The species diversification among animal-rearing households in each study site is expressed in Figure 3.14. In Chittagong 98 % of the respondent were rearing poultry while 8.3 % is rearing cattle and 30 % is rearing swine. Majority of the households in other three locations except Chittagong are rearing cattle than the poultry. Goat rearing can be observed in Jhikhu Khola and Hatton.

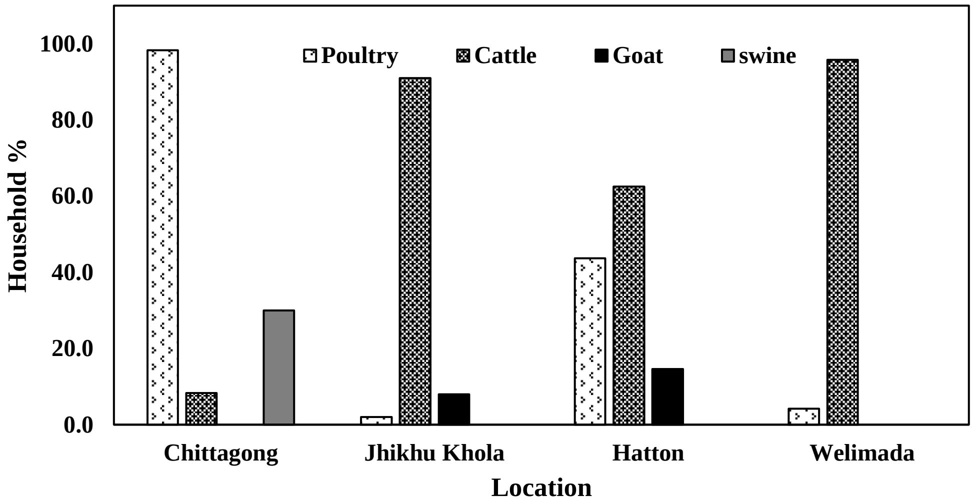

Figure 3.14: Animal species diversity in homegardens

3.2.12.7 Breed of the animals

Breed of animals that are reared in each location is illustrated in Figure 3.15 as a percentage among animal-rearing households.

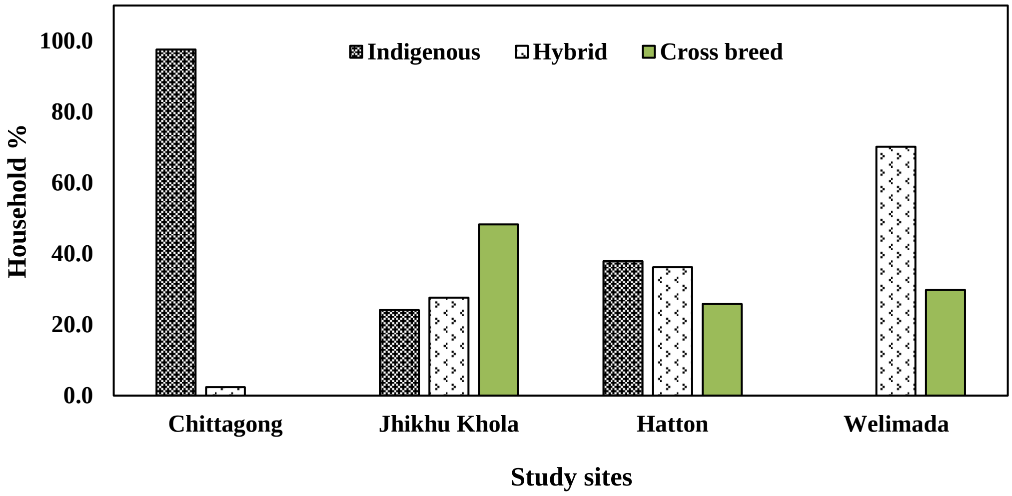

Figure 3.25: **Breed of the animals reared in homegardens**

In Chittagong 97.6 % of respondents were rearing indigenous animals and none of the responded households in Welimada had indigenous animals. Respondents in Jhikhu Khola and Hatton were rearing all three types of breeds.

3.2.12.8 System of Rearing Animals

There were three categories as extensive, intensive and semi-intensive. All interviewees in Chittagong animals are reared semi intensively. Extensive rearing can be seen only in Jhikhu Khola but majority of the interviewed households are intensively reared their animals. Large proportion of Hatton is rearing their animals intensively while large proportion of Welimada are rearing animals semi intensively. Percentages of households in those categories in four locations are shown in Figure 3.16.

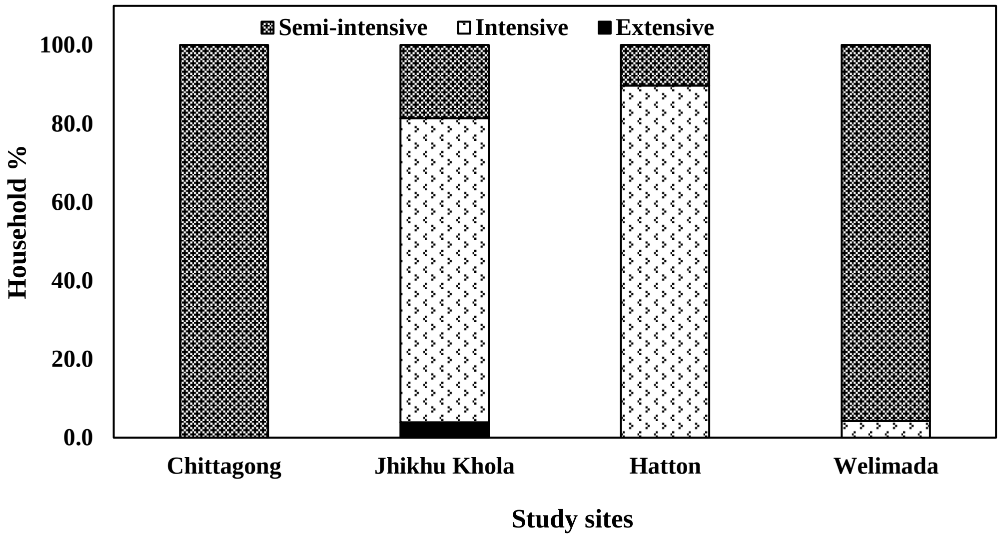

Figure 3.16: System of Rearing Animals

3.2.12.9 Method of Feeding Animals

Households that reared animals were categorized into five categories according to the method of feeding and illustrated as a percentage of animal-rearing households in Figure 3.17.

Majority of the responded households in Chittagong feed concentrates and majority of those in Jhikhu Khola and Hatton were practicing cut and fed method to feed animals. About 53% of respondent households Welimada were practicing cut and feed method while about 47% practiced concentrate feeding. Swill/waste feeding of animals was the highest recorded in Hatton.

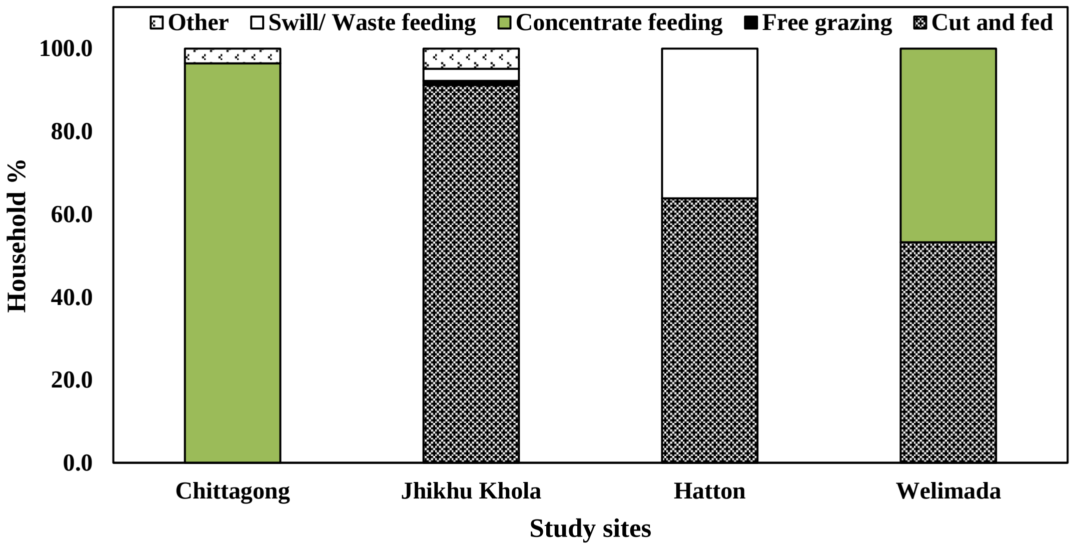

Figure 3.17: **Method of Feeding Animals**

3.2.13 Water and Soil Conservation Strategies

3.2.13.1 Water Usage

Households were grouped into three categories based on the water usage in the farming system as only rainfed, only irrigated, and both rainfed and irrigated (Figure 3.18). Among the households 99 % of Chittagong respondents had rainfed cultivations both in home gardens and uplands. They did not have lowland cultivations. All respondents in Hatton were cultivating under rainfed and irrigation but did not have lowland cultivations as described previously. In Jhikhu Khola, a higher proportion of respondents were cultivating their home gardens and uplands only as rainfed while majority of the lowlands were under rainfed and irrigattion. In Welimada, the majority of the home gardens were only rainfed while lowlands and uplands were rainfed & irrigated.

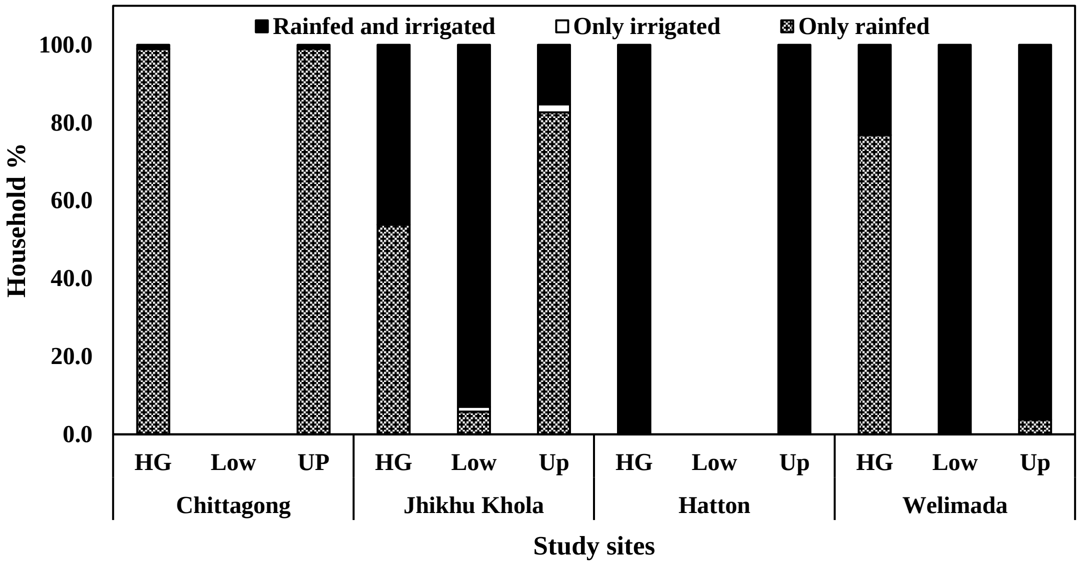

Figure 3.18: Water Usage in Farming Systems in study sites

One household among the respondents in Chittagong, which practiced both rainfed and irrigated cultivation was using a rainwater harvesting tank for home garden and tube well for upland cultivations. In Jhikhu Khola the majority of the households used other water sources to irrigate their cultivations. Majority of the households in Hatton used stream water for their home gardens and upland cultivations. All households in Welimada who irrigated their cultivations use dug well water to irrigate their uplands and water from irrigation scheme used to irrigate low lands while different water sources are used to irrigate their home gardens.

3.2.13.2 Practicing of soil and water conservation methods

Percentages of households who practiced soil and water conservation methods in each study site are illustrated in Figure 3.19.

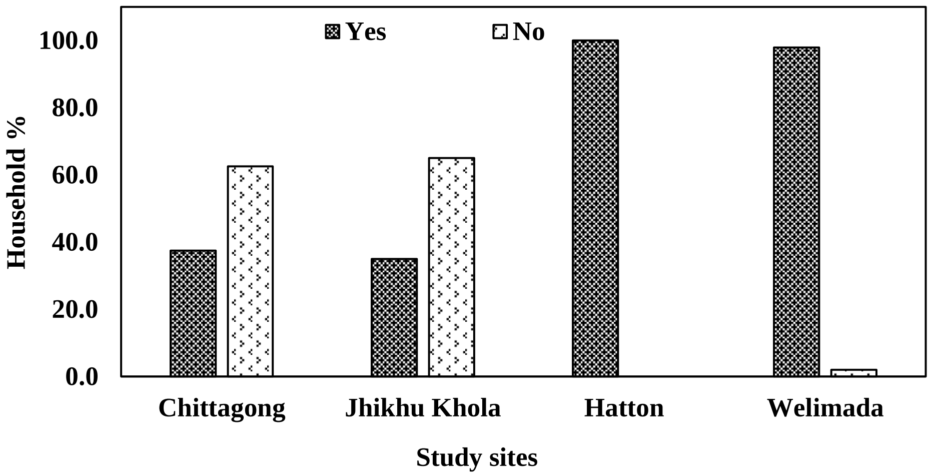

Figure 3.19: **Percentages of households who are practicing soil and water conservation methods**

Majority of the households in Chittagong and Jhikhu Khola were not practicing soil and water conservation methods while almost all households in Hatton and Welimada practiced soil and water conservation methods.

3.2.13.3 Soil and Water Conservation methods

Among households who practiced soil and water conservation methods, percentages of households who practice different soil and water conservation methods in each location is given in Table 3.8. In all locations, there are households who practiced more than one soil and water conservation methods.

Table 3.3: **Percentages of households who are practicing different soil and water conservation methods**

Soil and water conservation methods	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
Cover cropping	0.235	0.267	0.352	0.22
Mulching	0.865	0.256	0.428	0.4
Lock and spill drains	0	0.183	0.176	0.35
Stone bunds	0	0.528	0.312	0.43
Salt system	0	0.194	0.402	0.35
Other	0	0.033	0.08	0.06

3.2.14 Fertilizer Management

Households were categorized into three categories based on the type of fertilizer that they used in their cultivations as inorganic fertilizer only, organic fertilizer only and both organic and inorganic fertilizer (Table 3.9). Compost, cattle manure and poultry manure were considered as organic fertilizers.

Table 3.4: **Percentages of households based on the type of fertilizer used**

Type of fertilizer	Bangladesh	Nepal	Sri Lanka	
	Chittagong (%)	Jhikhu Khola (%)	Hatton (%)	Welimada (%)
Inorganic only	97	42.7	19.2	71
Organic only	3	12.6	5.6	9
Inorganic + Organic	0	44.6	75.2	20

Majority of the households in Chittagong were using only inorganic fertilizers while the majority in Hatton were using both inorganic and organic fertilizers for their crops. The results and the other details provided during interviews revealed that the majority of households knew the benefits of integrated fertilizer management.

3.2.15 Land Use Pattern in the Farming System

3.2.15.1 Slope of the Land

Percentages of households based on the slope category of the land for each cultivation in each location is illustrated in Figure 3.20. Among the study sample in Chittagong, 86.5 % had moderate slope, 12.5 % have steep slope and did not have undulating land or flat lands home gardens or in upland cultivations. Among the upland cultivations in Chittagong site, 96 % had steep slopes. All home gardens in Jhikhu Khola were undulating lands, while all lowland cultivations were in flat lands and almost all upland cultivations had moderate slope. Majority of the home gardens and uplands in Hatton had steep slopes. In Welimada, the majority of the home gardens, uplands and low lands had a moderate slope, 23 % of home gardens and 8.6 % of low lands were in flat lands while 15 % of uplands had steep slope.

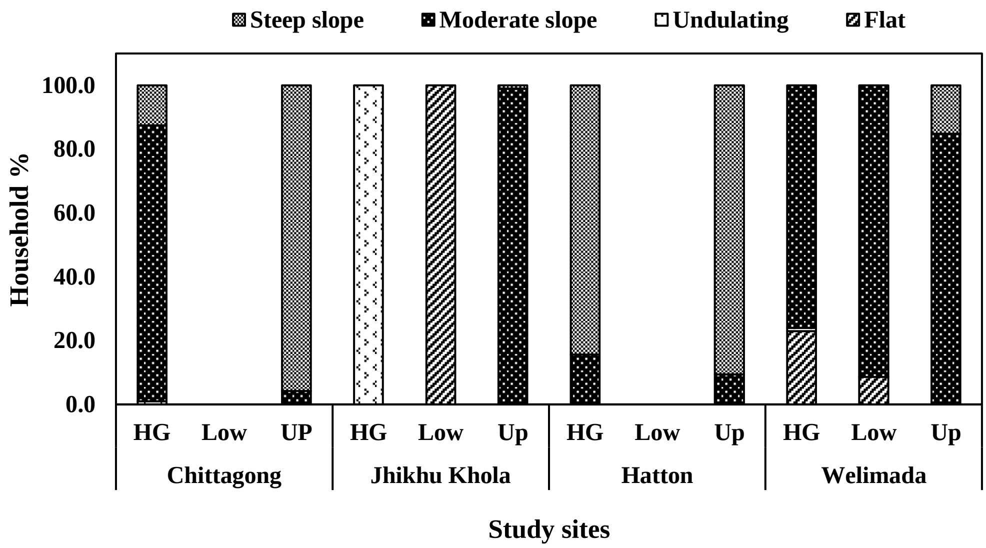

Figure 3.20: **Percentages of households based on the slope category**

3.2.15.2 Fertility Status of the Soil

According to the observations by the trained enumerators, all lands in Chittagong were non-fertile and all lands in Hatton were fertile. About 40 % of home gardens in Jhikhu Khola were non-fertile while the rest of the lands were fertile. More than 50 % of the home gardens, low lands and uplands in Welimada had fertile soil. Summary of the fertility status of the soil is given in Figure 3.21 based on the perception of the enumerators.

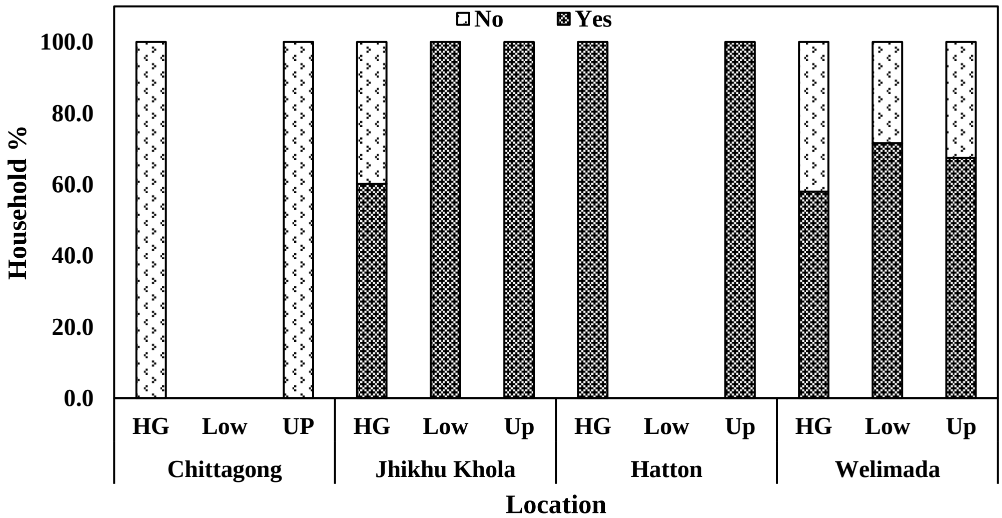

Figure 3.21: Fertility status of soil in home gardens, lowlands and uplands.
Note; The observations are based on perception of trained enumerators (Yes = fertile, No- not-fertile)

3.2.16 Climate Change Adaptation Strategies

3.2.16.1 Noticed changes in the Climate

Awareness of the households about changes in the climate in the area that they live is summarized in Table 3.10 as a percentage of total respondent households.

Table 3.5: **Percentages of households who noticed changes in Climate**

Changes Observed in the climate	Bangladesh	Nepal	Sri Lanka	
	Chittagong (%)	Jhikhu Khola (%)	Hatton (%)	Welimada (%)
Yes	100	72.8	100	100
No	0	16.5	0	0
No idea	0	10.7	0	0

All respondents in Chittagong, Hatton and Welimada have noticed the changes in the climate. Among the respondent households in Jhikhu Khola, 73 % had noticed the changes, 16.5 % have not noticed the changes while 11 % had no idea about changes in the climate.

3.2.16.2 Significant changes in the farming system

All respondents in Chittagong and Hatton have noticed significant changes in the farming system. Only 63 % of respondents in Jhikhu Khola have noticed the changes in farming system, 33 % had no idea about the changes in farming system and 5 % have not noticed the changes in the farming systems. Among the households in Welimada, 94 % have noticed the changes in farming system while 2 % did not notice the changes and 4% did not have idea about the changes in farming system. Awareness of the households about changes in the farming system in the area that they live is summarized in Table 3.11 as a percentage of total interviewed households.

Table 3.6: **Percentages of households who noticed changes in Farming system**

Response	Bangladesh	Nepal	Sri Lanka	
	Chittagong (%)	Jhikhu Khola (%)	Hatton (%)	Welimada (%)
Yes	100	63	100	94
No	0	5	0	2
No idea	0	32	0	4

3.2.17 Food Consumption Pattern

Amount of different food items monthly consumed by each household in each location was considered and means of each food item consumed by the households are shown in Table 3.12.

Table 3.7: **Average monthly consumption of food items**

Food items	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
Rice (kg)	54.06	72.72	30.94	52.14
Finger millet (kg)	0	4.3	0	1.11
Wheat (kg)	0	17.57	29.36	2.62
Other cereals ((kg)	0	19.18	3.16	4.13
Vegetables (kg)	7.34	20.79	13.98	21.42
Leafy vegetables (kg)	2.31	1.31	4.18	4.59
Meat (kg)	2.59	0.9	3.01	3.74
Eggs (No.)	21	1	25	17
Fruits (kg)	1.91	32.35	6.3	4.44

In all four locations, the major cereal consumed was rice. The highest average rice monthly consumption was observed in Jhikhu Khola. The lowest monthly rice consumption was recorded in Hatton with the highest wheat consumption. Vegetables and leafy vegetables consumption was the highest in Welimada. The lowest vegetable consumption was observed in Chittagong and the lowest leafy vegetable consumption was in Jhikhu Khola. Households in Welimada consumed high amount of meat, followed by Hatton, Chittagong and Jhikhu Khola. The highest egg consumption was in Hatton while the lowest was in Jhikhu Khola. Households in Jhikhu Khola consumed a high amount of fruits compared to other locations. The lowest fruit consumption was reported in Chittagong.

3.2.18 Income and Expenditure in Household

3.2.18.1 Average Income

The highest average income per household was reported in Welimada while the lowest was observed in Chittagong. However, the statistical analysis revealed that there is no difference in the average income ($P<0.05$). The average income of the households is shown in Table 3.13.

Table 3.8: Average Income of the Households

Location		Average Income (USD / Month)
Bangladesh	Chittagong	207.5 ± 134.5[a]
Nepal	Jhikhu Khola	201.7 ± 163.1[a]
Sri Lanka	Hatton	221.66 ± 105.95[a]
	Welimada	255.7 ± 199.5[a]

Within a column, means followed by the same letters are not significantly different at p = 0.05

3.2.18.2 Average monthly expenditure

The average monthly expenditure of the households in each location is given in Table 3.14. The highest average monthly expenditure was reported in Welimada and the lowest in Chittagong.

Table 3.9: **Average monthly expenditure of the Households**

Location		Average Expenditure (USD / Month)
Bangladesh	Chittagong	151.84 ± 89.99[a]
Nepal	Jhikhu Khola	145.43 ± 86.05[a]
Sri Lanka	Hatton	171.24 ± 76.59[a]
	Welimada	241.1 ± 237.7[a]

Within a column, means followed by the same letters are not significantly different at p = 0.05

3.2.19 Market

3.2.19.1 Marketing of output

Almost all the households were marketing their products while only 2 % of Jhikhu Khola households did not market their products. Proportions of households who market their products in each location is given in Table 3.15.

Table 3.10: Percentage of households who market their products

Marketing of products	Bangladesh	Nepal	Sri Lanka	
	Chittagong (%)	Jhikhu Khola (%)	Hatton (%)	Welimada (%)
Yes	100	98	100	100
No	0	2	0	0

3.2.19.2 Distance to market

Households were grouped into four categories based on the distance to markets as <1 km, 1-5 km, 5-10 km and > 10 km (Figure 3.22).

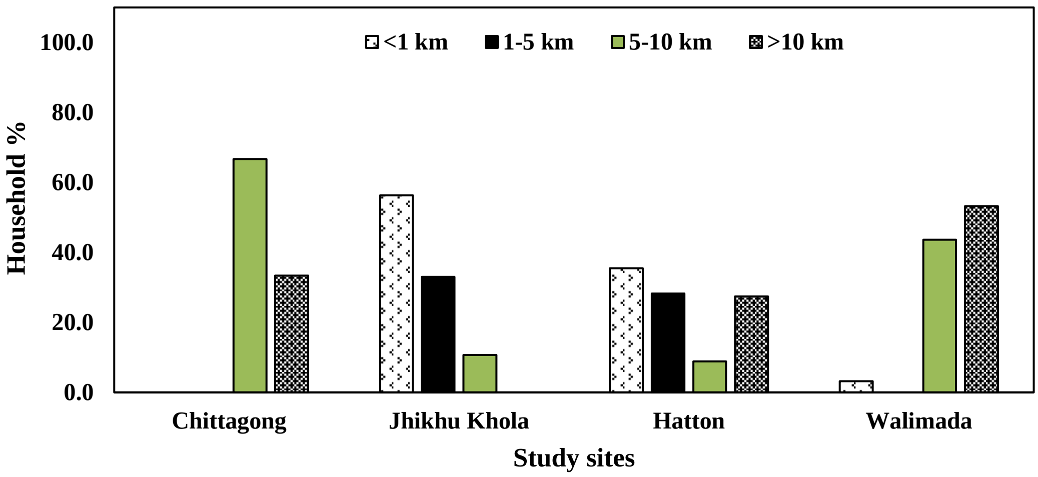

Figure 3.22: **Percentage of households in each category of market distance.**

In Chittagong, the distance to market was 5-10 km for 67 % of households and for rest it was >10 km. In Jhikhu Khola all households had to travel <10 km to markets. Among them 56.3% have less than 1 km distance. In Hatton, households were found under all categories, where the highest proportion is observed in <1 km category and lowest proportion is in 5-10 km category. Nearly equal proportions were in 1-5 km category and >10 km category. Respondents in Welimada did not have markets in 1-5 km distance while majority of them had markets in >10 km distance, 43 % of households had to travel 5-10 km distance for the market and only 3 % of households had markets at <1 km distance.

3.2.19.3 Presence of Middleman

Majority of the respondents in Chittagong and Jhikhu Khola and all in Welimada had the influence of middleman while the majority (94 %) in Hatton did not obtain the support of a middleman when marketing their products (Table 4.16).

Table 3.11: Percentage of households based on the presence of middleman

Support of a middleman to market products	Bangladesh	Nepal	Sri Lanka	
	Chittagong (%)	Jhikhu Khola (%)	Hatton (%)	Welimada (%)
Yes	91	87	6	100
No	9	13	94	0

3.2.19.4 Availability of Storage Facilities

All households in Chittagong and Welimada had their own storage facilities and majority of the households in Jhikhu Khola and Hatton did not have storage facilities (Figure 3.23).

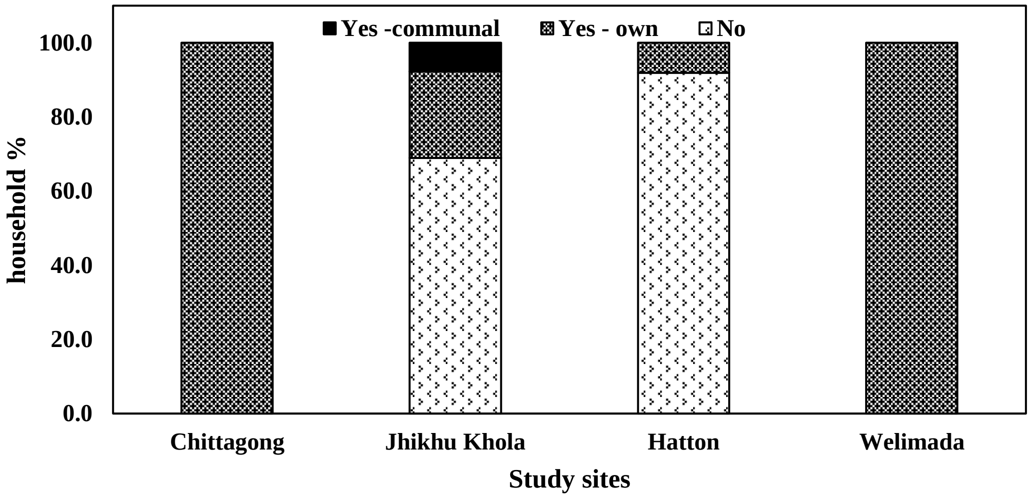

Figure 3.33: **Availability of storage facilities**

All households in Chittagong and Welimada had own storage facilities and majority of the households in Jhikhu Khola and Hatton do not have storage Facilities.

3.2.20 Enumerator's Observations

Construction material of the wall, major material of the roof, type of toilet, necessity of conservation of soil in the farming system, practicing of integrated farming and the type of integrated farming were compared among four locations based on the enumerator's observation.

3.2.20.1 Major construction material of the wall of homes

Households in each location were compared based on the construction materials of the wall. As illustrated in Figure 3.24, all households in Hatton and majority of the households in Welimada had constructed their walls in homes using bricks. Majority of the households in Jhikhu Khola have construct their walls using mud and in Chittagong, majority have used other construction materials.

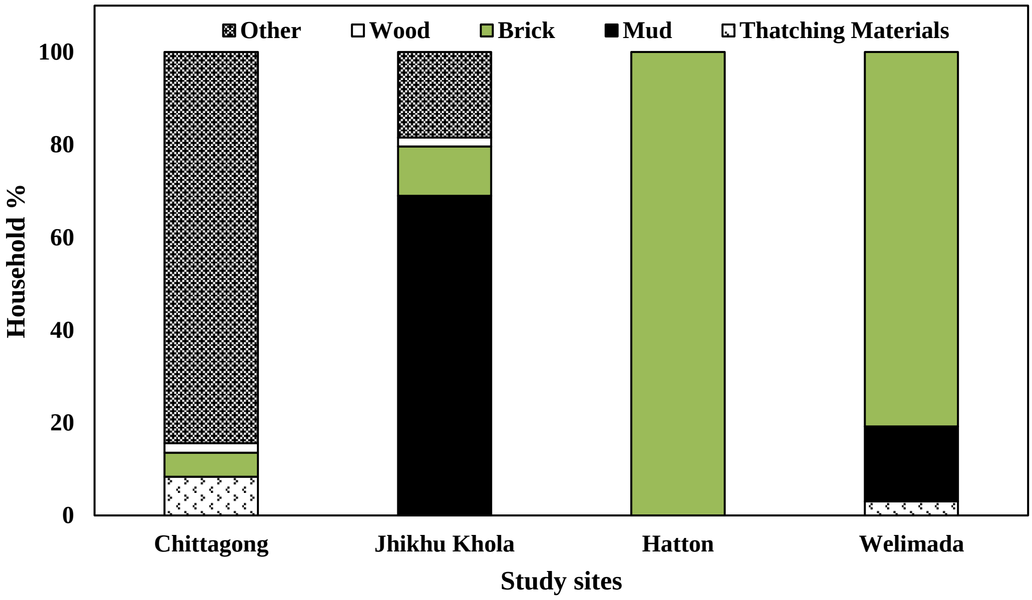

Figure 3.24: **Major construction material of the wall**

3.2.20.2 Major construction material of the Roof in homes

As illustrated in Figure 3.25, tin was the major material of the roof of all households in Chittagong and Hatton. Ten percent of households in Jhikhu Khola had asbestos sheets as their roofing material while majority of the households in Welimada have used sheets as the roofing material and 27 % of households have used tile for roofing.

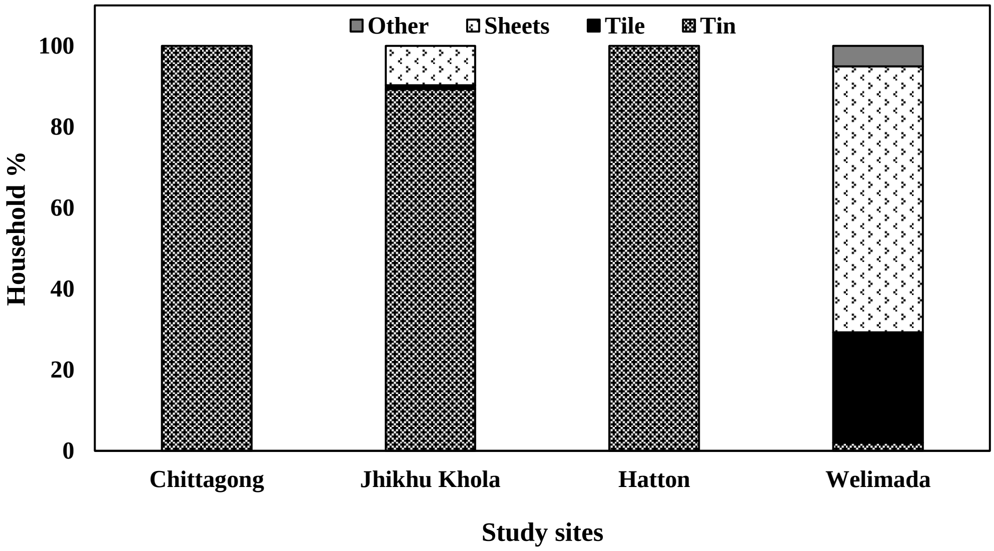

Figure 3.45: **Major construction material of the Roof**

3.2.20.3 Type of Toilet

As shown in Figure 3.26, all households in Hatton and Welimada had septic tanks. In Chittagong, majority of the households were using other types of toilets and only 3 % had open pit type of toilets. Using outside/land can be seen only in Jhikhu Khola (7 % of the total respondents), while 91 % is having septic tanks.

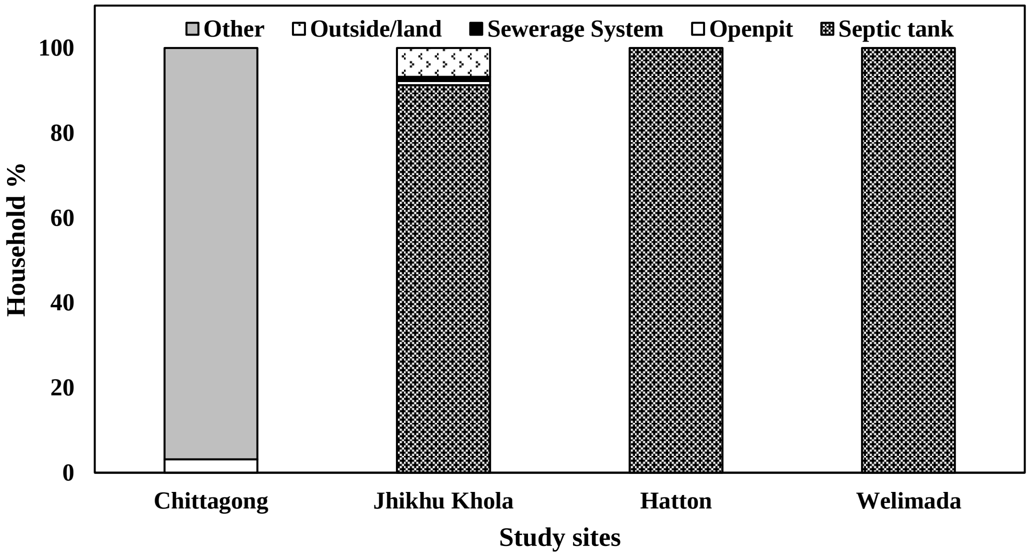

Figure 3.26: **Type of Toilet in homesteads**

3.2.20.4 Practice of integrated Farming

Percentage of households who practiced integrated farming among the respondent households in each study site is given in Figure 3.27.

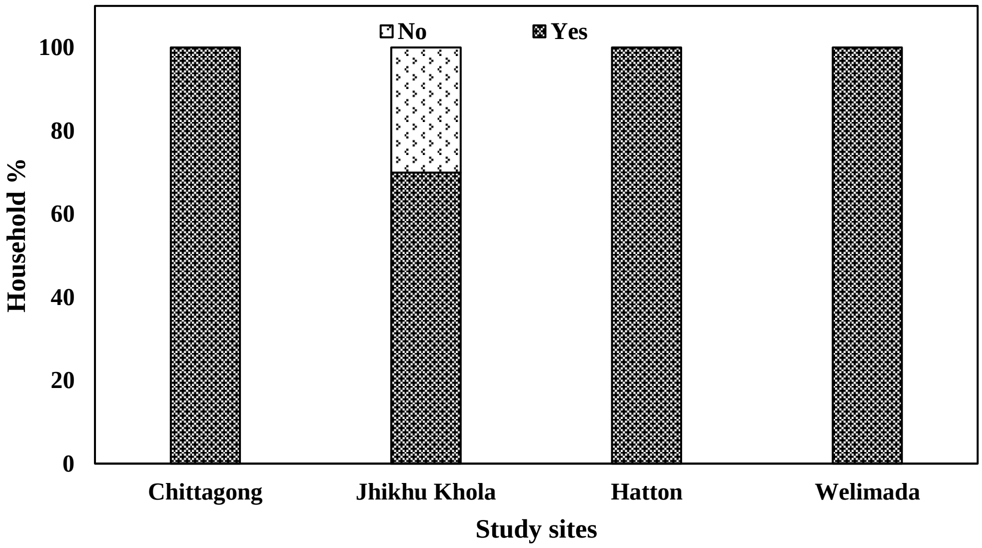

Figure 3.27: Percentage of households who practice integrated farming

All respondent households in Chittagong, Hatton and Welimada were practicing integrated farming while only 70% in Jhikhu Khola are practicing integrated farming.

3.2.20.5 Type of Integrated farming

Figure 3.28 illustrates shows the diversity of integrated farming practices among households in each study site as a percentage of households who practiced integrated farming.

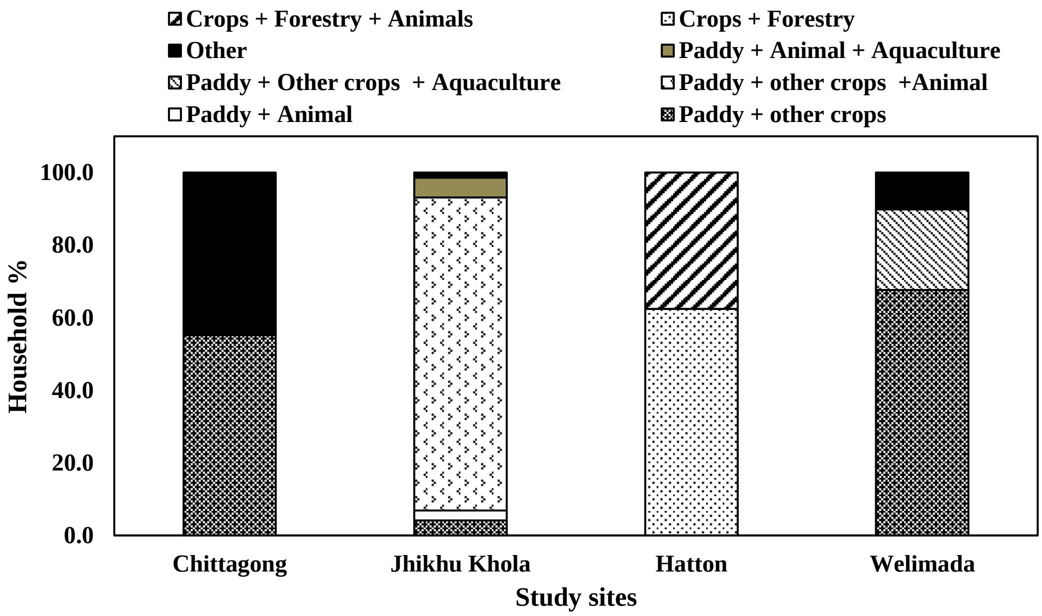

Figure 3.28: **Percentage of households who practiced different integrated farming methods**

In Chittagong 55 % of households are integrating paddy and other crops while rest of the households are practicing other integrated farming methods, which are not indicated in the list given in the questionnaire. Majority of the Households in Jhikhu Khola were integrating paddy, other crops and animals. Among the respondent households In Hatton, 62.4 % were integrating crops with forestry while rest of the households had integrated crops, forestry and animals. In Welimada the majority had integrated paddy and other crops, 22 % paddy, other crops and aquaculture and 10 % used other integrating methods which are not listed here.

3.3. Climate Projections

In this study, NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) of 6 GCM models namely CanESM2, CNRMCM5, CSIRO-MK3-6-0, GFDL-CM3, MRI-CGCM3 and NCAR-CCSM4 (Expressed in Table 3.17) with 25 km grid spacing were selected to develop future projections based on the findings of Herath and Jayawardena (2017). Projections were made for changes in number of precipitation extremes from 2011 to 2100 with a significance level of 5% using those 6 GCM models for both RCP 4.5 and RCP 8.5 scenarios and discussion was made based on the ensemble mean of 6 GCM models of RCP 4.5 scenario.

Table 3.17: General circulation models used in the study

CanESM2	The Second Generation Coupled Global Climate Model Canadian Centre for Climate Modelling and Analysis (2.8*2.8)
CNRM-CM5	National Centre for Meteorological Research/ Meteo-France (1.4 * 1.4)
CSIRO-MK3-6-0	Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Queensland Climate Change Centre of Excellence (QCCCE). (1.895*1.875)
GFDL-CM3	GeoPhysical Fluid Dynamic Laboratory NOAA, USA Coupled Climate Model (2 * 2.5)
MRI-CGCM3	Global Climate Model of the Meteorological Research Institute, Japan (1.132*1.125)
NCAR-CCSM4	National Center for Atmospheric Research, USA Coupled Climate Model (0.942 * 1.25)

Bangladesh has a tropical to subtropical monsoon type climate characterized by rainfalls varying widely seasonally, high temperature and humidity. Annually, the average rainfall within the country varies between 1500 mm and 4300 mm from the northwest to the northeast. In addition, annual and seasonal variability of rainfall is very high (Alamgir *et al*. 2019). More than 75% of the rainfall in Bangladesh occurs during the monsoon season (Alamgir *et al*. 2015). Khan *et al*. (2019) found that the average monthly maximum temperature (T_{max}) and minimum temperature (T_{min}) have increased significantly by 0.35 °C/decade and 0.16 °C/decade, respectively while the monsoonal and annual precipitation have decreased by 87.35 mm/decade and 107 mm/decade, respectively during the period from 1988 to 2017.

Future projections shows that there will be a little increment in extreme events in *Kharif* I season and *Rabi* season while slight reduction of extreme events in *Kharif* II season over the years. The changes in extreme precipitation events in *Kharif* I, *Kharif* II and *Rabi* seasons are expressed in Figures 3.29, 3.30, and 3.31, respectively. However, according to the findings number of extreme events in *Kharif* I and *Kharif* II seasons will be increased by 13% and 7% respectively while 42.8 % reduction in *Rabi* season in 2051-2060 decade compared to the 2011- 2020 decade.

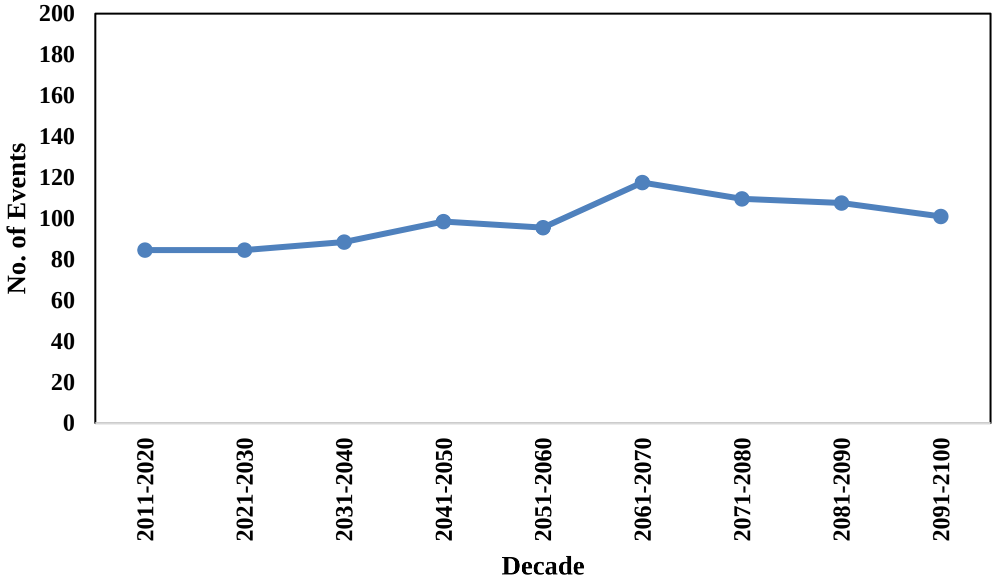

Figure 3.29: Changes in precipitation extremes from 2011 to 2100 in *Kharif I* season of Chittagong

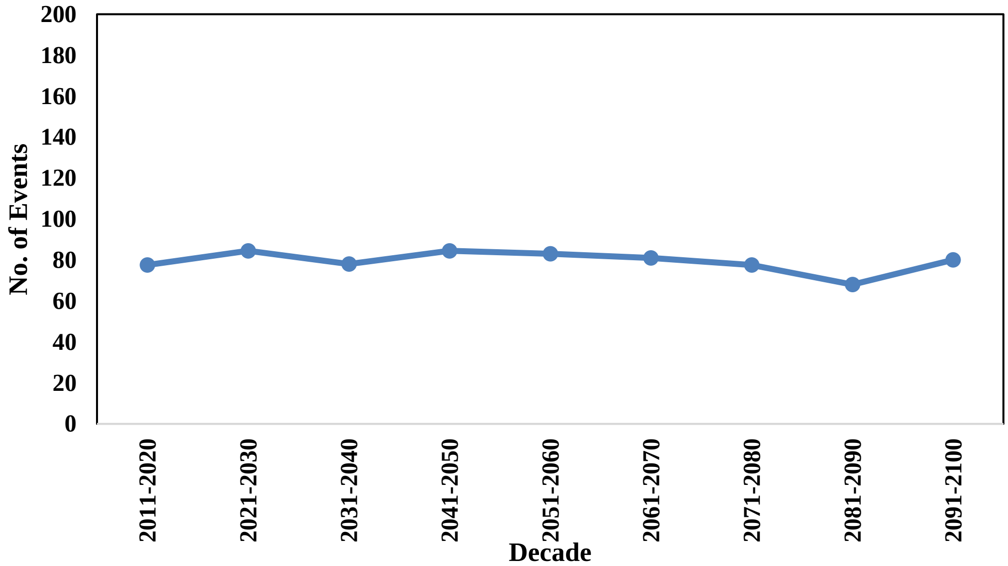

Figure 3.30: Changes in precipitation extremes from 2011 to 2100 in *Kharif II* season of Chittagong

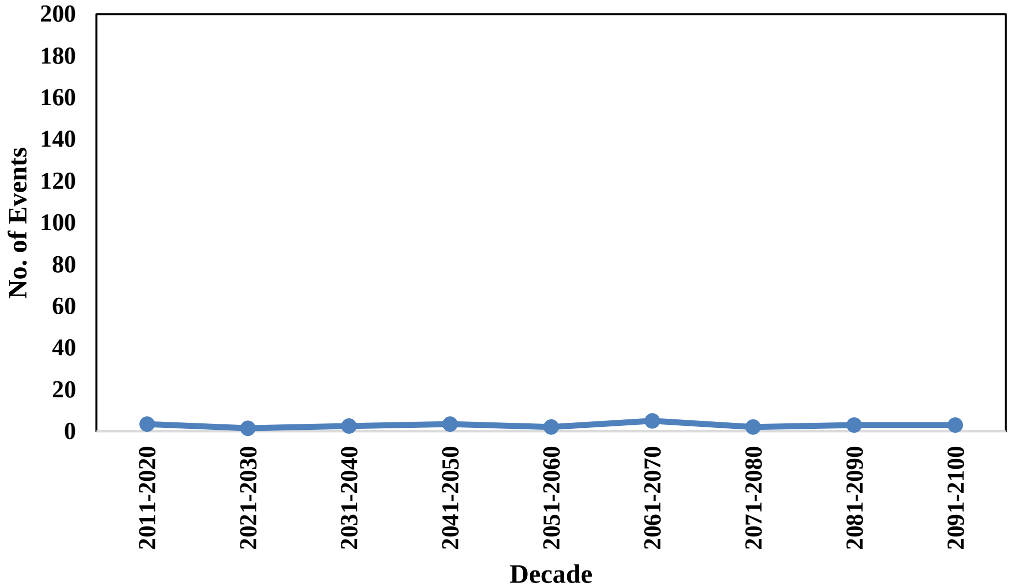

Figure 3.31: **Changes in precipitation extremes from 2011 to 2100 in *Rabi* season of Chittagong**

In Nepal, there are different climates such as temperate climate, polar climate, cold climate, arid climate and the sub-climate types such as temperate climate with dry winter and warm summer, temperate climate with dry winter and hot summer, cold climate with dry winter and cold summer, cold climate with dry winter and warm summer, polar frost climate, polar tundra climate, and arid cold steppe climate due to complex topographical conditions which produce substantial spatial variation in variables such as local radiation, air temperature, and precipitation pattern (Karki *et al*. 2015). Further, Nepal receives the precipitation by two major weather systems. During the monsoon season, the southwest monsoon greatly impacts the southeastern parts of the country while the western disturbances predominantly affect the northwestern high mountainous parts during the winter season (Karki *et al*. 2017)

As stated by Ghimire, (2019), maximum temperature was found to be increasing by 0.05°C/year and minimum temperature was found to increase by 0.03°C/year. Though the trend of precipitation in Nepal is not clear like temperature, most of the studies have concluded increasing in monsoon precipitation in coming years.

Future projections shows that there will be a little increment in extreme events in winter season, pre-monsoon season and monsoon season while slight reduction of extreme events in post-monsoon season. The changes in extreme precipitation events in winter season, pre-monsoon season, monsoon season and post-monsoon season are expressed in Figure 3.32, 3.33, 3.34 and 3.35, respectively. However, according to the findings number of extreme events in winter season, pre-monsoon season and monsoon season and post-monsoon season will be increased by 500%, 53.6%, 24% and 43% respectively in 2051-2060 decade compared to the 2011- 2020 decade.

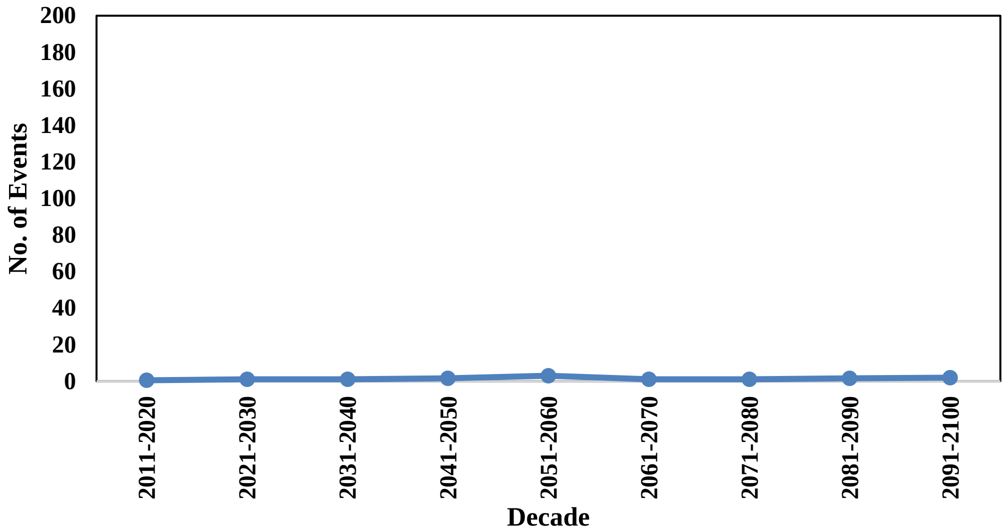

Figure 3.32: Changes in precipitation extremes from 2011 to 2100 in *Winter* season of Jhikhu Khola

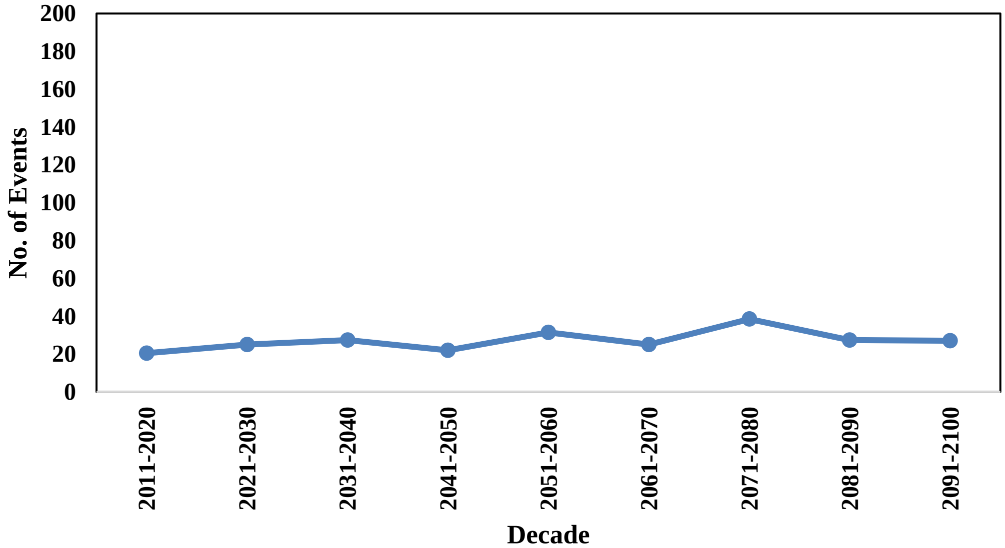

Figure 3.33: Changes in precipitation extremes from 2011 to 2100 in Pre- monsoon season of Jhikhu Khola

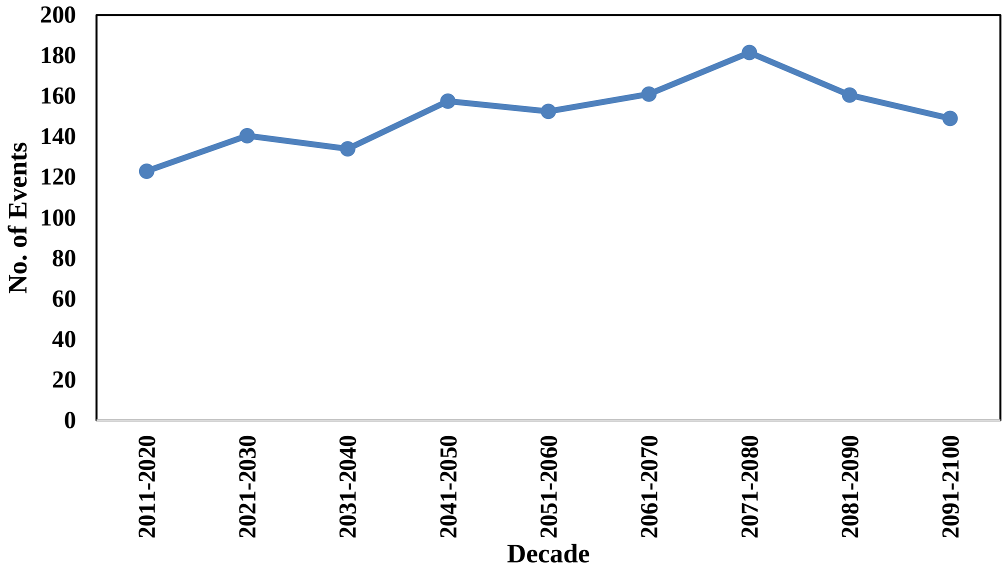

Figure 3.34: Changes in precipitation extremes from 2011 to 2100 in Monsoon season of Jhikhu Khola

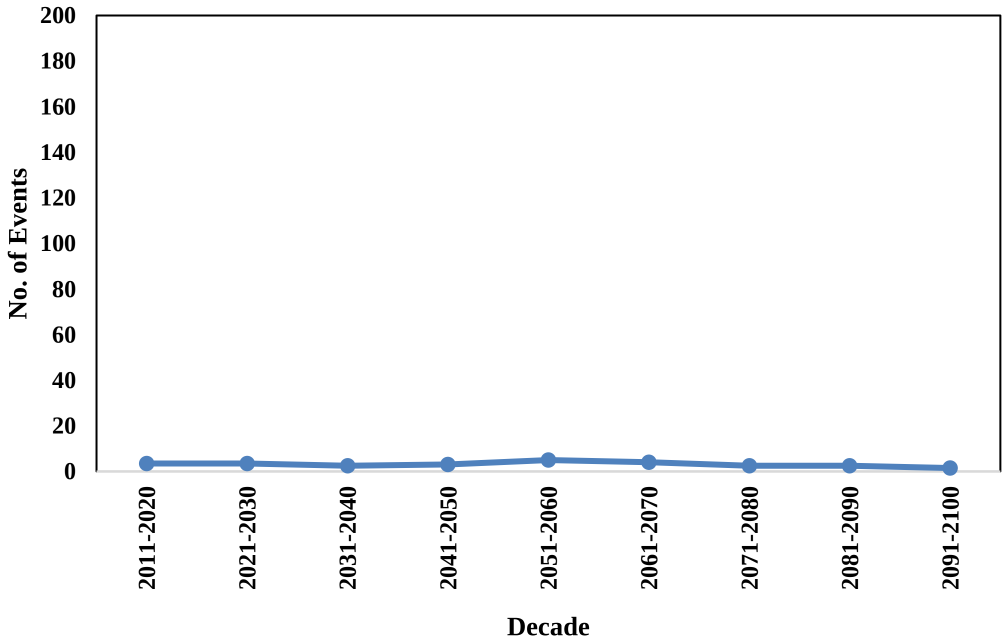

Figure 3.35: Changes in precipitation extremes from 2011 to 2100 in Post-monsoon season of Jhikhu Khola

Sri Lanka has a tropical monsoonal climate with a marked seasonal variation of rainfall. The mean annual rainfall varies from under 900mm in the driest parts to over 5000 mm in the wettest parts and the mean annual temperature various between 26.5 °C to 28.5 °C, with an annual temperature of 27.5 °. The topographical features of the country strongly affect the spatial patterns of winds, seasonal rainfall, temperature, relative humidity and other climatic elements, particularly during the monsoon seasons (NAP, 2014).

Nissanka *et al*. (2011) stated that there is no significant change in annual or seasonal rainfall of major climatic zones in Sri Lanka during the period of 1961-2010 and the variability of seasonal rainfall during the most recent decade (2001-2010) has increased compared to the previous decade (1991-2000) in most places of the island across all three climatic zones.

Future projections shows that there will be an increment in extreme events in all the climatic seasons in both Hatton and Welimada. The changes in extreme precipitation events in Hatton for first inter-monsoon, Southwest monsoon, second inter-monsoon and Northeast monsoon season are expressed in Figure 3.36, 3.37, 4.38 and 3.39, respectively. According to the findings number of extreme events in first inter-monsoon, Southwest monsoon, second inter-monsoon and Northeast monsoon season will be increased by 12.9%, 31.9%, 49.6% and 44.8% respectively in 2051-2060 decade compared to the 2011-2020 decade.

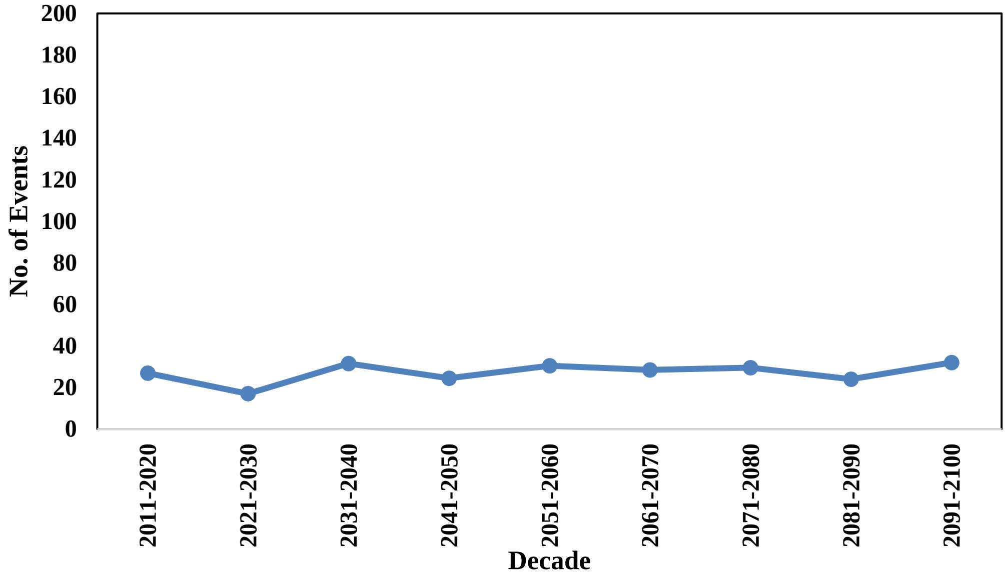

Figure 3.36: Changes in precipitation extremes from 2011 to 2100 in First Inter-monsoon of Hatton

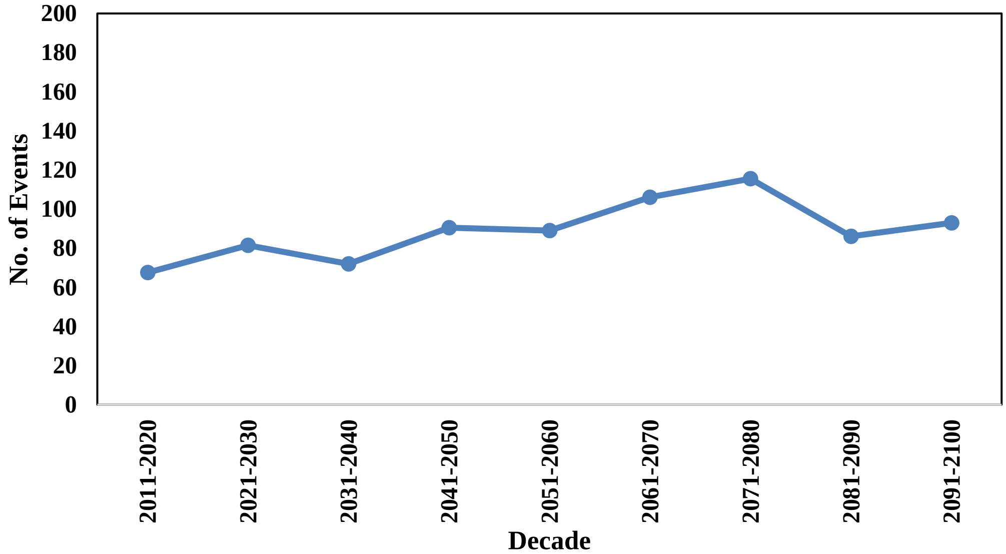

Figure 3.37: Changes in precipitation extremes from 2011 to 2100 in Southwest Monsoon of Hatton

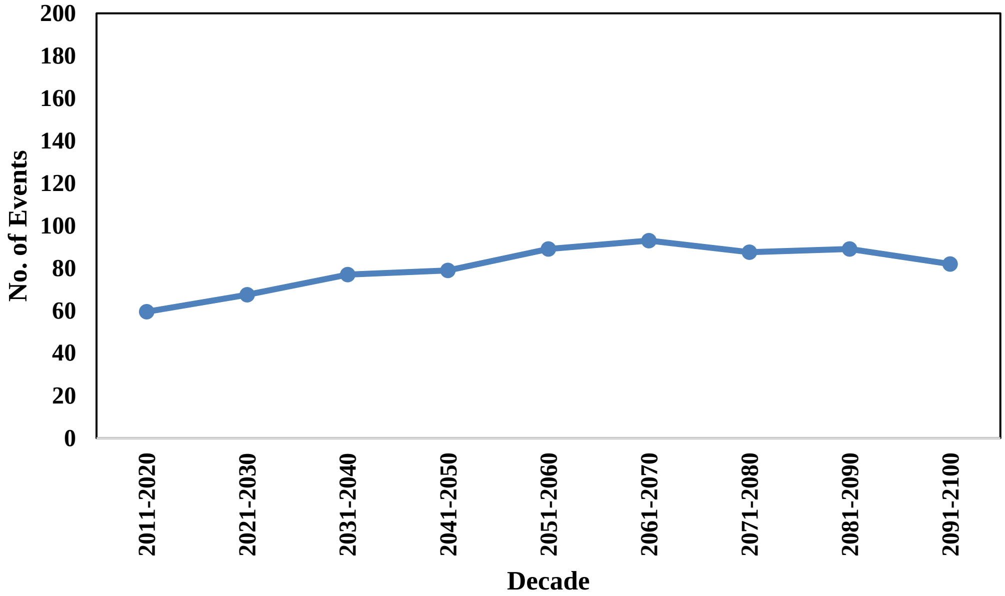

Figure 3.38: Changes in precipitation extremes from 2011 to 2100 in Second Inter-monsoon of Hatton

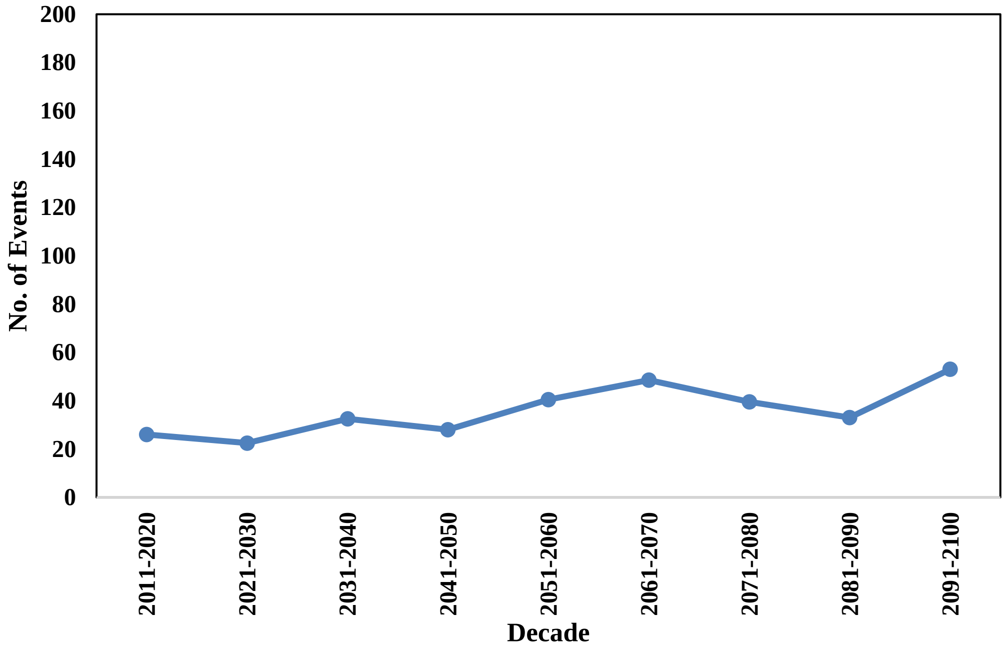

Figure 3.39: Changes in precipitation extremes from 2011 to 2100 in Northeast Monsoon of Hatton

The changes in extreme precipitation events in Welimada for first inter-monsoon, Southwest monsoon, second inter-monsoon and Northeast monsoon season are expressed in Figure 3.40, 3.41, 3.42 and 3.43, respectively. According to the findings number of extreme events in first inter-monsoon, Southwest monsoon, second inter-monsoon and Northeast monsoon season will be increased by 26.5%, 28.2%, 38.9% and 38.7% respectively in 2051-2060 decade compared to the 2011- 2020 decade.

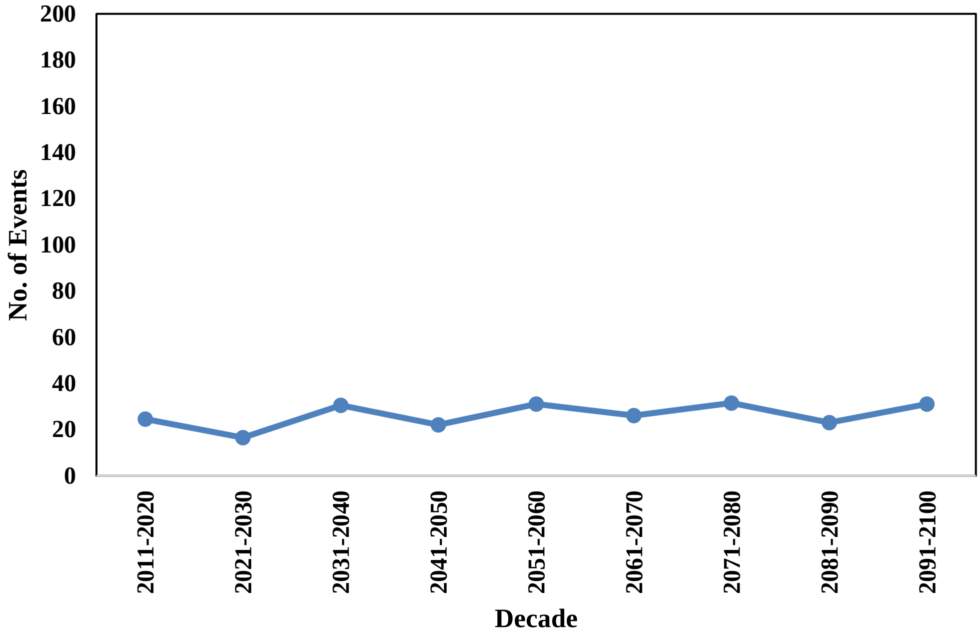

Figure 3.40: Changes in precipitation extremes from 2011 to 2100 in First Inter-monsoon of Welimada

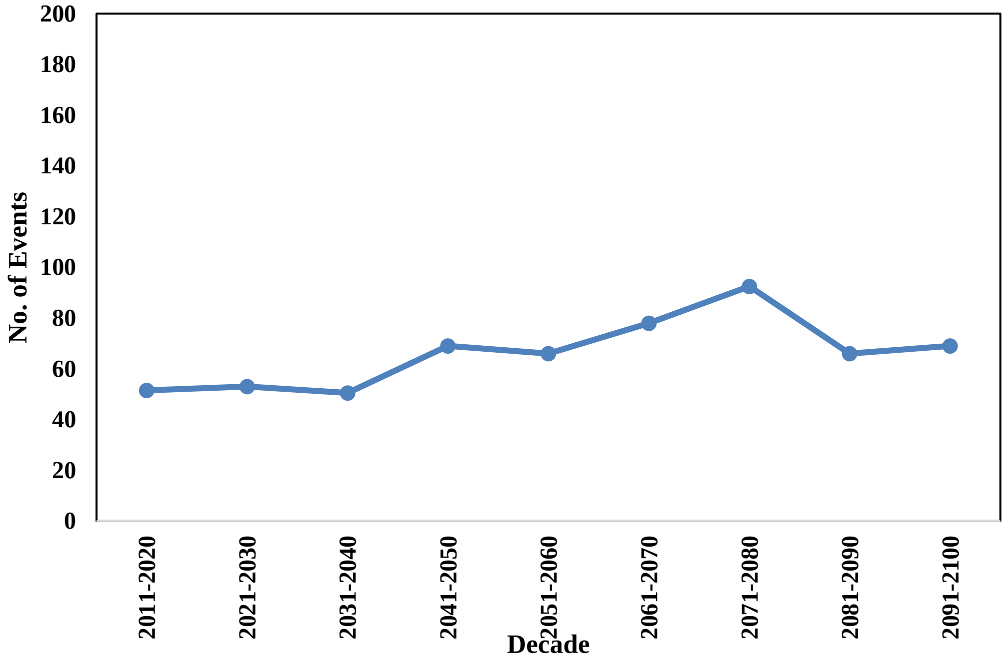

Figure 3.41: Changes in precipitation extremes from 2011 to 2100 in Southwest Monsoon of Welimada

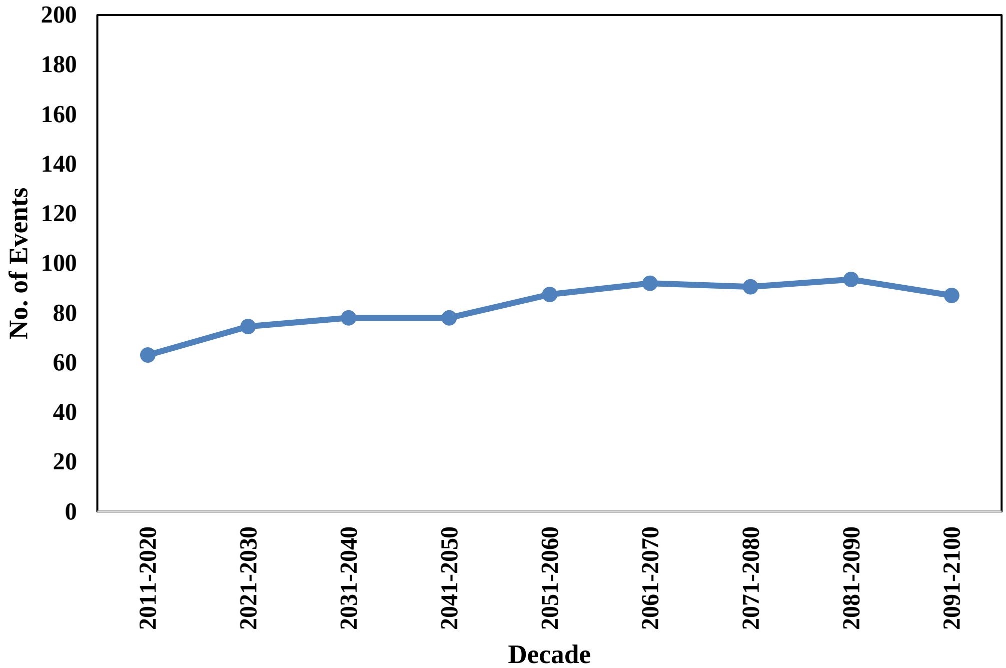

Figure 3.42: Changes in precipitation extremes from 2011 to 2100 in Second Inter-monsoon of Welimada

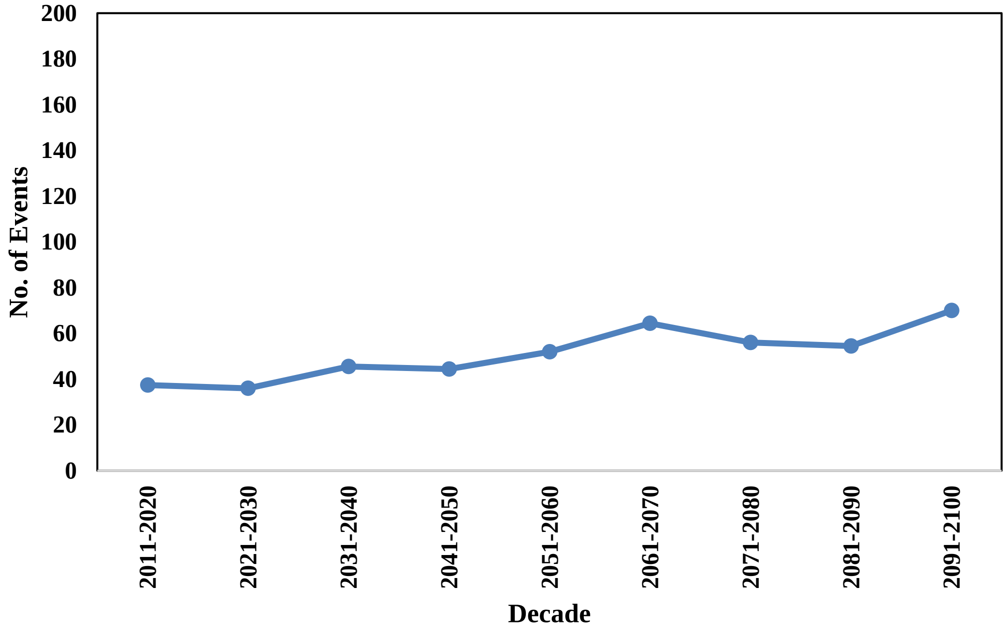

Figure 3.43: Changes in precipitation extremes from 2011 to 2100 in Northeast Monsoon of Welimada

In general there is an increment in extreme precipitation events by 2050 in all locations. This might be a result of increased temperature and, consequently, increased evapotranspiration, antecedent soil moisture conditions etc. As the rainfall intensity is one of the main drivers of soil erosion and run-off, this increment in e xtreme precipitation events may lead to higher soil erosion and soil degradation i.e. loss of organic matter and nutrients, threatening to agricultural productivity which is already under pressure from increasing food demands.

3.3 The indicator approach

3.3.1 Climate Vulnerability index

According to the procedure adopted, values of exposure, sensitivity and adaptive capacity is ranges between 0 and 1. Therefore, the maximum value for the CVI is (+2) and the minimum value is (-1). When the adaptive capacity exceeds that of exposure and sensitivity, the climate vulnerability score become negative. The higher value means higher vulnerable. If the value is closer to (-1), households become less vulnerable to climate change and if the value is closer to (+2), households become higher vulnerable to climate change. Though (+2) and (-1) are the extreme values which a household can obtained, all households despite the location, range between (-0.62) and (0.26).

The average climate vulnerability values for each location are expressed in Table 3.18. Among four locations average value for climate vulnerability is highest in Chittagong followed by Jhikhu Khola, Welimada and Hatton. Therefore, compared to other three locations, Chittagong has the highest climate vulnerability and Hatton has the lowest climate vulnerability.

Table 3.18: Average CVI values

Index	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
CVI	0.03	-0.2	-0.32	-0.26

Households were classified into five vulnerability categories based on the minimum and maximum values obtained by the households and cut-off points were decided using equal interval classification method. Table 3.19 shows the cut-off points for each climate vulnerability category. The cut-off points of the index are relative measure and this categorization supports within site and between sites comparison.

Table 3.19: Cut-off points of vulnerability categories

Vulnerability category	Cut-off Points
Least Vulnerable	(-0.62) - (-0.444)
Less Vulnerable	(-0.444) - (-0.268)
Moderate Vulnerable	(-0.268) - (-0.092)
High Vulnerable	(-0.092) - 0.084
Highest Vulnerable	0.084 - 0.260

Based on the cut-off points, categorization was done for each location separately and the summary is given in Table 3.20.

Table 3.20: Percentage of households in each vulnerability group

Group	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
Least Vulnerable	0	3.9	21.6	3
Less Vulnerable	1	22.3	43.2	49
Moderate Vulnerable	12.5	55.3	29.6	37
High Vulnerable	56.3	16.5	5.6	10
Highest Vulnerable	30.2	1.9	0	1

As expressed in Table 3.20, among interviewed households in Chittagong, major proportion which is 56.3% are in high vulnerable group, 30.2 % are in highest vulnerable group, 12.5% are in moderately vulnerable group while only 1% are in less vulnerable group and no one is in least vulnerable group.

Based on climate vulnerability index values of individual households, climate vulnerability map was developed to represent the population of Chittagong and Figure 3.44 demonstrates the spatial distribution. As per the climate vulnerability map, many areas in Chittagong are vulnerable for climate change.

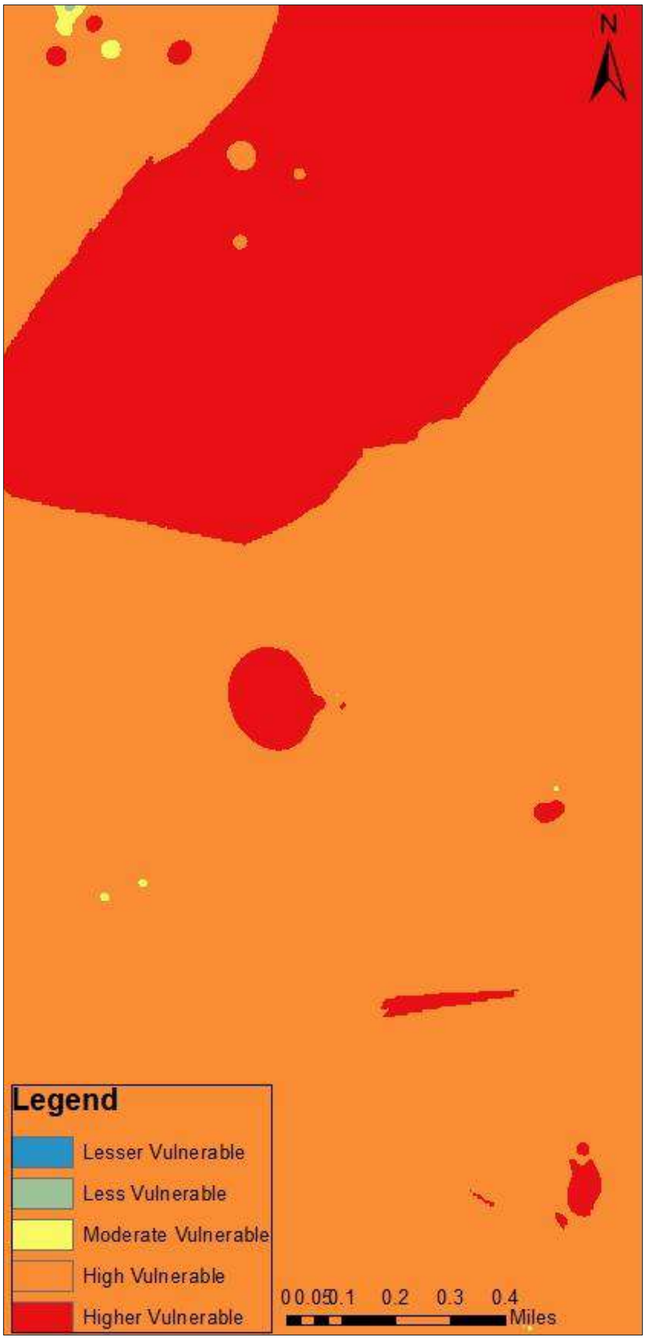

Figure 3.44: Climate vulnerability map of Chittagong

According to the findings, majority of the households in Chittagong, not having proper education, having only one income source and no employed members in the household, relying only on agriculture, use of high number of hired labour, cultivating only hybrid varieties, not having irrigation facilities and practice rainfed agriculture, not having proper sanitary facilities, having lands with steep slope and not following soil and water conservation methods could be identified as most contributing factors for higher climate vulnerability in Chittagong.

In Jhikhu Khola higher proportion (55.3%) of interviewed households can be found in moderately vulnerable group followed by less vulnerable group (22.3%), high vulnerable group (16.5%), least vulnerable group (3.9%) and higheest vulnerable group (1.9%). Figure 3.45 illustrates the spatial distribution of population climate vulnerability. Higher proportion of Jhikhu Khola is moderately vulnerable to climate change.

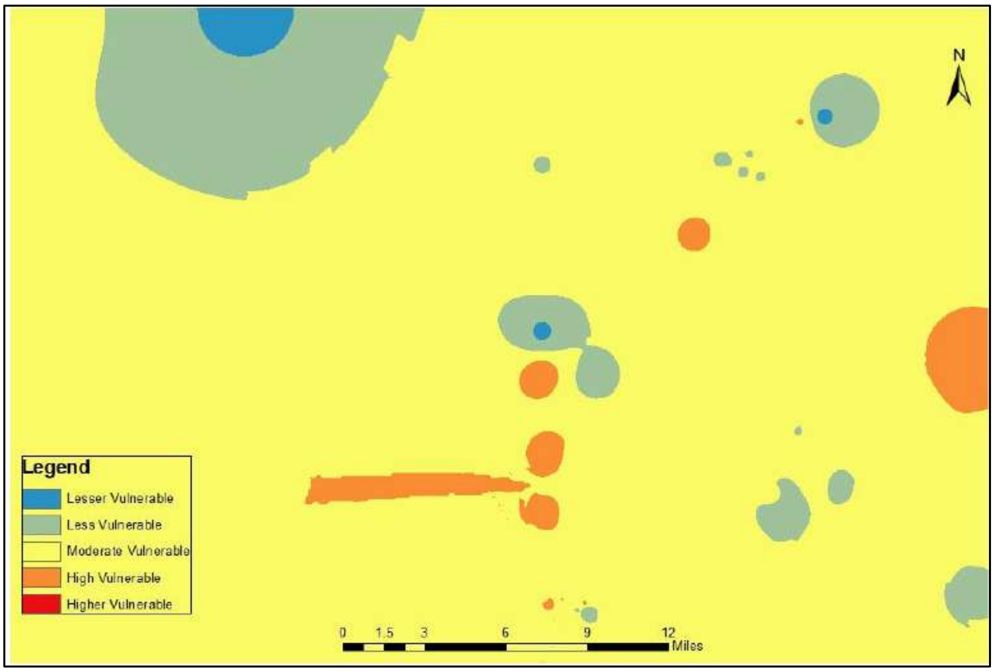

Figure 3.45: Climate vulnerability map of Jhikhu Khola

Not having proper education, no employed members in the household, use of high number of hired labour, cultivation of hybrid varieties, not having irrigation facilities and practice of rainfed agriculture, not having storage facilities, not practicing animal husbandry, not followingsoil and water conservation methods, houses are constructed with thatching materials and mud are the common features of the households in moderately vulnerable and high vulnerable categories. However, having more than one income sources, not relying totally on agriculture base income, use of organic fertilizers in their cultivations, presence of naturally grown plants in their lands, having fertile lands like factors could contribute to reduce the climate vulnerability of households in moderately vulnerable group and less vulnerable groups.

As shown in Table 3.20 there is no households in the highest vulnerable category in Hatton and only 5.6% of the interviewed households are in high vulnerable category. Higher proportion (43.2%) of the interviewed households are in less vulnerable category, 29.6% are in moderately vulnerable group and 21% are in least vulnerable group. Figure 3.46 expressed the spatial distribution of climate vulnerability in study site. Higher proportion of Hatton is less vulnerable to climate change.

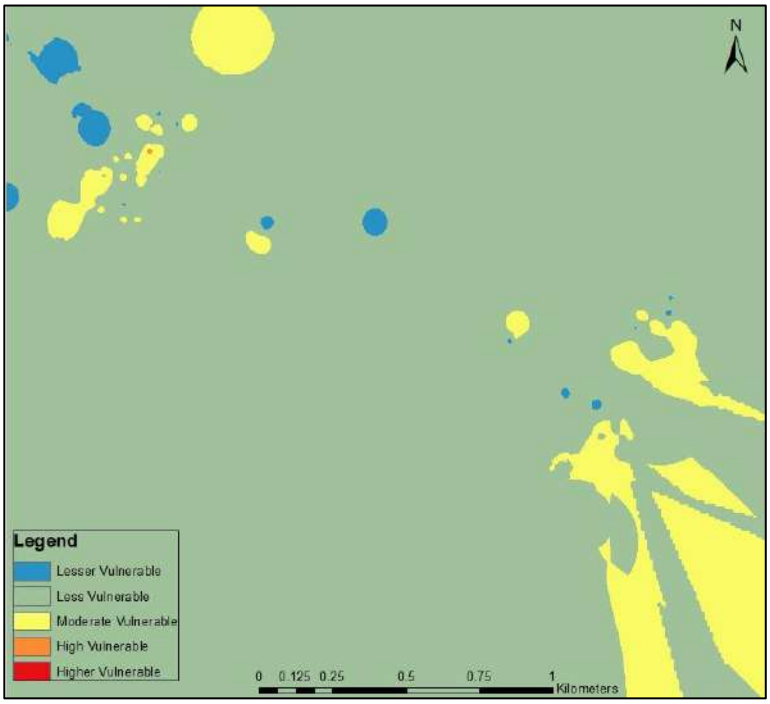

Figure 3.46: Climate vulnerability map of Hatton

Having more than one income source, presence of employed members in the household, not relying totally on agriculture-based income, having houses with good condition and proper sanitary facilities, not using hired labour, cultivating more than three crops and cultivation of local varieties, availability of irrigation facilities, use of integrated nutrient management in their cultivations, presence of woody trees in their lands, following soil and water conservation methods, and having fertile lands like factors could be identified as the common features of households with less climate vulnerability. Do not have proper education, do not have storage facilities, having lands with steep slope like factors may lead to increase the climate vulnerability.

In Welimada also higher proportion of interviewed households are in less vulnerable group (49%) and moderately vulnerable group (37%). Only 1% are in highest vulnerable group, 10% are in high vulnerable group and 3% are in least vulnerable group. Figure 3.47 demonstrates the spatial distribution of the climate vulnerability in Welimada. Percentage of the least or less vulnerable to climate change in Welimada is near zero.

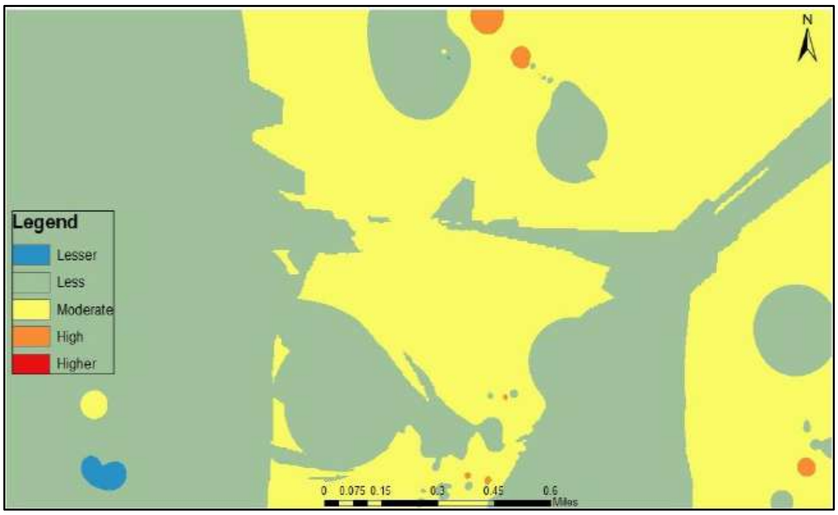

Figure 3.47: Climate vulnerability map of Welimada

Have more than one income sources and do not rely totally on agriculture, have storage facilities, have houses with good condition and proper sanitary facilities, cultivate more than three crops, presence of naturally grown plants and woody trees in their lands, following soil and water conservation methods are the common features of the less vulnerable households in Welimada. However, do not have proper education, no employed members in the household, less savings, use high number of hired labors, cultivate only hybrid varieties, do not have irrigation facilities and practice rainfed agriculture, less use of organic fertilizers, do not practice animal husbandry, having less fertile soils like factors are contributed to increase the climate vulnerability.

This categorization also revealed that, Chittagong is the most vulnerable site to climate change compared to other three locations. Ninety three percent of households have one income source, 99% of households are not employed, share of income from farming is greater than 50% in 99% of households, only 67% of households are cultivating there lands by them, using hired labors, majority of households (99%) are not irrigated their lands, 97% is using only inorganic fertilizers, no household is having proper toilet facilities and all households are having non fertile lands like factors may contributing to overall highest vulnerability of Chittagong compared to other three locations.

Majority of the households have more than one income source, 84% of households are employed, 94% do not have middleman when marketing their products, share of income from farming is less than fifty percent in 83% of households, all the households have houses with good condition, majority of the households have cultivated local crop varieties, all households have irrigation facilities to irrigated their cultivations, use organic fertilizers by 81% of households and following soil and water conservation methods by all households may lead to least vulnerability in Hatton compared to other three locations.

3.3.2 Food Nutrition and Health Vulnerability Score

In this study, 18 parameters were used to compute food nutrition and health vulnerability score based on the literature across the world on similar issues as well as expert opinion. The FNH score is ranges between 0 and 1. If the value is closer to 0, food nutrition and health insecurity of the household is less and if the value is closer to 1, food nutrition and health insecurity of the household become higher. Though 0 and 1 are the extreme values which a household can obtained, all households despite the location, range between 0.13 and 0.68.

The average food nutrition and health vulnerability values for each location were expressed in Table 3.21. Among four locations average value for food nutrition and health vulnerability is highest in Chittagong followed by Welimada Hatton and Jhikhu Khola. Therefore, compared to other three locations, Chittagong has the highest food nutrition and health vulnerability and Jhikhu Khola has the lowest food nutrition and health vulnerability.

Table 3.21: Average FNH Values

Index	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
FNH	0.51	0.35	0.39	0.42

Households were classified into five vulnerability categories based on the minimum and maximum values obtained by the households and cut-off points were decided using equal interval classification method. Table 3.22 shows the cut-off points for each food nutrition and health vulnerability category. The cut-off points of the index are relative measure and this categorization supports within site and between sites comparison.

Table 3.22: Cut-off points of food nutrition and health vulnerability categories

Vulnerability category	Cut-off Points
Least Vulnerable	0.13 - 0.24
Less Vulnerable	0.24 - 0.35
Moderate Vulnerable	0.35 - 0.46
High Vulnerable	0.46 - 0.57
Highest Vulnerable	0.57 - 0.68

Based on the cut-off points, categorization was done for each location separately and the summary is given in Table 3.23.

Table 3.23: Percentage of households in each vulnerability group

Group	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
Least Vulnerable	0	2.9	0.8	0
Less Vulnerable	0	54.4	36	13
Moderate Vulnerable	21.9	38.8	42.4	68
High Vulnerable	59.4	3.9	19.2	18
Highest Vulnerable	18.8	0	1.6	1

Among interviewed households in Chittagong, higher proportion (59.4%) is in high vulnerable group, 18.8 % are in highest vulnerable group and 21.9 % are in moderately vulnerable group while no one is in less vulnerable group or least vulnerable group. Figure 3.48 demonstrates the spatial distribution of the food nutrition and health vulnerability in Chittagong.

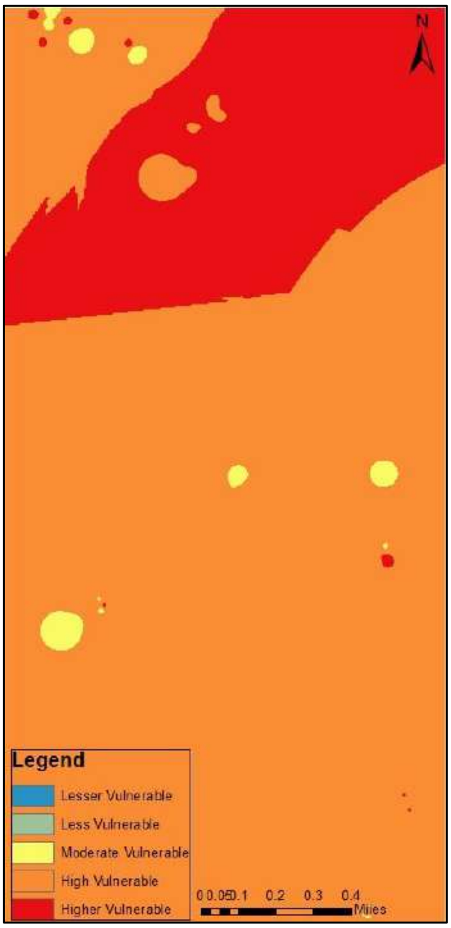

Figure 3.48: Food Nutrition and Health vulnerability map of Chittagong

According to the findings, majority of the households in Chittagong, do not have proper education, have only one income source and there is no employed members in the household, rely only on agriculture, cultivate hybrid varieties and do not have proper sanitary facilities (i.e. septic tank or sewerage system type toilets). Those factors could be identified as most contributing factors for higher food nutrition and health vulnerability in Chittagong. However, having cultivated more than three crops, practicing of animal husbandry, having storage facilities, consume products from own cultivation and animal husbandry like factors could contribute to reduce the food nutrition and health vulnerability.

As depicted in Table 3.23 and Figure 3.49, among interviewed households in Jhikhu Khola, higher proportion (54.4%) of households can be found in less vulnerable group followed by moderate vulnerable group (38.8 %), high vulnerable group (3.9 %), least vulnerable group (2.9 %) and no one highest vulnerable group.

Not having proper education, no employed members in the household, cultivation of hybrid varieties, absence of storage facilities and not practicing animal husbandry are the common features of the households in moderately vulnerable and high vulnerable categories. However, factors such as having more than one income sources, not relying totally on agriculture-based income, use of organic fertilizers in their cultivations, presence of naturally grown plants in their lands, and having fertile lands could contribute to reduce the food nutrition and health vulnerability of households in moderately vulnerable group and less vulnerable groups.

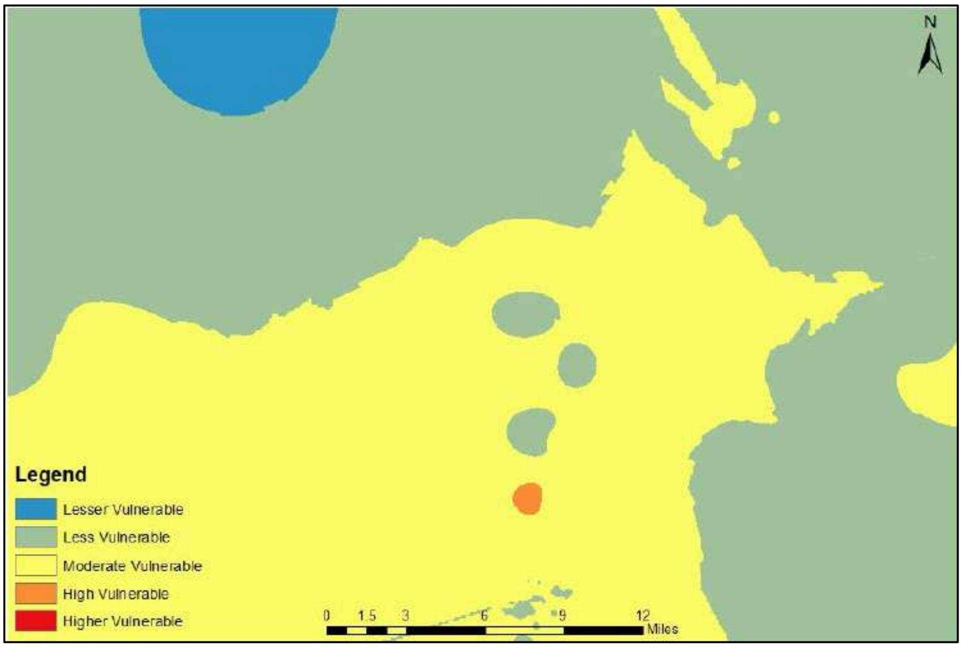

Figure 3.49: Food Nutrition and Health vulnerability map of Jhikhu Khola

In Hatton, a higher proportion (42.4%) of households can be found in moderately vulnerable group followed by less vulnerable group (36.0 %), high vulnerable group (19.2 %), and only 1.6 % is found in highest vulnerable group. Similarly, Figure 3.50 expressed the spatial distribution of food nutrition and health vulnerability. Hatton is less vulnerable compared to Chittagong and Welimada. But the vulnerability is high compared to Jhikhu Khola.

Having more than one income source, presence of employed members in the household, not relying totally on agriculture base income, having proper sanitary facilities, not using hired labour, cultivating more than three crops and cultivate local varieties, use of organic fertilizers in their cultivations, consume products from own cultivation and animal husbandry could be identified as the common features of households with less food, nutrition and health vulnerability. Factors such as not having proper education, not having storage facilities, and not practicing animal husbandry may lead to increase the food, nutrition and health vulnerability.

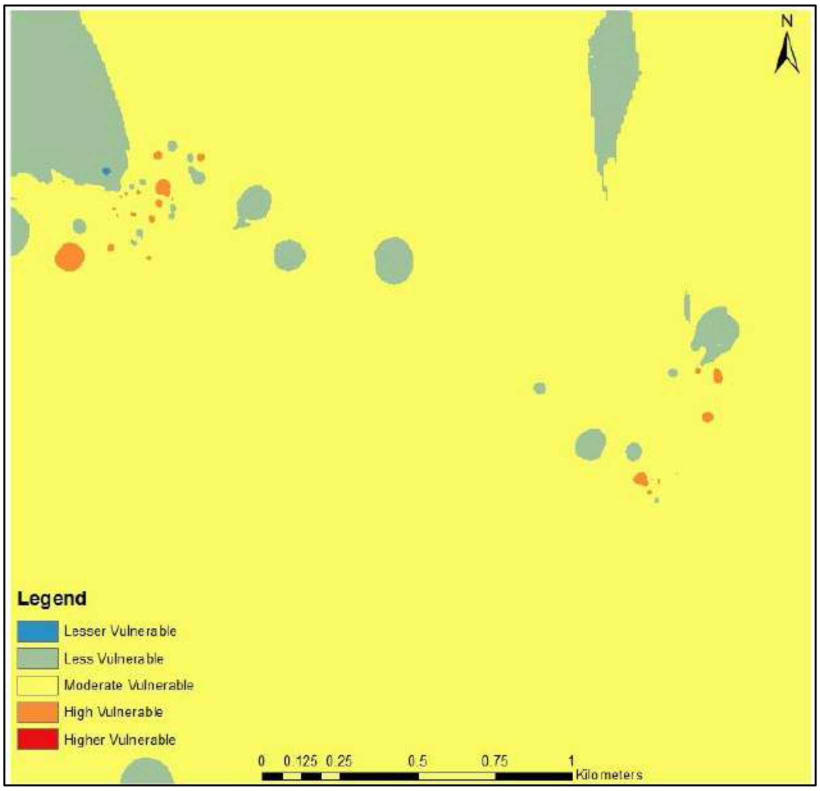

Figure 3.50: Food Nutrition and Health vulnerability map of Hatton

In Welimada too, a higher proportion of respondent households are in moderately vulnerable group (68 %) while 13 % are in less vulnerable group and 18 % are in high vulnerable group. Only 1% of the interviewed households are in highest vulnerable group. Figure 3.51 demonstrates the spatial distribution of the food nutrition and health vulnerability in Welimada. Comparatively Welimada is less vulnerable than Chittagong while vulnerability is higher than Hatton and Jhikhu Khola.

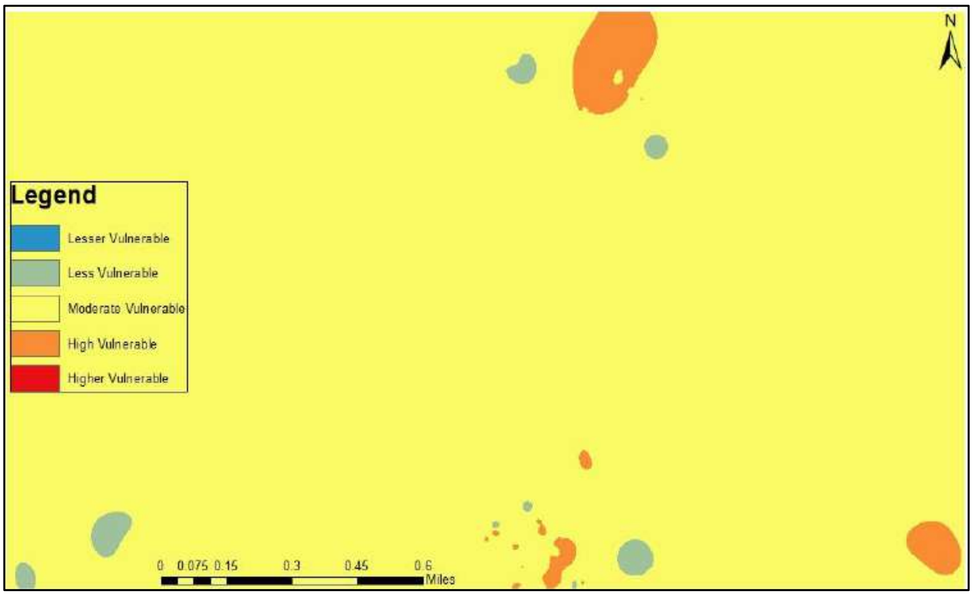

Figure 3.51: Food Nutrition and Health vulnerability map of Welimada

Having more than one income sources and not relying totally on agriculture, having storage facilities and proper sanitary facilities, cultivation of more than three crops, presence of naturally grown plants and woody trees in their lands, are the common features of the less vulnerable households. However, not having proper education, no employed members in the household, less savings, cultivation of hybrid varieties, not practicing animal husbandry are some important factors that may contribute to increase the food, nutrition and health vulnerability in Welimada.

Jhikhu Khola showed the least overall food nutrition and health vulnerability and Chittagong was the most vulnerable. However, in each location food nutrition and health vulnerability varies among households. Cultivation of more than three crops as mixed cropping, practicing animal husbandry, consuming foods from own cultivation and animal husbandry, availability of storage facilities, presence of naturally grown plants, use of organic fertilizers in their cultivations, having more than one income source, presence of employed members in the household like factors which are contributing to food security and having proper sanitation facilities (r.g. have septic tank or sewerage system type toilet) like factors could be identified as most contributing factors in lower food nutrition and health vulnerability as per the database.

As stated by Otto *et al*. (2017), climate change can affect food security either directly through food production losses and crop failures or indirectly through increased food prices caused by decreased supply. Further, food availability and prices could be further affected by extreme weather-related disruptions to transport and food distribution infrastructure (Otto *et al*. 2017). Households who have ability to cope with climate related impacts are less vulnerable to food insecurity. For example, if a household has cultivated more than one crop, food insecurity is less than that of a household who have cultivated only one crop. Because, impacts of climate related shocks may not affect in similar way on all crops. Thus crop losses or crop failures will be minimized ensuring the food security up to a certain extent.

3.3.3 Social Vulnerability Index

As the social vulnerability includes many aspects, it is impossible to measure directly. So, in order to measure social vulnerability, social vulnerability index was developed. Based on the available literature and the expert opinion, 22 parameters were selected in constructing the social vulnerability index.

The SVI score is ranges between 0 and 1 and if the value is closer to 0, social vulnerability of households is less and if the value is closer to 1, households become higher vulnerable. Though 0 and 1 are the extreme values which a household can obtained, all households range between 0.22 and 0.66. The average social vulnerability values for each location were expressed in Table 3.24.

Table 3.24: Average SVI Values

Index	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
SVI	0.52	0.42	0.35	0.44

Among four locations average value for social vulnerability is highest in Chittagong followed by Welimada, Jhikhu Khola and Hatton. Therefore, compared to other three locations, Chittagong has the highest social vulnerability and Hatton has the lowest social vulnerability.

Households were classified into five vulnerability categories based on the minimum and maximum values obtained by the households and cut-off points were decided using equal interval classification method. Table 3.25 shows the cut-off points for each social vulnerability category. The cut-off points of the index are relative measure and this categorization supports within site and between sites comparison.

Table 3.25: Cut-off points of social vulnerability categories

Vulnerability category	Cut-off Points
Least Vulnerable	0.22 - 0.308
Less Vulnerable	0.308 - 0.396
Moderate Vulnerable	0.396 - 0.484
High Vulnerable	0.484 - 0.572
Highest Vulnerable	0.572 - 0.660

Based on the cut-off points, categorization was done for each location separately and the summary is given in Table 3.26.

Table 3.26: Percentage of households in each vulnerability group

Group	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
Least Vulnerable	0	2.9	27.2	0
Less Vulnerable	2.1	27.2	46.4	19
Moderate Vulnerable	21.9	61.2	26.4	68
High Vulnerable	53.1	8.7	0	11
Highest Vulnerable	22.9	0	0	2

As expressed in Table 3.26 and Figure 3.52, among interviewed households in Chittagong, higher proportion (53.1 %) is in high vulnerable group, 22.9 % are in highest vulnerable group, 21.9 % are in moderately vulnerable group while only 2.1 % are in less vulnerable group and no one is in least vulnerable group.

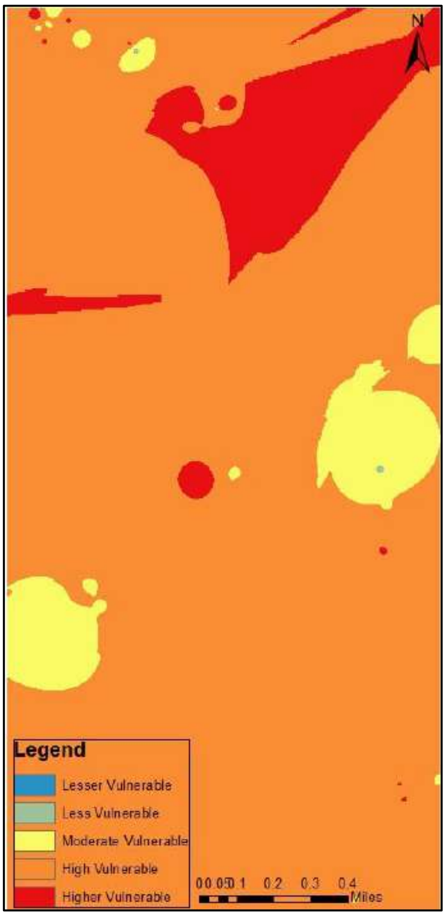

Figure 3.52: Social vulnerability map of Chittagong

According to the findings, majority of the households in Chittagong, do not have proper education, have only one income source and there is no employed members in the household, rely only on agriculture, use high number of hired labour, cultivate hybrid varieties, do not have proper sanitary facilities (i.e. septic tank or sewerage system type toilets), have lands with steep slope and do not following soil and water conservation methods. Those factors could be identified as most contributing factors for higher social vulnerability in Chittagong. However, having cultivated more than three crops, practicing of animal husbandry, having storage facilities, consume products from own cultivation and animal husbandry like factors could contribute to reduce the social vulnerability up to some extent.

In Jhikhu Khola higher proportion (61.2 %) of households can be found in moderately vulnerable group followed by less vulnerable group (27.2 %), high vulnerable group (8.7 %), least vulnerable group (2.9 %) and no one is in highest vulnerable group. Similarly, Figure 3.53 expressed the spatial distribution of social vulnerability. Jhikhu Khola is less vulnerable compared to Chittagong and Welimada while the vulnerability is high compared to Hatton.

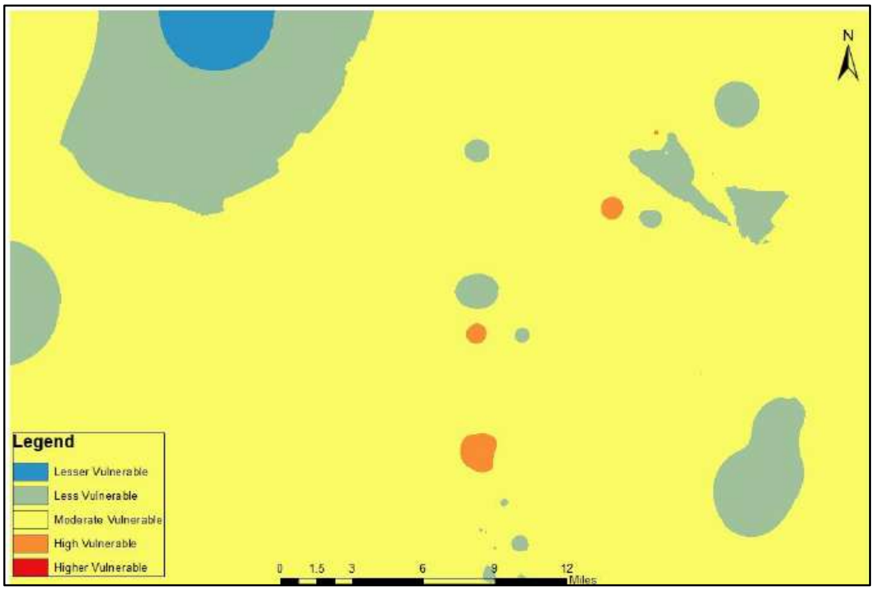

Figure 3.53: Social vulnerability map of Jhikhu Khola

Not having proper education, no employed members in the household, use of high number of hired labour, cultivation of hybrid varieties, not having storage facilities, not practicing animal husbandry, not following soil and water conservation methods, houses are constructed with thatching materials and mud are the common features of the households in moderately vulnerable and high vulnerable categories. However, having more than one income sources, not relying totally on agriculture base income, and presence of naturally grown plants in their lands could contribute to reduce the social vulnerability of households in moderately vulnerable group and less vulnerable groups.

As expressed in Table 3.26, there is no households in the highest vulnerable category and high vulnerable category in Hatton. Higher proportion (46.4%) of the interviewed households are in less vulnerable category, 26.4% are in moderately vulnerable group and 27.2% are in least vulnerable group. Figure 3.54 demonstrates the spatial distribution of the social vulnerability in Hatton. Hatton has the least social vulnerability among four locations.

Having more than one income source, presence of employed members in the household, not relying totally on agriculture base income, having houses with good condition and proper sanitary facilities, not using hired labour, cultivation of more than three crops and cultivation of local varieties, presence of woody trees in their lands like factors could be identified as the common features of households with less social vulnerability.

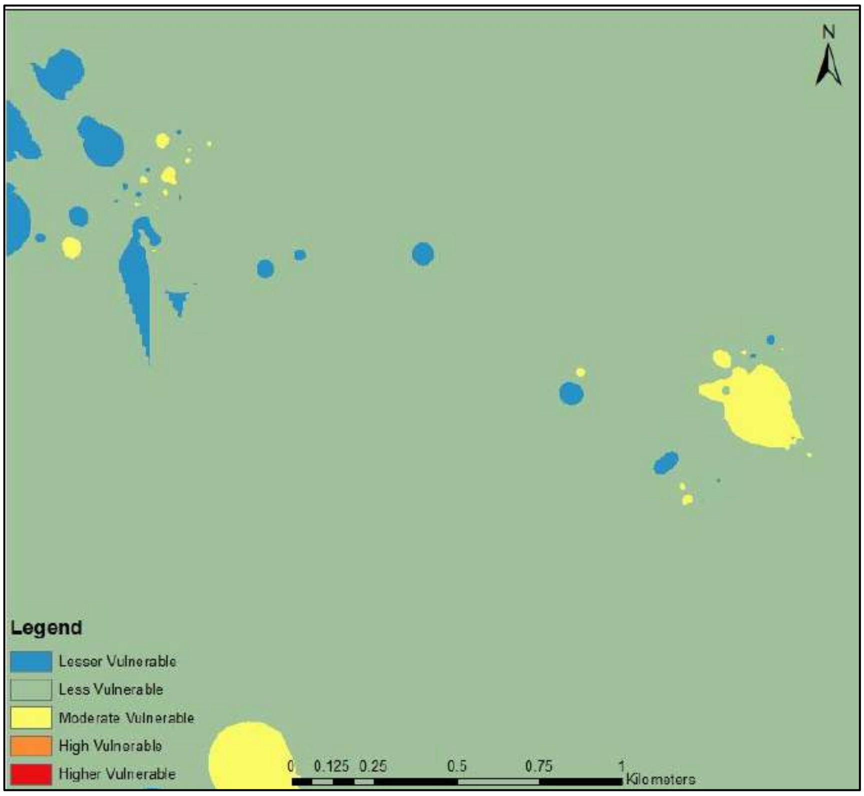

Figure 3.54: Social vulnerability map of Hatton

In Welimada, higher proportion (68 %) of interviewed households are in moderate vulnerable group. Only 2% are in highest vulnerable group while 11 % are in high vulnerable group and 19% are in less vulnerable group. There is no households in least vulnerable group. Figure 3.55 demonstrates the spatial distribution of the social vulnerability in Welimada.

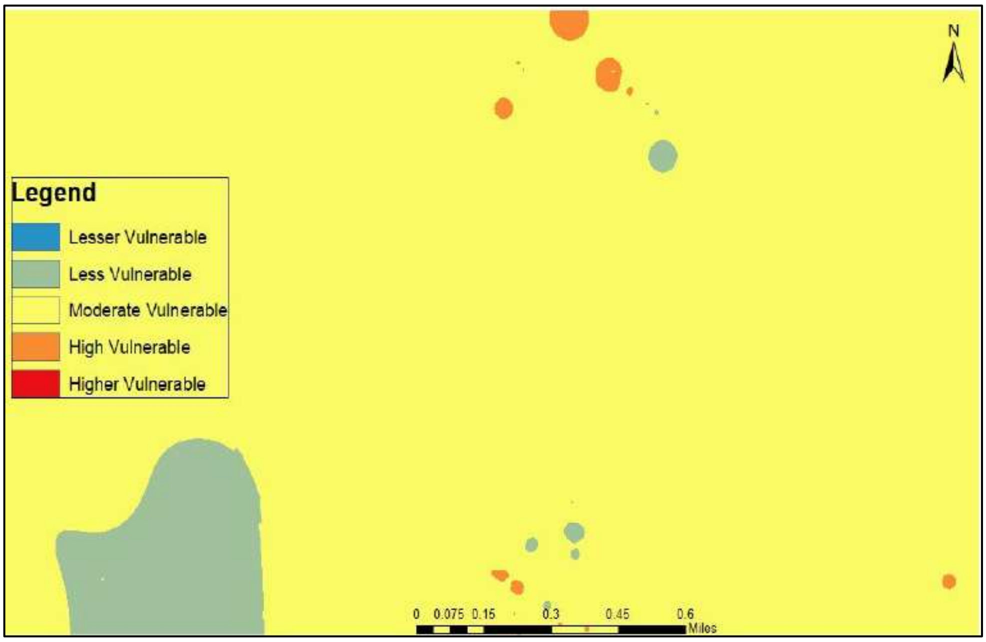

Figure 3.55: Social vulnerability map of Welimada

Having more than one income sources and not relying totally on agriculture, having storage facilities, having houses with good condition and proper sanitary facilities, cultivation of more than three crops, and the presence of naturally grown plants and woody trees in their lands are the common features of the less vulnerable households. However, factors such as not having proper education, no employed members in the household, less savings, use of high number of hired labour, cultivation of hybrid varieties, and not practicing animal husbandry may contribute to increase the social vulnerability in Welimada.

3.3.4 Climate Change Adaptability Index

As the climate vulnerability, food nutrition and health vulnerability social vulnerability etc., adaptability to climate change also cannot be directly measured. So, to assess the adaptability of the households to climate change, Climate Change Adaptability Index (AI) was developed. In this study 28 parameters were selected to compute the adaptability score. The maximum value which a household can obtain is 1 and the minimum value is zero. Higher score indicates the higher adaptability and wise versa. Though 0 and 1 are the extreme values which a household can obtained, all households despite the location, range between 0.40 and 0.77.

The average climate change adaptability values for each location were expressed in Table 3.27. Among four locations average value for climate change adaptability is highest in Hatton followed by Welimada, Jhikhu Khola and Chittagong. Therefore, compared to other three locations, Hatton has the highest climate change adaptability and Chittagong has the lowest climate change adaptability.

Table 3.27: Average AI Values

Index	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
AI	0.47	0.58	0.67	0.59

Households were classified into five adaptability categories based on the minimum and maximum values obtained by the households and cut-off points were decided using equal interval classification method. Table 3.28 shows the cut-off points for each climate change adaptability category. The cut-off points of the index are relative measure and this categorization supports within site and between sites comparison.

Table 3.28: Cut-off points of climate change adaptability categories

Adaptability category	Cut-off Points
Least Adaptable	0.40 - 0.474
Less Adaptable	0.474 - 0.548
Moderate Adaptable	0.548 - 0.622
High Adaptable	0.622 - 0.696
Highest Adaptable	0.696 - 0.77

Based on the cut-off points, categorization was done for each location separately and the summary is given in Table 3.29.

Table 3.29: Percentage of households in each adaptability group

Group	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
Least Adaptable	53.13	5.83	0	2
Less Adaptable	42.71	25.24	1.6	16
Moderate Adaptable	3.13	43.69	18.4	45
High Adaptable	1.04	21.36	45.6	36
Highest Adaptable	0	3.88	34.4	1

Among interviewed households in Chittagong, higher proportion is in least adaptable group and less adaptable group (53.13% and 42.71 respectively). Only 3.13% are in moderate adaptable group and 1.04 % are in high adaptable group while no one is in highest adaptable group. Figure 4.56 demonstrates the spatial distribution of the climate change adaptability in Chittagong.

According to the findings, majority of the households in Chittagong, not having proper education, having only one income source and there is no employed members in the household, relying only on agriculture, use of high number of hired labour, cultivation of hybrid varieties, not having irrigation facilities and practicing rainfed agriculture, not having proper sanitary facilities (i.e. septic tank or sewerage system type toilets), having lands with steep slope and not following soil and water conservation methods are the factors that could be identified as most contributing for least climate adaptability in Chittagong.

Figure 3.56: Climate Change Adaptability map of Chittagong

In Jhikhu Khola, households could be found in all categories. As expressed in Table 3.29 and Figure 3.57, among interviewed households, higher proportion (43.69%) of households are in moderate adaptable group followed by less adaptable group (25.24 %), high adaptable group (21.36 %) and 3.88% are in highest adaptable group. least adaptable group has only 5.83% of the interviewed households.

Having more than one income sources, not relying totally on agriculture-based income, use of organic fertilizers in their cultivations, presence of naturally grown plants in their lands, and having fertile lands are the common features of the households in moderately resilient and high resilient categories. However, factors such as not having proper education, no employed members in the household, use of high number of hired labour, cultivation of hybrid varieties, not having irrigation facilities and practicing rainfed agriculture, not having storage facilities, not practicing animal husbandry, not following soil and water conservation methods, houses are constructed with thatching materials and mud could contribute to reduce the climate resilience of households in moderately resilient group and less resilient groups.

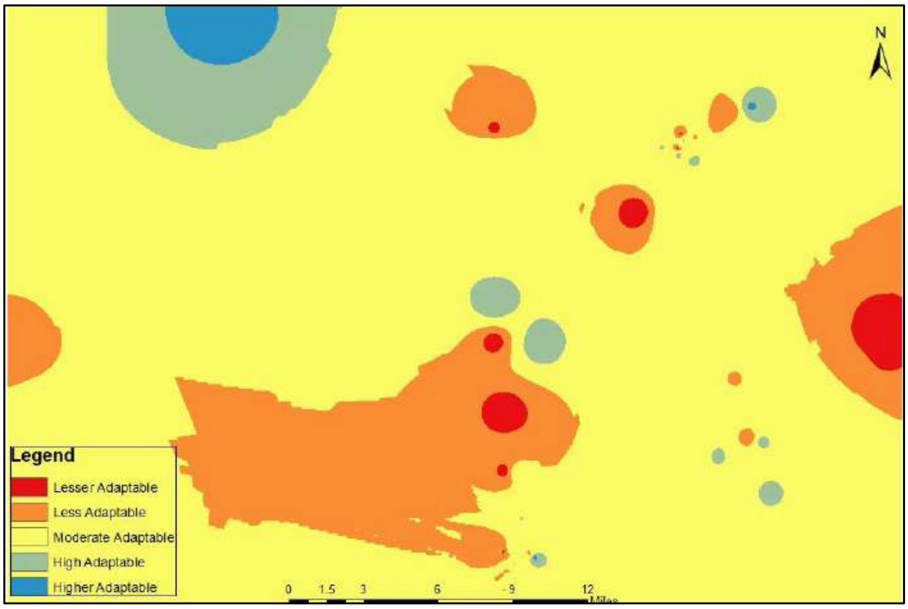

Figure 3.57: Climate Change Adaptability map of Jhikhu Khola

In Hatton higher proportion (45.6%) of households can be found in high adaptable group followed by highest adaptable group (34.4 %). In moderate adaptable group 18.4% of households are there and only 1.6% of households are in less adaptable group while no one is in least adaptable group. Similarly, Figure 3.55 expressed the spatial distribution of Climate change adaptability in Hatton.

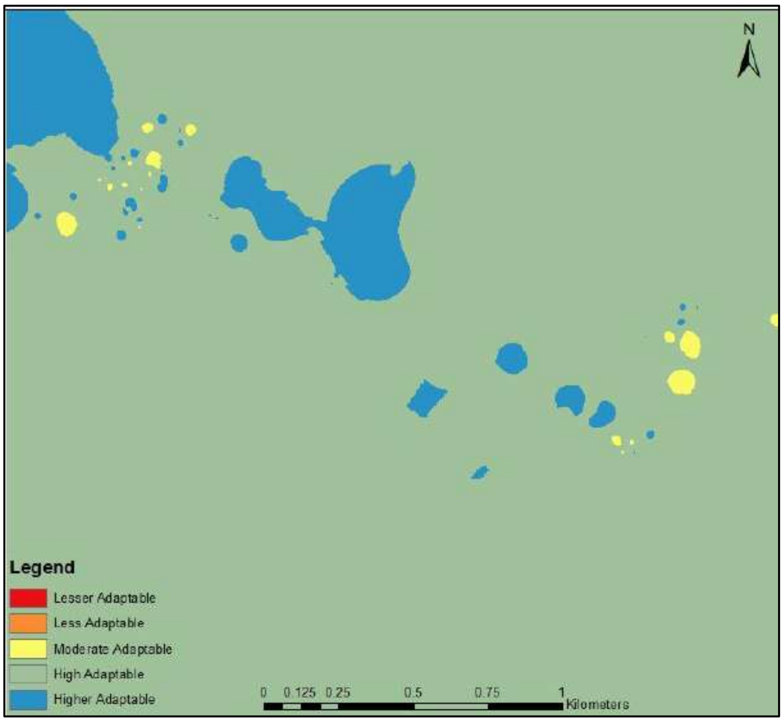

Figure 3.58: Climate Change Adaptability map of Hatton

Having more than one income source, presence of employed members in the household, not relying totally on agriculture base income, having houses with good condition and proper sanitary facilities, not using hired labour, cultivation of more than three crops and cultivation of local varieties, availability of irrigation facilities, use of organic fertilizers in their cultivations, presence of woody trees in their lands, following soil and water conservation methods, and having fertile lands like factors could be identified as the common features of households with higher climate adaptability. Not having proper education, not having storage facilities, and having lands with steep slope may lead to reduce the climate adaptability in Hatton.

Among interviewed households in Welimada, 45% are in moderate adaptable group, 36% are in high adaptable group, 16% are in less adaptable group. One percent of the households are in highest adaptable group and only 2% of households are in least adaptable group. Spatial distribution of climate change adaptability in Welimada is expressed in Figure 3.59.

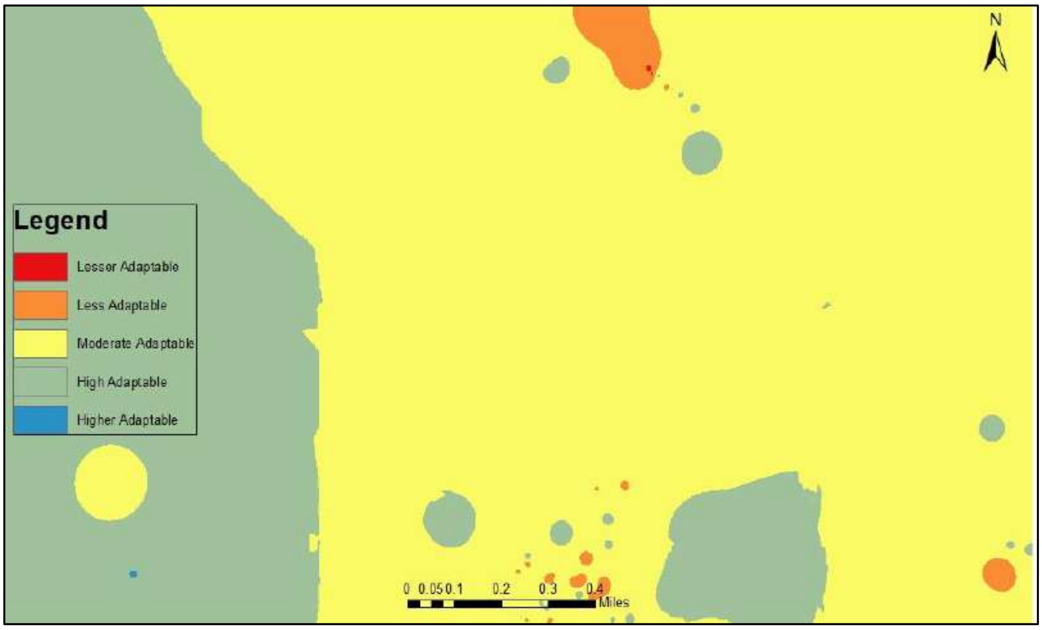

Figure 3.59: **Climate Change Adaptability map of Welimada**

Having more than one income sources and not relying totally on agriculture, have storage facilities, having houses with good condition and proper sanitary facilities, cultivation of more than three crops, presence of naturally grown plants and woody trees in their lands, following soil and water conservation methods are the common features of the high adaptable households. However, not having proper education, no employed members in the household, less savings, use of high number of hired labour, cultivation of hybrid varieties, not having irrigation facilities and practicing rainfed agriculture, less use of organic fertilizers, not practicing animal husbandry, and having less fertile soils like factors may contribute to reduce the climate adaptability.

4.3.5 Climate Resilience Index

In this study, 31 parameters were used to compute climate resilience score based on the literature across the world on similar issues as well as expert opinion. The CRI score is ranges between 0 and 1 and if the value is closer to 0, climate resilience of the household is less and if the value is closer to 1, climate resilience of the household become higher. Though 0 and 1 are the extreme values which a household can obtained, all households despite the location, range between 0.36 and 0.76.

The average climate resilience values for each location were expressed in Table 3.30. Among four locations average value for climate resilience is highest in Hatton and lowest in Chittagong.

Table 3.30: Average CRI Values

Index	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
CRI	0.48	0.59	0.67	0.6

Households were classified into five Resilience categories based on the minimum and maximum values obtained by the households and cut-off points were decided using equal interval classification method. Table 3.31 shows the cut-off points for each climate resilience category. The cut-off points of the index are relative measure and this categorization supports within site and between sites comparison.

Table 3.31: Cut-off points of Climate Resilience categories

Group	Cut-off Points
Least Resilient	0.36 - 0.44
Less Resilient	0.44 - 0.52
Moderate Resilient	0.52 -0.60
High Resilient	0.60 -0.68
Highest Resilient	0.68 - 0.76

Based on the cut-off points, categorization was done for each location separately and the summary is given in Table 3.32.

Table 3.32: Percentage of households in each resilience group

Group	Bangladesh	Nepal	Sri Lanka	
	Chittagong	Jhikhu Khola	Hatton	Welimada
Least Resilient	18.8	1	0	0
Less Resilient	60.4	8.7	0	6
Moderate Resilient	18.8	39.8	11.2	40
High Resilient	2.1	43.7	46.4	51
Highest Resilient	0	6.8	42.4	3

In Chittagong, majority of the households (60.4%) are in less resilient group. Among interviewed households, least resilient group has 18.8% of the households while moderate resilient group also having 18.8% of the households. High resilient group has only 2.1% and there is no households in highest resilient group. Figure 3.60 shows the spatial distribution of climate resilience in Chittagong.

According to the findings, majority of the households in Chittagong, not having proper education, having only one income source and no employed members in the household, relying only on agriculture, use of high number of hired labour, cultivating hybrid varieties, not having irrigation facilities and practicing rainfed agriculture, not having proper sanitary facilities (i.e. septic tank or sewerage system type toilets), having lands with steep slope and not following soil and water conservation methods are the factors that could be identified as most contributing factors for least climate resilience in Chittagong.

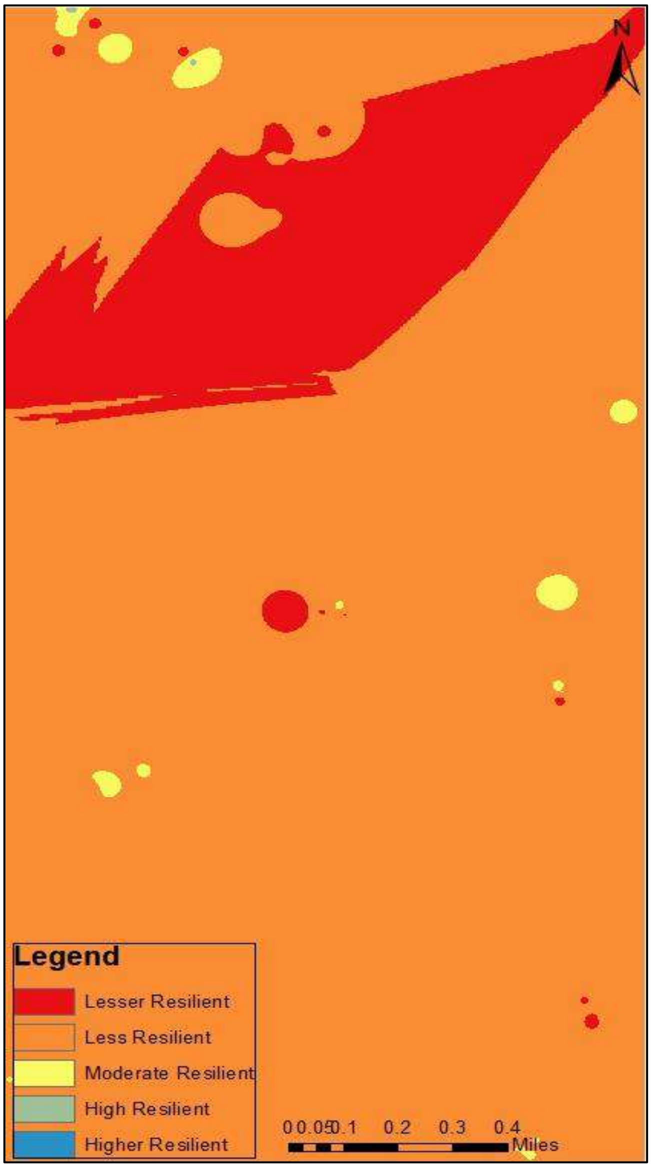

Figure 3.60: Climate Resilience map of Chittagong

Compared to Chittagong, climate resilience is high in Jhikhu Khola. Higher proportion (43.7%) of the households are in high resilient group followed by high resilient group (39.8%). Highest resilient group also has 6.8% of the households. Among interviewed households 8.7% are in less resilient group and only 1% are in least resilient group. Spatial distribution of the climate resilience is demonstrated in Figure 3.61.

Having more than one income sources, not relying totally on agriculture base income, use of organic fertilizers in their cultivations, presence of naturally grown plants in their lands, having fertile lands like factors are the common features of the households in moderately resilient and high resilient categories. However, not having proper education, no employed members in the household, use of high number of hired labour, cultivation of hybrid varieties, not having irrigation facilities and practicing rainfed agriculture, not having storage facilities, not practicing animal husbandry, not following soil and water conservation methods, houses are constructed with thatching materials and mud could contribute to reduce the climate resilience of households in moderately resilient group and less resilient groups

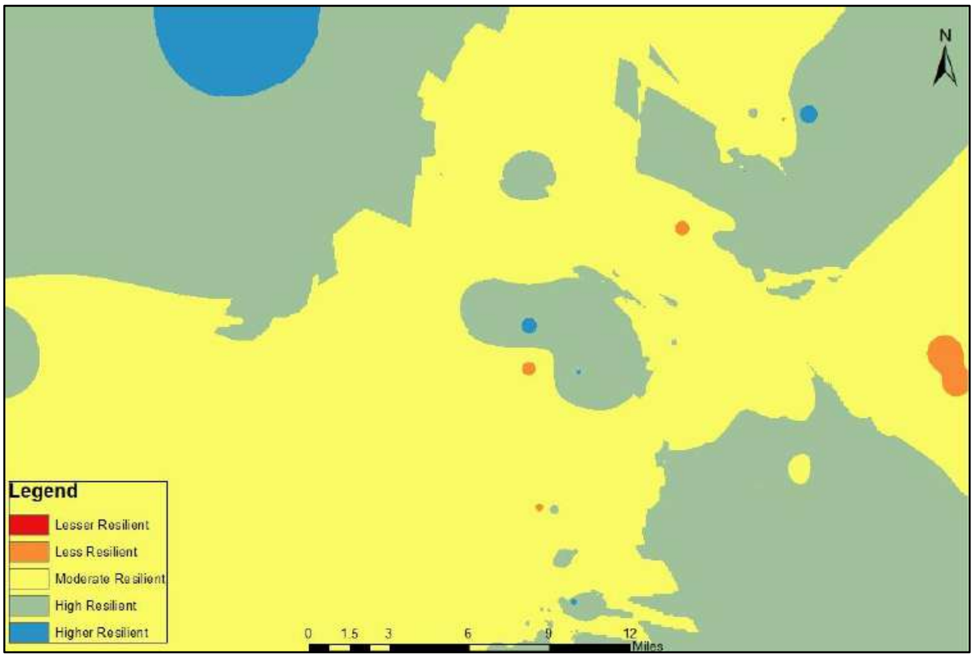

Figure 3.61: **Climate Resilience map of Jhikhu Khola**

As expressed in Table 3.32, there is no households in least resilient group and less resilient group in Hatton. Higher proportion (46.4%) of the interviewed households are in high resilient group, 42.4% are in highest resilient group and 11.2% are in moderately resilient group. Figure 3.62 demonstrates the spatial distribution of the climate resilience in Hatton. Hatton has the highest climate resilience among four locations.

Having more than one income source, presence of employed members in the household, not relying totally on agriculture base income, having houses with good condition and proper sanitary facilities, not using hired labour, cultivating more than three crops and cultivating local varieties, availability of irrigation facilities, use of organic fertilizers in their cultivations, presence of woody trees in their lands, following soil and water conservation methods, and having fertile lands like factors could be identified as the common features of households with higher climate resilience. However, do not have proper education, do not have storage facilities, having lands with steep slope like factors may lead to reduce the climate resilience in Hatton.

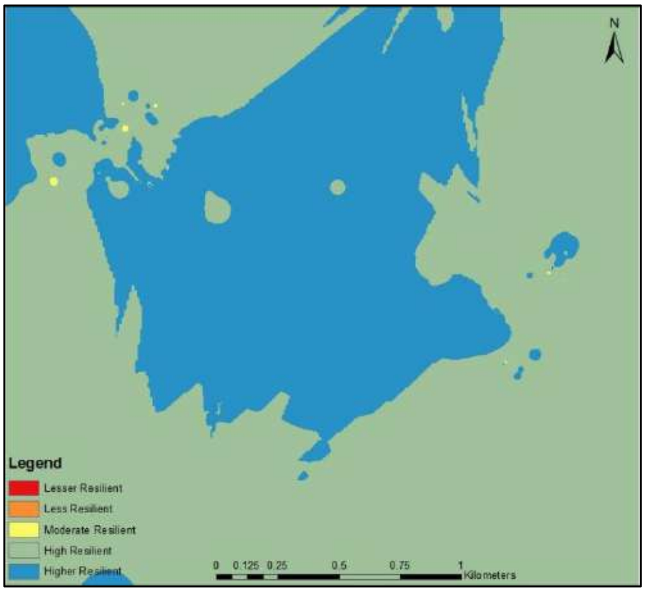

Figure 3.62: Climate Resilience map of Hatton

In Welimada, 51% of interviewed households are in high resilient group, 40% are in moderate resilient group. Only 3% are in highest resilient group while 6 % are in less resilient group. There is no households in least resilient group. Figure 3.63 demonstrates the spatial distribution of the social vulnerability in Welimada.

Having more than one income sources and do not rely totally on agriculture, having storage facilities, having houses with good condition and proper sanitary facilities, cultivating more than three crops, presence of naturally grown plants and woody trees in their lands, following soil and water conservation methods are the common features of the high resilient households. However, not having proper education, no employed members in the household, less savings, use of high number of hired labour, cultivating hybrid varieties, not having irrigation facilities and practicing rainfed agriculture, less use of organic fertilizers, not practicing animal husbandry, and having less fertile soils may contribute to reduce the climate resilience.

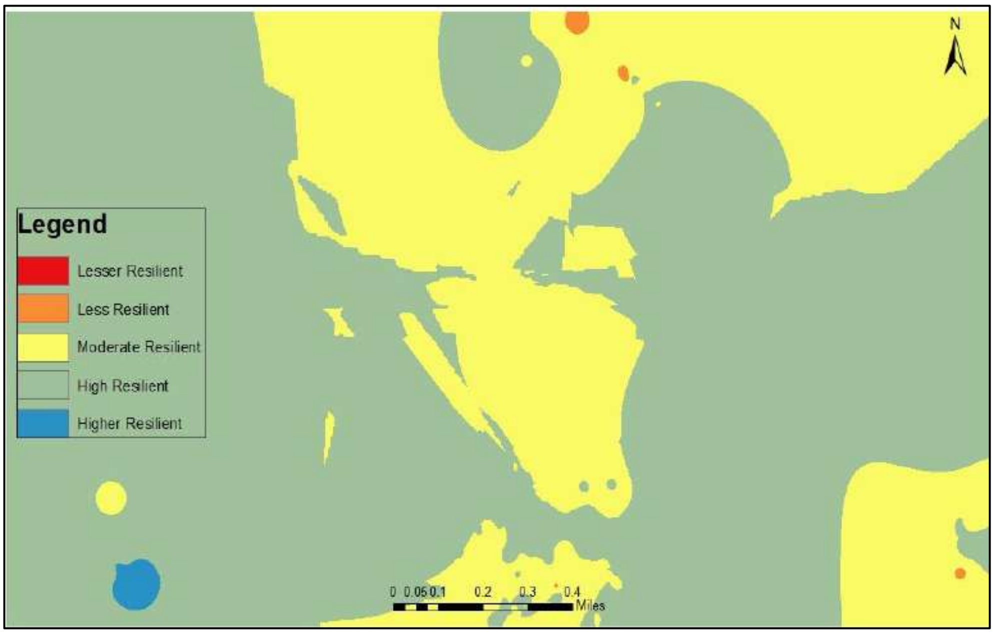

Figure 3.63: Climate Resilience map of Welimada

4. Conclusions

Key study question – What is the description of the best farming practices for hilly areas of SA that minimize resource degradation and ensure environmental sustainability, while enhancing food security and resilience

Study aim – To assess resilience of different FS in SA by characterization of diverse FS based on their adaptation capacities, with special emphasis on food and nutrition security.

The study revealed that the farming systems in hilly areas in Chittagong (Bangladesh) Jhikhu Khola (Nepal) and Hatton and Welimada (Sri Lanka) differ in their size (extent), composition, resource utilization, and sustainable management practices adopted by the farmers. The resilience of the faming systems in hilly areas (slopy lands) in three countries were assessed using five indices namely climate vulnerability index (CVI), social vulnerability index (SVI), food nutrition and health Vulnerability Index (SNH), adaptability index (AI) and the climate resilient index (CRI). The CVI was estimated by using exposure (represented by 3 parameters), sensitivity (represented by 11 parameters) and adaptive capacity (represented by 18 parameters). The FNH vulnerability score was calculated using 18 parameters, SVI using 23 parameters, AI by using 28 parameters, and CRI by 31 parameters by aggregating absorptive capacity, adaptive capacity and transformative capacity.

The CVI was the highest in Chittagong (Bangladesh) followed by Jhikhu Khola (Nepal), Welimada (Sri Lanka) and Hatton (Sri Lanka). The FNH vulnerability score was the highest in Chittagong followed by Welimada, Hatton and Jhikhu Khola. Therefore, compared to other three locations, Chittagong has the highest food nutrition and health vulnerability and Jhikhu Khola has the lowest food nutrition and health vulnerability. The SVI was highest in Chittagong followed by Welimada, Jhikhu Khola and Hatton. The climate change AI was the highest in Hatton followed by Welimada, Jhikhu Khola and Chittagong. Therefore, compared to other three locations, Hatton has the highest climate change adaptability and Chittagong has the lowest climate change adaptability.

The CRI could be considered as the best out of five indices used in this study to evaluate farming systems in Hilly areas (slopy land). The 31 parameters to be used in describing the climate resilience of the farming systems are given below:

Capacity	Components of climate resilience	Parameters selected for analysis	Description of parameters	Hypothesized relationship between parameter and climate resilience
Adaptive capacity	Socio-Demography	Gender of the household head	Whether the household is a male or female	Households with female head, lower the resilience
		Dependent household head	Household heads who older than 65 years	Households with dependent Household head, lower the resilience
		Condition of the house	Based on the construction materials of the walls, roof and the floor	Poorly constructed houses, lower the resilience
	Education	Educational level	Whether the household head has completed the primary education, secondary education or post-secondary education	Household heads with no formal education, lower the resilience
	Economy	Property regime	Availability of own lands	Households that do not own a private land, lower the resilience
		Income sources	Diversified income sources	Having more than one income source, higher the resilience

		Household employment	Whether the members of households are employed or not	Any member of household is not employed, lower the resilience
		Savings	Ratio of income and expenditure	Households with little or no savings, lower the resilience
		Dependence on agriculture	Percentage of agriculture base income	Households that depend on agriculture as major source of Income, lower the resilience
Adaptive capacity	Animal Husbandry	Practicing of animal husbandry	Whether the household is practicing animal husbandry	Practicing of animal husbandry, higher the resilience
		Diversity of Species	No. of animal species	Have more than one species, higher the resilience
		Animal breed	Whether animals are hybrid, cross bread or indigenous	Have hybrid breeds, lower the resilience
		System of animal rearing	Whether animals are rearing as extensive, intensive or semi-intensive system	Practicing of extensive system for animal rearing, lower the resilience
		Feeding method	Whether animals are feed with concentrate, cut and fed, free grazing or other	Feeding animals with concentrate feeds, higher the resilience
	Awareness	Farming knowledge	Years of experience in farming	lower the farming experience, lower the resilience
		awareness about the area	Living period in the area in years	lower the living period, lower the resilience
		Climate change	Noticed the changes in climate	Having notice the changes in climate, higher the resilience
		Changes in farming system	Noticed the changes in farming system	Having notice the changes in farming system, higher the resilience
	Food	food from own cultivation	Whether households consume food from animal husbandry	Consuming food from own cultivation, higher the resilience
		food from animal husbandry	Whether households consume food from their cultivations	Consuming food from animal husbandry, higher the resilience
	Sanitation	Improved toilets	Type o toilet	Having improved toilets, higher the resilience
Absorptive Capacity	Technology utilization	Diversity of crops	No. of crops cultivated	Having cultivated more than three crops, higher the resilience
		Cropping System	Whether cultivated as sole crop or mixed cropping	Cultivated as sole crop, lower the resilience
		Cultivated variety	Cultivated variety	Cultivated hybrid varieties, lower the resilience
		Fertilizer management	Type of fertilizers used in the cultivation	Using organic fertilizers, higher the resilience
	Irrigation Potential	Cultivation under irrigation	Sources of water for agricultural activities	No potential to irrigation, lower the resilience

	Ecological Stability	Presence of naturally grown plants	No. of naturally grown plants available	Presence of naturally grown plants, higher the resilience
		Presence of woody trees	No. of woody trees available	Presence of woody trees, higher the resilience
		Soil and water conservation	Practicing of soil and water conservation methods	Practicing of soil and water conservation methods, higher the resilience
		Slope of the land	Whether the land is flat, undulating, moderate slope or steep slope	lower the slope, higher the resilience
Transformative Capacity	Infrastructure	Availability of storage facilities	Whether households have storage facilities	Having storage facilities, higher the resilience
		Access to basic public services	Distance to market	Higher the distance to market, lower the resilience
	Social capital	Presence of middleman	Presence of middleman when marketing their products	Presence of middleman, lower the resilience
		Hired labour	No. of hired labour used in farming activities	Use of hired labour, lower the resilience

Among four study sites, the average value for climate resilience was the highest in Hatton (Sri Lanka) with a CRI of 0.67 and the lowest in Chittagong (Bangladesh) with a CRI of 0.48. Having more than one income sources, presence of employed members in the household, not relying totally on agriculture base income, presence of employed members in the household, not using hired labour, use of organic fertilizers in their cultivations, presence of naturally grown plants in their lands, presence of woody trees in their lands, having houses with good condition and proper sanitary facilities, cultivating more than three crops and cultivating local varieties, availability of irrigation facilities, following soil and water conservation methods, having fertile lands, having storage facilities are the common features of farming systems with high climate resilience across study sites in Bangladesh, Nepal and Sri Lanka. These parameters can be effectively used to identify climate resilient farming systems in hilly areas (slopy lands) in the region.

5. Future Directions

The project can have vertical and lateral expansion on educating the policy makers on the vulnerability of farming systems in hilly areas with a special focus on home gardens. Hence, the project will lead to a capacity building exercise across countries, media coverage on the climate vulnerability drawing urgent attention of the respective government in the region of the project outcomes. Climate resilient mapping and food and nutrition and health security mapping should be carried out for different farming systems at the lowest administrative level to assess the level of present resilience.

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1. Appendix

Questionnaire (Appendix 1)

Funding sources outside the APN

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Glossary of Terms

FS	-	Farming systems
CVI	-	Climate vulnerability index
FNH	-	Food, Nutrition and Health score
SVI	-	Social Vulnerability Index
AI	-	Adaptation index
CRI	-	Climate Resilient Index