ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

LAND-USE DYNAMICS AND CLIMATE VARIABILITY: LOCAL PROCESSES, AND LIVELIHOOD IMPLICATIONS ON SMALL-SCALE FARMERS IN ANGER WATERSHED, SOUTHWESTERN ETHIOPIA

BY

GEMECHU YIGEZU OFGEHA

OCTOBER, 2021

ADDIS ABABA, ETHIOPIA

Land-use Dynamics and Climate Variability: Local Processes, and Livelihood Implications on Small-scale Farmers in Anger watershed, southwestern Ethiopia

Gemechu Yigezu Ofgeha

Adviser: Muluneh Woldetsadik (Associate Prof.)

A Dissertation Submitted to the Department of Geography and Environmental Studies in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Geography and Environmental Studies (Specialization in Climatology and Water Resource Management)

Addis Ababa University

Addis Ababa, Ethiopia

October, 2021

Addis Ababa University

School of Graduate Studies

This is to certify that the thesis prepared by Gemechu Yigezu, entitled: Land-use Dynamics and Climate Variability: Local Processes, and Livelihood Implications on Small-scale Farmers in Anger watershed, southwestern Ethiopia and presented in fulfillment of the requirements for the Degree of Doctor of Philosophy in Geography and Environmental Studies (Specialization in Climatology and Water Resource Management) compiles with the regulations of the University and meets the accepted standards with respect to originality and quality.

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_______________________________ Signature__________ Date___________
Adviser

Declaration

I, the undersigned, declare that this thesis is my original work, and all sources used in the dissertation have been appropriately acknowledged.

Name: Gemechu Yigezu Ofgeha

Signature: ________________

Date: ______________________

Acknowledgements

I would first like to thank those who have directly involved in the process leading to this dissertation. My supervisor, Dr. Muluneh Woldetsadik contributed tremendously, both as supervisor and co-author. His continuous dedication to the subject and encouragement have had a vital influence on my development as a researcher and the emerging of this thesis. Nothing to say but, I would express my deepest gratitude for his patience, motivation, enthusiasm and fatherly support from the beginning to the completion of this research. It is due to his incredible support and guidance that this research appears in its present form.

I am grateful to Wollega University for their consent on my study leave, and Addis Ababa University for financing this research. The cooperation of East Wallagga Agricultural Office, Investment office at zone and district level is also highly appreciated. My heartfelt gratitude also goes to all rural households in Anger watershed who kindly support me through providing the information. I would like to thank the local people who taught me the local processes environmental change, and implications on their respective area. Development agents and officials of various administrative positions in the study area were also very cooperative during the field work. Among others, Mr. Fantahun, Desalegn expert in rural development at Gutu Gida district, deserves special gratitude for his companionable support during data collection.

Many individuals not included in the above list also provided supports and ideas for this research. Special thank goes to Dereje Hinawu (PhD) and Tesfaye Tolessa (PhD) for their guidance on the contexts of the issues in the study area which has tremendous role to frame the research; Mr. Tesfaye Muluneh for the inspiring times we shared during writing together. My family and friends supported me all along the project: thank you Gemeda Fekadu (PhD) for your companionable supports in the entire time of the study; Genet Mulugeta (my wife) for your love, inspiration and encouragement. I am most grateful for Dandi Gemechu and Gadaa Gemechu (my sons) for their patience and love which have a big part in the success of this work. I thank all my friends, Gimbi campus staff, AAU class-mate and staff who make me complete this journey.

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Acronyms and Abbreviations

Acronyms

CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
ENSO	El Niño Southern Oscillation
EPCC	Ethiopian Panel for Climate Change
ETM+	Enhanced Thematic Mapper Plus
FAC	Future Agriculture Consortium
FAO	Food and Agriculture Organization
FED	Finance and Economic Developments
FED	Finance and Economic Developments
FGD	Focused Group Discussion
GDP	Gross Domestic Product
GPCC	Global Precipitation and Climate Centre
HPG	Humanitarian Policy Group
IPCC	Inter-governmental Panel for Climate Change
ITCZ	Inter-tropical Convergence Zone
JJAS	June, July, August, September
LUCID	Land Use Change Impacts and Dynamics
LULC	Land Use Land Cover
MAM	March, April, May
MSS	Multi-spectral Scanner
NAP	National Adaptation Plan
NGO’s	Non-governmental Organizations
NMSA	National Meteorological Service Agency
ONDJF	October, November, December, January, February
PCA	Principal Component Analysis
PCI	Precipitation Concentration Index
SD	Standard Deviation
SRA	Standardized Rainfall Anomaly

TLU	Tropical Livestock Unit
UNDP	The United Nations Development Program
UNEP	The United Nations Environment Program
UNFCCC	United Nations Framework Conventions on Climate Change
USAID	United States Agency for International Development
WB	World Bank

Abbreviations

E	East
Ha	Hectare
Km	Kilometer
Max	Maximum
Min	Minimum
N	North
Temp.	Temperature

Abstract

The study focuses on the assessment of impacts of global environmental change processes such as climate variability and land-use dynamics on the livelihood of small farm households as emerging challenges facing local communities. Hence, the general objective is to assess the dynamics in rural community's access to land resources and land use/cover dynamics, the state of climate change in the watershed to explore the effects of these changes in combination or individually on vulnerability situations and adaptation strategies of the smallholder farmers. The remote sense data sources were used for land use land cover (LULC) dynamics detection and analysis from 1976 to 2019. The gridded data of rainfall and temperature were used to analyze the status and trend, and variability of rainfall and temperature. The socioeconomic, and other household data were collected from 335 randomly selected households, group discussants, and officials and experts' interview. The LULC change detection was made using ArcGIS 10.4 and ERDAS IMAGINE 2015 software packages, and integrated with descriptive, and qualitative analysis of data to assess the structural land use dynamics and local implications. The Mann-Kendall test for trend analysis, and different variability measures were used for rainfall and temperature analysis, while community perceptions were analyzed descriptively and qualitatively. The principal component analysis (PCA) based analysis of variance, measures of difference (T-tests, and Pearson's linear correlations), and descriptive and qualitative techniques were used for vulnerability analysis. Descriptive statistics and multivariate analysis of variance (One-way MANOVA), and qualitative techniques were used for analysis of household's adaptation. Observations showed that agricultural land and settlements were increased at the expense of other land cover in the watershed. The condition was severe in the kolla agroecology due to unique historical land use dynamics, besides adversely affecting small-scale farmers' access to land resources in the area. Increasing trends of temperature, and high variability and insignificant but increasing rainfall trend, with remarkable agroecological differences were observed. Although community's perceptions in the process and impacts vary across agroecology, unpredictability of rainfall time, concentrations etc. were major challenges resulting multifaceted impacts on the farmers. Household's vulnerability magnitude ranges from high to moderate in the watershed, while in aggregate, kolla agroecology was more vulnerable than the highland. Social adaptability factors, and sensitivity to land resources were significantly contributed for the vulnerability differences. Although, climate variability was notable, structural land use dynamics was unequivocal stressor deepened the households' vulnerability in the kolla. Households' adoptions of the adaptation and coping strategies show significant differences along case studies. Although free ecosystem-based strategies become less practical and have been replaced, the processes were gradual, internal to the community and managed through adaptive learning in the highland, while the situations were toward maladaptive, due to state's 'development' interventions which disrupted free adaptations, and deteriorated adaptive learning of the community in kolla. In general, the thesis signifies the acumens of structural land use analysis for LULC researches, micro-scale agroecology-based climate variability analysis benefit to integrate the knowledge with site specific non-climatic processes to understand local livelihood trajectories, relatively the overweighted impacts of largescale agricultural investments induced structural land use dynamics for household's vulnerability, and to constrain their inherent adaptation strategies. Future research, and any development policy should comprehend knowledge on, and consider the accounts on local community's livelihood sensitivity to changes which deny their access to agroecologically provided land resources in the phase of changing climate, recognize simultaneous impacts of such processes in the livelihood studies and policy decisions, and enhance stakeholders' familiarity and consensus on local environmental and livelihood contexts to achieve win-win relationship among the actors in the watershed

Key Words: Land-use change, climate variability, vulnerability, adaptation strategies

CHAPTER ONE

GENERAL INTRODUCTION

Background of the Study

Global environmental change processes of climate variability and land use dynamics are emerging challenges facing local communities in the 21st century. Although the problem is worldwide, some areas are more vulnerable to the processes than others because of significant spatio-temporal variations in nature and extents of the stressors, and unique micro-scale livelihoods sensitivity of human beings. Particularly, the geographic complexity and the impact magnitude is more acute in developing countries due to vast causal linkages of the insecure livelihood pathways with a socioeconomic, historical and political milieu of a community (Adger, Barnett, Brown, Marshall, & O'Brien, 2013), heavy dependency on sensitive sectors, and hurdled policy and institutional developments(Few et al., 2015; Gutu, Emana, & Mengistu, 2012). The differential impacts of these processes are superimposed on dissimilar livelihoods status, which have been resulting complex geography of local livelihood outcomes. For instance, global climate change has been taking place simultaneously with changing land use land cover obsessed by economic globalization are among the global environmental changes affecting local livelihood systems (Leichenko and Eisenhauer 2017).

The issues of these change processes and impacts on small-scale farmers' livelihood in Ethiopia in this context have been addressed by research either under climate change impacts or national/and global land deals issues separately. However, the recent recommendations for local livelihood studies are toward simultaneous examinations of causations through identification of site-specific problems/ issues, context specific analysis of the impacts of these process/s on local livelihood resilience/vulnerability, and detecting how they constrains adaptation strategies of a community. Thus, two aspects of environmental change processes, namely climate variability, and structural land use dynamics were examined to pinpoint their socioeconomic and biophysical implications, and livelihood impacts on small-scale farmers of Anger watershed. These change processes have either an individual or combined effects on the livelihood security of the community.

The evidence that could be associated with climate change has already started appearing in Ethiopia. According to the GFDRR report, the mean annual temperature of Ethiopia increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade. The most prominent trend has been a tendency towards lower rainfall and declining growing season approximately by 15% (Conway et al., 2011). Baseline climate data of temperature and precipitation indicate a year-to-year variation of rainfall over the country (NMSA, 2001) and sources such as in-situ measurements, remote sensing from satellites and other platforms, paleoclimate reconstruction indicates a significant variability in climatic conditions in Ethiopia (EPCC, 2015). The projected changes and variability would have thoughtful implications on peoples' livelihoods, and the general environment (Allen et al., 2014; Echeverría & Terton, 2016). The process has multifaceted impacts and created several costs in Ethiopia (Emerta, 2013). It has been affecting the lives and livelihoods of a local community in multiple dimensions (Niang et al., 2014).

Furthermore, the ecosystems on which small-scale farmers livelihoods rely face substantial non-climate stressors related to the intensity of natural resource use, mismanagement practices, and conflicts between competing uses (Leichenko, 2018) by which the current economic globalization induced structural land use dynamics in different parts of Ethiopia in general and in the study area in particular could be observed as an important aspect of the processes affecting the livelihoods, and general environment of the community. Specifically, the present local livelihood and environmental problems of land grabs, lack of access to natural resources, and loss of carbon sinks are not only because of local causations internal to a community's socioeconomic dynamics, but the increasing importance of corporate actors in land-use decision making. Thus, these conditions necessitate a reconsideration of the conceptualizations for the land use change processes and local implications by considering the global actors, and their power relations with local community on land use decisions, because the community-environment interrelationship and a livelihood system operate in a globalized world (Munroe, McSweeney, Olson, & Mansfield, 2014).

In this context, there is very evident for the interventions in the rural environment for land use mainly since imperial period in the watershed, particularly to empower state farm prior to 1991, and large-scale private agricultural investment at present (De Zoysa, 2013; Dessalegn, 2011). The processes have spatiotemporal aspects for implications on local livelihood systems, and the situations have been shaped by the national/and global economic systems and policy of a time. Thus, the land use change processes were described as the structural land use dynamics in this thesis, with the argument for the need of conceptualizing the issue by considering these locally represented teleconnections to understand the spatiality of the interventions processes, and resultant impact differences on a local community. Moreover, the relationship between the local situations of the land use changes (i.e., the processes and impacts) and global economy are neither separate nor common for all places, but the result of site-specific entrenched historical, and economic interconnections (Meyfroidt, Lambin, Erb, & Hertel, 2013).

Structural land use dynamics is the changes in ownership of land and its property as a result of changes in resource use governance (land tenure system). In this case, it is the dynamics of land ownership among local community, the state, private domestic and international investors driven mostly by national land policy changes and globalization unlike commonly argued drivers of land use land cover changes in Ethiopia. This change process is highly structured in the study area since the 1970s which has been motivated through the state's interventions in the name of 'development' (Dessalegn, 2011), and the influence upshot with the recent global foods and energy demands (Makki and Geisler 2011; Clover and Eriksen 2009; Stephen 2013; Makki 2014) in which the worlds are looking for Africa believing that land is excess and natural resources are untapped in the continent. The change processes have unique characteristics defined by the economic and land use policy of the regimes, abrupt environmental and livelihoods impacts the courses, and end with the systems and policy change; unlike usual LULC dynamics in Ethiopia resulted from natural processes, dependency on the agriculture and natural resources; changing demographics and socio-economy of the local community which most of the time is gradual. Thus, the situations of the study area and the issue is conceptualized with strong assumption that the area has been served as a test site for development politics through international and national driven interests of land utilization for long period. These conditions resulted in several structural changes in land use and tenure insecurity, and associated implications on small scale farmers' access to land resources and the general biophysical status of the study area.

Although rural household's vulnerability and adaptation strategies to global environmental changes in Ethiopia have drawn attention, too often, however, the studies were less in considering non-climate stressors in general and along with their externality to a community, and as global change processes specifically. However, the recent studies become resonant in considering these non-climate global environmental change impacts (e.g., globalization) rather than identifying a single source (e.g., climate change) for livelihood assessments of a community exposed to such double/multiple stressors, believing that livelihood outcomes are the function of such interconnections (McCubbin, Smit, & Pearce, 2015). To this end, this thesis scrutinized how the processes have been altered the biophysical, socioeconomic, and institutional settings, and create feedbacks on the local community's livelihood assets and strategies, and continue to reshape the contextual livelihood systems, and determine the livelihood pathways. Specifically, the study was intended to assess the local states of global environmental change processes, the livelihood implications, and vulnerability to the processes and situations of local adaptation and coping strategies in the Anger watershed of southwestern Ethiopia.

Statement of the Problem

The impacts of climate variability and dynamics on access to scarce resources mainly the most abundant but also most contested, land and associated natural resources become prominent issues for the small-scale farmers of the Anger River watershed. The context in the study area shows remarkable spatial differences in the environmental changes processes, and associated livelihood impacts on the local communities, and which are linked to the process of biophysical, historical, political and socioeconomic footprints. Particularly, the characteristics and magnitude of the impacts have been site-specific which could be attributed to the socioeconomic constructions associated with agroecology (Gonzalez, 2013) such as potentials of an area for state ‘development’ planning, and the interests of global and national corporates for large scale agricultural investments (Dessalegn, 2011), and the inherent biophysical/ and climate conditions (Niang et al., 2014).

Climate variability, as one aspect of global environmental change process in the study area, at micro-scale level, is argued for its spatial variations in trends and variability observed across agro-ecologies and this has been affecting the livelihood of the communities. Even though southwestern Ethiopia where the Anger River watershed be situated is believed as the region of relatively sufficient amount of rainfall, large-scale regional climate investigation couldn’t amplify the site-specific situation while the livelihood system of small-scale agrarian is highly sensitive to slight change and variability. Moreover, there have been no adequate research was made to that indicate the trends and variability in rainfall and temperature specific to an identified study area. Most of the studies in Ethiopia were focused in the northern and central highlands; and some in the rift valley and arid and semi-arid parts of eastern and southeastern Ethiopia, while the studies in southwestern highlands and low lands of Ethiopia are overlooked.

The second locally eminent global environmental change is structural land use dynamics in this context has spatiality in the processes and impacts in the study area. Over the last century, small-scale farmers have been exposed to several national/ and global economy induced ‘development’ interventions. This have constituted the most powerful leverage for production intensifications of large-scale agricultural investments through breaking inherent traditional and indigenous agro-ecosystem services and local livelihood contexts. The changes have been implemented mainly in Africa as a national development option, fueled by global market demands for agricultural products. In many cases, the processes have been external to local communities, overlooked their livelihood contexts, become the source of vulnerability, and the powerful stimulus for conflicts and environmental problems (Gonzalez, 2013).

Historically, the *kolla* agroecology of the Anger River watershed has been experiencing large-scale mechanized farms since the mid-20th century. In 1970, three Dutch citizens established the Anger-Gutin Agricultural project, motivated by the presence of an agriculturally conducive climate, appropriate soil type, and equipped with modern medicine to combat malaria and animal diseases. Later on, the large scale state farm was established during the *Derg* Regime under Welaga Agricultural Investment Enterprise in 1975 (Dereje, 2018). The interventions were continued increasingly even after the collapse of state farms by changing its feature to private large-scale agricultural investment in the post-1991. Moreover, the area has been affected by rapid sedentarization following the establishment of enterprises and resettlement program at different times. Although, there is a lack of empirical information specific to the area, like any other communities in Ethiopia affected by such changes (Makki, 2014). These structural changes in land use and associated resources tenure insecurity have the capacity to breakdown the local community's livelihood system and deny access to land resources, disturbs their traditional socioeconomic and ecological benefits from the natural resources, heighten their vulnerability, and compromise their inherent adaptation and coping strategies.

Although dynamics in land use land cover, and climate variability comprise substantial areas in contemporary researches in human dimension of global environmental change, the specification on rural household livelihood pathways, and conceptualizations and methods to assess the local processes of these changes and site-specific impacts of the changes in a way suitable to comprehend local household's vulnerability and adaptations to the changes were lacking. Specifically, no study has considered both global change processes together, neither the status and trends of the processes at local level nor their simultaneous impacts at household in Ethiopia.

The researches on land use land cover studies in Ethiopia were thorough on the change/dynamics, land use policy, and the change impacts such as land grabbing, the dynamics in land tenure arrangements, land dispossession due to large scale agricultural investments, (Daniel, 2011; Davide, 2017; De Zoysa, 2013; Desalegn, 2013; Dessalegn, 2011; Makki, 2014; Mesfin, 2013; Mosley, 2012; Rakotonarivo, Jacobsen, Poudyal, Rasoamanana, & Hockley, 2018; Wulp, 2013). These researches were inadequate and less implied for rural livelihood assessments mainly in examining household's vulnerability and adaptations. The studies have limits in methodology to integrate the social contexts with change science for LULC analysis. Most of the studies interested in social aspects applied political ecology approach and methods while LULC studies were used land use change science approach.

Thus, we have designed a common ground of both approaches and their methods were embedded in one another in this study. For example, for LULC analysis the dates for remote sense data were determined on the basis of historical events of structural land use dynamics on top of integrated methods of data collections and analysis in this study. The integrations help to comprehend the issue toward the objectives of the study. Specifically, the links between local socioeconomic contexts and political dynamics in one hand, and actual LULC change on the other hand have paramount importance for a place-based account on the history of the processes, and used to model LULC analysis applicable in local impact assessments especially livelihood vulnerability to the change.

There are ample of researches on climate variability, and impacts for Ethiopia. The focus include: the change/and variability analysis at different scales, the impacts of climate change on livelihood systems, vulnerability of different sectors to the change, the effects on agriculture and food security, and determinants of climate change adaptations (Abayineh & Simane, 2017; Gutu, Emana, & Mengistu, 2012; Paulos & Simane, 2017; Shiferaw et al., 2014; Woldeamlak, Radeny, & Mungai, 2015; Zenebe, Alemu, Rahel, & Samuel, 2014). However, the studies were lacking spatial coverage for southwestern Ethiopia, conducted at bold geographic area without considering unique features of an area such as agroecological differences, and the purposes of the studies were less appropriate to use the results for local vulnerability and adaptations assessments. This study was designed to examine the temperature and rainfall trends at micro-scale with the aim to understand the local spatiotemporal variations, and perceived trends and implications on livelihood systems of the community. The ultimate goal of the study was to examine the climate processes in a technique implied for livelihood systems of local community, and in a manner suitable to integrate the result with the studies on other local processes of global environmental change, and changing socioeconomic, political and organizational conditions in the community. Thus, the results were used as an input to assess the household's vulnerability and the situations of adaptation strategies in the study area.

In general, in the previous research both change processes didn't studied in a manner fit for their simultaneous/and individual impacts, particularly in vulnerability and adaptation assessment at household level. Above all, the emerging interest is to examine the processes within a context, assess their interactive effects, and evaluate their combined impacts mainly in areas like the Anger watershed. Thus, a comprehensive understanding of the processes and their individual/and joined impacts is vital to portray the geography of global environmental change processes at local level, and underscore the differential impacts of the processes on small scale farmers.

Methodologically, the researches on these issues in Ethiopia come-up with frontiers for their incompatible epistemologies, mostly positivist and interpretivist. The tendency of analytical power seems toward positivism with several limitations for holistic understanding of the processes, the causalities, and local impacts. For instance, most of the studies conceptualized local non-climate stressors as internal and inherent to a local community, and identified climate variability as the only external disturbance. These researches failed to recognize these change processes as external, and imposed up on a local community due to national/and global economic change, the processes are context specific, and result differential impacts. Thus, in their analysis of local livelihood, the local impacts of global political economy in rural livelihood vulnerability assessments were obscured.

The interpretivists focused on the descriptions of the processes and impacts, while fail to measure the impacts such as magnitude of vulnerability to the change processes. In general, lack of integrations on the previous research resulted shortage of methodological exercises for holistic analysis of resilience pathway of rural households. However, comprehensive understanding of the processes and impacts needs integrations of multiple perspectives and methods. Therefore, in this study the pragmatic, mixed method approach, and the socioecological ties were used in line with the recent research recommendations mainly from human dimension of global environmental change. Specifically, the integrated methods are crucial to understand the complex assemblages of socioeconomic energies internal to the community, non-climatic change processes external to a community, and meteorological forces together in constructing differential vulnerability and constraining the adaptation strategies of a local community. Thus, conceptual and methodological missing of these issues is problematic.

Rationale of the Study

Most of the previous studies on the livelihood vulnerability, and adaptation strategies in rural areas were fixed to climate variability, inadequate on conceptual and methodological considerations of non-climate stressors. However, now a day climate change is not the only global environmental change external to a community on the way to disturb the livelihood systems of local poor. Therefore, it is crucial to understand the local situations of non-climate factors, and how they combined with climate factors in altering land and environmentally important natural resource endowments, and lead to vulnerable livelihood system, and constrain adaptation strategies of local community. On top of identifying differential vulnerability along places, such considerations are decisive to identify the real and pressing change process/s, explore causal linkage between livelihoods outcomes and the stressor/s, anticipate future impacts of the change/s, and identify potentially useful interventions.

The purpose of this study were comprehensive understanding of the local processes of global environmental changes, exploring courses of these dynamics, the spatial differences in their occurrences, the local level magnitudes and impacts through case study-based assessments of the processes, context specific implications of the dynamics, and their simultaneous impacts on the small-scale farmers livelihood by systematic examinations of households' vulnerability situations and adaptation strategies.

Therefore, the study covers a number of specific objectives procedurally which ranges from the inquiries of the states of the change processes- the structural land use dynamics and climate variability at local level, to explore the livelihood implications of the processes on small-scale farmers households, and examine vulnerability to the changes and effects of the processes on the local adaptation strategies. Generally, the identified knowledge and methodological issues in this thesis has potential to develop detailed accounts on the local contexts of the change processes and implications on local livelihood, the household's vulnerability to the simultaneous impacts of the processes, and on the constraining local adaptation strategies, exploring causal linkage of the processes with the vulnerability situations in one hand and the adaptations and coping strategies on the other hand.

Global environmental change is wide concept portrayed in multifaceted processes and impacts at different scales; while in this study the local agroecology context was used. Thus, the study was spatially delimited to Anger River watershed of southwestern Ethiopia, and its conceptual entity among the global environmental change was only climate variability and structural land use dynamics. Moreover, although different impact assessment methods and perspectives are prevailing of the dynamics, the vulnerability and adaptation perspective was used for livelihood impacts investigations of the dynamics on small-scale farmers' households. The research was conducted from June, 2018 to June, 2021.

The audiences for this dissertation will be from academic, experts, development practitioners and policy makers, that all will benefit from the findings of the study. It will add to the existing literature on global environmental change processes and impacts, rural development, and vulnerability and adaptations. The research will fill the knowledge gaps particularly on the link among theory, empirical and methodology to understand multiple environmental change processes, comprehend single/and simultaneous effects of these processes, identify causal linkages and examine their differential impacts at the local level. Moreover, the research will provide future research pathways and policy recommendations on the issues.

Background of the study area

Anger river watershed is part of the biggest watershed of Dhidhessa River catchment, which drains to the Abay River (Blue Nile River). The watershed covers ten woredas of East Wallagga administrative zone, a portion of three districts found in Horo Guduru administrative zone, and two woredas of Kemishi administrative zone of Benishangul Gumuz region. However, the watershed area of this study lies in the East Wallagga administrative zone is the focus of the study. Astronomically, the study area lies extending from 09°12' N to 10°00' N and 36°30' E to 37°11' E (Figure 1.1).

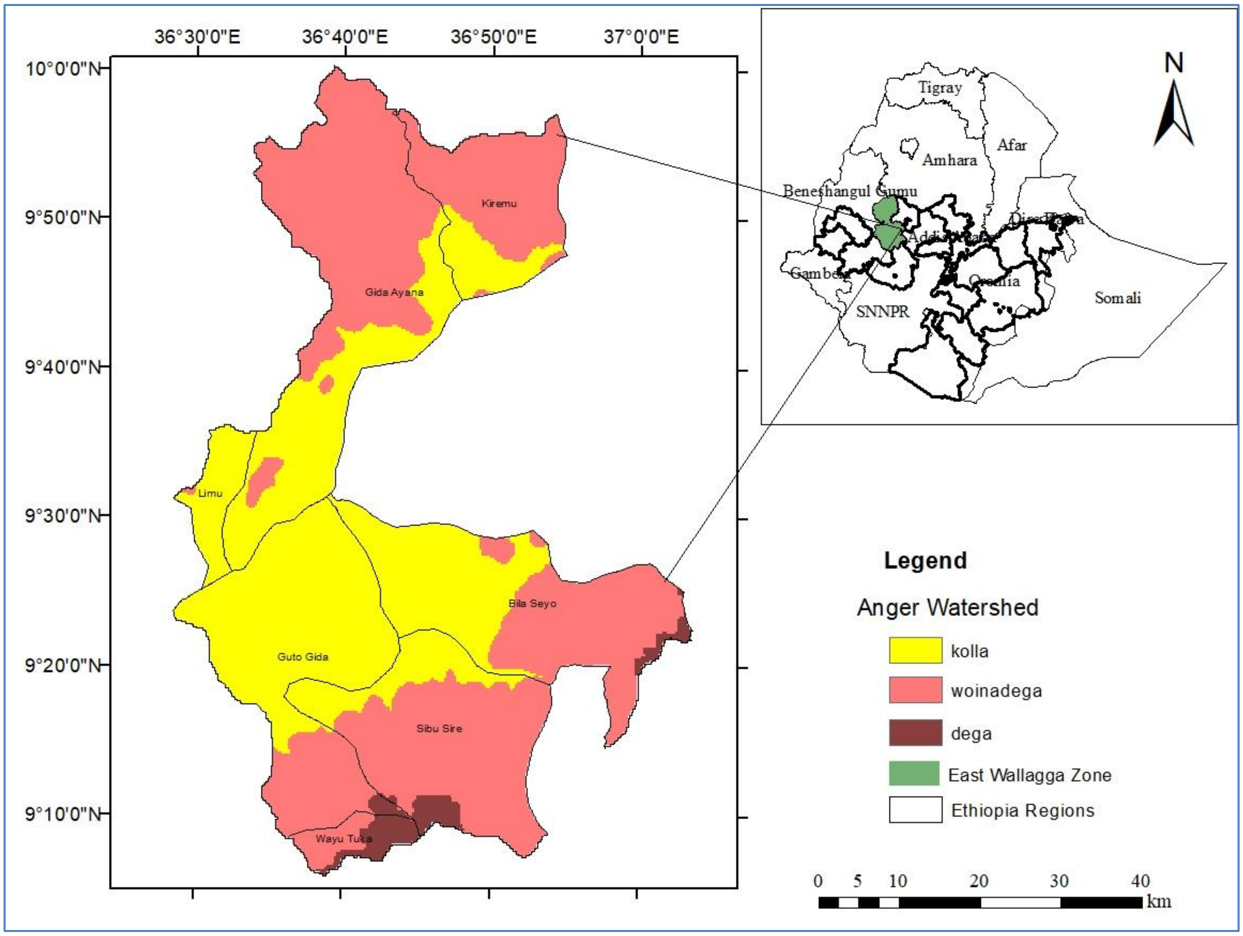

Figure 1.1. Map of the study area

The watershed consisted of *dega* (3.4%), *woinadega* (39.6%), and *kolla* (56.1%) (Figure 1.1). The watershed receives a mean annual rainfall of 1577mm mostly contributed by *kiremt* rain. The trends of rainfall show substantive spatio-temporal differences in the watershed. However, there is a general increase in annual rainfall amount for the entire watershed. The temperature trends show an increase in both maximum and minimum temperature with spatiotemporal variations which is among the manifestations of global climate change. The dega areas experienced the lowest mean annual minimum and maximum temperature of the watershed, particularly around Ilfata mountain of Wayu Tuka and highlands of Gida Ayana and Kiramu districts; while an extensive part of *kolla* agroecology partakes highest mean annual minimum and maximum temperature.

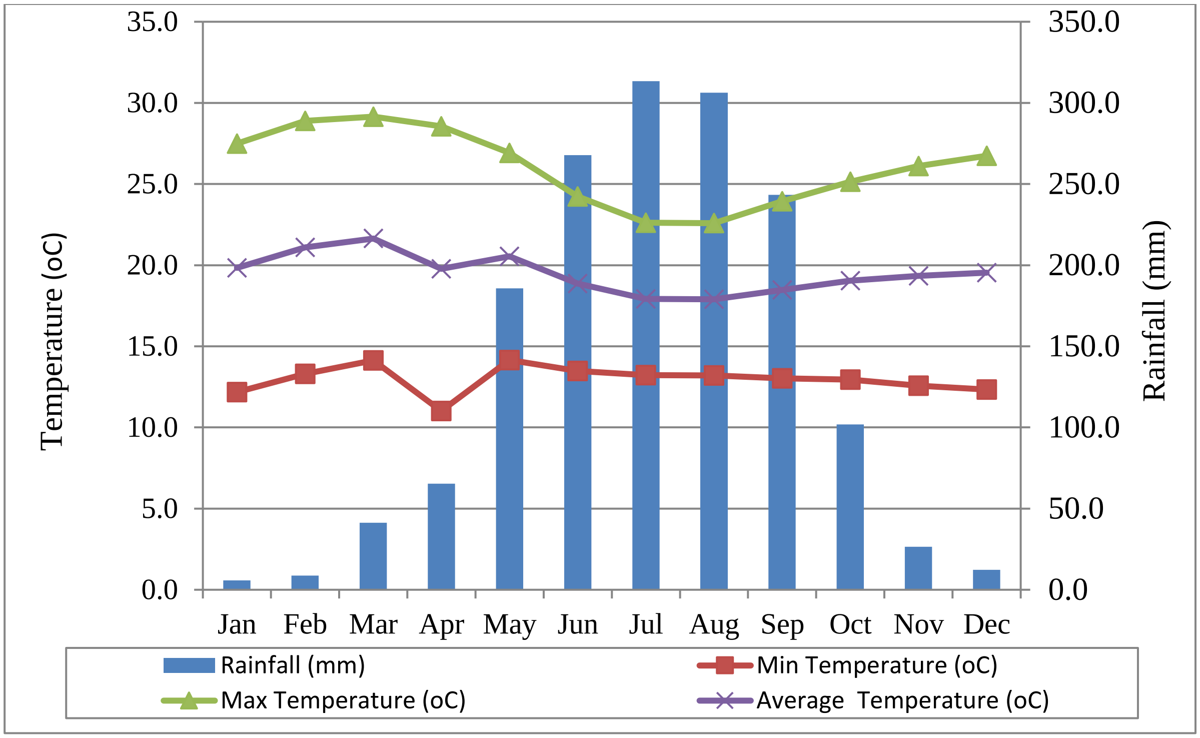

Figure 1.2. Mean Monthly Rainfall (cm) and Temperatures (°C) in the Anger watershed for the period 1983 – 2018 (Computed from NMSA's Climate data)

Land use land cover status and dynamics in the watershed has significant ecological and livelihood implications for the local community. Five LULC classes, namely forest land, agricultural land, grass/and bush land, wetland, and settlement are known in the study area (Figure 1.3). The dynamics in LULC and types showed significant spatio-temporal variations in the last four decades. The time-based trend was toward an increase in land use (agricultural land and settlements) and a decrease in land covers (grass/and bushlands, forest lands and wetlands). Although the trend is common in Ethiopia, the situations were astonishing in the *kolla* area, while relatively continuous innate trends comparable with other parts of the country were observed in the highland.

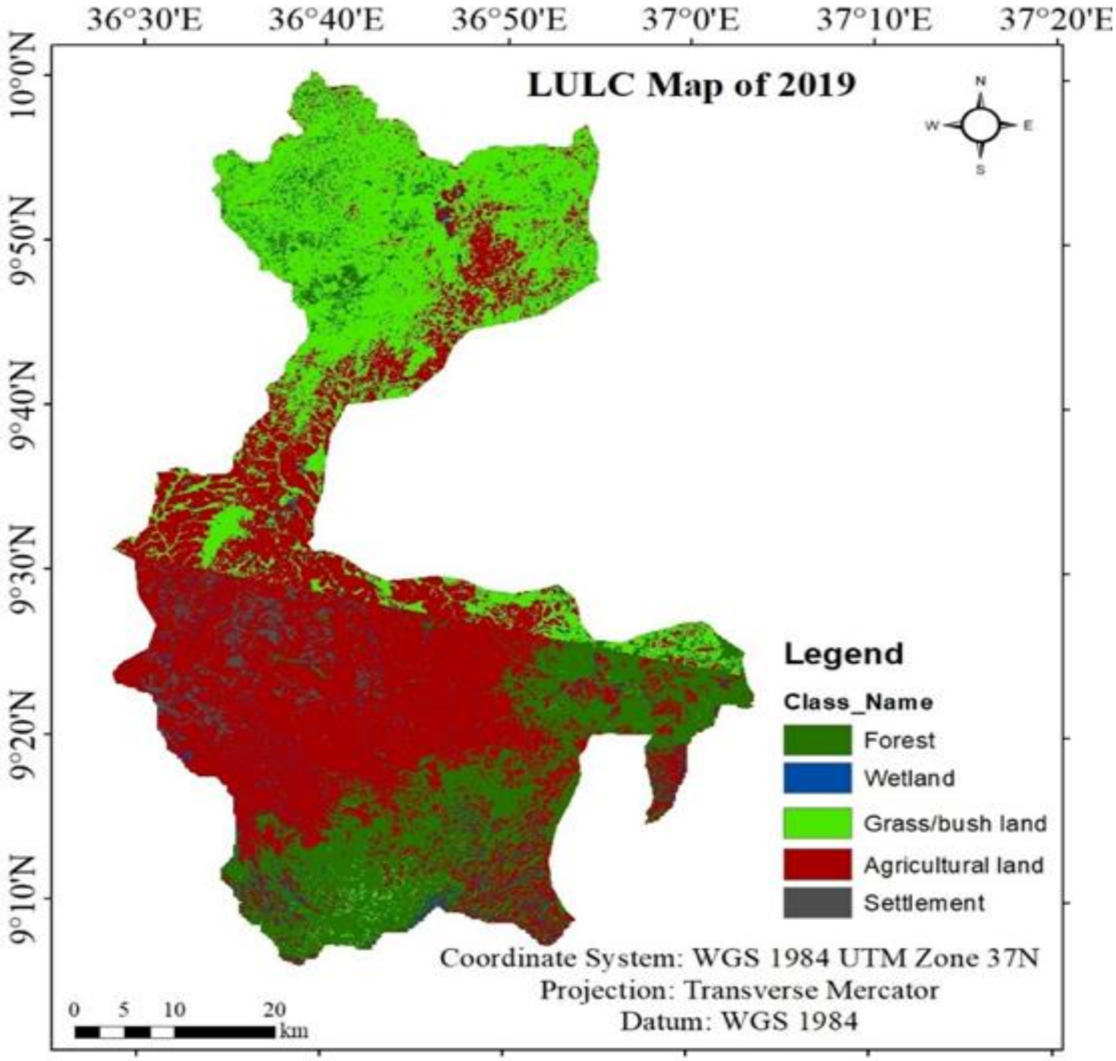

Figure 1.3 The recent LULC map of Anger watershed

The diverse biophysical features, and associated climate and natural resources distribution shape the livelihood systems of the local community on top of historical and political dynamics. About 82.28 % of the total population were rural and, directly engaged in agriculture. The mixed farming livelihood systems provide the main livelihood base for the local communities in the study area. Different types of crops such as cereal, pulses, and oilseeds are produced largely throughout the zone. Similarly, livestock rearing and beekeeping play a key role in the watershed. The vast communal natural ecology of forest and grasslands in *kolla* agroecology provides grazing, wild food gathering, honey productions, etc. to sustain the local livelihood. However, abundance and access to the resources have been diminishing due to economic interventions and demographic factors, on top of biophysical dynamics. Although the situations are varying from place to place, the livelihood systems of the community in the watershed have been affected by several socioeconomic and environmental factors such as land degradation, erosion, unreliable rainfall, small landholding size and land fragmentations, backward farm technology, lack of technical and financial supports, and poor infrastructures (Zone's FED, 2014).

Objectives of the study

General objective

The general objective of the research was to assess the global environmental change processes of climate variability and land use dynamics at micro-scale, explore the impacts of the changes on livelihoods (in combination and individually) of small-scale farmers in Anger watershed of southwestern Ethiopia.

The specific objectives were:

- ❖ To assess the processes of structural land use dynamics, and its local biophysical and socioeconomic implications on the livelihood systems of small-scale farmers
    - To examine the dynamics of land use/land cover in line with historical land use policy and tenure systems in Ethiopia since 1975, and
    - To explore implications of the land use dynamics on access to land resources and livelihood systems of small-scale farmers.
- ❖ To analyze the variability and spatio-temporal trends of climate, and impact perceptions
    - To examine the rainfall and temperature trends, variability, seasonal changes and occurrence of extreme events, and
    - To assess community's perceptions on the trends/and variability of rainfall and temperature, and impacts on their livelihoods along agroecology.

- To examine the magnitudes and spatial patterns of households' vulnerability and characterize the factors along case studies.
- To assess the status of adaptation and coping strategies, and the causal linkages of adaptation constraints.

Research questions

- How does the land use dynamics go on, and what are the implications of the dynamics on the local small-scale farmers' access to land resources and livelihood systems?
- What climate conditions have been observed in the study particularly in connection with rainfall and temperature trends, variability, and seasons? Is there observed significant difference among agro-ecologies? How do the local communities perceive the processes and impacts on their livelihood?
- What is the magnitude and spatial pattern of households' vulnerability to these global environmental changes (climate variability and structural land use dynamics)? Is there any difference along with case studies on the characteristics of vulnerability factors?
- What are the adaptation and coping strategies commonly adopted in the study area? How is the status of the small-scale farmers on the sustainable practices of these strategies? What are the constraints to the adaptation strategies in the study area?

Conceptual framework of the study

The local status and processes of global environmental changes such as climate variability and structural land-use dynamics has crucial livelihood implications on the local communities. Thus, in this study we have linked the state of these change processes with their impacts on the livelihood situations of small-scale farmers in the study area (Figure 1.4). The resilience and agroecology frameworks were integrated for a better understanding of the global environmental change processes at the local level, spatio-temporal variations in the underlying drivers of the changes, and the livelihood impacts of the processes on the local community.

The agroecological concept were used to understand the local contexts of climate variability and structural land use dynamics through case-based analyses of the processes along with agro-ecologies in the study. Although the recent studies and policy directions are contextualizing agroecology toward the interactions of biophysical and socioeconomic processes that manifest according to different site-specific contexts (FAO, 2015), most of the studies guided by this approach to conduct an assessment on the rural household's livelihood situations in Ethiopia have narrowly defined the agroecological perspectives. These researches have framed by production ecology and focused on how the biophysical dynamics, mainly resulted from climate change along different agroecology have been affecting their production functions, and impacting the livelihood systems of a community. Moreover, these researches give less attentions for the agroecology of national/and global political and socioeconomic processes and impacts.

Although climate change as an aspect of the global environmental changes was considered in these studies, other site-specific non-climate processes were overlooked in conceptualizing the issues. However, in this study the simultaneous perspectives of the production ecology and political ecology were considered for the constructions of the agro-ecology approach. Thus, the local contexts of global environmental changes were framed by this approach to examine the local processes of the changes, and integrated with the resilience framework to assess the impacts, particularly, the household's vulnerability to global environmental changes and the situations of the local level adaptation strategies.

Putting its foundation on sustainable livelihood approach, the resilience approach was appropriate for the study mainly due to criticality of analysis at the household-level livelihood pathways, and keen attention to a range of asset statuses and vulnerability contexts of the rural poor. However, the limitations are centrality to internal capacity of a household in practices; albeit consider externalities of intervening processes in analyzing the local livelihood pathway, oriented to non-farm livelihood diversification strategies and assumption that agriculture is no longer a major source of sustainability in rural livelihoods. Thus, toward complementarity to these limitations, the agroecology approach (with its production ecology and political ecology perspective) was integrated in this study.

The resilience framework (Frankenberger, Langworthy, Spangler, & Nelson, 2012) is flexible solely appropriate in such studies, and could be combined with double/multiple exposure framework (Leichenko and O'Brien, 2008) to solve the centrality to internal capacity, and shallow emphasis in the processes and causal linkage of non-climate externalities. It incorporates a livelihood framework, disaster risk reduction framework, and elements of climate change approach to address the issues under consideration. It also helps to understand how long-term propensities to institutional, socio-economic and environmental factors affect livelihoods security of a community, and the need to formulate policies and programs to address critical needs. It focused on adaptive capacity of households which consists of access to assets, transformative structures and processes as well as diverse adaptation strategies.

As far as the study is focused on the smallholder farmers' vulnerability to climate change and structural land use change, the double exposure framework is used to indicate the context and disturbance relevant for the study area, identify the underlying causes of vulnerability, and constraints of adaptation and coping strategies of the community.

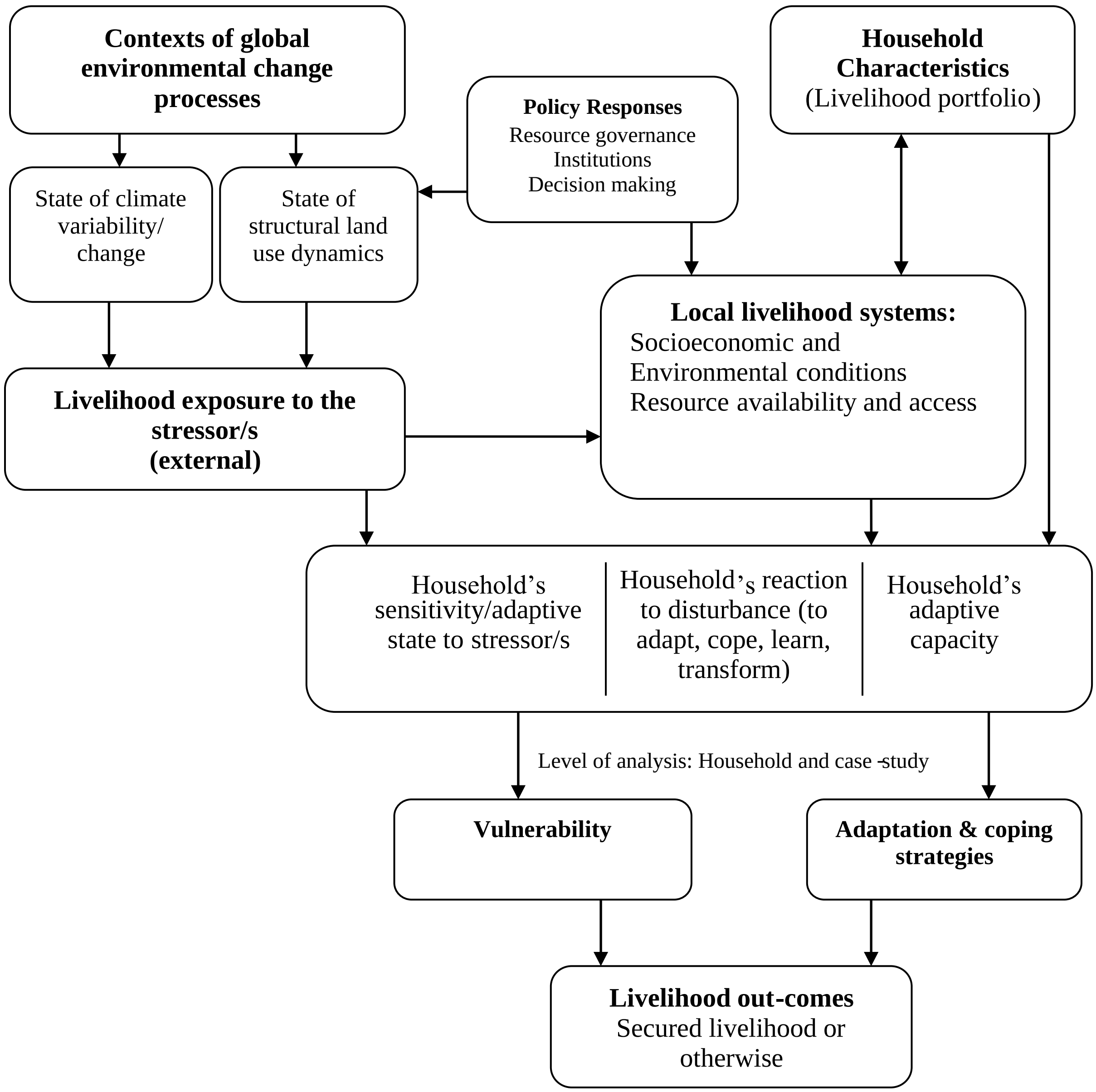

Figure 1.4. A schematic chart showing the state of global environmental change, the processes, and local impacts on households' livelihood.

The framework is relevant for the study because it integrates a number of local specific global environmental change processes for the local impacts assessments and livelihoods out-comes. It helps to identify the necessary requirements for acquiring and capitalizing upon the local assets structures through a process of appropriate policies, legislation, power relations, norms, market stability, and general rule. It offers knowledge on why and how a local community could be vulnerable to these processes and their inherent adaptation and coping strategies could be constrained by the change processes. This knowledge informs how to achieve greater resilience to those under site-specific stressor/s, and better adaptation strategies applicable to the conditions. In general, these integrated frameworks help to connect the key components that make up the local livelihoods and the contextual factors that influence them.

Research methodology: philosophical foundation, approach and design

Identifying philosophical background was relevant for this study due to the fact that methodological debates in the issue of this research was not understood without reference to the wider cultural setting in which those discussions took place (Oftedal, 2014). The logical structures of the enquiry starts from a clear set-up of philosophical world view, strategies of investigation and identification of research methods (Creswell, 2012). More specifically, it includes hierarchal structures of ontological, epistemological, theoretical perspectives, research design, and associated research methods. Each phase informs the perspective next to it. Therefore, identifying ontological underpinning helps the researcher to know which epistemology fit the identified ontology and which theoretical perspective goes with the selected epistemic view and continued up to the specific research methods used in the study (Gray, 2017).

From two opposing ontological traditions, the study was oriented to ontology of being which expresses reality in organized and permanent manner opposite to becoming ontology which conceive reality as formless and chaos (Earl, 2008). The justification beyond the use of being ontology is that the global environmental change processes are reality which permanently existed in the area and believed that they manifest by their impact features such as abnormal climate conditions and denying access to livelihood assets through their agents of changing local biophysical, socioeconomic and political contexts, and results vulnerable livelihood outcomes for small-scale farmers.

Two epistemological stances (objectivism and constructivism) are proposed for this study due to the fact that there is no single holistic epistemic view used to address the range of realities in the study. The study consists an array of issues from very objective way of analyzing the global environmental change processes (LULC dynamics and climate variability analysis) to constructing the reality through in-depth exploration of community's concern on the processes and impacts on their livelihood systems. Positivism is the dominant theoretical perspective under objectivism epistemology and compatible with objectives of the study. The core argument in positivism is that the social world exists externally to the researcher, and that its properties can be measured directly through scientific observation and empirical inquiry.

Interpretivism is the second theoretical perspective proposed for the study due to the fact that it is closely linked to constructivism epistemology and appropriate for the variables to be studied in this research. It asserts that all realities are not similar and therefore require different kinds of methods. Looking for consistencies in the data in order to deduce 'laws' is not enough that social reality often attained through dealing with the actions of the individuals(Crotty, 2009). Therefore, the change processes and impacts, and associated socioeconomic, political and ecological reality in the study area were investigated in the context of that specific area and generalization were made profoundly.

According to Gray, both positivism and interpretivism hold different epistemological positions, but they are based on being ontology. Therefore, he prescribes to use both at the same time for those researchers covers the range of issue to be studied through both theoretical perspectives (Gray, 2017). The justification for dual epistemology in this research includes: the research consists number of objectives that epistemology and associated theoretical perspective and methods appropriate for one objective is not appropriate for the others; synergistic effects whereby the result from one methods can often shape/inform other methods; the study was intended to extend the breadth and range of global environmental change study through investigating the processes, impacts and associated vulnerability and adaptations procedurally to produce detailed finding and answer new/ and modified questions.

Nature of the research problems and the identified philosophical background demand the mixed research method approach. Moreover, the existing literatures in areas of the issues recognized the importance of mixed method to clearly understand the implication of global changes at local level. More generally, the growing interest is toward 'multi-strategy designs', where there is substantial collection of both qualitative and quantitative data in different phases or aspects of the same research (Marczak, David, & David, 2005). A mixed methods research approach is “a procedure for collecting, analyzing, and mixing both quantitative and qualitative data and methods in a single study or a series of studies to understand a research problem comprehensively” (Creswell, 2012). In line with these, there are objectives in the study which requires both qualitative and quantitative data at the same time (one method embedded in the other) with the same objective to complement or substantiate each other. In the other way, both methods were applied to address a series of objectives.

The approach allows the use of multiple research methods and design depending on fitness to objectives of the study, the type of data required, methods of data collections and analysis. Thus, both survey and case study research designs were used in the study. Therefore, types of data, methods of data collections and analyses were guided by these designs.
The purpose of descriptive in the study was to provide a picture of a phenomenon as it naturally occurs and compare the data against some standards (Gray, 2017). Therefore, the data on temperature and rainfall, and land use were collected, analyzed and the results were compared with some standard to describe the processes, their implication and impacts on small-scale farmers’ livelihood in the study area.

However, these issues are not easily understandable by only what observed and measured from the external, some variables are internal to the community, and even the are cognized by the local community differently; and the underlying causal linkages among the processes and their impacts could not be understood only by measuring the reality as it is naturally occurs. Therefore, exploratory study was used to discover the in-depth perception and knowledge of the local community and other stakeholders. Therefore, the data were collected using FGD, interview, relevant document analysis and analyzed qualitatively.

The mixed research method approach solves the problems of dichotomy in reasoning (deductive and inductive approaches). Therefore, based on the specific objectives of the study (either to test the hypotheses or answer the posed research question) both deductive and inductive reasoning were applied in the research. The cross-sectional timeframe was for the study. The justification for cross-sectional timescales is that, the data was collected at one point in time which was compatible with the research design.

In general, concurrent mixed method procedures were used, by which the researcher combines quantitative and qualitative data in order to provide comprehensive analysis of the research problems. Moreover, both forms of data were gathered concurrently during the fieldwork and then integrated in the analysis according to their relevance. All data were managed appropriately to ensure the over-all validities and reliabilities of the research; and used in a manner to give clear meaning to each other, to explain the gaps, and to draw conclusions and formulate policy options.

Dissertation outline

The dissertation contains six chapters. Chapter one is an introductory part which consists background of the study, contexts of the issues in the study area, rationale, objectives, research questions, conceptual framework and methodology. The second chapter deals with dynamics in structural land use in the study area. The chapter explores the processes of structural land use changes, associated LULC dynamics and its implication on small scale farmers' access to land resource.

In the third chapter, the spatio-temporal trends and variability in rainfall and temperature revealed. Particularly, agroecology-based difference in the climate variability and trends, and community perceptions on the trends of rainfall and temperature and their concerns on the livelihood impacts of the changing climate situations were reported. The fourth chapter exhibited the extent of small-scale farmers' vulnerability at household level, illustrate the spatial differences in magnitude and characteristics of vulnerability factors along case studies. The underlying vulnerability factors, subsequent livelihood outcomes and its causal linkage with global environmental change are identified for each case study.

Chapter five presents the small-scale farmers' adoption status of adaptation and coping strategies, and local specific adaptation constraints. The difference in status of adoptions and extent of adaptation constraints were reported for case studies which were attributed to the difference in exposure to global environmental changes. It reports the local farmers' experiences in the human–environment co-existence and their ecological knowledge for natural dynamics in ecosystem, and how the experiences have been aggravated by the transformation of the rural landscape. The sixth chapter consists the summary of key findings, contributions of the study to knowledge, policy implications and future research agendas.

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CHAPTER TWO

Structural Land Use Dynamics and its Implications on Local Community's Access to Land Resources in Anger Watershed, Southwestern Ethiopia

Article in Press: *Gemechu Yigezu & Muluneh Woldetsadik (2021). Structural land use dynamics and its implications on the local Community's access to land resources in Anger watershed, Southwestern Ethiopia, African Geographical Review*, Taylor and Francis Group, DOI: *10.1080/19376812.2021.1962374.*

Structural Land Use Dynamics and its Implications on the Local Community's Access to Land Resources in Anger Watershed, Southwestern Ethiopia

ABSTRACT

We examined the micro-scale spatiotemporal dynamics in structural land use and its differential impacts on small-scale farmers' access to land resources in Anger watershed, southwestern Ethiopia. The analysis of historical land use land cover change detections was integrated with data obtained from 335 households, group discussants, and interviews with experts and officials. The results revealed that agricultural land and settlements increased at the expense of other land covers. These conditions were severe in the kolla agroecology due to unique historical land-use dynamics mainly in the late 1976 and since 1988 which were associated with the state-farm and private investment respectively. The process affects small-scale farmers' access to land and natural resources and contributed to differential livelihood adverse. The kolla community expressed land deal processes in the area negatively, labeled the investment activities as contrasting to investment initiatives of the country, and the conditions have been compromising their livelihood system. Thus, the issues of land resources rights of the local community and the state policy dynamics on the land investments, mainly referring to the livelihood systems in the kolla agroecology seek more attention. The development interventions such as the large-scale agricultural investments in the area need a prior policy and strategic planning on how to realize the sustainable co-existence among the large-scale investors, local community, and natural environment.

Keywords: structural land use dynamics, access to land, resources entitlements, global environmental change processes

1. Introduction

Access to land and natural resources is fundamental for poor rural dwellers for they provide livelihood assets and social sustainability (Clover & Eriksen, 2009). Small scale farmers' access to land in southwestern Ethiopia is based on custom, through the act of original clearance of the land and settlement by ancestors. However, as resources become scarcer and more valuable, those with weak rights and poor access to this resource especially the poor local community tend to lose out (Brasesco, 2012; Saturnino, 2016). These conditions have been aggravated with recent dynamics in land use and land cover (LULC) associated with national and global socioeconomic drivers (Adger et al., 2015).

Small scale farmers' livelihood systems in the Anger watershed depend tremendously on access to ecologically diverse land, to ensure livelihoods through crop productions, rear livestock and exploit natural forests. Consequently, lack of access to the resource and its deterioration due to states' large scale agricultural 'development' induced dynamics in land use and tenure systems have significant livelihood implications on the community. Moreover, addressing the resource access security of the group is crucial for social justice, political stability, promoting rural development, and even to create conditions that encourage large scale investments.

The observed land-use dynamics in the study area are characterized as structural in this study, particularly as the ownership of land and properties are a result of resource use governance and the land tenure system. Specifically, the dynamics of landholding among the local community, the state, private domestic, and international investors are mostly driven by national land policy changes and the global demands for agricultural land. Moreover, the drivers of land use and land cover changes, in this case, are dissimilar from commonly observed drivers in Ethiopia. This change process is highly structured because it has been motivated through the state's intervention in the name of 'development'(Dessalegn, 2011) since the 1970s in the Anger watershed. These change processes have been increased with the recent global foods and energy demands (Makki, 2014; Stephen, 2013) in which global large scale investments are targeting Africa, believing that land is in excess. The change process at a certain time has unique characteristics defined by the adopted economic system and land use policy of the state at the time, resultant environmental and livelihood impacts, and end with policy changes. Thus, the issues were conceptualized in this study with a strong assumption that these change processes resulted from the international and national interests in land utilization that have been taking place for long periods in the study area. These conditions have had significant impacts on the physical environment and livelihood system of the local community.

Historically, Anger watershed of southwestern Ethiopia, mainly the *kolla* agroecology have been experiencing large scale mechanized farm since the mid-20th century. *Kolla* agroecology is the warm lowland area situated in the interior part of the watershed having rich biodiversity, favorable biophysical settings for agriculture and forestry. In 1970, three Dutch citizens established Anger-Gutin Agricultural Project; followed by large scale state farm established under Welaga Agricultural Investment Enterprise in 1975. These interventions for agricultural investments were continued by changing the features of the state farm to a private large scale agricultural investment after 1991 (Dereje, 2018). Although there is a lack of empirical data specific to the study sites these structural changes in land use and tenure systems (Prno et al., 2011) to encourage the large-scale state farms and private investments have affecting the community's access to land resources and their traditional livelihood systems similar to the other communities in different parts of Ethiopia (Clover & Eriksen, 2009; Desalegn, 2013; Dessalegn, 2011; Keeley, Seide, Eid, & Kidewa, 2014; Tariku, 2016).

Currently, in different parts of the country, the government has been accused of its implementation of the development activities at the expense of the local communities and physical environment. Similarly, the Anger watershed was and still is an area where the state made intensive interventions in the name of 'development'. Several studies have tried to identify the consequences of land alienation on the social economy of local communities (De Zoysa, 2013; Makki, 2014; Rakotonarivo, Jacobsen, Poudyal, Rasoamanana, & Hockley, 2018; Stephen, 2013). However, none of them have examined the historical accounts of LULC, associate the trends with underlying national and global environmental change processes at a local level to understand the livelihood implications of the processes at the household level.

This paper examined the links between changing land use and tenure system, and community's access to land resources since the 1970s in the Anger watershed of Southwestern Ethiopia. Inspecting the spatiotemporal dynamics of LULC and exploring the farmers' access to land resources can make significant contributions to understanding the small-scale farmers' livelihood pathways to the impacts of global environmental change processes. The general objective of the study was to assess the structural land use dynamics and its implications on small-scale farmers' access to land resources. Specifically, the study was intended to examine the LULCs' of the identified study area from 1976-2019, to explore the associations between the changes and the state interventions for 'development', and to identify the implications of the processes on the livelihood systems of the local community. The processes and impacts have spatio-temporal aspects in the watershed, as the *kolla* and highlands agroecology have different exposure to these development interventions. Moreover, the policy orientations for the political and development of the country have significant temporal differences, dependent on prevailing political regimes. Thus, LULC change detections and data from the research participants were analysed based on these spatio-temporal contexts, and comparisons were made.

2. Conceptual Frameworks

The recent global environmental change research have been served to reinforce public and scientific recognition that a significant structural land-use change has been happening, denying local community access to land resources, and affecting the livelihood systems of the poor small-scale farmers (Prno et al., 2011). By focusing on the arguments of these studies, we have intended to understand the local situations of these change processes and its impacts specifically on the livelihood systems, and well-being of small-scale farmers. Thus, both land use change science and political ecology were used as complementary approaches. The common ground of the approaches tied the specific objectives which ranges from examining LULC changes, explore the link between the change conditions and 'development's interventions', and identify the implications of the processes on the livelihood systems of local community.

The land use science viewed as a contemporary study, devotes attention to human-environment dynamics on the terrestrial surface of the Earth (land dynamics), seeking to understand land uses and covers, and the processes of their changes to inform the sciences of global environmental change and sustainability. The field of political ecology typically examines the same dynamics with an emphasis on informing a pathway for the well-being of small-scale farmers. Both sub-fields acknowledge land dynamics in terms of interactive processes of the human and environmental subsystems. They share interests in topical problems such as institutions and governance, socioeconomic impacts of development endeavours, equity and environmental trade-offs. In addition, the work in both sub-fields shares interests in spatial themes to understand human-environment relationships (e.g., access to land resources along different agroecology), and the use of spatial knowledge and information(Turner & Robbins, 2008).

The application of remote sensing-based LULC studies has contributed to land-use change science. Coupled with the ready availability of historical remote sensing data, the reduction in data cost, and increased resolution from satellite platforms, remote sensing technology appears poised to make an even greater impact on researchers, planning agencies, and land management initiatives work on LULC change at a variety of spatial scales(Yadav and Roy, 2013).

The LULC pattern of a region is an outcome of natural and socioeconomic factors. Land use and land cover are closely related and have been used interchangeably in many LULC change studies. Although demarcating the concept of land use and land cover is difficult, perceiving them as similar concept and using them alternatively is problematic. Thus, based on previous research(Forkuor & Cofie, 2011; Habtamu & Abate, 2018) on LULC, the following LULC classes were identified and used in this study: grass and bushlands, forests, wetlands, agricultural land, and settlements. The change detection process allows a pragmatic approach (George et al., 2016). Therefore, the observations of LULC conditions, historical accounts on land deal processes, and associated changes in land use and tenure systems in the watershed were used to identify the years for LULC data, the time intervals for change analysis, and to define the types. Specifically, the satellite image for the year 1976 was used to identify the

LULC situations when the land resources were used by the local community before the introduction of large-scale state farms. The interventions for the investments were insignificant in the times before this year. The data for the year 1991 was used to characterize the LULC situations during the state farms (1976-1991), 2001 for the situations when the land use was returned to the local community (1991-2001), 2019 for the present situation of LULC when the private large-scale investments dominated the land use (2001-2019). Finally, change detection was made focusing on four basic analyses: detecting the changes, measuring the area extent of the change, identifying the characteristics of the change periods, and assessing the spatio-temporal pattern of the changes. The land-use change science informed by the political ecology approach was applied in this study to explore the implications of the change processes for the small-scale farmers' access to land resources through discourses on the causal linkage of the processes and outcomes(Turner & Robbins, 2008).

3. Research Methods and Materials

3.1 Descriptions of the study area

The focus of this study was the Anger watershed, which lies in east Welaga administrative zone in Ethiopia. Astronomically, the study area lies extended from 09°12' to 10°00' north and 36°30' to 37°11' east (Figure 1). The area within a single administrative zone was selected to reduce heterogeneity in the socio-economy and governance of land resources.

Anger watershed encompasses various landforms with altitudinal ranges of 1200-3018 meters above sea level (Figure 1). Similar to other parts of the country, these altitudinal differences remain the significant factors for the climate variations, and the associated distributions of natural resources, and have shaped the socioeconomic conditions of the local community on top of historical and political factors. About 82.28 % of the total population is rural, directly engaged in agriculture. Different types of crops such as cereal, pulses, and oilseeds are produced in this area. Similarly, livestock rearing, hunting and gathering, and beekeeping have key livelihood roles(FED, 2014).

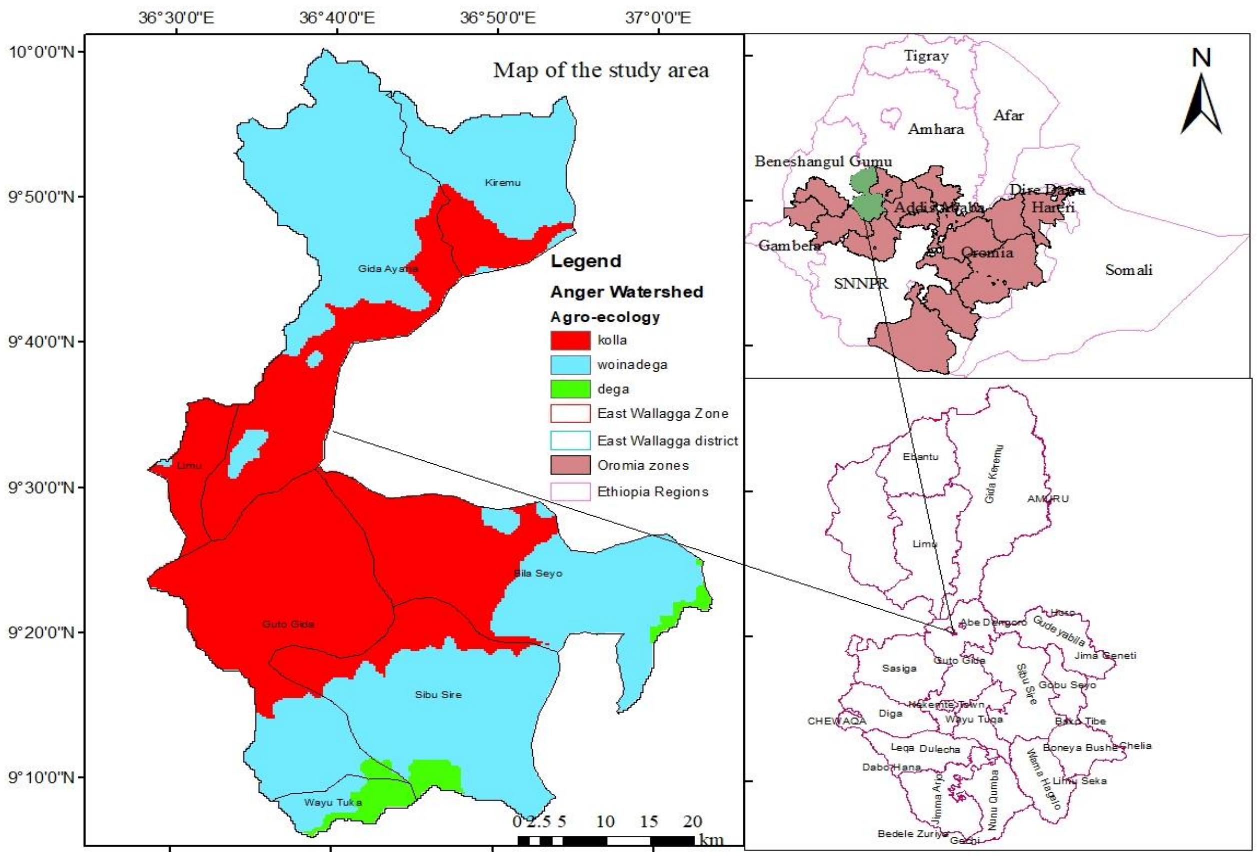


Figure 2.1. Map of Anger watershed

3.2 Research design

The study consists of an array of issues from examining LULC dynamics to identifying reality on the processes and its livelihood implications through exploration of the community's concerns. Therefore, a mixed research method approach was used for the study. The household heads questionnaire survey and satellite based LULC data were conducted quantitatively and substantiated by qualitative data obtained from the elderly, experts and officials. It is an appropriate design to collect several data from diverse sources and systematic analyses due to its quantitative orientations in one way, and explain self-reported ideas of the respondents in another way.

3.3 Research methods

The multistage sampling techniques were used for the study. The smallholder farmers household is the unit of analysis of the study. First, districts and *kebeles*[1] with different land use and tenure systems and livelihood situations were identified and randomly selected. After random selection, the lists of households were obtained from the relevant office (i.e., their respective *kebeles*). The following sample formula (Kothari, 2004) was used to determine the sample size. The formula provides the sample size needed with a given degree of accuracy when the population is finite.

$$n = \frac{z^2.p.q.N}{e^2(N-1) + z^2.p.q}$$

Where; p = proportion agreeing, $q = 1 - p$; $p = 0.50$ would assume to provide the maximum sample size so that q=0.5; z = the value of the standard variate at a given confidence level. The margin of error 5% were used, z-score (1.96); n = size of sample; e = the desired margin of error which is 5% (0.05); N= total population.

The required sample size from the total 2,642 households in all *kebeles* was 335. The sample size for each *kebele* was determined based on the proportionality of their household size. Finally, a random sampling technique was used to select household heads for the questionnaire. Participants for the interview and focused group discussions were purposively selected from the local elderly, experts, and government officials having better experiences on the ecological and livelihood systems, and expertise on the issues. The data were obtained from Landsat-based satellite images, farmers' household heads, the elderly, experts, and government officials.

Satellite based LULC data from Landsat MSS (Multi-spectral Scanner), Landsat TM (Thematic Mapper), ETM+ (Enhanced Thematic Mapper Plus) and Landsat- 8 were used to detect and analyse the spatial and temporal dynamics in land use and land cover, and substantiated by the data obtained from all participants on the study of structural land use dynamics. The dates for remote sense data were determined on the basis of historical events

[1] *Kebele is the lowest administrative tier at the grassroots level in Ethiopia; it may be equated with parish/county.*

of structural land use dynamics (Dereje, 2018; Dessalegn, 2011). Therefore, Landsat MSS image of 1976 (before introduction of large-scale state farm), the Landsat TM images of 1991 (state farm banned and small-scale farmers begin to use the land), ETM+ image of 2001 (after introduction of private large-scale agriculture) and Landsat-8 image of 2019 (present situation of LULC) were used. The structured questionnaire, semi-structured interview and Focus Group Discussions (FGD) were used to collect data regarding the historical situations of land use and tenure systems, the trends in socioeconomic development of the local community, and the implications of these change processes on the livelihood systems of the local community from the participants. Field observations were used to have clear insights on observable conditions such as land use and land cover status and the local livelihood situations in the study area.

The study applied two data analysis techniques. The LULC change detection was made by ArcGIS 10.4 and ERDAS IMAGINE 2015 software packages, the questionnaires were analyzed descriptively, while interviews, FGDs, and field observations notes were analyzed qualitatively. LULC change is the observed quantity of given land use and land cover type during a given period. In this case, the annual rate of change for each LULC class was calculated using the following formula (Batar, Watanabe, & Kumar, 2017):

$$r = \left(\frac{1}{t2-t1}\right) * \ln\left(\frac{A2}{A1}\right)$$

where r is the rate of LULC change for each class per year; and A1 & A2 is area of the LULC type for two different periods.

4. Results and Discussions

4.1 Land use and land cover types and dynamics in the watershed

The extent of LULC and their relative change over 43 years (Figure 2.1), and LULC area and the annual rate of change (1976 - 2019) are presented in Table 2.1. Five LULC classes were identified in the watershed, namely: forest land, agricultural land, grass and bushland, wetland and settlement. The spatio-temporal LULC change analysis was made to compare the changes in the *kolla* against the entire watershed to pinpoint the different dynamics.

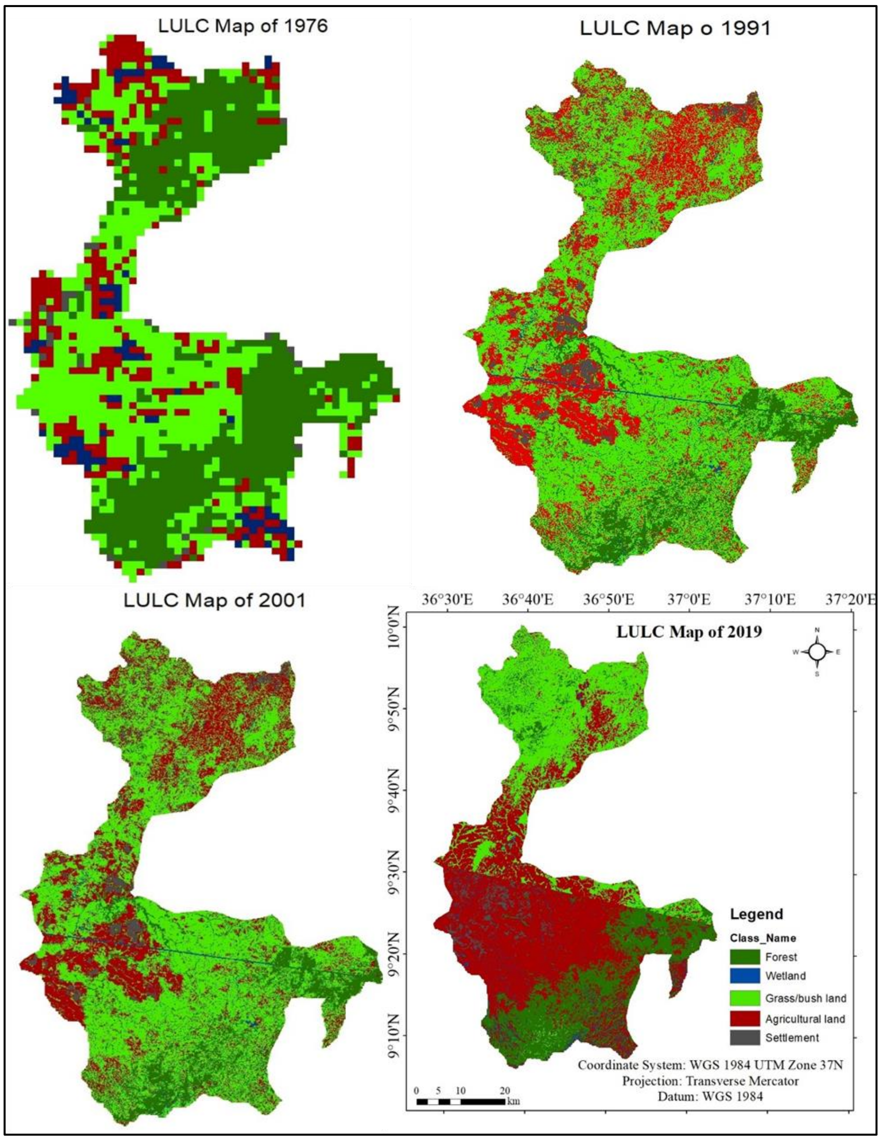


Figure 2.1: LULC change detection in Anger watershed

The agricultural lands and settlements increased from 1976 to 2019, while grass and bushlands, forest lands, and wetlands decreased (Figure 2.2). After 1976 there has been an extensive change to agricultural land use at the expense of other land covers (i.e., grass and bushlands, forest lands, and wetlands) in the watershed. However, this condition was not uniform, as the *kolla* showed remarkable changes in inter-conversion, mainly from grass and bushlands and forest lands to agricultural lands (Table 2.1).

The annual rate of change in agricultural land in the kolla was four times greater than the increase observed for the entire watershed in the last 43 years, while the rate of increase in settlements was higher for the entire watershed. Similarly, other land covers have decreased in the kolla at rates distinct from the entire watershed. These results indicated that the dynamics in the LULC situation of the watershed were significantly contributed by the dramatic conversions into the agricultural land in the *kolla* mainly for the large-scale investments. Although, shift from other land covers to agriculture and settlement is commonly observed in Ethiopia (Habtamu & Abate, 2018; Markos, Mihret, Teklu, & Getachew, 2018; Obang, Sintayehu, & Dessalegn, 2017), the changes are mostly due to high livelihood dependency on land resource, rapid population growth primarily in rural, and bio-physical drivers such as climate change (Berhan & Woldeamlak, 2014; Teshome, Tolera, Kefyalew, & Habtemariam, 2019) unlike the situations in the study area. Particularly, the FGD results from *kolla* revealed that the conditions were different from the rest of the watershed, which was attributed to historical dynamics in land use resulting by the state interventions for investments.

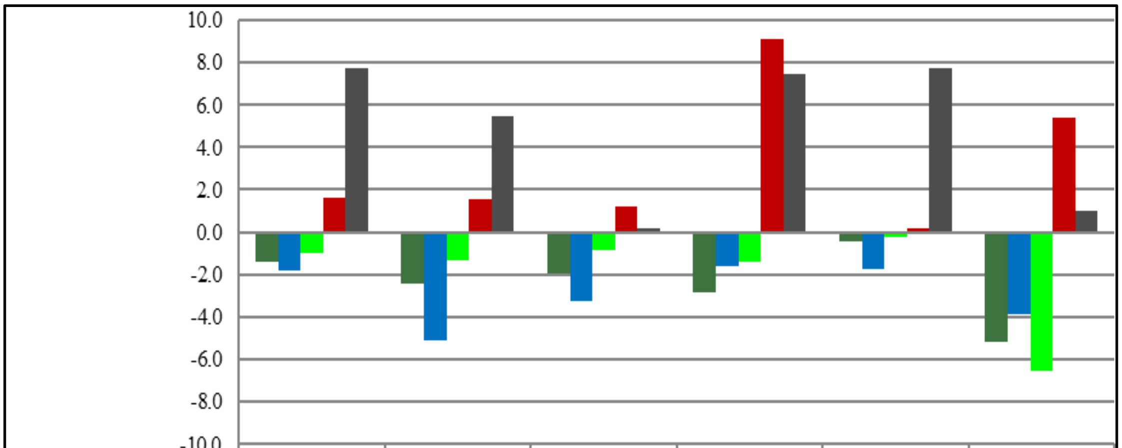
Moreover, the consistent and slow rate of LULC changes were observed along different change periods for the entire watershed, while these characteristics were different for the *kolla*, where each change period has the unique rate of change for most of the LULC types. These situations in the *kolla* imply the exceptional land use and tenure systems which resulted in the highest rate of increase in agricultural lands in the first and third change period. For instance, the annual rate of increase in agricultural lands for the *kolla* was about six-fold higher than the rate observed for the entire watershed in the first change period (Figure 2.3) was resulted from the state farms in 1976-1991.

Table 2.1. Land use land cover changes in Anger watershed (from 1976-2019)

LULC Classes	LULC for watershed (ha)					LULC for *kolla* (ha)				
	1976	1991	2001	2019	1976-2019 (Δ/Y) %	1976	1991	2001	2019	1976-2019 (Δ/Y) %
Forests	631860	513852	403346	282265	-1.88	413452	280949	269518	106432	-3.15
Wetlands	176040	133708	80402	24686	-3.14	106815	91016	83951	41904	-2.17
Grass and bush lands	1201499	1031913	902946	797397	-1.01	638092	533228	519442	159088	-3.23
Agricultural Land	727900	930125	1087233	1358986	1.45	86400	333172	339255	897758	5.44
Settlements	58042	185743	321414	332005	4.11	13381	18975	40974	49366	3.04

The annual rate of change in LULC types along identified change periods was presented in Figure 3. The analyses were done based on the history of structural dynamics in land use situations in the study area. The first change period (1976-1991) represented the conditions from the start to the end of large-scale state farms. The second period (1991-2001) was when the small-scale holders were provided the land resources for agricultural transformation (during this period, most of the land which was under the state farm previously was given to the local farmers), and the third period (2001-2019) was when large scale investors take over the lands in the valley.

Although the total detection period (1976-2019) showed significant change, the different LULC change periods showed relatively uniform rate of changes for the entire watershed (Figure 2.3). However, the situation was different for *kolla* area in that all individual change periods had distinct characteristics. Agricultural land was significantly increased in the first change period at expense of forest, grass and bush lands, and wetlands, while the annual rate of increase for the settlement was high for the *kolla* in the change period but less than the change rate observed for the entire watershed. This was in line with aggregate annual rate of change observed (Table 2.1), where increase in agricultural land was the largest contributor to decrease in other land covers.



LULC Classes	Rate of Change/Year for Entire Watershed: 1st Change Period	2nd Change Period	3rd Change Period	Rate of Change/Year for kolla: 1st Change Period	2nd Change Period	3rd Change Period
Forest	-1.4	-2.4	-2.0	-2.9	-0.4	-5.2
Wetland	-1.8	-5.1	-3.3	-1.6	-1.8	-3.9
Grass and Bushland	-1.0	-1.3	-0.8	-1.4	-0.3	-6.6
Agricultural Land	1.6	1.6	1.2	9.1	0.2	5.4
Settlement	7.8	5.5	0.2	7.5	7.7	1.0

Figure 2.3. Comparisons on the annual rate of LULC change along detection periods between entire watershed and *kolla* agroecology from Landsat Images

The rate of change in all LULC classes except the settlements was the lowest for the *kolla* in the second change period. This condition could be attached to the political changes in late 1991. According to the group discussants in the *kolla*, the land previously owned by the state farms was returned to the small-scale farmers. However, this condition ended when the government turned to large-scale agricultural investors after 1998. Thus, the agricultural land was increased at the lowest rate in this period, and the forest lands and grass and bushlands were decreased at the lowest rate, while relatively the highest rate of wetlands depletions was observed as compared to the first change period. The settlement was continuously increased, and unlike other LULC classes, it had the highest change rate observed in this period (Figure 2.3).

The dramatic rate of change in LULC was observed in the third change period in the *kolla* when agricultural land shows a remarkable rate of increase at the expense of the highest rate of decrease in grass and bushlands followed by forest lands. The introduction of private agricultural investment resulted in aggressive land investments, even the pocket forest and grassland left after state farm was converted to private agricultural land by investors. This result is in line with the findings from other parts of Ethiopia which experienced similar socio-economic and institutional factors, particularly in Gambella and Benishangul Gumuz regional states (Dessalegn, 2011; Mesfin, 2013; Obang et al., 2017; Tsegaye & Spoor, 2015).

The observed difference between the second and third change period (2001-2019) could be associated with several factors. First, during the transitional period in post-1991, the government pursue small-scale-based agricultural development when the local community was encouraged to cultivate the land previously under the state farms. During this period even self-initiated small-scale farmers were migrated to the area, but the time was characterized by a lesser increase of agricultural land. However, this initiative did not last long and was replaced by large-scale private agricultural investment. These conditions contributed to dramatic land cover depletions in two ways. First, most farmers became landless and relocated to virgin land clearing forests and grasslands. Second, the investors' aggressive land investments and illegal expansions resulted in landslide transfers to agricultural land. Similar to the research findings in the other parts of the country regarding the administrations of large-scale agricultural investments (Dessalegn, 2011), these processes were mainly due to mismanagement of the investments' activities in the mid-2010s.

Group discussants in the *kolla* explained that the rapid expansion of illegal settlement in and around state farms due to lawlessness during the 1991 political transition in Ethiopia resulted in the increase of the settlements. Moreover, open access to the land under state farms with the collapse of the enterprise, and later on, the government promotion of small-scale farmers during the first half of the 1990s was given the rise in self-initiated settlements. According to the group discussants, this population influx was continued due to laborers migrated to the area with the coming of private investors.

4.2 Small-scale farmers' access to land resources

Table 2.2 describes the comparative status of farmers' engagement in agriculture, landholding conditions, processes, size, and their options to access land in the kolla with their counter-highland small-scale farmers. Almost all small-scale farmers in the watershed engaged in agriculture with significantly high access to land. However, the extent, processes, and landholding size show significant differences between the *kolla* and highlands. Most of the farmers in the *kolla* are landless, the majority were engaged in agriculture as workers in the investments, and the holding size was < 2 hectares. However, all farmers have access to land in the highland, by which most of them hold > 2 hectares (Table 2.2). All group discussants report a decrease in landholding size in the last 10-20 years in the watershed.

Table 2.2 Status of small-scale farmers' access to land resources in Anger watershed (comparisons between *kolla* and highlands)

Status of small-scale farmers	**Indicators**	***Kolla***		**Highland**		**Total**	
		Freq.	%	Freq.	%	Freq.	%
Households engaged in agriculture*	No	14	10.1	2	1	16	4.8
	Yes	125	89.9	194	99	319	95.2
	Total	139	100	196	100	335	100
Households own land	No	47	37.6	6	3.1	53	15.8
	Yes	78	62.4	188	96.9	266	79.4
	Total	125	100	194	100	319	100
Process of access to land	Inheritance	60	48.0	166	84.5	226	70.8
	Resettlement	29	23.2	4	2.1	33	10.4
	Lease/purchase	21	16.8	13	6.7	34	10.6
	Gifts	15	12.0	11	5.7	26	8.2
	Total	125	100	194	100	319	100
Landholding size of the households	< 0.5 hectare	15	12.0	14	7.2	29	9.1
	0.5- 1 hectare	36	28.8	20	10.3	56	17.5
	1-2 hectares	49	39.2	38	19.6	87	27.3
	>2 hectares	25	20.0	122	62.9	147	46.1
	Total	125	100	194	100	319	100
Sources of land for landless households engaged in agriculture	Contract land	10	21.3	6	100	16	30.2
	Sharecropping	21	44.7	0	0	21	39.6
	Labourer in investment	16	34.0	0	0	16	30.2
	Total	47	100	6	100	53	100

NB: * The succeeding sub-sections show only the status of households engaged in agriculture (n=319)

However, the causes for decreasing landholding size were mainly attributed to the growing number of households dependent on agriculture in the highland and investment acquisition in the *kolla*. Thus, landless farmers in the *kolla* engaged in agriculture through contracting land, entering sharecropping, and laboring in the private agricultural investment (Table 2.2).

Cropping and livestock rearing were the basic livelihood system for which the land has utilized in the watershed. However, the situation was not uniform as the role of land to its natural resources such as beekeeping, hunting, gathering, salt-leak for cattle were more common than agriculture in the *kolla*. According to group discussants, these livelihood assets are more important in the valley than crop productions. These conditions make them different from highland communities. Moreover, these land resources are sources of socio-economic ties between the *kolla* and highland communities. However, these ties have been impaired from time to time due to the interventions in the *kolla*. For instance, the transhumance from the highland to the kolla known as *darabaa*[2] and other *kolla* resources such as leaked salt for the cattle, honey, and other ecological provisions for the highland community become unpractical.

The observed difference between *kolla* and highland on the LULC dynamics, and the situations of farmers' access to land resources signifies the influences of the interventions for the land investments in the *kolla*. Thus, farmers' perceptions of the processes and implications on their access to the land resource in the *kolla* were assessed (Table 2.3) to identify the impacts of these interventions on the local community.

[2] *darabaa* is a system in which highland community migrates with their livestock to kolla area in time of scarce grass and watering; which provides significant livelihood ties between the communities.

Table 2.3 Small-scale farmers' perception on their relationship with investors, land deal processes, and impacts on the farmers in the *kolla*

Indicators	**Variables**	**Freq.**	**%**
Household heads were consulted transparently on the land deals	No	107	96.4
	Yes	4	3.6
The compensation was paid for lost opportunities	No	95	85.6
	Yes	16	14.4
The role of large-scale agricultural investments in the area	Technology transfer	4	3.6
	Crop production and supply increased	3	2.7
	Employment opportunity	13	11.7
	Infrastructure development	3	2.7
	Agricultural products reach local markets	11	9.9
	No benefits at all	77	69.4
The main environmental entity adversely affected by the investments	Water resource	5	4.5
	Natural forest	56	50.5
	Wetlands	11	9.9
	Soil degradations	28	25.1
Livelihood source adversely affected by the investment	Crop productions	14	12.6
	Livestock productions	29	26.1
	Forest based products	57	51.3
Extents of natural resources conservation practices (the harmony of large-scale investment with nature and local community)	Very poor	34	30.6
	Poor	60	54.1
	Good	6	5.4
	Very good	2	1.8
	Undetermined	9	8.1

Farmers' perceptions on their relationship with the investors/investment activities, land deal processes, and impacts were also assessed (Table 2.3). Regarding land deal processes, most of the respondents explained that they were not consulted when land deals were made, and hence, the process was not transparent. They recognize the direct impact of large-scale agricultural investment on their livelihood and mostly emphasized the adverse sides. However, they were not compensated for the impacts. Among others, the reasons provided for no compensations were that most of the land was defined as open and common land, that the farmers didn't have holding certificates, and a policy that doesn't recognize the landholding contexts of the local community. The paradoxes of open-land, communal land, and land certification for landholding were critical during FGD. Two things are common in the kolla as far these issues are concerned. First, the area experienced dynamic ownership unusual to other parts of the region because of the interests of different actors: government, local people, investors, and settlers. Second, the highest percentage of land is communal, where significant livelihood assets are located, and the ownership is claimed by utilization rather than a legal certificate. Thus, when customary holdings are abolished, they lose the resources. The farmers characterized the situation in the valley as a highly insecure tenure system and painful land deals for the local community since 1976. These conditions have been explained similarly in different parts of Ethiopia (Davide, 2017; De Zoysa, 2013; Desalegn, 2013; Dessalegn, 2011; Getnet, 2012; Keeley et al., 2014; Mesfin, 2013)

The roles of large-scale agricultural investment for the local community were appraised in this study (Table 2.3). This was done by evaluating these aspects in line with the investment objectives and initiatives of Ethiopia. The role of the investments for technology transfer, increase in production and supply of crops, employment opportunity for the local community, local infrastructure developments, and extent of product accessed local markets were evaluated by the respondents. In this regard, the respondents didn’t recognize the role of investment in technology transfers. Moreover, a high percentage of the valley community claim that infrastructure facilities are not developed as a result of the investment, and the agricultural productions of the investment are not accessed by local markets to satisfy the demand for a grain of the community.

The concerns of group discussants in the *kolla* agroecology on the characteristics of investment practices, and its implications on farmers’ access to the land resource is outlined as follows: First, the discussants claim that they were dispossessed as a result of the state-farm in 1976, and recently for the large-scale private investments, because the government believed that small scale farmers are not mechanized and have a lesser contribution to ‘development’. Accordingly, only after a short period of utilizations (1991-1998/2002) by the local community after the collapse of the state farm due to regime change in the country, the land was given to private investments. However, according to the discussants, there is a difference between the government’s perception of the investors' capacity and their actual capacity. Most of the investors are domestic with experience of the area, mainly workers of state farms during the *Derg* regime, local influential people with larger social capital, and merchants providing hotels services in the surrounding urban centers. According to the discussants, the difference between the small-scale farmers and the private investors in agricultural technology, capital, and infrastructure was not significant. Moreover, most of the investments were confined to rain-fed and used traditional farming mechanisms similar to the local community. The discussants explained that some transnational investors have been participating in the area, but insignificantly different from the domestic in their investment practices, and local socio-economic and environmental impacts.

Secondly, the discussants described that some investors have corrupt investment objectives and incentives in different ways such as withdrawing from the agricultural investment after securing land ownership through re-contracting the land they obtained for investment, entering sharecropping, and leaving the land ideal for several years. For instance, the hiring of workers was the formalized procedure by which the workers were exploited by the investors through contract land to cultivate and share the crop with landholders (i.e., the investors). The discussants explained that gradually, the investors became considered as landholders by dispossessing small-scale farmers in the name of investment, basically turning the process into a transfer of landholding titles. This indicates that the land deal processes brought about new socioeconomic classes in the area, where those able to get land in the name of investment became rich and small-scale farmers without land became poor. Moreover, the discussants claim that the investment incentives were misused by the investors. They purchased different equipment such as agricultural inputs and cars at low cost or without taxations in the name of investment, then left the agriculture after exploiting the incentives for large-scale agricultural investments.

Thirdly, the discussants characterized most of the investors as unsympathetic to the environment and ignorant of the socioeconomic contexts of the community. Since 1976, the focus of land management in the kolla has been on productivity, rather than realizing environmental and socioeconomic stability. These conditions get worse following the introduction of private large-scale agriculture in late 2001. Moreover, the discussants claim that the continuous belt of investment plot enforce them to travel long distances, and hinder their old path to natural resources and social connectedness. The illegal farm expansion by investors caused a reduction in wild animals, forests, and wetlands, and reduced the availability and access of the local community to the resources. Moreover, some investors quit the investments contract after harvesting wild trees for the market in the name of cleaning land for agriculture in their initial phase. The area known as *'plotdar'*[3] (forest covers) during state farms that was buffer zone between two adjacent state farms were cleared by the investors.

Moreover, the *kolla* discussants identified a lack of investors' interest to discuss and cooperate with the local communities on their mutual benefits. Besides, some investors responded negatively when the community claims something opposite to their interest. One of such practices discussed was the activity of 'Agro-plantation[4]' in Uke *kebele*. According to the discussants, immediately after the company quit the investment contract because of conflict with the local community, new plant diseases not known in the area quickly spread in the plantations of the local community. Although additional pieces of evidence were not available on the cause of the disease, the discussants have suspected the company for this incident as a response to the contesting interests from the local community.

Lastly, the discussants in the *kolla* outlined several investment and land governance problems, which was in line with observations and interview results from experts and government officials. Similar to observed poor management of the large-scale agricultural investments in different parts of the country (Dessalegn, 2011; Mosley, 2012; Tsegaye & Spoor, 2015), no sufficient guideline or rule for land transfer to investors or no checklists for evaluating investment applications and business plans could be provided from the responsible officials. The experts and officials described that appreciating the investment commitments of the private investors is the method used in the zone rather than imposing strict responsibility in the processes. They believe that the statement on financial capacity is the focus in the investments' evaluations.

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[3] *Plotdar* is a buffer area that was used to separate one farm plot from the next during the state farm of Wallagga Agricultural Enterprise.

[4] The name of the company is not mentioned for confidentiality

5 Conclusions

The local situations of the structural land-use changes and associated LULC dynamics since 1976; most importantly, the recent land transfer to the large-scale agricultural investors, and the implications of the processes on the local community's access to land resources were assessed in this study. LULC in the watershed shows significant spatio-temporal changes in the last 43 years. The temporal trend was toward an increase in agricultural land and settlements and a decrease in grass and bushlands, forest lands, and wetlands. The LULC change periods were examined in line with historical land deal processes in the watershed, where all change periods in the *kolla* were found to have distinct characteristics, while trends in the highlands were relatively constant".

The comparative analyses show extensive changes in the *kolla*, mainly in with the introduction of state farming in 1976 to 1991 and recent private agricultural investment in late 2001. The change was relatively slow in the second change period (1991-2001) which was characterized by local farmers’ land and resource utilization. These exceptional LULC change conditions and land deal processes observed in the *kolla* were due to state interventions that had unique influences on the small-scale farmers and the biophysical environment.

The community labelled the investment activities in general and land deal processes in the *kolla* agroecology in particular as contrasting to investment aims of the country and denying them access to land resources and compromising their livelihood system. Moreover, the results revealed that the land deal processes, investment practices and community-investors relationship in the area were characterized as: low investors’ capacity and know-how, corrupt investment aims and incentives, a lack of understanding from investors and bureaucrats of the physical environment and socioeconomic context of local community, and a lack of mutual benefit and consensus among stakeholders.

These problems were emanated from an immature investment policy, a lacks of guidelines and rules for land transfer and stakeholders’ misconception of the role of agricultural investments. The government officials and experts believed that the investors who applied to their offices to invest in the *kolla* were the committed individuals and companies to participate in the development activities and shouldn't be subject to similar investment requirements in the highland areas. Hence, this perception made the investments applications easy, resulting in the hardly applied rules and guidelines in providing the land for the investors, and weakened the monitoring and evaluations of the impacts of the investments. This lack of administrative capacity and policies which open blind eyes toward large-scale agricultural investment paves the way for investors to exaggerate their perceived benefits through institutionally facilitated and relaxed exploitation of the resources. These processes have resulted in the unfair treatment of the local community for access to land resources and the physical environment. Moreover, these conditions have threatened the local livelihood systems by deteriorating the indigenous land resource use and tenure systems and undermining the local community's decision-making power on the resources. These courses have far rich consequences, which has now led to a tendency toward class formation and struggle between investors and small-scale farmers.

In general, the observed contesting issues on the land rights of the local community and the state policy dynamics on the land investments seek sufficient attention. These frequently changing in the structure of 'development' interventions and land use policies have been hindering the local community's land and resources tenure systems, insecure the landholding situations, and denies their access to natural resources. Because of their ownership at a certain time and the inherent livelihood attachments, the communal lands and the resources on them have a crucial role for the small-scale farmers in the *kolla*. These resources play a significant role for the local livelihoods and have historically belonged to the local community; despite claims of the government officials in the area that lands now given to large-scale agricultural investments previously were owned by the state, and that communal lands never belonged to the local community. These justifications from the government do not consider the local biophysical and livelihood contexts. Although there being a high level of agreement on what constitutes 'good' investment policy and objectives in Ethiopia, this study revealed that these have not granted satisfying implementations at the local level. Perceptions and practices in these aspects that have been taking place by the stakeholders in the study area should be tracked into a path that realizes mutual benefits. Above all, the local livelihood systems in the *kolla* agroecology should be given more attention. The claim from the government of 'open and unused land for investments' has arisen from a lack of knowledge on local livelihoods. In this manner, the basic livelihood assets of the local community such as grasslands, forests, water sources, and others have been transferred to the investors. However, it is impossible to realize secure livelihood outcomes for small-scale farmers in the area when their access to the surrounding natural resources is denied.

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CHAPTER THREE

Spatio-temporal Variability and Trends in Rainfall and Temperature in Anger Watershed, Southwestern Ethiopia

Article published: *Gemechu Yigezu & Muluneh Woldetsadik (2021). Spatio-temporal Variability and Trends in Rainfall and Temperature in Anger watershed, Southwestern Ethiopia, Journal of Applied Geospatial Information System, DOI: 10.30871/jagi. v5i1.2825*

Spatio-temporal Variability and Trends in Rainfall and Temperature in Anger Watershed, Southwestern Ethiopia

ABSTRACT

Insights to broadly argued research gap on lack of climate studies at micro-scale considering unique features of an area, this paper intended to examine agro-ecological level spatio-temporal trends and variability in rainfall and temperature in Anger watershed of southwestern Ethiopia. The gridded data managed by the Ethiopia National Meteorological Services Agency (NMSA) for 1983-2018 were used. The Mann-Kendall test for trend analysis and different variability measures were used. Questionnaire and FGD data on community perceptions gathered from 214 households and elders were analysed descriptively and qualitatively. The study reveals the consistent increasing trends in temperature; and high variability and insignificant but increasing rainfall trend. The trends and variability show spatio-temporal differences along agro-ecologies. The watershed is characterized by moderate to high rainfall coefficient of variations, significant years of high rainfall concentration, and considerable negative annual rainfall anomalies; that the variability was severe in woinadega followed by kolla agro-ecology. Although, the perceptions on trends, variability and its implications show difference across agro-ecology, the propensity to increased temperature, unclear rainfall trend and significant inter-annual and seasonal variability were witnessed. Unpredictability of rainfall time, concentrations in kiremt, and unexpected rain during harvesting was major challenges resulting multifaceted impacts on the small-scale farmers' livelihoods.

Keywords: Climate variability; Trend analysis; Variability analysis; Community perceptions

Introduction

Climate change, associated variability in temperature and rainfall is rapidly unfolding challenge for agrarian community; and have been resulting wide range socioeconomic and environmental problems mainly among poor small scale farmers (Henderson 2018. Although, the trend is inconsistent and characterized by complex geographical dimensions; the tendency is toward increased in temperature and decreased in rainfall since the mid-twenties century (Chen et al. 2013); and significant spatiotemporal variability with general increase in temperature by 0.72 ^{0}C, increasing rainfall by 0.5-1.0% at mid and high latitude to decline at low latitude at the rate of 0.3% (Deliang et al. 2013). For Africa, the trends have been toward increasing temperature and increasing but inconsistent trends in the rainfalls. In the recent decades, the variability in rainy seasons characteristics to more intense and intermittent; for instance, concentrated wetting in the late rainy season. Particularly, significant increases in temperature and spatio-temporal variability in rainfall such as occurrences of dry spells, seasonal droughts and episodes of torrential rainfall with heavy runoff and flooding are recently more frequent in the east Africa than in the past (Biasutti, 2019; Ruppel et al., 2014; Serdeczny, Adams, Coumou, Hare, & Perrette, 2016).

The evidences for Ethiopia indicated less consistency mainly in rainfall trends; and the general trend has been a tendency in lower rainfall, year to year increase in rainfall variability and extremes; and general increase in temperature have been reported in most parts of the country. The seasonal and monthly state of rainfall have been showing remarkable spatio-temporal variability (Amogne, Simane, Ali, & Bantider, 2018; Arragaw & Woldeamlak, 2017; Asaminew & Diriba, 2015; Befikadu, Simane, Teferi, Victor Ongoma, & Tefera, 2019; Convey & Schipper, 2011; EPCC, 2015; Fazzini, Bisci, & Billi, 2015; Feyisa, 2017; Jury & Funk, 2013; Magarsa & Budiastuti, 2020; McSweeney, 2012; Melkamu & Getnet, 2019; Messay, Degefaa, & Gezahegn, 2017; Shiferaw et al., 2014; Solomon, G/Selassie, Getachew, & Gedif, 2015; Tagel, Veen, & Van, 2013; Wagaye & Endalew, 2020; Woldeamlak, 2009).

Climate system of Ethiopia is strongly influenced by topography, seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) and associated atmospheric circulations(Dinku, Hailemariam, Maidment, Tarnavsky, & Connor, 2014; EPCC, 2015; McSweeney, 2012) Spatially, the country has a diversified climate ranging from semi-arid desert (*bereha*) type in the lowlands to cool (*wurch*) type in the mountainous area >3300m amsl; which traditionally classified in to five agro-ecological zones. Mean annual rainfall distribution has maxima (>2000 mm) over the Southwestern highlands and minima (<300 mm) over the South eastern & North eastern lowlands. Mean annual temperature ranges from < 15^0C over the highlands to > 25^0C in the lowlands. Ethiopia has three seasons based on rainfall occurrence namely; *bega*/dry season, *belg*/short rainy season and *kiremt*/long rainy season (Few et al., 2015). Particularly, the study area entertains in three agro-ecologies: warm lowland(*kolla*) having altitude less than 1500m amsl situated in central part of the watershed; midland (*woinadega*) having altitude 1500m-2300m amsl in northern and southern half of the watershed; and cool temperate (*dega*) in the mountainous areas of the watershed. These diversified climate state have significant socio-economic and environmental opportunities. However, empirical evidences have been warning that present global climate changes have knocking the ecological and livelihoods systems of the country; and the study area is not exceptional.

The empirical observations conducted at national level implied a significant spatial difference on the extents of the climate variability (Biasutti, 2019; Chris et al., 2010; Convey & Schipper, 2011; EPCC, 2015; Fazzini et al., 2015; McSweeney, 2012); and the magnitudes of impacts on human and natural systems(Emerta, 2013; Mintewab, Salvatore, & Alemu, 2014; Zenebe, Alemu, Rahel, & Samuel, 2014) in the country. Therefore, examining the rainfall and temperature trends and variability at micro-scale with unique biophysical characteristics along agro-ecology has paramount importance to understand the spatial variations in change/variability and differential impacts.

The reviewed empirical research for this paper revealed that spatially most of studies were focused in the northern and central highlands; and some in the rift valley and arid and semi-arid parts of eastern and south eastern Ethiopia; while the studies in southwestern highlands and low lands of Ethiopia are overlooked. Moreover, scholars argue that although the knowledge on climate change is growing fast, it is merely organized in the way suitable to integrate with other global change processes in assessing the impacts (Barnett, 2020)**.** Among others, the problems are associated with lack of climate studies at micro scale considering unique features of an area, and convoluted concepts and methodologies in integrating the knowledge with site specific non-climatic stressors. Therefore, the study was intended to examine climate situations at agro-ecological level in the watershed focused on comparative analysis trends and variability along agro-ecologies vitally to integrate the knowledge with other site specific non-climate stressors to contribute for the recent research on human dimensions of global change processes impacts (Antwi-Agyei et al., 2018).

Particularly, there are a number of reasons why site-specific climate analysis take due concerns for small scale farmers of Ethiopia. The main natural resources and associated assets are very much the reflection of the unique conditions they have, entail their socioeconomic activities and the main stay economy are sensitive to variability manifested. Thus, identifying agro-ecological based rainfall and temperature trends, seasonal changes and occurrence of extreme events has paramount importance. Specifically, the study was ascertained to analyse the status of rainfall and temperature, the long-term trends and variability across agro-ecologies and assess the community perceptions on trends, variability and the impacts on their livelihoods.

Research Methods and Materials

Background and contexts

Anger river watershed lies in east Wallagga administrative zone extended from 09°12' to 10°00' north and 36°30' to 37°11' east were the focus the study. The area within a single administrative zone was selected to reduce the heterogeneity due to administrative difference; to pinpoint magnitude and spatial variations of vulnerability of household within the same administrative; while the situation is place-based and context specific that the households' exposure to the stressors such as climate variability along agro-ecologies; and the historical socio-economic and natural resources access could be complex if the entire watershed is included in the study.

The study area is composed of various land forms with altitudinal ranges of 1200-3018 meters above sea level. The mean annual temperature ranges between 14^0c to 25^0c; and average annual rainfall is also between 1000 mm to 2400 mm. The rainfall shows mono-modal pattern and more than 80% of which occurs between May and October. Numbers of rivers and streams drain the watershed. There are different types of soils found in the zone.

The micro-scale climate, soil types, varied species of forest ecology, wild animals and other natural resources supported vast livelihood options and shaped the socio-economic and demographic characteristics of the region on top of historical national and global change processes. Currently, about 82.3% of total population are rural dwellers directly engaged in agriculture. Different types of crops such as cereal, pulses and oil seeds are produced largely throughout the study area. livestock rearing, beekeeping and direct exploitations of natural resources play a key role in the peasant sector. The area is characterized in poor infrastructure that the road quality/and network density is low; less than half of the rural population has supplied potable water; source of energy is limited to firewood, animals dung, crop residues and charcoal(FED, 2014).

Research methods

Research design

The climate change and variability are reality which permanently exist and impacting the local community when abnormal; and the change become beyond the adaptive capacity of a system (Gray 2017). Thus, study of the change and variability has paramount importance to mitigate, adapt and reverse the adverse impacts. To this end, the paper is designed to examine rainfall and temperature trends, variability and extreme events at agro-ecological level in the study area. The study consists an array of issues from objectively analysing the long-term trends and variability to construct the reality through in-depth explanations of community's perceptions. Thus, the research problems demand mixed research method approach, guided by survey design due to its appropriateness with identified approach and fitness to objectives of the study, the type of data, methods of data collections and analysis. It comprises the systematic gathering and analysis of data through different instruments including gridded data of rainfall and temperature from Ethiopia National Meteorological Services Agency (NMSA) in addition to tools for households' survey.

Sources of data

The behavioural ecology models (Hennemuth et al., 2015) arguments for context specific and objective oriented climate variability and change analysis was applied in the study. Thus, measurements of trends and variability appropriate to evaluate the impacts on the immediate agricultural activities and exploitation of natural resources in the region imply for small scale farmers were chosen.

The gridded data of rainfall and temperature for the study area managed by the Ethiopia National Meteorological Services Agency (NMSA) were used. The data are reconstructed at 10×10 km resolution from weather stations records and meteorological satellite observations by NMSA in collaboration with International Research Institute for Climate and Society to solve the limitations of both sources in climate analysis. The studies on scientific climate data and users for empirical researches recommended gridded data particularly in developing countries. First, weather stations are limited in number, unevenly distributed and situated in urban areas. Second, meteorological satellite observations suffer from heterogeneous time series, short period of observations, and poor accuracy due to low resolutions. Most importantly, our research objective demands accurate representation of the real spatiotemporal variability inputs; which severely limited in the above sources, and spatially interpolated data is subject to large uncertainties(Bigiarini, Nauditt, Birkel, Verbist, & Ribbe, 2017; Dinku et al., 2014). To this end, through discussion with experts in NMSA, the time series data for 35 (1983 to 2018) years for monthly rainfall and the monthly maximum and minimum temperature of the same period was used. Moreover, data for community perceptions on climate change/variability and impacts were gathered from sampled household heads of above 45 years (n=214) drawn from *kebeles* representing each agro-ecology through questionnaire and elderly farmers through FGD (one group for each agro-ecology were facilitated; having eight members per group).

Methods of analysis

Both methods of trend and variability analysis were used. Trend analysis was conducted by Mann-Kendall statistical test method. The Mann-Kendall test method is non-parametric which has several advantages over parametric and suitable for the study. It does not require the data to be normally distributed, it is appropriate for analysing trends in data over time, and has low sensitivity to abrupt breaks due to inhomogeneous time series(Feng et al., 2016; Tímea, Kovács-Székely, & Anda, 2017).

Table 3.1. Research materials and techniques

Data	Sources	Techniques
Monthly rainfall (1983-2018)	Global Precipitation and Climate Centre (GPCC V7), Ethiopian NMSA	Mann-Kendall test
		Rainfall CV, SRA, PCI
Monthly max. & min. temperature (1983-2018)	Climate Research Unit (CRU TS 3.23), Ethiopian NMSA	Mann-Kendall test
		standardized temperature anomalies
Questionnaire and FGD	Household survey	Descriptive statistics
		Qualitative method

The Mann-Kendall Statistic measures the trend in the data. Positive (+) values indicate an increase in constituent concentrations over time, whereas negative (-) values indicate a decrease (Mudelsee and Wegener, 2010). The strength of the trend is proportional to the magnitude of the Mann-Kendall Statistic (large magnitudes indicate a strong trend). The Mann-Kendall statistics “S” is calculated by the following formula:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\ (Xj - Xi)$$

Xj and Xk are annual value in year j and k, where j>k respectively

$$sgn(Xj - Xk) = \begin{cases} 1\ if\ Xj - Xk > 0 \\ 0\ if\ Xj - Xk = 0 \\ -1\ if\ Xj - Xk < 0 \end{cases}$$

The variance statistic is given as:

$$VAR\ (S) = \frac{1}{18}[n(n-1)(2n+5) - \sum_{p=1}^{q} tp\ (tp-1)(2tp+5)$$

Here q is the number of tied groups and tp is the number of data values in the p^{th} group. Finally, the values of S and VAR(S) are used to compute the test statistic Z as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}}\ if\ S > 0 \\ 0 \qquad if\ S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}}\ ifS < 0 \end{cases}$$

The presence of a statistically significant trend is evaluated using the Z value. A positive (negative) value of Z indicates an upward (downward) trend. The statistic Z has a normal distribution.

Among methods of variability measures the coefficient of variations, standardized anomalies/percentage departure from mean and precipitation concentration index were applied.

(a) **Coefficient of Variations (CV)** was used to evaluate the variability of rainfall in the study area along different agro-ecology. A higher value of CV is the indicator of larger variability, and vice versa which is computed as:

$$CV = \frac{\sigma}{\mu} * 100$$

Where; CV is the coefficient of variation; σ is standard deviation and μ is the mean precipitation. The degree of variability of rainfall events are assigned as less variable (CV < 20), moderate (20 < CV <30), and high (CV >30) (Befikadu et al., 2019; Dinku et al., 2014)

(b) **Precipitation Concentration Index (PCI)** was used to examine the variability or heterogeneity pattern of rainfall at annual or seasonal scale. The annual PCI is computed as follows.

$$\text{PCI}_{\text{annual}} = \frac{\sum_{i=1}^{12} Pi^2}{(\sum_{i=1}^{12} Pi)^2}$$

Where: Pi = the rainfall amount of the i^{th} month. The PCI values for uniform monthly distribution of rainfall (low precipitation concentration) is less than 10, values between 11 and 15 denote moderately distributed rainfall concentration, 16 to 20 indicates high concentration, ≥ 21 indicate very high concentration.

(c) The standardized anomalies of rainfall were used to examine the nature of the rainfall trends, to identify the dry and wet years and to assess frequency and severity of droughts.

$$Z = \frac{(Xi - \bar{X})}{s}$$

Where, Z is standardized rainfall anomaly; Xi is the annual rainfall of a particular year; $\bar{X}$ is a long term mean annual rainfall over 35 years and ‘s’ is the standard deviation of annual rainfall over 35 years. The drought severity classes are: extreme drought ($Z < -1.65$), severe drought ($-1.28 > Z > -1.65$), moderate drought ($-0.84 > Z > -1.28$) and no drought ($Z > -0.84$) (Amogne et al., 2018).

Results and Discussions

The Analysis of 35 years mean monthly rainfall and monthly minimum and maximum temperatures from about 166 grid points were used to cover the watershed. The points were taken based on area proportion of the agro-ecologies and represented 10×10km areas. Accordingly, 94 for *kolla*, 13 for *dega* and 59 points for *woinadega*.

The spatial variations in distribution of annual rainfall, and mean annual minimum and maximum temperature were observed in the watershed (Figure 3.1). The *woinadega* areas in the northern parts of the watershed particularly Gida Ayana and Kiramu districts experienced highest mean annual rainfall; while *kolla* in southern part of Gida Ayana and western part of Kiramu; and *woinadega* in Guto Gida, Limu, northern Bila Sayo districts in central and southern parts of watershed have relatively medium annual rainfall pattern and southwestern parts of Sibu Sire and Bila Sayo districts showed lowest mean annual rainfall of the watershed. The lowest mean annual minimum and maximum temperature were observed in *dega* areas particularly around Ilfata mountain of Wayu Tuka and highlands of Gida Ayana and Kiramu districts; while extensive part of *kolla* agro-ecology shows highest mean annual minimum and maximum temperature in the watershed (Figure 3.1).

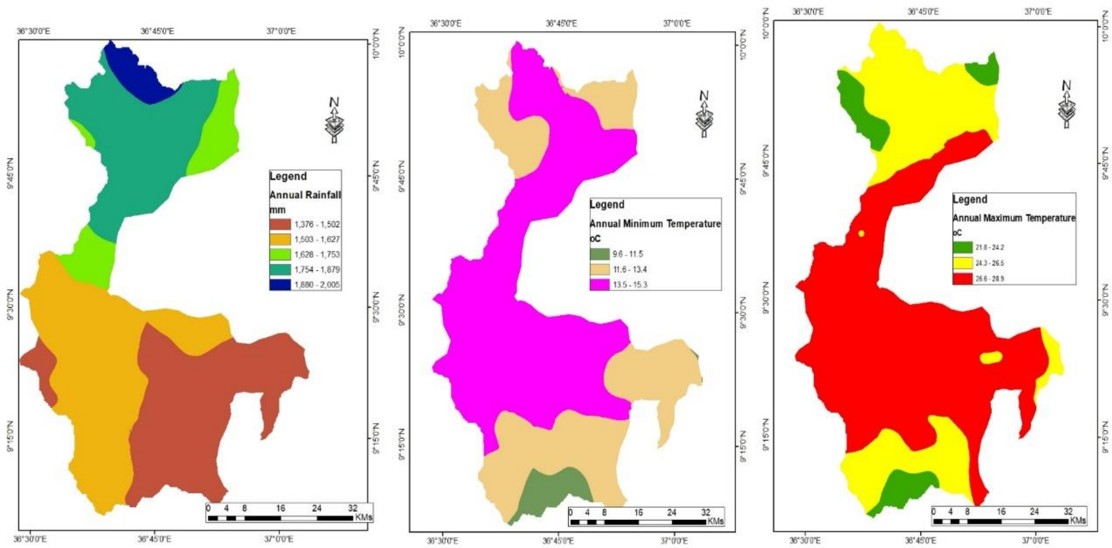

Figure 3.1. Spatial distributions of annual rainfall, annual minimum and annual maximum temperature in Anger watershed from left to right respectively

Rainfall patterns, trends and variability across agro-ecologies

Rainfall pattern and trends

The watershed receives mean annual rainfall of 1577mm which ranges from 1493mm in *dega* to 1873mm in *woinadega* while 1520mm in *kolla* agro-ecology. K*iremt* (JJAS) is the major rainy season for all agro-ecology, contribute 56.2%, 55.2% and 56.0% of total annual rainfall for *dega*, *woinadega* and *kolla* respectively. Nearly, half amount of annual rain in *woinadega* contributed by rain in two months (July and August) while the distribution is relatively uniform among rainy months of *dega* and *kolla* (Table 3.2).

The trends of rainfall show substantive spatio-temporal differences in the watershed (Table 3.1). On monthly base, March and December shows decrease in rainfall trend; while January, May, June and November exhibit increasing trends for the entire watershed. However, significant increase ($p<0.05$) was observed in June and September for *dega*; while both *woinadega* and *kolla* experienced significant increase ($p<0.05$) only in September. This implies that September is the only month with significant increase in rainfall in the entire watershed. Although, July contributes highest percentage of annual rainfall for the entire watershed, the decreasing trend was recorded in *kolla* and *dega*; but significant ($p<0.05$) in *dega* agro-ecology in the month. However, it doesn't show decreasing impact on the aggregate *kiremt* rainfall of the agro-ecology.

Table 3.2. Rainfall trends across agro-ecology in Anger watershed (1983-2018)

Month/ Season	**Agro-ecology**					
	Dega		***Woinadega***		***Kolla***	
	MK-test	Sen's Slope	MK-test	Sen's Slope	MK-test	Sen's Slope
Jan	0.774	0.000	0.757	0.000	0.996	0.035
Feb	-1.045	-0.077	1.045	0.016	-0.374	-0.025
Mar	-0.503	-0.339	-0.308	-0.131	-0.130	-0.050
Apr	0.535	0.453	-0.438	-0.536	0.276	0.258
May	0.989	1.452	1.378	2.527	0.681	1.098
Jun	**1.719***	1.418	0.519	0.622	1.151	0.865
Jul	**-2.092****	-1.690	0.892	0.951	-1.476	-0.990
Aug	0.130	0.154	1.605	1.893	-0.438	-0.250
Sept	**2.044****	1.231	**2.124****	2.286	**1.800***	0.924
Oct	0.373	0.377	0.000	-0.030	-0.049	-0.058
Nov	0.324	0.140	1.492	0.597	0.535	0.228
Dec	-0.462	0.000	-0.989	-0.078	-0.804	-0.063
Belg	0.276	0.451	-0.178	-0.365	0.114	0.109
Kiremt	0.016	0.055	**1.854***	1.762	**1.776***	0.326
Annual	1.168	0.254	**2.368****	0.728	0.778	0.176

Note: *, ** and ** statistically significant at 0.1, 0.05 and 0.01 alpha level of significance respectively.

The trends of rainfall across agro-ecologies on seasonal base show remarkable differences.

The *belg (MAM)* rain shows increase for both *dega* and *kolla*; while decrease for *woinadega*, but not statistically significant. The *kiremt* was characterized with increase in rainfall for all agro-ecologies, but significant at $p<0.1$ for *woinadega* and *kolla*. Moreover, there is increase in mean annual rainfall for entire watershed but significant only in *woinadega* agro-ecology (Table 3.1). The findings for the trends of *kiremt* were agree with the results from great rift valley basins, central highlands, Amhara region, north central highland and north eastern Ethiopia((Amogne et al. 2018; Arragaw and Woldeamlak 2017; Fitih et al. 2019; Wagaye and Antensay 2020; Woldeamlak 2009). However, most of them reported negative trends for *belg* which fit with the condition in *woinadega* in our study area; In general, spatially disaggregated analysis of rainfall trends along agro-ecologies revealed the persistence of significant difference contributed by variations at micro scale in the watershed.

Rainfall variability

Variability measures are important to comprehend monthly, seasonal and annual variations and distribution of rainfall which has paramount importance due to the fact that rain fed agrarians are sensitive to these variabilities. To this end, rainfall coefficient of variations (Table 3.2); annual precipitation concentration index and annual standardized rainfall anomaly (Table 3.3) and seasonal standardized rainfall anomaly (Figure 3.2) were analysed for all agro ecology separately and comparison was made.

Table 3.3. Agro-ecology based rainfall coefficients of variability in Anger watershed (1983-2018)

Month	**Agro-ecology**											
	Dega				**Woinadega**				**Kolla**			
	Mean	%	SD	CV (%)	Mean	%	SD	CV (%)	Mean	%	SD	CV (%)
January	9.2	0.6	11.9	129.6	3.3	0.2	6.0	180.7	5.9	0.4	7.8	132.2
February	9.6	0.6	13.6	142.0	5.8	0.3	9.5	163.9	7.6	0.5	10.1	132.3
March	47.6	3.2	35.1	73.7	30.2	1.6	27.2	90.0	44.5	2.9	33.7	75.7
April	73.1	4.9	48.8	66.8	60.3	3.2	53.1	88.1	64.4	4.2	41.9	65.0
May	166.0	11.2	72.2	43.5	214.0	11.4	97.3	45.5	174.0	11.4	69.8	40.1
June	274.4	18.4	52.4	19.1	310.2	16.6	59.4	19.1	264.0	17.4	33.9	12.9
July	284.4	19.1	50.2	17.6	374.1	20.0	46.2	12.3	302.1	19.9	38.3	12.7
August	283.6	19.1	53.9	19.0	369.4	19.7	56.4	15.3	293.4	19.3	48.4	16.5
September	193.5	13.0	31.8	16.4	342.5	18.3	57.3	16.7	220.0	14.5	31.5	14.3
October	105.1	7.1	71.3	67.8	124.8	6.7	69.1	55.3	104.2	6.9	68.5	65.7
November	27.4	1.8	23.9	87.4	27.7	1.5	21.3	77.0	27.2	1.8	19.6	72.0
December	14.0	0.9	24.9	177.8	10.3	0.5	14.3	139.1	12.9	0.8	21.3	165.2
Belg	95.6	6.4	52.0	61.3	101.5	5.4	59.2	74.5	94.3	6.2	48.5	60.3
Kiremt	259.0	17.4	47.1	18.1	349.1	18.6	54.8	15.9	269.9	17.8	38.0	14.1

Except for June, July, August and September (CV<20); all months have shown high rainfall variations with considerable difference across agro-ecologies. Moreover, the variations observed in January, February and December in *kolla* and *woinadega* was exceptionally highest with remarkable difference along the cases; because these months are the driest (i.e., consisted in *bega* season) in the watershed. Conversely, *kiremt* was characterized by less variability for all agro-ecologies (CV<20) while *belg* experienced high variability with notable difference between *dega* and *kolla* (CV≈60) on one hand and *woinadega* (CV=74.5) on the other hand (Table 3.2). Although, the highest coefficient of variations observed from December to February was agree with previous results (Amogne et al., 2018; Ashenafi, Bazezew, & Kebede, 2013; Befikadu et al., 2019; Birhan, 2018; Daniel, 2011; Fazzini et al., 2015; Feyisa, 2017; Fitih et al., 2019; Solomon et al., 2015; Woldeamlak, 2009) the time is more extended in other parts of Ethiopia mostly from October to February in north, north central, central, southern, rift valley and north eastern.

Table 3.4. Rainfall (PCI and SRA) across agro-ecology in Anger watershed

			Proportion of years across agro-ecology					
			Dega		*Woinadega*		*Kolla*	
	Index	**Descriptions**	Years	%	Years	%	Years	%
a) PCI	< 10	Low concentration	1	3.1	1	3.1	0	0
	10 to 15	Moderate concentration	22	68.8	10	31.3	18	56.3
	>15-20	High concentration	9	28.1	18	56.3	14	43.7
	> 20	Very High concentration	0	0	3	9.4	0	0
b) SRA	≥ -0.84	No drought	29	90.6	23	71.8	30	93.7
	<-0.84 to -1.28	Moderate	2	6.3	4	12.5	2	6.3
	≤-1.29 to -1.65	Severe	1	3.1	2	6.3	0	0
	< -1.65	Extreme	0	0	1	3.1	0	0

The watershed is characterized by moderate and high rainfall concentration with considerable difference across agro-ecology (Table 3.3a). High concentration was observed in *woinadega* followed by *kolla*. The *dega* agro-ecology is relatively characterized by moderate rainfall concentration. The same spatial variations in rainfall concentration were observed in south and south-eastern Ethiopia (Magarsa & Budiastuti, 2020; Messay et al., 2017) comparable to *dega* of our study area; while the irregularities and high concentration resembling *woinadega* were observed in north, north central and central rift valley of Ethiopia (Amogne et al. 2018; Melkamu and Getnet 2019;Feyisa 2017).

Although, the proportion of positive anomalies in the watershed ranges from 28.3% in *kolla*, 34.8% in *dega* and 37.0% in *woinadega*; the annual standardized rainfall anomalies show a moderate to extreme drought in few years in all agro-ecologies (Table 3b). It revealed that no drought situations (SRA ≥ -0.84) were observed for most of years in the climatologic time in the watershed. The 1986 was the year of extreme drought (SRA < -1.65) for both *woinadega and dega;* while and severe drought (SRA ≤-1.29 to -1.65) was happened in 2002 in *dega* and in 1991 and 2009 in *woinadega* agro-ecology. However, except the moderate droughts in 1984 and 1995, no any extreme and severe droughts were recorded in the *kolla* agro-ecology (Table 3.3b).

The annual standardized anomalies indicate extreme and severe drought in *woinadega* implied only moderate droughts for either *belg* or *kiremt* of the years. Nevertheless, the moderate to severe negative anomalies observed (1988, 1990, 2002, 2003, 2004 and 2012) in *belg* season; and (1989, 1992, 1995, 1998, 2000, 2008 and 2014) in *kiremt* of *woinadega* while annual anomalies show no droughts (SRA ≥ -0.84) for these years. Similarly, the extreme and severe drought of 1986 and 2002 in *dega* observed in annual anomalies were implied the moderate drought in the year for *belg* and *kiremt* respectively. However, the moderate to severe negative anomalies recently observed (1983, 1988, 1998, 2003, 2012, and 2013) in *belg* season; and (1985, 1994, 1999, 2001 and 2011) in *kiremt* of *dega* while annual anomalies show no droughts (SRA ≥ -0.84) for these years. Therefore, although *kiremt* and *belg* negative anomalies and drought index were relatively higher in most of the years; the annual anomalies show fewer dry conditions in both *dega* and *woinadega*. Contrary, the *kolla* agro-ecology where extreme and severe droughts were not recorded for annual anomaly has experienced significantly high negative anomalies in *kiremt* and *belg* for the same years. For example, the extreme drought (SRA < -1.65) in 1999 and severe drought (≤-1.29 to -1.65) in 1997 and 1999 were recorded for *kiremt*. Similarly, several years of extreme and severe droughts in *belg* were observed (1983, 1988, 2012, and 2013) while annual negative anomalies are either highest (>-0.5) or positive in these years.

Most of the years identified as severe and extreme droughts in the study area were mentioned in the other parts of Ethiopia. Moreover, below the average long term was recorded for more than half of the years (1975-2003) in Amhara region (Woldeamlak, 2009); negative standardized rainfall anomalies were observed for >50% of years in central highland and in the northern Ethiopia(Arragaw & Woldeamlak, 2017; Birhan, 2018; Wagaye & Antensay, 2020). Nevertheless, the annual anomalies have direct relationship with anomalies in the *kiremt* and *belg* seasons in some parts of Ethiopia indicated above unlike the observed results in the Anger River watershed.

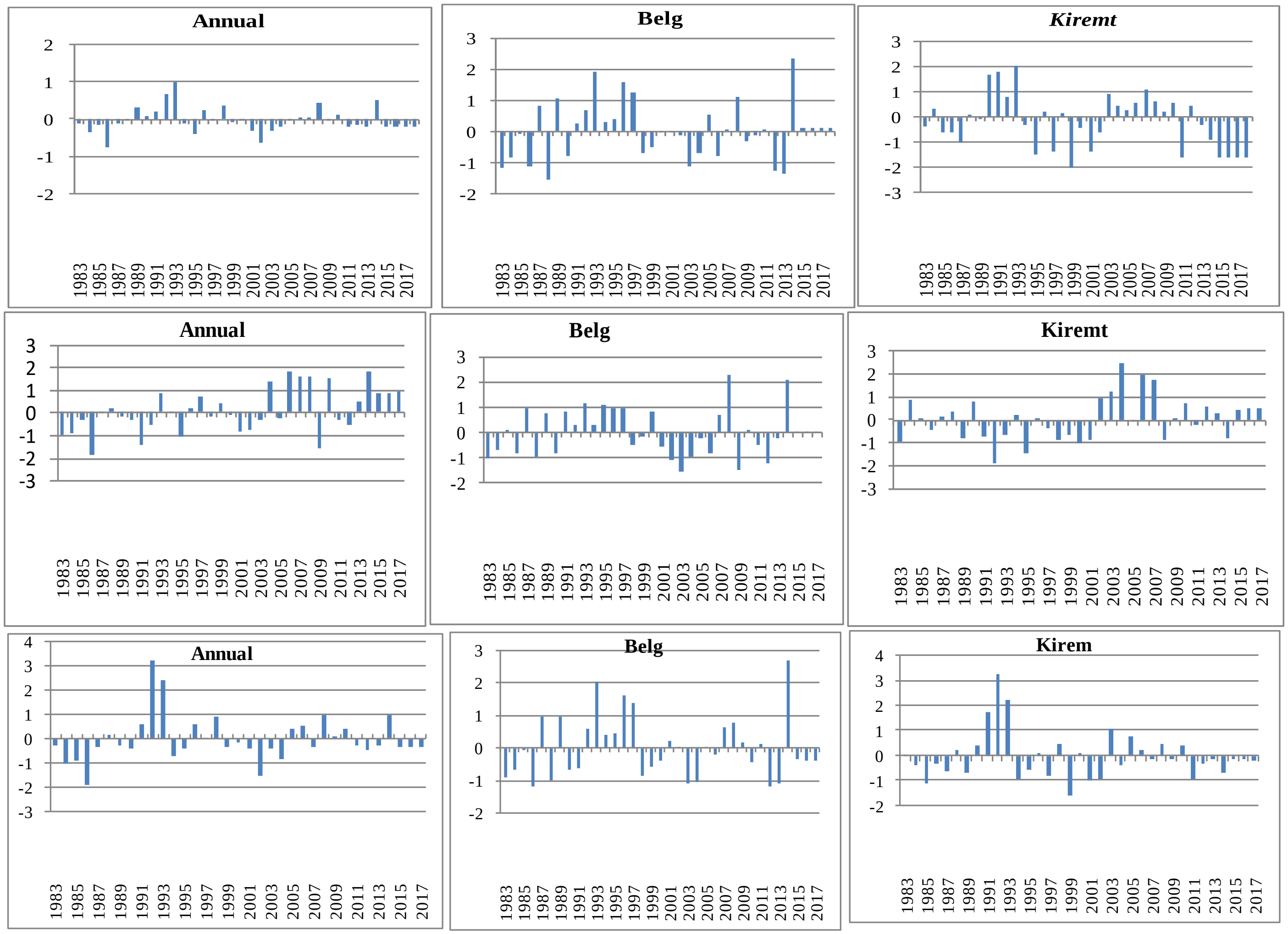

Figure 3.2. Annual and seasonal (*belg* and *kiremt*) standardized rainfall anomalies along agro-ecologies (*woinadega*, *kolla* and *dega* from top to down)

Temperature trends and variability

Table 3.5. MAKESENS trend analysis of temperature across agro-ecologies in Anger river watershed (1983-2018)

	Mean Max-temp.						Mean Min-temp.					
	Dega		*Woinadega*		*Kolla*		*Dega*		*Woinadega*		*Kolla*	
Months	MK-test	Sen's Slope	MK-test	Sen's Slope	MK-test	Sen's Slope	MK-test	Sen's Slope	MK-test	Sen's Slope	MK-test	Sen's Slope
January	2.19	0.038	**2.48**	0.035	2.09	0.031	2.79	0.030	**2.22**	0.0345	0.98	0.013
February	**3.61**	0.091	**3.94**	0.060	**3.55**	0.065	1.42	0.026	**2.18**	0.0442	1.08	0.017
March	**3.47**	0.068	**4.13**	0.056	**3.00**	0.047	1.37	0.020	**3.29**	0.0559	0.66	0.013
April	1.82	0.048	**2.27**	0.049	1.61	0.050	1.16	0.019	**1.99**	0.0437	0.63	0.012
May	1.17	0.030	**2.23**	0.056	2.12	0.060	1.26	0.021	**2.54**	0.0447	0.69	0.014
June	**3.16**	0.059	**3.77**	0.053	**4.31**	0.066	**2.40**	0.024	**4.07**	0.0351	**2.91**	0.027
July	**3.27**	0.057	**2.80**	0.039	**3.87**	0.056	**3.78**	0.046	**5.01**	0.0424	**3.81**	0.033
August	**2.82**	0.039	1.81	0.025	**2.19**	0.029	**3.44**	0.034	**3.90**	0.0276	**3.09**	0.027
September	1.88	0.034	**2.64**	0.031	**3.00**	0.037	**4.56**	0.045	**3.84**	0.0312	**4.33**	0.037
October	1.80	0.034	**2.87**	0.037	1.84	0.032	**3.57**	0.040	**3.12**	0.0410	**3.19**	0.032
November	1.51	0.020	**2.33**	0.022	1.57	0.015	**4.08**	0.050	**3.68**	0.0481	**3.26**	0.038
December	0.60	0.013	**2.22**	0.025	1.61	0.013	0.47	0.008	**2.28**	0.0340	0.83	0.013
Average	**3.81**	0.043	**4.10**	0.042	**4.33**	0.036	**2.92**	0.032	**3.51**	0.0372	**2.32**	0.023

Bold value indicates statistically significant results at P=0.01 and 0.05

The MK trend test result revealed that maximum and minimum average temperatures have been increasing through the time at different significance level for all agro-ecologies (Table 3.4). However, the magnitude was different across agro-ecologies. The trend in mean maximum in *dega* and *kolla* shows significant increase for February, March, June, July and August ($p<0.01$ and

<0.05) while significant increase in mean minimum trend was observed from July to November in both areas. The *woinadega* is characterized with increasing trends in both maximum and minimum for all months at different significance level except for mean maximum of August (Table 4.4). In general, the temperature trends show an increase for the watershed with considerable spatio-temporal differences.

Mean annual based temperature anomalies was analyzed to identify the characterstics in each year against the aggregate for climatologic time (Figure 3.2) to pinpoint the spatio-temporal variation in the years of extreme mean annual temperature conditions in the climatologic time and along agro-ecologies.

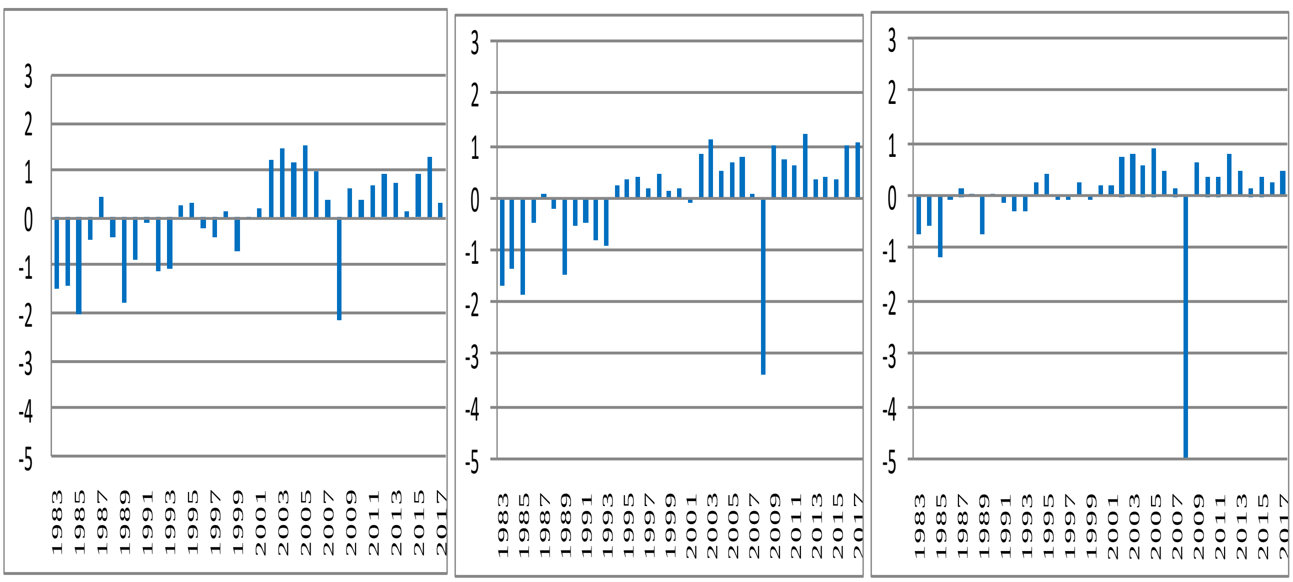

Figure 3.3. Mean annual based temperature anomalies in *dega*, *woinadega* and *kolla* from left to right.

The years from 1983 to 1985 was characterized with high negative anomalies for all agro-ecologies due to relatively low mean annual temperature recorded in the years. Since then, inconsistent temporal trends were observed in all agro-ecologies at different extents approximately till 2000/2001 for *dega* and *kolla* and till 1994 for *woinadega*. However, except for 2008 when the lowest mean annual temperature of watershed was recorded in the climatologic time, the anomalies become positive without any interrupt decrease in mainly for *dega* while some interrupting negative anomalies were observed for *woina dega* and *kolla* (Figure 3.2). The result revealed the spatio-temporal variation in the years of extreme temperature conditions in the watershed.

The overall trends of temperature which revealed increasing pattern were agrees with the findings in the other parts of Ethiopia(Arragaw & Woldeamlak, 2017; Magarsa & Budiastuti, 2020; Messay et al., 2017; Wagaye & Endalew, 2020); while agro-ecologies based spatial analysis in central, southern and northern Ethiopia (Ashenafi et al. 2013; Befikadu et al. 2019; Birhan 2018)showed highest significant increase *kolla;* unlike in our case where significant increase in trends were observed for almost all months of *woinadega***.** In general, the anomaly and trends analysis show steadly increasing in temperature with delineated spatio-temporal variations.

Perceptions on climate variability

Households' perception on trends of rainfall is more complicated compared to perception on temperature along agro-ecologies. In *kolla* remarkable percentage of respondents explained the trend as undetermined and increasing. However, significant percentage in *dega* and *woinadega* explicated on decreasing trends. However, most of households in all agro-ecologies agreed on increasing temperature in their area. This revealed that, the community has clear perception on temperature trends; while rainfall trend was relatively less clear for the community, mainly in *kolla* (Figure 3.3).

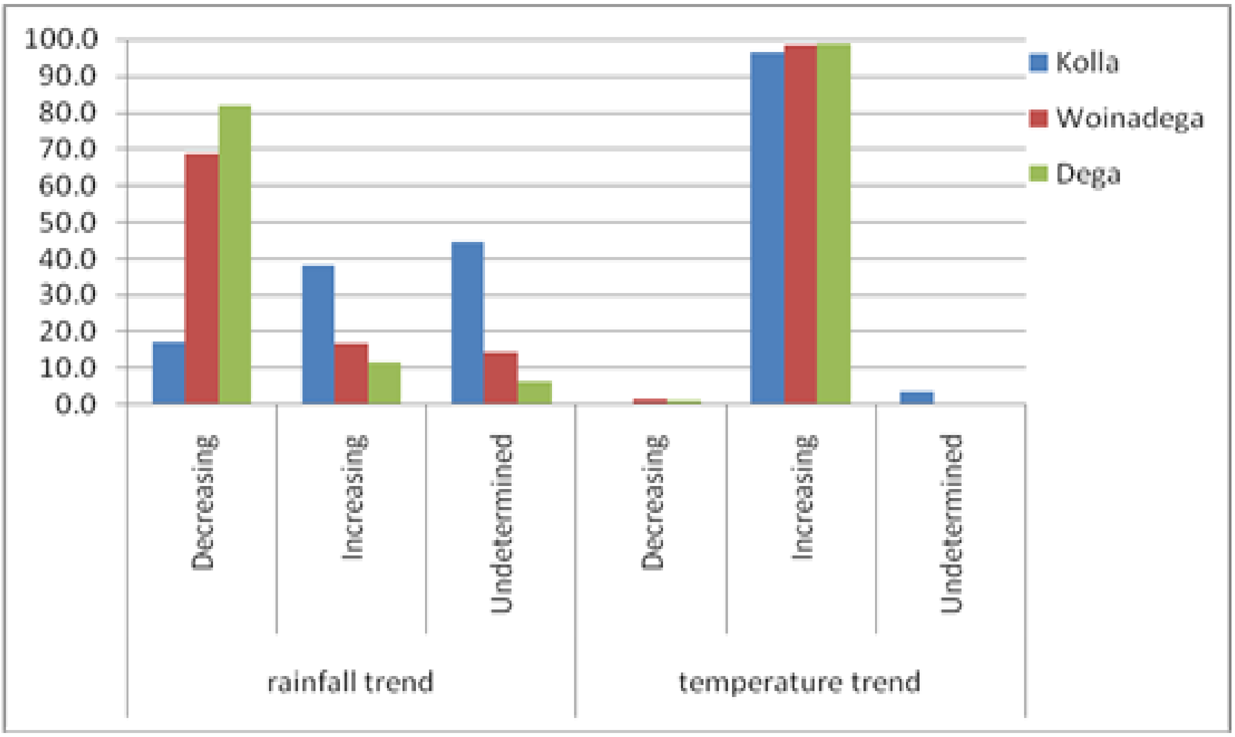

Figure 3.4. Community perception on trends of rainfall and temperature in the last 30 years across agro-ecology

Moreover, the *woinadega* and *kolla* discussants explained that the temperature increases and the extremes have been observed on diurnal, monthly and seasonal pattern. Although, they explained increased in overall trends of temperature, the condition in *kiremt* season was exception for *dega* discussants mainly the recent extreme high night temperature. These were in line with the spatial difference in trends of mean maximum and minimum temperature observed in the study area. Although, *dega* was relatively least in numbers of months with significant increase; all months of *kiremt* season shows significant increase for both mean monthly minimum and maximum temperature.

Additionally, the unpredictability of rainfall time (mostly late onset of *belg* rain), concentrations, and unexpected rain during harvesting were major challenges elevated by discussants in all agro-ecologies. Particularly, they explained the late rain multifaceted impacts on their livelihoods such as reducing productions and productivity of "*dafee*[5]" crops which has significant implication for households' food security in *kiremt*; diminishing of grazing land due to elongated dry season; and late *belg* rain results an increase in concentration for the next *kiremt*. Although, heavy rainfall in *kiremt* is climatic attribute of the study area according to the group discussants, the recent rainfall concentration in June and July were argued as disastrous which have been aggravate soil degradation, crop destructions because of associated storm, and unsuitability for some crop's germination and growth.

Moreover, the *kolla* discussants explicate the increasing in unpredicted rain during harvesting period. The impacts of rainfall in late November on production of crops mainly sesame and maize which are the most important crops in the *kolla* of Anger River valley were attentive. In general, the agro-ecological based perception study in the watershed shows remarkable difference in perceptions on trends, variability and impacts of climate variability among households reside in different agro-ecologies. Although, the research on the issues didn't consistently assessed perception aspects along designed spatial classifications in Ethiopia rather merged them in the perception studies, examined the determinants of perceptions and concluded for the entire study area regardless of place difference(Amogne et al., 2018; Befikadu et al., 2019; Gutu, Emana, & Ketema, 2012), the studies conducted in different parts of the world relatively claim for spatial aspects of perceptions (Boissière, Locatelli, Douglas, Padmanaba, & Sadjudin, 2013; Chibinga, Musimba, Nyangito, & Simbaya, 2010; Kashaigili, Levira, Liwenga, & Mdemu, 2014).

Conclusions

Insights to broadly argued research gap on lack of climate studies at small geographic region by considering unique features of the area, deficiency of climate change studies for southwestern Ethiopia and specific to the study area; this research is intended to examine spatio-temporal trends and variability in rainfall and temperature in Anger River watershed of southwestern Ethiopia. Ultimately, the research was designed to integrate the result with the studies on other global change

[5] A short spell crops sowed in the early onset of rain (*belg*) mainly served to coup the food scarcity in the upcoming *kiremt*.

processes and changing socioeconomic, political and organizational conditions in the community to understand the possible vulnerability pathways and adaptation responses of small-scale farmers in the study area. Examining the trends and variability of the elements of climate at micro scale having unique biophysical and socioeconomic characteristics has paramount importance to understand the system differential vulnerability to the changes; identify adaptation strategies within change processes; and to explore the causal linkage of adaptation constraints so as to recommend options suited to the identified case studies to enhance resilience of small-scale farmers in the study area.

About 166 grid points were used to cover the watershed for rainfall and temperature gridded data from 1983 to 2018. The watershed receives mean annual rainfall of 1577mm mostly contributed by *kiremt* rain with no significant difference in patterns among agro-ecologies. The trends of rainfall show substantive spatio-temporal differences in the watershed on monthly, annual and seasonal bases. However, there is general increase in annual rainfall for entire watershed but significant only in *woinadega* agro-ecology. The trends of rainfall on seasonal base across agro-ecology show some remarkable differences. The *kiremt* rain shows increase for entire watershed but significant for *woinadega* and *kolla* agro-ecologies while *belg* rain show non-significant increase in *dega* and *kolla*; and decrease in *woinadega*.

Unlike the trend, the result of rainfall coefficient of variation, concentration index and anomalies show remarkable variability; and the situation has spatial aspects in the watershed. All months excepts rainy months of *kiremt* (JJAS) have shown moderate to high rainfall coefficient of variations; while dry months of *bega* (ONDJ) shows exceptionally highest for all agroecology with considerable difference across agro-ecologies. Although, low coefficient of variations was confirmed for *kiremt*; remarkable spatial difference was observed that; relatively highest variability was recorded in *woinadega* followed by *kolla* agro-ecology. The moderate to high rainfall concentration with considerable difference across agro-ecologies were observed in the study area. High concentration was observed in *woinadega* followed by *kolla*; while *dega* is relatively characterized by moderate rainfall concentration. On the basis of the annual anomalies, rainfall shows moderate to extreme drought in few years in all agro-ecology. The 1986 was the year of extreme drought for both *dega* and *woinadega* while severe drought was happened in 2002 and 2004 in *dega* and 1991 and 2009 in *woinadega* agro-ecology. The *kolla* agro-ecology weren't experience any extreme and severe drought in annual standardized rainfall anomalies. However, these negative annual anomalies weren't implied for *kiremt* and *belg* droughts in the study area that most of moderate to extreme droughts in these seasons were observed in significant numbers of years dissimilar with the years when severe and extreme annual anomalies-based drought were recorded.

The temperature trends show an increase in both maximum and minimum temperature with spatiotemporal variations which is among the manifestations of global climate change. The increasing situation is severe in *woinadega* where trends for both mean annual maximum and minimum for all months at different significance level shows increment except for mean maximum of August.

The small-scale farmers in the study area have clear perception on status and trends of temperature; while relatively blurred on rainfall conditions. Moreover, significant difference was observed among agro-ecology regarding perception on rainfall trends and variability while temperature was perceived as increasing for all agro-ecology. Most of *kolla* community perceived the trend of rainfall as undetermined and explained the situation as highly variable; than those from *dega* and *woinadega*. Accordingly, unpredictability of rainfall time (mostly late onset of *belg*), concentrations, and unexpected rain during harvesting were major challenges in the watershed. These have multifaceted impacts on their livelihoods such as reducing production and productivity of *belg* crops; soil degradation and crop destructions because of heavy rainfall and associated storm in *kiremt*; unpredicted rain in late November have been devastating crops under harvesting.

Although the overall trend observed for rainfall has increasing tendency in southwestern highlands of Ethiopia; these couldn't grant positive climate situation while inter-annual, seasonal, and monthly variability was significantly witnessed in the study area; which has potential to hamper livelihoods of local community. Small scale farmers' worry was toward decreasing inconsistency of rainfall (onset and off-set), seasonality and fuzzy optimum adequacy; increasing in extreme events such as storms and heavy rainfall; and extremely increasing trends of temperature; rather than overall trends in rainfall. Therefore, future research works focusing on comprehensive variability measurements including other elements of climate is important. Moreover, in addition to scientific contribution for climate science, the climate analysis seems rewarding when take place at micro-level and applied to identify confined status. Most of vulnerability and adaptation studies in Ethiopia have been take place by adopting large scale empirical data on recent trends, experts/and community perceptions; and even without these data claiming climate variability as inevitable natural processes. However, probing the issues to the change without site specific micro-scale knowledge on the status, trends, magnitude, spatial variations and distributions with parameters implied for the livelihoods systems of a community would affect development practitioners' interventions to enhance the resilience, and recommend appropriate adaptation options and implement the strategies.

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CHAPTER FOUR

Characterizing Small-scale Farmers Differential Vulnerability to Global Environmental Change: Case Studies in Anger Watershed, Southwestern Ethiopia

Article published: *Gemechu Yigezu Ofgeha & Muluneh Woldetsadik Abshire (2020). Characterizing Small-scale Farmers Differential Vulnerability to Global Environmental Change: Case Studies in Anger Watershed, Southwestern Ethiopia, Journal of Sustainable Rural Development, DOI: https://doi.org/10.29252/jsrd.01.02.101*

Characterizing Small-scale Farmers Differential Vulnerability to Global Environmental Change: Case Studies in Anger Watershed, Southwestern Ethiopia

Abstract

Global environmental change of climate variability and land use dynamics are emerging livelihood challenges facing local poor. Although, the synergetic impacts of these processes have been cognate in Ethiopia, vulnerability researches were fixed to climate variability, inadequate on conceptual and methodological considerations of non-climate stressors. To this attention, we assessed small-scale farmers' vulnerability situations in Anger watershed of southwestern Ethiopia. The case study design guided by mixed methods approach was used. Multistage sampling technique was used for the study. The data collected from 335 household heads were analysed by multivariate analysis, measures of differences, and substantiated by qualitative enquiry based on focus group discussions and observations. Household's vulnerability magnitude ranges from high to moderate, while in aggregate, kolla agroecology was more vulnerable than highland. The effects of social adaptability and sensitivity to land resources were significantly contributed for the vulnerability differences. Although, climate variability was notable, structural land use dynamics was unequivocal stressor deepened the household's vulnerability in kolla. Vulnerability is the result of interactive and interconnected processes of climate, non-climate stressors, and households' internal capacity in the study area. Thus, attributing local vulnerability to only climate variability, neglecting local non-climatic disturbances could mislead development planning. Hence, future studies should consider such processes simultaneously to provide comprehensive evidences on vulnerability situations. The national adaptations program needs to integrate climate change with the emerging other global changes in planning rural resilience. Policy fortifying agricultural investments should synchronize win-win strategy for relationships between investors and local community.

Keywords: Climate Variability, Land Use Dynamics, Access to Land Resources, Livelihood Stressors, Vulnerability Factors

Introduction

Global environmental change processes of climate variability and land use dynamics is emerging challenge facing local communities. However, the spatio-temporal variations in nature and magnitudes of stressors, and unique micro-scale livelihood systems sensitivity to the processes have been resulted differential vulnerability on top of internal socioeconomic capacity of a community. Thus, some areas are more vulnerable to the changes than others that the complexity in geography have been observed (Burkett et al., 2014; Shameem, Momtaz, & Rauscher, 2014) and the situations are more acute in developing countries because of vast causal linkages of the vulnerabilities with socio-economic, historical and political milieu of the region (Adger, Barnett, Brown, Marshall, & O'Brien, 2013), while the livelihood strategies of the community such as agriculture and the immediate land resources are heavily sensitive to the impacts of these processes (Shackleton, Ziervogel, Sallu, Gill, & Tschakert, 2015). Thus, the existing climate variability have been taking place simultaneously with rapidly changing LULC (Denton et al., 2015; Fazey et al., 2018; O'Brien & Barnett, 2013) heightening vulnerability and challenging inherent adaptation and coping strategies of local community.

The synergism among such global environmental change processes in affecting life and livelihoods of poor got prominent position in today's development research (Burkett et al., 2014; Jeffers, 2013; Leichenko, O'Brien, & Soleck, 2010; Prno et al., 2011). The dynamics in land use, and associated change in local communities' access to land/and natural resources resulted from globalization; and the impacts of climate variability could be considered areas of such changes in Ethiopia. Particularly, the condition has significant implications for the small-scale farmers of Anger watershed than any community having similar livelihood background in the area. Although, there is lack of empirical data specific to the area, like any other community in Ethiopia affected by such changes(Dessalegn, 2011; Makki, 2014), the structural changes in land use and climate variability have capacity to disrupt local community's livelihood system and deny their resource access in one way or the other, and accentuate their vulnerability. On top of impacts of climate variability which have been modifying the state of the community's vulnerability, they have been affected by diminishing land size, limited access to water source and other natural resources due to structural land use dynamics. Thus, the study argued that the livelihood out-comes of small-scale farmers in the study area is the reflection of both stressors, that the processes have spatiality in the watershed, and the farmers' socioeconomic development in general and vulnerability conditions in particular are significantly constructed based on the extents of their exposure/ and sensitivity to both or one of the stressors.

Although, numbers of development institutions, practitioners and researchers are recommended for assessing vulnerability at micro-scale by considering simultaneous impacts of such contextual stressors mainly among poor like small scale farmers in Anger river watershed(Burkett et al., 2014; Butler et al., 2014; Grineski et al., 2015; Prno et al., 2011; Simonds & O'Brien, 2018), previous studies in Ethiopia were addressed the issues separately, no research considered the combined impacts of the changes, most of them were fixed to vulnerability to climate change, and attributed causalities to local human-environment interrelationship. However, we shouldn't fail to notice the extensive global economic changes that our world is facing, evolving rules of the processes on resource access/utilizations, and the pressures that these could potentially exerts on the poorest small-scale farmers. Particularly, most of the studies conducted in Ethiopia on both issues could be thematized as the impacts of land use dynamics, and vulnerability to climate change. For instance, some have focused on the impacts of land use policy, land tenure arrangements, and large-scale land acquisition on local community (Dessalegn, 2011; Lankester & Davis, 2016; Tsegaye & Spoor, 2015; Wulp, 2013) and other focus on livelihood vulnerability to climate change, vulnerability of economic sectors to climate change such as agriculture, and determinants of vulnerability to climate change (Abayineh & Simane, 2017; Kindie, Abate, Berhanu, & Belay, 2015; Paulos & Simane, 2017; Shiferaw et al., 2014; Woldeamlak, Radeny, & Mungai, 2015). Moreover, most of the studies were conducted in the central and northern highlands of the country, while other parts mainly southwestern of Ethiopia rarely researched.

These thorough review of previous studies on household's vulnerability in Ethiopia show that the researchers adopted out-come based vulnerability analysis while context specific methods are overlooked, climate change was considered as the only stressor that no research has been considered non-climate stressors in framing livelihood disturbances, and vulnerability indicators are selected deductively and applied for analysis without considering local situations. Furthermore, no research has been attempted to combine climate and other micro-scale global environmental change such as structural land use dynamics while such contexts have had capacity to shape vulnerability situations of a community.

Therefore, further studies are needed to consider these issues and others in order to provide sufficient evidences on spatial patterns of these global environmental change processes, individual/ and simultaneous impacts of the processes on the livelihood system of a community, and to describe the associations between impacts of the processes and local specific vulnerability situations. So, this study could fill the knowledge gaps of previous studies on the local livelihood vulnerability assessment. In this regard, the justifications for this study were that the identified processes (i.e., climate variability and structural land use dynamics) have global courses and impacts, external to the 'vulnerable' unit of analysis, and boldly observed in the study area with distinguished spatiotemporal settings due to differences in agroecological, historical and political spurs. Therefore, considering the site-specific conditions and the simultaneous/and individual impacts of these global environmental change processes have had significant implications on the vulnerability situations of households encountered by either individual or concurrent stressors.

Methodologically, the previous research on vulnerability come-up with frontiers between environmental scientists and social studies, to their incompatible epistemologies, mostly positivist and interpretivist respectively. For instance, several studies on the impacts of global economy induced large-scale land acquisition in Ethiopia are oriented by the second frontier. In this regard, most of them are restricted to qualitative approach oriented by political economic explanations. Although, the researchers reported that the processes have been increased the vulnerability of those who are dispossessed (Desalegn, 2013; Tsegaye & Spoor, 2015), their methodologies are inadequate to examine the extents of vulnerability, spatial difference in factors' effects on vulnerability. Contrary, others are highly positivists dedicated to models-based measurements of vulnerability focusing on climate change as the only stressor (Schneiderbauer, Calliari, Eidsvig, & Hagenlocher, 2017; Simonds & O'Brien, 2018), particularly fails to inductively identify site-specific non-climate external stressors and in-depth explorations of local contexts and issues qualitatively. These edge along disciplines resulted shortage of methodological exercises for holistic understanding of local vulnerability situations. Thus, in this study multiple perspectives and methods were used, believing that synergizing these disciplinary positions and lessen the methodological edge is crucial to achieve the objectives of the study. This was done through integrating relevant conceptual frameworks and models, designing case-study by considering unique issues and processes at case unit, adopting mixed research methods approach to grasp a range of data sources and types with multiple techniques of analysis.

The general objective of the study was to assess small-scale farmers' vulnerability to global environmental changes in Anger watershed of southwestern Ethiopia. Specifically, the research was intended: (1) to examine the small-scale farmers' vulnerability at household level, (2) to portray the spatial differences in magnitude of household's vulnerability, and (3) to characterize household's vulnerability factors across case studies. Therefore, in addition to measure magnitude of vulnerability at household level, the comparative case study was conducted to explore the differential vulnerability i.e., whom/ and where is more vulnerable? what is the extent of vulnerability differences along case studies? What factors' effects are contributed for the difference? and how the stressor/s have shaped the vulnerability situations of households.

The study was focused on the unique feature of the case study units i.e., *kolla* agroecology in Anger valley partaking tropical warm (*kolla*) climate, and the second case study 'highland' has subtropical (*woinadega*) and small area of temperate (*dega*) climate. In addition, the cases are different in their political economy experiences, particularly, *kolla* area has long history of 'development' interventions, and subsequent structural land use dynamics while the process was relatively slight in the highland. Thus, the outcome will provide new insight for vulnerability literature, contribute for emerging vulnerability frameworks, and provide policy recommendation on rural resilience. We hypothesized that high levels of vulnerability will be related to low adaptive capacity, high exposure and sensitivity to the current global environmental change processes, particularly climate variability and structural land use dynamics. In relation to differences for climate variability situation across agroecology and situation of structural land use dynamics, as found by previous empirical findings (Jeffers, 2013; Leichenko et al., 2010; Mubaya, Njuki, Mutsvangwa, Mugabe, & Nanja, 2012; Simonds & O'Brien, 2018) we expected that the households with low adaptive state, high exposure to the stressor/s, and low adaptive capacity will be more vulnerable and the situation has spatially different along the case studies.

Literature Review

Global environmental change was emerged as a major scientific research arena since the mid-1980s(Leichenko et al., 2010), while vulnerability to these processes has emerged as a cross-cutting theme in research on the human dimensions of the changes(Patterson 2013;Barrett and Constas 2014).These served to reinforce public, policy makers and development practitioners through scientific recognition that fundamental global-scale biophysical dynamics resulted climate change (IPCC, 2007), and recently different external factors such as globalizations and national economic and institutional changes (Leichenko et al., 2010) and associated structural changes in resource ownership (Dessalegn, 2011; Hjerpe & Glaas, 2012) have been happening, heightening risks and reducing opportunities, especially for poor.

Both theory of disaster and entitlement has contributed for major perspectives of human vulnerability research, while within each theory different approaches and discourse are persisting. Given the diversity of uses and definitions, the concept traces its epistemological origins to the disciplines such as disaster management, environmental sciences, economics, anthropology/ sociology, and health science by which the researchers from these disciplines addresses the concept differently based on their respective disciplinary orientations, objectives of a study, nature of a system subjected to study (Burkett et al. 2014; Eriksen and Kelly 2007; Kelman et al. 2016; Reed et al. 2013; Wisner et al. 2003).

The diversity in conceptualization and uses (Schneiderbauer et al., 2017; Simonds & O'Brien, 2018), persistent multiple frameworks(Cutter et al. 2009; Shameem et al. 2014; Turner et al. 2003), the relationship between biophysical and social aspects in measurement, integration of the concept with other related terms such as risk, hazard, sensitivity, adaptive capacity, and overlaps with concepts such as resilience and adaptation (Costache, 2017; Miller et al., 2010) oblige to apply the concept with great caution. For instance, some argued that, different formulations of research needs, research methods, and normative implications of vulnerability research built on objectives of study or the system to be studied (Mcdowell and Hess 2012; Reed et al. 2013). Although, the recommended approach is toward a general framing of vulnerability, the specific variables and relationships to be studied, and the methods should realistic to achieve the objectives of a study(Schneiderbauer et al., 2017), the recent studies have been criticized for fragile argument on purpose of assessing vulnerability, deficiency in condensing complex state-of-affairs such as the vulnerability of regions, households or countries into a single number that cannot then be easily used by policy makers, and lack of clarity in approaches and methods of data collections (Hinkel, 2011).

These all conceptual and methodological issues were addressed in designing the study. In this paper, vulnerability is the state of small-scale farmers' livelihood susceptibility to harm from exposure to stresses associated with environmental and historical socio-economic and cultural changes and from the absence of capacity to adapt. The reviewed literature consistently considers particularly livelihood vulnerability as a function of three key elements: exposure and sensitivity to stress/stresses, and adaptive capacity. The situation is context specific that the households' exposure to the stressors has spatial variations, particularly climate variability along agroecology, and the structural land use dynamics vary along case units due to historical political economy of the region. Thus, coupled deductive and inductive approaches were used to identify the vulnerability indicators to index and characterize households' vulnerability. The approaches were appropriate to capture realistic indicators which comprise the situations of case studies.

The livelihood vulnerability indicators adopted from previous research works (Abayineh & Simane, 2017; Kelman et al., 2016; Pandey, Jha, Alatalo, Archie, & Gupta, 2017) were used as check list during inductive surveys beforehand conducted on local knowledge from the communities and experts to determine list of indicators (Brink and Wamsler 2018) . Thus, we able to pick out variables that approved the discriminate households in to the group of designed case studies, and the variables were added to or replaced the deductively adopted indicators. The key elements of livelihood vulnerability (Field et al., 2014) contextually operationalized based on previous empirical researches companionable in the approach, framework, methodology and purpose of this study (Dong et al., 2011; Field et al., 2014; Jeffers, 2013; Leichenko et al., 2010; Shameem et al., 2014; Simonds & O'Brien, 2018).

Exposure refers to the degree of stress upon a small-scale farmers household. In this context, it represented long-term changes, variability and the magnitude and frequency of climate extreme in one way, and undesired change in access to land and natural resources resulted from structural land use dynamics. Exposure is employed to refer to the location of the small-scale farmers and their livelihoods, environmental services and resources, infrastructure, economic, social and cultural assets that could be adversely affected by physical events of climate variability and structural land use dynamics, thereby, are subject to harm, loss, or damage. Sensitivity refers to the degree to which a household respond to the changes i.e., to climate variability and structural land use dynamics either positively or negatively. The sensitive households respond to the changes negatively due to inability to exploit the opportunity, while less sensitive could respond positively by realizing the opportunity and reduce the threat of the changes. Adaptive capacity describes the ability of the households to adjust to actual or expected stressors' impacts, or to cope with the consequences. It is considered as a function of economic and socio-demographic status of households such as wealth, skills, infrastructure, access to resources, education, information, stability, technology, management capabilities, family conditions, social networks and etc.

Therefore, the households exposed to negative and undesired changes, negatively respond due to inability to exploit the changes and characterized by low socioeconomic development are vulnerable. The household vulnerability has spatial aspects in the study area due to the contexts of the stressors. The vulnerability indicators were adopted (Abayineh & Simane, 2017; Gutu, Emana, & Mengistu, 2012), modified to the contexts of the study area. The detail of the indicators is presented in Table 1.1.

Methodology

Study area

Anger watershed lies in east Wallagga administrative zone (Figure 4.1) were the focus the study, while the watershed covers more areas in the region. The area within a single administrative zone was selected to reduce heterogeneity due to administrative difference because the situations are place-based and context specific that the climate and historical, political and socioeconomic outgrowths are more complex if the entire watershed is included in the study.

The study area is composed of various land forms with altitudinal ranges of 1200-3018 meters above sea level. The mean annual temperature ranges between 14^0c to 25^0c; and average annual rainfall is also between 1000 mm to 2400 mm. The rainfall shows mono-modal pattern and more than 80% of which occurs between May and October. Numbers of rivers and streams drain the watershed. There are different types of soils found in the zone. Most of the northern parts of the zone are covered by Orthic Acrisols and Cambisols; while Eutric Nitosols is the dominant in the central part; and Dystric Nitosols occur almost throughout the zone. These soils have contributed for development and good potential of agriculture in the watershed (FED, 2014).

The micro-scale climate, soil types, varied species of forest ecology, rich wild animals and other associated natural resources supported vast livelihood options. The socio-economic and demographic characteristics are shaped by the dynamics in these bio-physical factors on top of historical national and global change processes. Particularly, the physical environment, social, cultural and livelihood system of community in *kolla* is more unstable than highlands due to these external interventions mainly associated with introduction of large-scale agriculture and resettlement programs since 1970's. Thus, the status and trends in small scale farmers socio-economic and demography have been showed significant difference within small area due to difference in magnitude of the extrusions.

Currently, the estimated total population size of the zone was 1,552,689 in 2019 out of which 82.28% were rural populations directly engaged in agriculture (projected from Zone's FED 2014). Thus, agriculture is the major economic activity that different types of crops such as cereal, pulses and oil seeds are produced largely throughout the study area. Similarly, the livestock rearing, beekeeping and direct exploitations of natural resources play key livelihood roles. The infrastructure development is poor mainly among rural dwellers. The road quality/and network density is low; less than half of the rural population has supplied potable water; source of energy is limited to firewood, animals dung, crop residues and charcoal (FED, 2014).

Research Design

The study consists an array of issues from objectively examining magnitudes of vulnerability to constructing reality on who is vulnerable to what, why and how the cause/s shaped the vulnerability situation of the community through in-depth exploration of community's concerns. Therefore, mixed research method approach was used. Collection of observations and measurements of incidences of livelihood vulnerability was conducted quantitatively to make inferences about magnitude and spatial variations in households' vulnerability, while qualitative data was used to substantiate the model-based results (Creswell, 2012).

The approach was guided by the principles and procedures of survey research design. The justification for the design includes: it is one of the widely employed in mixed research approach helps to infer to the total population, and in-depth analysis of the concern of different stakeholders. It allows to ask about many things at one time, that it is compatible with cross-sectional design for the time frame of the study. The reliability and validity are critical in the study. Thus, the issue of stability, internal reliability and inter-observation consistency were checked to realize the reliability of the study. Moreover, the research validity was attained through careful sampling, appropriate instrumentation and statistical treatments of the data.

Research Techniques and Tools

The sources of data for the study include small scale farmers' household heads, group discussants drawn from elderly who lived for a long in the area with experiences of ecological and livelihoods systems, experts on the issues, and relevant published and unpublished documents.

Multistage sampling technique was used in the study. The areas found within the Anger watershed in the East Wallagga administrative zone were the focus of the study. The smallholder farmers' household heads were the unit of analysis in the study. The divisions within the region were made on the basis of agro-ecology and the situation of structural land used dynamics to discriminate households in to the group of designed case studies; which was followed by random selection of districts and kebeles represent both case studies.

Accordingly, Ukke and Anger Magarsa kebele represent the first case study. They were selected from *kolla* agro-ecology and both are under the influence of large-scale agricultural investment. Gari from *woinadega* and Haro Chalchisa from *dega* agro-ecology represent the second case study. Out of total 2,642 household heads, 335 were identified by the following formula (Kothari, 2004). The sample size for each kebele was determined based on the proportionality of their size and simple random sampling technique was used to select households for the questionnaire survey.

$$n = \frac{z^2.p.q.N}{e^2(N-1)+z^2.p.q}$$

Data analysis was performed by STATA for principal component analysis (PCA) based vulnerability index, and T-tests and Pearson's linear correlations to characterize vulnerability factors along case units. The rationale is that PCA may perhaps use to construct indices for which there are no well-defined weights (Li, Zhang, Yuan, Liu, & Fan, 2012), it helps to summarize variables in to components through looking for 'clumps' to develop small number of coherent components (Pallant, 2010), and above all, the components were used to characterize vulnerability factors across case studies.

The model specification for PCA:

Vulnerability = (Adaptive capacity) – (Sensitivity + Exposure) …………….........Eq. 1

In this study, both households level index (Equation 2 and 3); and spatial (case studies) index (Equation 4) were used. The households were classified into highly vulnerable, vulnerable and less vulnerable based vulnerability index for each household; while the two case units were classified as vulnerable and less vulnerable based on net value of vulnerability index in the area. The index was computed based on relative measure, representing the households' own perception on their socioeconomic and environmental conditions. All statistical assumptions and data suitability were realized.

The vulnerability index at household level is expressed as:

$$VI_{hh}= (A_1X_{1j} + A_1X_{2j}+\ldots +A_1X_{nj}) – (A_1Y_{1j} + A_1Y_{2j}+\ldots +A_1Y_{nj}) \ldots\ldots\ldots\ldots\text{Eq. 2}$$

Where; VI_{hh} is vulnerability index of the household; Xs are the values of elements of adaptive capacity; Ys are the values of elements of sensitivity and exposure for the household. The matrix of Xij showed as follows:

$$\text{Xij/Yij} = \begin{matrix} (X11 + X12 + \cdots + X1n) - (Y11 + Y12 + \cdots + Y1n) \\ (X21 + X22 + \cdots + X2n) - (Y21 + Y22 + \cdots + Y2n \ldots.) \\ (Xm1 + Xm2 + \cdots + Xmn) - (Ym1 + Ym2 + \cdots + Ymn \end{matrix} \ldots\ldots\ldots\text{Eq. 3}$$

The i and j implies the number of rows (participants; n=335) and the number of columns (variables). In this regard, the first principal component of a set of variables (i.e., the linear index of all the variables that capture the largest amount of information common to all the variables) for each observation (Gutu et al., 2012) were used to label households under three vulnerability status. Moreover, the following matrix (Equation 4) was used to calculate vulnerability index along case study.

$$VIcase = \begin{matrix} A1 \\ A2 \ldots \\ An \end{matrix} \text{ X } \begin{pmatrix} (X11 + \cdots X1n) - & (Y11 + \cdots + Y1n) \ldots . \\ (Xm1 + \cdots + Xmn) - & (Ym1 + \cdots + (Ymn) \end{pmatrix} \ldots\ldots\ldots\ldots \text{Eq.4}$$

The value of X and Y obtained by normalization using mean and standard deviation from factor scores (X1=(X1-X*)/SD). The A's are the factor score of variables along case studies. X_{mn} are the summation of the normalized values of adaptive capacity, and Y_{mn} are of sensitivity and exposure, VI_{case} is vulnerability index for case studies. The normalized values of indicators are annexed (Annex1).

The PCA based components of vulnerability indicators were characterized for case study using T-tests and Pearson's linear correlations. Moreover, the FGD, field observations and discussions with experts were analysed to construct evidences on the similarities and differences in vulnerability factors across the cases studies, and assess the causalities; i.e., how the factors are caused the results, particularly outcomes and impacts.

Findings

We conducted factorial analysis with PCA and Varimax rotation, using eigenvalues >1. After repeated analyses, results demonstrated the better four-components solution than the others, eliminating five variables because of reported low communality. Thus, 30 variables (Table1) were used for entire analysis.

Moreover, the KMO = 0.82 and Bartlett's test of sphericity $\chi 2$=4179.318, *p*=.00, the Cronbach's alpha coefficient (α=.85) indicated the suitability of PCA and internal consistency of the indicators.

Table 4.1. Socioeconomic and environmental indicators of vulnerability

S.N	**Indicators**	Percent
1	Sex: female headed	19.0
2	Education: No formal education and > grade 3	76.2
3	Duration: Stay over the area for >5 years	19.9
4	Experiences on livelihood sources: >5 years	6.3
5	Number of relatives: No relatives and < 5HH	29.2
6	Number of institutions:<=2 institutions	58.0
7	Information: no access to climate and land management information	89.6
8	Dependency:> half of household size	70.8
9	Extension: no access to extension services	11.9
10	Livestock ownership:< 4.02TLU (average for household)	56.5
11	Land under perennial crop: No area under perennial crop	69.9
12	No̱ of plot:>one plot and (separated home and farmland)	66.7
13	Non-farm income: No non-farm income	73.2
14	Crop diversity:< 50% of crop produced in the area	61.3
15	Artificial fertilizer: No access at all & <50% of land	45.5
16	Improved Seed: No access at all & <50% of land	56.8
17	Irrigation: No access to irrigation	78.3
18	Deposit: No food/money deposit for time of recession	74.7
19	SWC: No practices on the farmland	85.7
20	Land holding size:< average landholding size of the area	55.1
21	Communal/open land for grazing: No access	42.6
22	Open natural resources such as forest: No access at all	42.3
23	Competition on resource: high competition	42.0
24	Slope: > =15% (Very steepy) and flat (near 0%)	69.0
25	Vegetation: Bare land and sparsely vegetated	70.8
26	Natural fertility: Poor (require heavy fertilizer)	77.4
27	Frequency of natural hazards: Frequent (> twice in 5years)	77.7
28	Rainfall: Insufficient /and variable	90.2
29	Temperature: Increasing /and variable	92.9
30	Wind: Noticed unusual change	31.3

Source: Field survey, 2020

Household Level Vulnerability

The factor score of the first principal component for entire observation was used to construct vulnerability index at household level. The value ranges from -1.72 for household characterized as highly vulnerable to +2.12 for least vulnerable among the observations. The result shows that the majority of households fall within the moderately vulnerable category in the watershed followed by high vulnerability status (Table 4.2).

Table 4.2. Households' classification by range of their vulnerability index

S. N	Vulnerability Index	Vulnerability category	Frequency	%
1	<-1.00 to -1.76	Highly vulnerable	86	25.67
2	-1.00 to 1.00	Moderately vulnerable	197	58.81
3	>1.00 to 2.12	Less vulnerable	52	15.52
	Total			100

Source: Field survey, 2020

Spatial Analysis of Vulnerability Situations

The vulnerability indicators of households were clumped in to four components for both cases based on statistical assumption of PCA. The first component was named "*economic component*", it included 12 items. The second component was called *"social component"*, constituted seven items. The third component termed as "*climate and environmental component*", constituted seven items. The fourth component was named "*land and natural resource*", with four items (Table 4.3).

The principal component-based factor analysis was made for both case studies to identify spatial variation in extent of vulnerability in the watershed. The factor scores of the first and the second principal component was positively associated with the majority of the indicators identified under economic and social components respectively, while the third components was negatively associated with majority of climate and environment indicators in both case study. However, the fourth component was positive for most indicators under land and natural resources in highland and negative for *kolla* (Table 4.3). In order to construct index, the normalized indicators scores (Annex) were used.

Table 4.3. Factor scores for principal component analysis across case studies

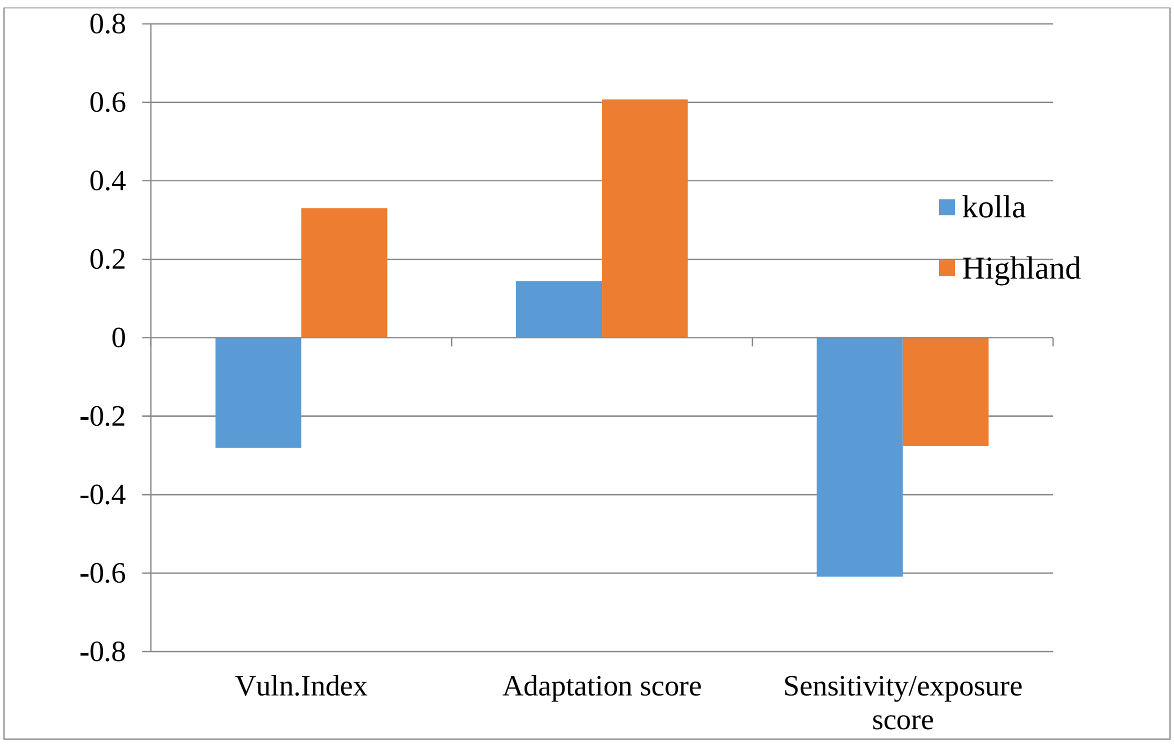
SN	Variables	Economic		Social		Climate and environment		Land resources	
		Kolla	High land	*Kolla*	High land	*Kolla*	High land	*Kolla*	High land
1	Sex of household head			-0.75	0.61				
2	Education			0.74	-0.58				
3	Duration in the area			0.81	0.77				
4	Experience			0.61	0.81				
5	Number of relatives			-0.33	0.60				
6	Extent of dependency			0.41	0.51				
7	Number of institutions			-0.92	0.53				
8	Access to information	0.71	-0.81						
9	Access to extension	0.76	0.49						
10	Livestock ownership (TLU)	-0.52	0.82						
11	Land for perennial crops	-0.41	0.76						
12	Numbers of plots	0.35	0.75						
13	Non-farm income	0.86	-0.57						
14	Amount of crop types	0.71	0.70						
15	Artificial fertilizers	0.92	0.51						
16	Improved seeds	0.60	0.58						
17	Engagement in irrigation	-0.72	0.56						
18	Landholding size	-0.53	-0.57						
19	Deposit(money/food)	0.50	0.63						
20	Extent SWC practices							-0.43	0.48
21	Access to communal grazing							-0.42	0.18
22	Access to natural forests							-0.51	-0.16
23	Competition on resource							-0.38	0.15
24	Slope on farm land					0.53	-0.46		
25	Vegetation cover					-0.51	0.64		
26	Natural fertility of land					-0.63	-0.70		
27	Natural hazards					-0.64	0.62		
28	Rainfall condition					-0.58	-0.57		
29	Temperature condition					-0.46	-0.57		
30	Wind condition					0.43	-0.18		

Source: Field survey, 2020

The higher net value of the vulnerability index (Figure 4.2) show less vulnerability and vice versa. The aggregate value of social and economic components was positive for both case studies (+0.144

for *kolla* and +0.607 for highlands), climate and environmental component was negative with value ranges from (-0.414) for *kolla* and (-0.276) for highland, while land and natural resources component shows negative for *kolla* and positive for highlands (-0.271 and +0.402 respectively). The net value of the index was negative (-0.281) for *kolla* and positive (+0.324) for highlands (Figure 4.2).

The two cases differ significantly in their social contexts such as number of institutions, education and number of relatives; economic capacity such as land size for agriculture, access to irrigation, extent of perennial crops on their farmland and livestock ownership; and environmental conditions such as status of vegetation cover and slope of farmland. Moreover, access to land and natural resource such as grazing land, and other land resources was significantly different across the case studies (Table 4.3).



Source: Field Survey, 2020

Figure 4.1. Vulnerability index of households along case units

Characterizing Vulnerability Factors

The significance of the factors scores along case studies, their relationship and differences in effects on magnitude of vulnerability along the case study were examined to attribute the underlying factors for differential vulnerability.

Descriptive analyses on vulnerability components showed higher social than economic adaptability, low sensitivity to land and natural resources access and high exposure to climate and environmental adverse in the highland. However, the situations in *kolla* showed relatively higher on economic than social adaptability and high sensitivity to land and natural resources access and exposure to climate and environmental adverse (see Mean and SD in Table 4.5).

The components difference and relationship along case unit were analysed to identify the significance of the factors' effects on households' vulnerability. Accordingly, the result of independent sample t-test shows significant differences among the components for their effects on vulnerability (Table 4). Specifically, both cases are different in their social adaptability (t(335)= -1.54, sign.2-tailed =.002) and sensitivity to land and natural resource component (t(335)= -13.36, sign.2-tailed =.000) so, highlands obtained higher scores on both social adaptability and low sensitivity to land and natural resource than *kolla* (see Mean and SD in Table 5). The result indicates that the difference in vulnerability status (shown on Figure 2) along the cases were significantly contributed by these two components, while the two other components show difference but statistically not significant. The economic adaptability, and climate and environmental adverse was higher in the highland.

Table 4.4. Effect difference of vulnerability components along case studies

Vulnerability Component	Levene's Test for Equality of Variances		t-test for Equality of Means		Sig. (2 tailed)	Mean d/c	Std. Error D/c	95% Confidence Interval of the Difference	
	F	Sig.	t	df				Lower	Upper
Economic	0.22	0.65	-0.21	22.0	0.83	-0.05	0.25	-0.57	0.46
Social	13.9	0.15	-1.54	12.0	0.02*	-0.35	0.22	-0.84	0.14
CEF	0.04	0.84	-0.31	12.0	0.76	-0.09	0.29	-0.72	0.54
LNR	1.14	0.33	-13.3	6.0	0.00**	-0.79	0.05	-0.93	-0.64

Equal variance is assumed for significant variables

Source: own computation: Survey, 2020

The components correlations along case studies (Table 4.5(2)) demonstrated the extent by which factors are correlated in their effects of vulnerability along case studies. The economic in *kolla* and social factors in highland showed significant correlation ($p<0.05$) in their effects of adaptive capacity of the households. The exposure to climate and environmental in *kolla* and economic adaptability in highland have significant inverse relationship ($p<0.01$) which show that the effects of climate and environmental adverse in *kolla* contribute as significant as adaptability due to economic capability in highland for vulnerability difference. Moreover, the effect of climate and environmental adverse in highland is as significant as the effect of sensitivity to land and natural resources in the *kolla* ($p<0.01$).

Table 4.5. Comparative factors analysis of vulnerability components

1. Independent sample t-test for case units				
Cases	Economic M, (SD)	Social M, (SD)	CEF M, (SD)	LNR M, (SD)
Kolla	.27(.58)	.42(.58)	-.32 (.05)	-.44(.58)
Highland	.32(.62)	.77(.12)	-.27 (.57)	.35(.11)
2.Component correlations along case units				
Kolla	**Highland**			
	Economic	Social	CEF	LNR
Economic	-0.17			
Social	0.57*	-0.22		
CEF	-0.96**	0.10	-0.20	0.86**
LNR	-0.12	-0.19	0.32	0.05
Level of significance for (**) p<.001 and (*) for p<0.05 M, (SD)= Mean and Standard deviations CEF=climate and environmental factors; LNR= land and natural resources				

Source: Field survey, 2020

The FGD based findings confirmed the model-based characterized factors of vulnerability. The discussants in both cases explained their livelihoods vulnerability to the adverse climate and environmental factors. The increased in temperature and the variability in rainfall have been adversely affecting their livelihood. For instance, the late rain multifaceted impacts on productions and productivity of crops and shortage of grass and water for livestock (due to elongated dry season) were observed in the study area. Moreover, the rainfall concentrations in *kiremt* have been resulting soil degradation, increased unsuitability for crops, and destructions associated with heavy storms.

However, climate variability was not explained as the main livelihood stressor in *kolla* unlike highland discussants. Although, land and natural resources mainly communal forests and grazing are the decisive livelihood assets in *kolla* than any other agroecological zones in the area, access to these resources have been reduced due to state interventions in various time including the current policy prefers for large scale agricultural investments. The discussants claim that 'development' induced state interventions for resource utilizations have long history in the *kolla* agroecology from 1970's of Dutch's large scale farm introductions, socialism-oriented state farm in the late 1975 and recent large scale private investments. These conditions have been exacerbating their vulnerability through a number of its adverse. The tenure insecurity, diminishing agricultural land and lack of access to natural resource such as forests and grazing land for economic and no-economic purposes were explained as the direct impacts of these processes.

The processes are discouraging those discussants in the *kolla* explained that most of small-scale farmers have no interest to stay over the area. The shift from agriculture and natural resources-based livelihoods to what they explained as 'quotidian' based income such as daily labourer and non-farm activities were increase sense of unsustainability. For example, the conditions weakened the systems they believed as vital for sustainable livelihood strategies such as productions of perennial crops, livestock rearing and irrigations, less in agricultural land conservations, and increased sense of over-utilizations of natural resources utilization and less on conservations/ and protections. The social interactions within the agroecology/and with surrounding highland have been diminished, and withdrawal from social institutions have been increased.

Discussion

The study ascertained to assess the simultaneous impacts of climate variability and structural land use dynamics to understand the context specific vulnerability situations, spatial variation in magnitude of household's vulnerability and local level insistent vulnerability factors. The study revealed that the small-scale farmers' households in Anger watershed are vulnerable to the change processes, and the magnitude, causality and subsequent livelihood outcomes are varied among households and the situation showed spatial aspects. The differences in magnitude of vulnerability were the results of disparities in the households' exposure to the stressors, and their internal socioeconomic characteristics. Particularly, sensitivity to lack of access to land resources which have been associated with structural land use dynamics and social adaptability factors were significantly contributed for the vulnerability situations in the watershed.

The observed spatial variations in magnitude of vulnerability, the causalities, and resultant differential vulnerability across case studies revealed that the vulnerability is interactive and inter-connected (Barnett, 2020) in the study area, that such case based structured approach is important to construct the Barnett's 'axes of difference'. Thus, the joined effects of the stressors resulted vulnerable livelihood on those uniquely exposed to the simultaneous effects directly (Simonds & O'Brien, 2018), and indirectly deepened their vulnerability by imposing to unsustainable livelihood systems (Butler et al., 2014) and agitated their social adaptability (Adger et al., 2013), through policies and institutions which merely consider the economic and ecological dependency of local community (Dessalegn, 2011).

Although, the effects of climate variability were observed in both cases, denied access to land and natural resources due to historical state 'development' interventions was unequivocal stressor triggered vulnerability of households in *kolla*. The process, policies and institutions are relatively continuous and structured in *kolla* since 1970's; particularly, the recent large scale agricultural investments projects have been shaped the vulnerability through altering ecological, economic and social systems. On top of differential exposure to the stressors, livelihood systems context in *kolla* witnessed high sensitivity of the community due to the fact that communal resources (forest and grazing) are the decisive livelihood assets than any other agroecological zones in the area.

Besides, the conditions have been indirectly contributed for vulnerability pathways. First, the processes enforced the community to undesired livelihood which they described as ‘quotidian’ and increased the sense of unsustainability. Second, the continued interventions increased interests for the valley utilizations, unsecured land tenure systems, weakened their plan to stayover the area and hinders sustainable livelihood systems. Thus, the low social adaptability was the indirect consequences of the process in the *kolla* agroecology. Moreover, inter-community socioeconomic bonds with surrounding highland were weakened due to collapsing ecological ties.

The applied conceptual and methodological approach for this study enables to achieve the objective of the study and will provide insightful evidences and methodology for future research and policy recommendations. First, it implied the need for reflexive conceptualization of vulnerability. Contrary to most of the previous researches on livelihood vulnerability in Ethiopia, this study imply that the concept shouldn’t ‘fixed to vulnerability to climate change’. Therefore, in line with current research recommendations on the issue (Adger, Barnett, Brown, Marshall, & O’Brien, 2013; Hjerpe & Glaas, 2012; Waters & Barnett, 2018), this research showed the importance to be reflexive in conceptions, manipulating the study contexts and pragmatic methodology to provide comprehensive evidences on vulnerability situations of households encountered with dynamic disturbances, highly sensitivity to stressors hinder their access to immediate resources due to low socioeconomic developments.

Second, these previous studies have limitations in their inadequate focuses on vulnerability factors: households’ capacity/ defencelessness (internal situations of ‘the vulnerable’) and climate change (external stressor), while other site-specific external disturbance are either unnoticed or labelled as internal to a vulnerable (Barnett, 2020). Thus, same to previous research (Leichenko, 2012; McCubbin, Smit, & Pearce, 2015; Mubaya et al., 2012) the study hopes to contribute new insights on assessment of vulnerability by considering structural land use dynamics, explained the process as global change, and labelled as non-climate external stressor. Thus, both constructed global change processes were assessed simultaneously through designed methods of analysing the household’s exposure-sensitivity to the stressors, and digests on how the process/s are explicated in differential vulnerability. The results of this work revealed that when such non-climate processes are overlooked in area like Anger watershed, it is unlikely to identify insistent vulnerability factors, their interconnections, and difficult to capture the extent by which such processes contribute for or reduce local vulnerability.

Thirdly, the methodological efforts in this study may perhaps comprehensive for the currently endorsed research needs aimed at holistic evidences on local vulnerability. To this end, we have tried to integrate multiple perspectives and methods, to capture an array of issues ranges from model-based examination of vulnerability at household and case study level to construct reality through in-depth exploration of community's concerns on various issues. For instance, the proposed conceptual framework, the designed case-study approach by considering unique issues and processes at case unit, the attempts of case based comparative analysis of the magnitude vulnerability, and critical analysis of complex assemblages of vulnerability factors were helped us to reveal these holistic evidences on the vulnerability situations households in the study area.

Likewise, the study contributes better knowledge for decision-makers regarding the implications that global economy has had on local vulnerability situations of households through pressurizing public policy for 'development' interventions. Indispensable policy-relevant insights offered by this study may perhaps on how site-specific non-climate processes unique to an area shape the vulnerability of a given community over time, on top of the impacts of climate variability. Thus, this study hopes to bring attention to the need for better integrating development policies in general, and national adaptations program to climate change in particular with the goal of reducing local vulnerability to such global environmental processes- in our case the impacts of structural land use dynamics. Moreover, the results call up on policy that are designed to fortify large scale agricultural investments as strategies for development should have equally consider a plan to achieve win-win relationship between the investments and local poor.

Generally, granting impacts of climate change on agrarian community now a days, attributing small-scale farmers vulnerability to climate change and to the 'vulnerable' internal capacity without understanding local specific external stressors is awkward. Thus, research and policy toward rural development should not to consider these processes in isolation, rather their combined effects are vibrant mainly in areas like *kolla* of Anger watershed. The applied methodology has potential to comprehend vulnerability to global environmental changes, particularly in considering the spatio-temporal aspects of the processes to examine vulnerability situations at household level, portray spatial differences in extent of vulnerability, and characterize vulnerability factors.

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Annex: vulnerability index along case units for each variable (normalized PCA score using mean and standard deviation)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kolla	-0.09	0.07	0.08	0.06	-0.07	0.05	0.09	0.06	0.07	-0.07	-0.08	0.07	0.08	0.06	0.09
High land	0.05	-0.03	0.08	0.07	0.11	0.09	0.05	-0.48	0.07	0.10	0.09	0.11	-0.36	0.14	0.02
Variable	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Kolla	0.06	-0.08	-0.07	0.05	-0.08	-0.08	-0.09	-0.07	0.04	-0.09	-0.10	-0.10	-0.10	-0.08	0.03
High land	0.06	0.08	0.10	0.15	0.12	0.07	0.11	0.10	-0.15	0.22	-0.21	0.21	-0.15	-0.24	-0.30

Note: Refer Table 4.1 above for the variables name represented by the numbers

CHAPTER FIVE

Local Adaptation and Coping Strategies to Global Environmental Changes: Portraying Agroecology Beyond Production Functions in Southwestern Ethiopia

Article published: *Gemechu Yigezu Ofgeha & Muluneh Woldetsadik Abshire (2021). Local Adaptation and Coping Strategies to Global Environmental Changes: Portraying Agroecology Beyond Production Functions in Southwestern Ethiopia, PLOS ONE, DOI: 10.1371/journal.pone.0255813.*

Local Adaptation and Coping Strategies to Global Environmental Changes: Portraying Agroecology Beyond Production Functions in Southwestern Ethiopia

Abstract

The recent research recommendations on the adaptations of poor are toward local specific investigations, aimed at a comprehensive understanding of the adaptation strategies through in-depth analysis of the status, and the explicit on how climate and non-climate global change processes constrain the inherent strategies. Intent to this idea, we have designed this study to assess the small-scale farmers' adaptation and coping strategies in southwestern Ethiopia. The agroecology approach steered in case-study design was used for the conceptual and analytical framework. The data collected from 335 households were analyzed for descriptive and multivariate analysis of variance and substantiated by qualitative data obtained through focused group discussion, interview, and observations. The significant differences were observed in the watershed among households in the case studies on their adoption of the identified adaptation and coping strategies. The sustainability of preferred strategies was different along case studies, solely determined by the impact magnitude of the adaptations constraining factors. Although free ecosystem-based strategies become less practical and replacing by new strategies in the watershed, the processes were gradual, internal to the community and managed through adaptive learning in the highland. However, the paths were perceived as toward maladaptive, resulted by the state interventions which disrupted free adaptations, deteriorated adaptive learning of the community, and shaped the adaptation responses toward the interventions in the kolla agroecology. The study implies that the situations of households' adaptation strategies are beyond the reflections of their respective production ecology, designated within climate variability in the previous studies. The structural land use dynamics and associated resource tenure insecurity have greater constraining effects on the strategies than the impacts of climate variability in the kolla. Thus, subsequent research interested in such contexts, and any plan for the development interventions should (re)consider the impacts of non-climate national/and global environmental change in shaping the adaptation and coping strategies of the local community.

Introduction

The researches on the local livelihood of the poor in the developing world come up with the complexity of adaptation constraints due to highly dynamic and challenging impacts of global environmental changes of climatic and non-climatic site-specific factors (Forsyth & Evans, 2013; Hjerpe & Glaas, 2012). For instance, the synthesis of research on barriers of adaptation conducted on sub-Saharan African countries is typified by persistent poverty and socio-economic inequality, low levels of development, high dependence on climate-sensitive livelihood sectors, limited economic capacity, and numerous governance and institutional challenges on top of the impacts of climate change, resulting in low adaptive capacity and significant adaptation deficit (Gemechu & Muluneh, 2021; Shackleton, Ziervogel, Sallu, Gill, & Tschakert, 2015); most importantly forced the community to mal-adaptation strategies (Mcdowell & Hess, 2012).

Although agroecology has conceptualized in line with production functions in most of the studies conducted in Ethiopia, in this study we argued that the conceptualization should be beyond the ecological function mainly when applied for the local livelihood assessments. Particularly, the adaptation and coping strategies of small-scale farmers in the Anger watershed couldn't be understood by labeling agroecology zones as the production ecology only, fixing constraining factors to climate and biophysical features as far as the environment and livelihood situations of the community are concerned (Gemechu & Muluneh, 2020), but considering the site-specific non-climate national/ global change processes has paramount importance. Specifically, climate variability and structural land-use dynamics were identified and defined as global change processes external to the community and the ecosystems through observations of the contexts in the study area and critical review of previous studies(Gemechu & Muluneh, 2020, 2021; Jeffers, 2013; McKune & Silva, 2013).

For clarity, the identified processes of climate variability and structural land-use dynamics have global faces and impudent in the study area with distinguished spatiotemporal settings due to differences in climate state and variability situations across agro-climate in one hand and the historical socio-economic and political spurs of agroecology resulted mainly from national/ and global interventions on the other hand. To this end, such contextualization is crucial to understand the conditions of farmers' adaptation strategies, specifically, the status, trends, causal linkage of the constraints to adaptation strategies along with the processes' contexts in the study area (Gemechu & Muluneh, 2020).

Moreover, the recent recommendations are toward a much emphasis on the assessment of agroecological aspects of non-climate processes, and systematically incorporating the impacts of these processes with the climate variability to understand local situations of adaptation strategies (Graham, Barnett, Mortreux, Hurlimann, & Fincher, 2018; Waters, Barnett, & Puleston, 2014). Therefore, an in-depth investigation of the agroecological aspects of each change process separately and their combined impacts on the adaptation strategies of the local community was the central purpose of this study. These issues become among the insightful concerns of today's human dimension of global environmental change research (Barnett, 2020). However, these non-climatic contexts are seldom considered explicitly in identifying the spatio-temporal difference in their impacts on the adaptation strategies. Particularly, why adaptation strategies experienced by the community are sustainably effective in some specific local areas, but not in other places, what factors are significantly constraining the strategies, and how these constraints are associated with local specific environmental change processes.

The researches on the adaptation and coping strategies of the local community to climate change in Ethiopia were conducted at a large spatial scale, and a significant attention wasn't given to the unique characteristics of the local area in the assessments of the strategies (Conway & Schipper, 2011; Gashaw, Berhe, & Nigussie, 2014; Karanja, Wijk, Rufino, & Giller, 2016; Temesgen, Hassan, Ringler, Alemu, & Yesuf, 2009). Most of these researches used natural division such as agroecology for the comparative analysis (Arragaw & Woldeamlak, 2017; Gutu, Emana, & Ketema, 2012; Woldeamlak, 2012); and climate change was the only stressor considered in these studies. However, there are substantive roles of spatially different biophysical, socio-economic, and historical distinctiveness shaping the local adaptation strategies through the effects on the local community's resource endowments, entitlements, and adaptation capabilities. Thus, research on this issue, as settled on these specified gaps is crucial in the Anger watershed. These are toward identifying adaptation and coping strategies of small-scale farmers' households at the local level, examining the difference in the household's adoptions along with the case studies, and understanding the causal linkage of adaptation constraints with site-specific stressors. These have paramount importance provide new insight in adaptation research and development policy recommendations. These could be achieved through understanding the complex interactions of the processes, and the synergetic impacts of these local-specific environmental changes on the adaptation responses of the households along with agroecological segments of the community.

To this end, the lack of access to land resources due to structural land-use dynamics and climate variability were the stressors observed for their effects on the small-scale household's adaptation in the study area(Gemechu & Muluneh, 2020). The community has been responding to these environmental, socio-economic and political hurdles they are facing by their efforts through the local adaptation and coping strategies. These external disturbances have spatiotemporal differences in the study area. Consequently, where the magnitude of the impacts are acute the local community’s adaptation responses to the stressors, and the sustainability of their inherent strategies are adversely affected. Therefore, the status and trends of the local adaptation strategies are the reflections of these local specific environmental change processes, mainly for their current practicality, effectiveness, and sustainability.

In this study, the structural land-use dynamics is the changes in ownership of land and its property as a result of resource use governance (land tenure system), the changes in access to the resources among the local community, the state, and large-scale agricultural investors driven by national land-use policy changes (Dessalegn, 2011), and globalization- mainly with the recent increase in the global foods and energy demands(Davide, 2017; Keeley, Seide, Eid, & Kidewa, 2014) unlike commonly observed drivers of the land use and land cover change in Ethiopia. These change processes have unique characteristics defined by the economic systems and land policies of the time for their environmental and livelihood impacts and end with system and policy changes(Gemechu & Muluneh, 2020). Thus, the issues of the local adaptation have been conceptualized in this study with the strong assumption that these processes have differential implications on farmers’ adaptation situations along with the spatio-temporal patterns of these processes.

The general objective of this study was to appraise the local adaptation and coping strategies of the households by considering the agroecological contexts in the Anger watershed. The specific objectives of this study were as follows: (1) to assess the status and trends of household's adoption of the local adaptation and coping strategies. (2) to examine the spatial variations in the household's adoption of the identified strategies in the case studies. (3) to explore context-specific causalities of adaptation constraints. The working hypotheses were: 1) there is no difference in household's adoption on the linear combination of adaptation and coping strategies based on their difference in case locations, 2) the *kolla* and highland farmers do not significantly differ in their adoption of the adaptation strategies, 3) the *kolla* and highland farmers do not significantly differ in their adoption of the coping strategies.

Conceptual frameworks

Ontologically, human endeavours to adapt/cope with the impacts of global environmental changes for survival is a permanent reality has existed since antiquity. The concept of adaptation was in the debates about resource scarcity in the early development researches (Forsyth & Evans, 2013). But recent studies on livelihood adaptation strategies have increasingly been used in different contexts. For instance, the adaptation to the anthropogenic climate change (Ruppel et al., 2014), global economic changes (Leichenko, O'Brien, & Soleck, 2010), socio-political systems disruption by exposure to a civil war (Cutter, Emrich, Webb, & Morath, 2009; Shackleton et al., 2015) and many other context-specific studies have been taking place with different objectives and frameworks. These extensive uses have contributed to capturing different contexts in this study through integrating these conceptual frameworks. The issues and problems in this study were context-specific, which consist of various global environmental change issues such as climate variability and global economic changes. Thus, these conceptual frameworks are integrated into this study to understand how the processes at the local agroecology have been affecting household's adaptation strategies in the study area. The local adaptation impacts of global change process such as climate change, globalization, regional and local 'developments' (Leichenko et al., 2010) and how the processes exhibited in adaptation response of local farmers (Below, Artner, Siebert, & Seiber, 2010; Jeffers, 2013; Osbahr, Twyman, Neil Adger, & Thomas, 2008). These integrations were enabled us to identify how the local adaptation strategies are affected by the access to resources, entitlements, livelihood capabilities and power principles (Osbahr et al., 2008) among poor small scale farmers in the phase of changing climate. These were done through identifying trends in adaptation strategies, status on who adopt which strategy, and why; most importantly to imply constraints to adaptations, and livelihood pathways along with case studies. These have been rarely done while omission of these local contexts leads to critical weaknesses in understanding causal-linkages of adoptions constraints (Hjerpe & Glaas, 2012).

Adaptation is an adjustment to behaviour or economic structures that reduce the vulnerability of society in the face of scarcity or threatening environmental change(Osbahr et al., 2008). This definition is comprehensive which included response/and adjustment to any type of stressors typically observed in a specific area. The local-specific non-climate stressors have been superimposed upon the impacts of climate change to shape the adaptation strategies and adaptive response of farmers in Ethiopia (Woldeamlak, 2012). Therefore, the local adaptation situations and the status of strategies have complex spatiotemporal dimensions due to the difference in the area extent and impact magnitudes of these non-climate stressor/s on top of the impacts of climate variability which varies across agroclimatic.

The study was framed in the concepts of livelihood resilience to double exposure (Leichenko et al., 2010), integrated with agroecological approach (Yuichiro, 2011) to fit the central argument of the study. The double exposure framework captures the rapid, on-going and local context climatic and non-climatic processes, and the impacts in complicating households' adaptation. The agroecology approach in this case is socioecological constructions, the simultaneous applications of both production and political ecology. Thus, adaptation situations across the agroecology in the study area were not resulted by the biophysical dynamics and the associated resources and production functions of the ecology, but the power relations as well. There is a close relationship between agroecology and biophysical dynamics such as climate change on one hand, and the national/and global economic and political dynamics in the watershed. Therefore, the simultaneous impacts of these dynamics play a crucial role in the adaptation strategies and options of the local community (Gliessman, 2020). Particularly, the adaptation and coping strategies among the small-scale farmers in the Anger watershed couldn't be understood by labeling agroecology zones as production ecology, fixing constraining factors to climate and biophysical factors as far as the environmental and livelihood systems in the community are concerned (Gemechu & Muluneh, 2020).

Thus, we proposed the concept of agroecology of adaptation strategies for this study, hypothesizing the conditions for its applicability beyond the conception commonly applied in the previous studies. Explicitly, the agroecological-based difference in the biophysical/and climate processes and internal socioeconomic and demographic vitalities of a community have been used as central issues for the assessments of sustainability and constraints to local adaptation strategies. Acknowledging these, we claim that non-climate global environmental changes are a reality in the study area, the process has agroecological aspects, and the recommendations for considering such processes are crucial for the study. Specifically, through observations of the contexts in the study area and critical review of previous studies, the climate variability and structural land-use dynamics have been identified and defined as the global environmental changes, and these processes are external to the community and physical environment in the study area (Gemechu & Muluneh, 2020; Jeffers, 2013; McKune & Silva, 2013).

This adopted conceptual framework was followed by the case studies-based analysis of the adaptation situations. In the context of the watershed, the global environmental change processes vary from place to place. These spatial variations in these processes resulted in the impact difference on adaptation situations and in constraining the strategies. To this end, in line with the studies conducted by these approaches (Antwi-Agyei et al., 2018; Barrett & Constas, 2014; Prno et al., 2011; Shameem, Momtaz, & Rauscher, 2014), we have decided on a case-by-case analysis. The case studies were designed based on these contexts.

The studies on the local adaptation strategies are approached differently, which are broadly associated with the disciplinary orientations, system to be studied, the level of analyses, and the objectives of the study. Taking these into consideration, the development approaches to adaptation studies (Dong et al., 2011; Ford, Berrang-ford, Lesnikowski, Barrera, & Heymann, 2013) were used in this study. This approach provides to assess adaptation strategies at the household level, consider non-monitory measures, and integrate non-climate threats in the analysis. The small-scale farmers' adaptation at the local scale with the objective of assessing the difference in the status of adaptation strategies and the causal linkages of adaptation constraints were the central issues in this paper to be addressed by this approach. Moreover, both deductive and inductive approaches were used to identify the variables and collect data for this study. The researches on farmers' adaptation in Ethiopia were reviewed and integrated with the discussions with the experts and the local community during preliminary fieldwork were used in this study. Thus, the exhaustive lists of the strategies were summarized into eleven adaptations and seven coping strategies practiced in the study area. These strategies were separately used as adaptation and coping in this study due to the fact that the adoptions of the strategies were different among the households and along with the case studies which were explicated during preliminary fieldwork on top of previous empirical justifications. Accordingly, based on the duration of the stressors, copings are the strategy to the short-term shocks, and adaptation is for the long-term impacts (Antwi-Agyei et al., 2018; Arragaw & Woldeamlak, 2017) of climate variability and non-climate factors. Finally, we hypothesized that the situations of the local adaptation in the watershed is resulted by the synergetic impacts of these processes, that the differences along the agroecology on the sustainability of the strategies and their constraints were due to the spatial variations in the distributions of these stressors, and the associated differential effects at the local level (6).

Research methods and materials

Case studies

Anger watershed lies in east Wallagga administrative zone extended from 09º12' to 10º00' north and 36º30' to 37º11' east was the focus of the study, while the watershed covers other administrative zones of Oromia regional state and regional state of Benishangul Gumuz. The selected single administrative zone was to reduce heterogeneity in socio-economic, cultural, and livelihood systems and differences resulted from regional and local governance on the issues of this study. The watershed is composed of highlands(3.4%), midlands(39.6%), and lowlands (56.1%) with altitude ranges from 1200 to 3018 meters above sea level (Gemechu & Muluneh, 2020). The variations in relief and topographic arrangements resulted in differences in climate and distribution of natural resources such as soil types, drainage patterns and water resources, and forest ecology. The socio-economic conditions of the watershed, such as population distribution, land use pattern and potentials, and economic activities were shaped by these biophysical on tops of historical and political factors.

Two case units were identified in line with previous vulnerability study in the watershed (Gemechu & Muluneh, 2020) for the comparative analysis of persistent adaptation and coping strategies along with the case units, how the strategies are shaped by the local specific factors, and to associate the adaptation constraints with the underlying situations. Each case unit has its biophysical, socio-economic, and historical characteristics. These differences are believed to shape the small-scale households' adaptation and coping strategies. Accordingly, the households in the *kolla* were the first case unit characterized by tropical/*kolla* agroecological conditions and experienced structural land-use dynamics. The second case unit lies within sub-tropical/*woinadega* and temperate/*dega* agroecology and both are out of the influence of historical structural land-use dynamics.

The small-scale farmers in these case studies have a significant difference in their socio-economic contexts such as land size for agriculture, access to grazing land, water sources, and other land resources. These resources provide the livelihood assets for the local community, but the tenure conditions on the local resources and the extent to which the community depends on these ecological resources vary along with the cases. Moreover, the climate and biophysical situations have the difference. These differences have resulted from the agroecological positions in one way or the others. Thus, understanding the spatio-temporal dynamics of the local adaptation and coping strategies is crucial to identify who adopts which mechanism, the significance of adoption difference, and the causal linkage of the adaptation constraints. Therefore, the data collected from various sources through different techniques were analysed to examine the difference in adoptions along with case studies and to construct the causality; i.e., the extent to which these global environmental change interventions caused the results particularly, the perceived adaptation constraints and the local response to these stressors.

Approach and design

This study consists of an array of issues which ranges from examining the local adaptation and coping strategies along with case-studies by using the statistical models to constructing the causalities for the adaptation constraints through in-depth exploration of the local concerns. In line with these, the mixed research method approach was used (Gray, 2017). Specifically, the narrative inquiry was integrated with and embedded in the model-based examinations to understand the complex social-ecological system, particularly the interactive, systemic, and constantly emergent nature of the local community's adaptation situations. This approach was applied to collect a list of facts, a progression of events connected to ways the study participants learn, explain, and organize their experience on the issues (Nyumba, 2018) to capture the processes. Thus, the narratives on the local situations of the environmental change processes were interpreted critically and integrated with the local community's historical accounts on the adaptation and coping strategies.

The case study research design was used in this study. First, the case unit was defined as the area of the Anger watershed characterized by uniform conditions regarding the adaptation situation in the contexts of this study. Moreover, the case study design in this study was the comprehensive research strategy for intensive analysis of an individual case unit having a unique feature rather than methodological choice (Hollweck & Yin, 2015). Therefore, a case unit may be studied in different strategies. For instance, qualitatively or quantitatively, or mixed methods. The methodological choice is not decisive for whether it is a case study or not, rather the demarcation of the unit's boundaries according to sets of unique and uniform features was used to design the case study in this study. Therefore, the investigation and presentation were done through both descriptively and exploratory depending on the nature of the specific objectives. For instance, the status of adaptation and coping strategies and comparisons on the adoptions of the strategies along with case-studies were analysed by descriptive and inferential statistics respectively. The analysis on the causal linkage of adaptation constraints was guided by exploratory design. The issue on the why and how adaptation and coping strategies of the local community have been shaped by case-specific situations was discovered through an in-depth examination of the community's perception.

Research methods

The small-scale farmers' household heads, and the focus group discussants drawn from local notoriety individuals and the elderly in the Anger watershed, and experts from relevant zonal and districts offices in the east Wallagga administrative zone were the primary sources of data. The published and unpublished documents were used as secondary sources in this study. Both quantitative and qualitative data were collected through questionnaires, focused group discussions (FGD), discussion with experts, and observations.

The multistage sampling technique was used in this study. The areas found within the Anger watershed in the east Wallagga administrative zone were the focus of the study. First, small-scale farmers' household heads were purposively selected as the unit of analysis. Second, the divisions within the region were made on the basis of the agroecology and situation of structural land used dynamics. The study area entertains of three agroecology: the *kolla* agroecology within the area affected by the impacts of structural land use was identified for the first case unit. This area was characterized by the warm lowland climate having an altitude less than 1500m a.m.s.l situated in the central part of the watershed The second case unit consists of the midland (*woinadega*) and the cool temperate (*dega*) agroecology in the midland and mountainous areas of the watershed. Then, districts and kebeles that represent both cases were randomly selected, from which 335 sampled households were identified using the following formula (Kothari, 2004). In deciding sample size, all necessary criteria (Pandey, P. and Pandey, 2015) were considered. The sample size for each kebele was determined based on the proportionality of the size in the household's population. Finally, the simple random sampling technique was used to select household heads for the questionnaire survey.

$$n = \frac{z^2.p.q.N}{e^2(N-1)+z^2.p.q}$$

Moreover, the participants on FGD were purposively selected. Four FGD group having members of eight individuals for each group were arranged (i.e., one group for each kebele).

Data analysis was performed using by the STATA for the descriptive and inferential analysis. The descriptive method was used to assess the status of adaptations and coping strategies practiced by the households. The multivariate analysis of variance (MANOVA) was applied to test the hypotheses of the study.

Model specification for one way-MANOVA

The data comprised categorical independent variables (*kolla* and highland), two classes of dependent variables (adaptation and coping strategies) and individual dependent variable (11 under adaptation and 7 under coping class). The statistical model for a case design was:

$$Yij = \mu + \beta j + \varepsilon ij \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where; Yij is i^{th} observation in the j group; μ is the mean for all observations**;** βj is the treatment effects in j^{th} group; and εij is the error term.

The distinctive role of the model is to combines these multiple dependent measures into a single value that maximizes the differences across the groups. It provides additional insights into the implications of independent variables (being in the *kolla* or highland) on dependent variables (adoptions of the strategies) (Mbang, Owino, Kones, Meffeja, & Dibog, 2007).

MANOVA has several statistical assumptions by which three main assumptions are cautioned in several researches (Kanyama, 2011). First, the normality, which referring to the shape of the data distribution and its correspondence to the normal distribution should meet. Second, the covariance matrices for the treatments must be equal. Third, the observations must be independent. The household's survey was individually administered and observed independently. Moreover, for the significance tests, Wilks' Lambda is recommended for general use, but the Pillai's Trace was used due to unequal households size in the *kebeles* for the case studies(Pallant, 2010) to test the null hypothesis.

$$H_o = \begin{pmatrix} \mu 11 \\ \mu 21 \end{pmatrix} = \begin{pmatrix} \mu 12 \\ \mu 22 \end{pmatrix} = \ldots\ldots = \begin{pmatrix} \mu 1g \\ \mu 2g \end{pmatrix} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where; μ_{ig} (i = 1 and 2) is the population mean for the strategies in the *kolla* and highland respectively for both *g;* adaptation and coping group. To test the differences between the groups i; mean vectors of the *g* (11 for adaptation and 7 for coping); the significance test is specified as:

$$\Lambda = \frac{|S_{error}|}{|S_{effect} + S_{error}|} \quad \ldots\ldots (3)$$

The significant test statistic for MANOVA works closely with the F-test (Mbang et al., 2007). An estimate of *F* was calculated through the following equation:

$$F_{\text{approximate}} = \left(\frac{1-\sqrt{\Lambda}}{\sqrt{\Lambda}}\right)\left(\frac{n-g-1}{g-1}\right) \quad \ldots\ldots (4)$$

Where; n = sample size; and *g* is group of strategies.

Moreover, the data collected through the focus group discussions (FGD) and field notes were qualitatively analysed to explore the similarities and differences in the situations of adaptation and coping strategies across the case studies. This technique was applied to identify how and why a certain strategy has been sustainably practiced in a given area and not in other places. These were mainly to pinpoints the causal linkages of adaptation constraints. During the FGDs, the participants were facilitated to storytelling and to discuss their experiences in adaptations.

Ethical consideration

The ethical issues related to research subjects which broadly manifests in advocacy, anonymity, confidentiality, voluntary and informed consent have due consideration in this study. The research protocol was reviewed and approved by Wollega University Research Ethics Approval Committee of College of Social Sciences, Gimbi (Reference Number: WUGC 0015/D-18/12/2019). The letter issued by the committee was used to request permissions from concerned bodies in the study area before the commencements of data collection. Thus, the zone and districts administrations in the study area have approved to get access to the study site and participants. The focus of informed consent was realized during data collections through discussions with the participants on the purpose of the research, duties, and responsibilities of and participants. The letter was submitted to the participants and verbal consent was requested by reading the letter for those respondents cannot read the letter. All the participants were above 18 years that the written consent was directly obtained from them in the form of a signature and a thumbprint. Confidentiality and privacy of the respondents have been realized that the survey data and field notes were kept confidential.

Results

Status of adaptation and coping strategies

Both descriptive and multivariate analyses of variance were applied to compare adaptation and coping strategies along with case studies. The descriptive analysis (Table 5.1) was to identify the status of the identified types of adaptation and coping strategies practiced by the households across case studies.

Table 5.1. Extents of farmers' adoptions of adaptation and coping strategies across case studies

S. N	Adaptation mechanisms	*Kolla* (%)	High land (%)	Coping mechanisms	*Kolla* (%)	High land (%)
1	Change in planting date	2.2	79.6	Change in consumption	7.9	10.2
2	Crop diversification	41.0	77.6	Receiving support (PSNP)	8.6	14.8
3	Using improved seed	28.8	77.0	Accessing credit	51.8	65.8
4	Engaging on non-farm activities	80.6	21.4	Selling livestock	20.9	7.1
5	Reducing stocking density	61.2	60.2	Renting out land	5.8	20.0
6	Improving livestock farm	26.6	19.9	Seasonal migration	46.8	15.3
7	Employing small scale irrigation	25.9	75.0	Remittance	32.4	24.0
8	Practicing tree planting	61.9	54.1			
9	Practicing SWC	13.7	74.5			
10	Applying soil fertility management	38.8	81.1			
11	Using drought-tolerant crops	12.2	11.2			

Source: Household survey, 2020

All identified adaptation and coping strategies have been practiced by the local households in the watershed, while the extents of adoptions for each differ within and along with the case studies (Table 5.1). Except for reducing the stocking density that shows an equivalent adoption along with the case studies, all adaptation strategies show remarkable differences. The applications of soil fertility management, changes in planting date, crop diversification, uses of improved seed, small scale irrigations, practices of SWC were the most applied strategies in the highland. The engagements on non-farm activities and reducing stocking density, practicing tree planting were the most practiced adaptation strategies in the kolla. These results indicated that small-scale farmers in the highland have more engaged in adaptation strategies than farmers in the kolla, where non-farm activities were the most practiced strategy.

On the other hand, although the level of adoption was much lesser than adaptation strategies, several coping strategies have been practiced in the watershed. Accessing credit was the most practice strategy in both case studies but slightly more adopted in the highland. Among coping strategies, seasonal migration, remittance, and selling livestock have been more practical by the households in the kolla, while the extents of coping strategies through remittances and renting outlands were also remarkable in the highland. Contrary to the highland, where adaptation strategies were substantial, the results revealed that the small-scale farmers in the kolla were relatively higher in adopting most of the coping strategies (Table 5.1).

Comparative analysis of local adaptation and coping strategies

The MANOVA output presented below (Table 5.2) describe the difference among strategies on the dependent variate (i.e., whether or not they vary along with the cases, and the difference could produce a significant multivariate effect on the adoptions). In addition, it assumes a cause-effect relationship whereby the groups (independent variables) and controlled variables (adaptation and coping classes) cause a significant difference in the adoption of an individual strategy.

The statistical assumptions MANOVA such as missing values, outliers, linearity, normality, and homogeneity of the variance matrices were checked during data screening and presentations. Multivariate outliers were checked by computing a Mahalanobis distance measure for each strategy that no outlier observed in the model. The normality tests (the value of Mahalanobis distance) were higher than the critical value from the chi-square table, indicating that the violations of normality were not present in the dependent variables (Table 5.2[a]). Bartlett's test of sphericity was statistically significant for both adaptation and coping class (Table 5.2[b]), which indicates the sufficient correlation between the dependent variables.

Table 5.2. MANOVA output for the analysis of household's adoptions of the adaptation and coping strategies along with case studies in the Anger watershed

Adaptation mechanisms	**F-value**	**Tests of Between-Subjects Effects**		**Coping mechanisms**	**F-value**	**Tests of Between-Subjects Effects**	
		Partial Eta Squared	Sign.			Partial Eta Squared	Sign.
Change in planting date	593.79	0.914	0.000	Change in consumption	2.750	0.01	0.106
Crop diversification	137.73	0.864	0.000	Receiving support	5.278	0.02	0.020
Using improved seed	162.15	0.886	0.000	Accessing credit	7.616	0.02	0.01
Non-farm activities	248.52	0.854	0.000	Selling livestock	2.427	0.01	0.125
Reduce stocking density	.212	0.848	0.652	Renting out land	.012	0.00	0.912
Improving livestock farm	4.349	0.839	0.045	Seasonal migration	68.40	0.17	0.00
Small scale irrigation	135.06	0.852	0.000	Remittance	1.606	0.00	0.261
Practicing tree planting	.184	0.888	0.672				
Practicing SWC	228.05	0.857	0.012				
Soil fertility management	125.58	0.867	0.014				
Drought-tolerant crops	.108	0.762	0.745				
[a] Residuals Statistics: Mahal. Distance Max = 33.260				Residuals Statistics: Mahal. Distance Max = 29.48			
[b] Test of Equality of covariance Matrices:	Box's M	266.2010		Test of Equality of Covariance Matrices:	Box's M	151.826	
	F	3.8890			F	5.297	
	df1	66			df1	28.000	
	df2	283096.6310			df2	308188.333	
	Sig.	0.00			Sig.	0.00	
[c] Multivariate Tests: Pillai's Trace (F= 136.180, P=0.00; Partial Eta Squared= 0.82)				Multivariate Tests: Pillai's Trace (F= 13.252, P=0.00; Partial Eta Squared= 0.22)			
[d] Estimated Marginal Means: highland>*kolla* except for reducing stocking density				Estimated Marginal Means: highland>*kolla* for change in consumptions and renting outland			

Source: Household survey, 2020

The multivariate tests of significance indicated that there are statistically significant differences between the case studies on the adoption of both adaptation and coping strategies. The Pillai's Trace was used due to the unequal sample size for the case studies. The F-tests for Wilks' Lambda, Hotelling's Trace, and Pillai's Trace are identical in our multivariate test output. The multivariate main effect of adaptation strategies evaluated at hypothesis (between kolla and highland) show statistically significant (p=0.00) differences between the case studies on the adoption of adaptation strategies. Moreover, the partial eta-squared value shows the main effect accounts for about 82.3% of the total variance between the case studies. Similarly, the multivariate main effect of coping strategies adoption produced a statistically significant effect (p=0.00), indicating the difference between the case studies on the strategies. The partial eta-squared value shows the main effect accounts for only about 22.1% of the total variance between the case studies (Table 5.2[c]).

The statistically significant multivariate effect informs us that both adaptation and coping strategies are associated with differences between small-scale farmers on the level of adoptions along with case studies. This calls us, in turn, to presume that adoption difference exists and the next question is to discover which specific strategies are significantly different along with the case studies. Thus, the tests of between-subject effects (Table 5.2) output were used to answer this question. In this case, we have looked at a number of separate analyses of the variables, that a higher alpha level is expected to reduce the chance of a Type 1 error (i.e., finding a significant result when there isn't the real one). To this end, first Levene's test of equality of error variances was checked (the variable with $p< 0.05$ violated the assumption of the equality of variance for that variable). Accordingly, two variables of adaptation and four variables of coping violate the assumption. Thus, Bonferroni adjustment was done which involves dividing the original alpha level of 0.05 by the number of analyses (i.e., 0.05/2= 0.025) (Pallant, 2010). Thus, the variables with $p<0.025$ were considered.

Household's adoption of adaptation was significantly different along with case studies in all strategies except reducing stocking density, improving livestock farms, practicing tree planting, using drought-tolerant crops. These differences across the cases were significant again in three coping strategies, namely: receiving supports, accessing credit, and seasonal migration (Table 5.2).

The effect of being either in the *kolla* or highlands on the household's adoption of these adaptation and coping strategies can be evaluated using the effect size statistic provided in the Partial Eta Squared. It represents the proportion of the variance in the dependent variables (adaptation and coping classes) that explained by the independent variable (case studies: *kolla* and highland). These four significantly different adaptation strategies have Partial Eta Squared values that range from 0.763 to 0.841. These values, for instance, 0.841 represent that about 84.1% of the variance in reducing stocking density as an adaptation strategy explained by being in the *kolla* or highland among small-scale farmers, which, according to generally accepted criteria (Mbang et al., 2007), was the very high effect. In the same way, significantly different coping strategies along case studies have Partial Eta Squared values ranges from 0.02 to 0.69, imply very low to medium effects on the variance in adoption along with case-studies (Table 5.2).

The MANOVA based estimated marginal means showed that all significantly different adaptation strategies except for reducing stocking density, the highland has the higher mean scores than the *kolla*. However, reducing stocking density in livestock has been used in the *kolla* than highlands. Estimated marginal means for significantly variate coping strategies show the higher mean score for renting outland in the highland; while the mean scores for change in consumptions, selling livestock, and remittance was higher in the *kolla* (Table 5.2[d]).

Constraints to adaptation: the causal linkages along with case studies

The results of the focused group discussions revealed that the local community's livelihoods depended heavily on exploiting available natural resources, expanding human settlements, and cultivating subsistence crops. The exploitations of these resources were free from central planning and interventions, but the profound imprints of nature on the local community. Thus, the adaptation and coping strategies were free, provided by the surrounding physical environments, and affected by the natural processes. The group discussants claim that the local community has had the experiences to change the cultivation methods, farming systems, and resource exploitations for their livelihood guided by the natural processes for the changes in the provisions of the local biophysical environments previously. However, socioeconomic situations and biophysical environment have been changing from time to time that most of these strategies become unpractical; and the local community has been enforced for a frequent change in most of their inherent adaptation and coping strategies. The discussants have attributed to different factors for the hurdles to the traditional strategies, rather than positive transformation. These factors varied among the FGD groups and across case studies.

Most of the adaptation and coping strategies experienced in the watershed in the past were associated with climate and environmental dynamics and the socioeconomic factors mainly resulted from demographic pressure. Thus, the exploiting natural forest for food and materials traveling long distance, seasonal migration in search of grass and water for cattle(‘*darabaa’* system) from highland to the *kolla* area, planting trees for economic and non-economic benefits, cultivations of early mature crops such as barley, beans, peas and cabbages which they called as ‘*dafoo*’ and ‘*birroo*’, mulching and fallowing to sustain soil fertility, and diversification of incomes through forest gathering and non-timber harvest such as honey productions were recognized in the local community for their previously practiced adaptation strategies. However, most of these strategies become less practical and have been replaced by the intensification of agriculture through improved varieties and artificial fertilizers, reducing stocking density, selling livestock, practicing irrigation to cultivate high-value crops such as fruits and vegetables for markets.

The group discussants explained that now a day, different coping strategies less known in the past have been adopting by the local community in the watershed mainly in the *kolla*. Some of these strategies include seasonal migration, selling labour for a wage, reducing consumption and changing dietary, and enhancing remittance through sending children/daughters abroad. These newly emerged strategies were explained as unpleasant systems, forced by situations, and perceived as livelihood and social risks among the FGD discussants mainly in the *kolla*. For example, the deteriorating agricultural extensification such as mulching, fallowing, slash and burn practices have been affecting the local community's stewardship for the land and the appreciation of land values. According to these discussants, livestock rearing was the crucial livelihood system in the *kolla*, and the current land-use and grazing situations that have been enforcing the local community to adopt the strategies such as the selling of livestock and reducing stocking would be resulted in perpetuating poverty in the area. Reducing food consumption and changing diets have destructive health problems and erodes the cultural values of the households.

Most of the newly adopted strategies which were negatively explained by the *kolla* discussants were similarly perceived in the highland, but the causalities were different along with the case studies. The highland discussants have remarkably associated the problems with the local biophysical and socioeconomic processes. Among recently adopted strategies, the agricultural intensification was focused during the discussions. Accordingly, this strategy became increasingly adopted by the local community because of two reasons: First, the need for the increased production from the land which became scarce. Second, to cover the household's food demand through these techniques because the livelihood options have been decreased mainly due to lack of access to the natural resources for the livelihood assets. However, this strategy, for instance, has resulted in reduced crop diversity, economically inefficient due to the need for external inputs, and less adaptable among the community in its dietary and food preparation culture. Moreover, the discussants claimed that the increasing climate variability conditions have been affecting the strategies used to adapt/and cope with the seasonal food insecurity. For example, the local agroecological feasibility for the productions of '*dafoo*' and '*birroo*' crops has been reduced because of the late-onset and early cessation of rain. The '*dafoo*' crops are named after their production characteristics within a short period by using the rain in the early rainy season known as '*belg*'. These crops are crucial for the food security of rural poor in the next season of heavy rainfall known as '*kiremt*' when food scarcity reaches its peak in most of the study area. Although the productions of '*birroo*' crops take place on the off-set of the rainfall, the time of plenty of food, the crops in this season are mostly pulses which have significant contributions to the food culture and provide the sources of income for the community. The transhumans (the '*darabaa*' system) have a significant adaptation role for the highland community, when the grassing become scarce in their locality and they migrate to the *kolla* areas for the grazing and water for their cattle, in the past. However, this is not practical today that the land-use changes in the *kolla* have hindered the economic and ecological benefits they obtained from this agroecology.

Although causes for the unpleasant strategies in the highland were attributed to the resource's shortage due to natural increase in human population and climate variability, the *kolla* discussant claimed that the new adaptation represents the impacts of historical interventions by the national/ and global change processes. The adverse of these processes on the community's access to land resources resulted in the distorted agroecological contexts of adaptation and coping strategies in the *kolla*. Accordingly, as far as the livelihood in the kolla that depend on the common-pool resources are concerned, the land deal processes and interventions for large-scale agricultural investments at the expenses of these resources have been hindered the sustainable planning and implementations of inherent local adaptation strategies. Thus, most of the emerging strategies are generated from socioeconomic and environmental complexities resulted from these structural land-use dynamics. They claim that most of the present-day adaptation challenges facing small-scale farmers in the *kolla* were the result of the development policies that unrecognized the local community's livelihood and adaptation contexts.

The conditions of the adaptive learning process among the local community were one of the important issues raised during focus group discussions. The highland discussants explained that the local community in their area has been learning from the changing situations, mainly climate characteristics, landholding size, and environmental carrying capacity. Accordingly, the present strategies adopted in the highland were perceived as the result of local dynamics and the local community have been handling according to the demands of these situations. However, the *kolla d*iscussant explained that all the changes taking place since the 1970s are 'catastrophic' that they did not understand the natural state of change, unlike the highlanders. The *kolla* discussants suspected their extant knowledge on how to handle the environments if the investors left the valley 'supposed new policy doing so happen' because the inherent characteristics of the agroecology such as natural endowment have been changed at an alarming rate, and the change courses are complex, rapid and unnatural, and the community has been rarely learning from the processes of these changes.

Discussions

All human societies are adaptive to changes (Adger, Barnett, Brown, Marshall, & O'Brien, 2013; Forsyth & Evans, 2013), that the small-scale farmers in the Anger watershed are not exceptional. The local community in this area has had a long history of interactions with natural environments(Dereje, 2018), with rich experiences of exploiting the natural environment for the resources and knowledge to sustain their adaptation strategies to the impacts of changing environments. However, the recent global environmental changes and associated complexities have been shaping the local adaptation and coping strategies. These processes have been constraining the inherent local adaptation strategies that these conditions have been increasing from time to time with remarkable spatial differences in affecting the local adaptation. Thus, the geography of adaptation strategies becomes varied within a region. This study was intended to assess the local situations of adaptation and coping strategies in the Anger watershed by considering the spatio-temporal aspects of these processes at the local level. These were important to identify the local level status and trends in the adoptions of these strategies, the spatial conditions of adaptation sustainability, and constraints causalities in the local area through comparative case study technique.

Agroecology-based research on adaptation strategies in Ethiopia came up with several conclusions regarding the differences in types of mechanisms applied by farmers (Asrat & Simane, 2018; Ferede, Ayenew, & Hanjra, 2013), the determinants of adoptions (Atinkut & Mebrat, 2016; Belay, Recha, Woldeamanuel, & Morton, 2017), and the adaptation constraints(Elizabeth et al., 2009). However, this study is different from the previous researches in its conceptual and methodology that potentially contribute to future research and policy recommendations on rural adaptation. First, we have considered the local contexts on the specific conditions non-climate change processes such as the cases differences on the extents of structural land use dynamics for their effects on the local adaptation strategies, and the biophysical situations of agroecology (Altieri, 2020; Gliessman, 2020). Second, even those previous researches that considered agroecology, conceptualized for its production functionality, evaluated the status of the adaptation strategies by associating with climate variability situations along with these spatial differences. The climate change situations were the only considered external disturbance resulted from agroecology differences in these studies (FAO, 2015). However, the reality in our study area revealed that agroecology referring to livelihood systems and adaptation strategies are more socioeconomic and political precinct than its ecological functionality. Thus, the adaptation status and trends, the sustainability of local adaptation strategies, and the constraints to adaptation strategies require a detailed understanding of local situations. Therefore, this broader conceptualization and comprehensive methodology applied in this study provide to capture the local contexts which were crucial to understand the sustainability conditions of the local adaptations and factors of adaptation constraints.

The observed differences in household adaptation situations along with the agroecology were different from the research results in the other parts of Ethiopia. Most of the previous studies revealed that the adaptation strategies in the *kolla* agroecology were relatively sustainable that the communities are more adaptive than their counter highlands (Belay et al., 2017; Ferede et al., 2013; Gezie, 2019) unlike the condition observed in the Anger watershed, where the local adaptation situations were more sustainable in the highland. Moreover, the types of adaptation strategies implemented were different from our cases. For example, reducing stocking density and seasonal livestock selling were identified as the strategies more adopted in the highland than *kolla* agroecology in the other parts of Ethiopia. These were inverse in our cases that the first strategy was equivalent, and the second was higher in the *kolla* of our study area.

The local community's access to the land resources has been cognized for the effects on the local adaptation strategies in the previous studies in Ethiopia. However, these studies were insufficient on the causalities that the local adaptation problems were mostly attributed to the biophysical dynamics resulted from climate variability and the socioeconomic situations internal to the community. However, this study signifies causal linkages between the effects of local processes of non-climatic environmental changes external to the local community and the sustainability situations of the local adaptation. This study revealed that the conceptual and methodological efforts for local adaptation studies should be toward understanding the local contexts of the livelihood disturbances and the effects of these local processes in constraining the adaptation. To these ends, the in-depth explorations of the local community's perceptions on the causalities, how they perceive the relationship between the strategies they have been adopting, and the local processes of environmental changes were crucial. In this regard, this study revealed that the site-specific non-climate factors are significant to shape the community's adoptions on the types of adaptation strategies, and for their effects on the persistence of maladaptation, and in constraining the adaptation strategies labelled for their efficiency at the local level.

The national/ and global economic interventions were agroecological in the Anger watershed, and the impacts of the processes overweighted the power of ecological functionality. For instance, albeit livestock rearing is the most sustainable livelihood system of the *kolla* agroecology in Ethiopia, the strategies became less practical in the *kolla*. This condition was real in the study area before these interventions, when the highland community uses the *kolla* for their seasonal transhumans. Thus, opposite to the agroecological feasibility of the *kolla*, the farmers have been adopting reducing stock density and seasonal livestock selling. These adaptation strategies have been practiced in response to the effects of denied access to land resources resulted from large-scale agricultural investments. However, similar to other parts of Ethiopia, livestock rearing became less practical in the highland parts of the watershed due to biophysical, socioeconomic, and demographic factors, distinguished as internal to the local community.

As a typical ecological simplification of the state in rural Ethiopia (Dessalegn, 2011), the interventions for 'development' in the *kolla* agroecology for the large-scale agricultural investments since the 1970s have been altered the local community's adaptation and coping strategies. to previously inaccessible and uninhabited areas served for free adaptation practices. These national/ and global economy induced 'development' policy (Mesfin, 2013; Rakotonarivo, Jacobsen, Poudyal, Rasoamanana, & Hockley, 2018) in general and the state aspirations for the large scale agricultural (Keeley et al., 2014) in particular, lends itself to be the key driver that complicates the rural adaptation strategies, as it is pointing up in the forced and maladaptation context of the farmers in the kolla case study; and these processes ultimately harm the national sustainable development. The disclosed current situation makes it hard for small-scale farmers in the kolla to reverse to the original state of adaptation strategies (O'Brien & Sygna, 2013), but forcibly adapt to 'development' induced stressors in the phase of changing climate.

The causal linkage on adaptation constraints along case studies could be associated with the community's adaptive learning process (Vink, Dewulf, & Termeer, 2013). The effects of stressors on the local livelihood systems have been affecting the adaptive learning of the *kolla* community compared to the highland mainly in two ways. First, these disturbances have interactive processes that resulted in the complexities of the impacts which have the power to hinder their adaptive learning(Adger et al., 2013) The effectiveness of the adaptive learning in the kolla was affected by the magnitudes and frequency of the stressors' interruptions, where the effects of structural change in land use and tenure insecurity were high due to frequent interventions (Kelman, Gaillard, Lewis, & Mercer, 2016). Although learning from historical experiences is crucial to deal with stressor/s, the more the stressors are complex and frequent the less effective adaptive learning. The small-scale farmers' interactions with climate variability and internal dynamics in the socioeconomic and biophysical environment in the highland involved as an adaptive learning process, drawn from experience knowledge through gradual and stable changes helped them to moderate changes in the biophysical environments and changes in society in a sustainable manner, while these became less efficient in the *kolla*.

The local livelihood adaptation strategies insightful to ecological knowledge in the *kolla* have at a loss because of the transformations of the rural landscape, driven once by the socialists and at another time by the capitalist development policies. These processes result in the critical trade-offs in the study area that the land resources belong to the local community versus large scale agriculture is decisive to achieve national food security and enhance agricultural exports. The empirical evidence from different parts of Ethiopia (Davide, 2017; Dessalegn, 2011; Mesfin, 2013) and experiences from this study area revealed that all the time the development endeavours oriented by the large-scale agricultural investments were failed to meet the goals of these programs/projects and simultaneously has exposed substantial complexities to the local adaptation and coping strategies.

Conclusions

The local adaptation and coping strategies of small-scale farmers in the Anger watershed were assessed through comparative case studies. The variances in the households' adoptions have resulted from their agroecology positions. The highest variations were explained by adaptation strategies in which highland was higher in these strategies than the *kolla* community, while the difference in agroecology has the lowest effects for most of the coping strategies, even though the adoptions for these strategies was higher in the *kolla* in this regard. Although adaptation persisted in all history of the community, free adaptation and coping strategies profoundly depend on the natural environments in the past have become unpractical now a day in the study area. However, the constraints of adaptation in the watershed shows remarkable differences along with case studies for their causalities and magnitudes.

The impacts of climate variability and socioeconomic factors intentioned as internal to the local community were remarkable causes constraining the local adaptation in the highland, while the present-day adaptation and coping strategies in the *kolla* are forced by the historical state interventions of the local land resources for the expansions of large-scale development projects. These processes disrupted the free adaptation practices and eventually stimulated the reframing of the local adaptation and coping strategies to the impacts of large-scale agriculture on top of, and even rather than climate variability. Although adaptation are unavoidable processes, the adaptive learning practices in the highland contribute to the continual changes from free adaptation strategies when resources were relatively abundant and climate was relatively less variable to several new adaptation strategies fit with existing resources and environmental situations. However, the small-scale farmers in the *kolla* forcefully negotiating with the strategies they believed as maladaptation. The study revealed that the rich experiences in the human–environment co-existence of local farmers insightful to ecological knowledge are aggravated by the transformation of the rural landscape to stimulated large-scale agricultural investments. Thus, broad-spectrum policy and practices which recognize the adverse impacts of site-specific constraints and their implication on the small-scale farmers' adaptation options are recommendable to stipulating the adaptation options of the community.

This study signifies the local agroecology in the Anger watershed for its more socioeconomic and political precincts than ecological functionality. The national/and global actors external to the local community have been influencing the local community's inherent adaptation strategies even shape the natural functions of ecologies than the climate variability. Thus, superficial scrutiny of the internal socioeconomic conditions of a community, their biophysical characteristics, and climate variability situations in studying the adaptation situation of a community is problematic and may lead to wrong policy recommendations. Therefore, critical analysis of the historical political-economic interventions such as national/and global economy induced structural land-use dynamics, and resultant local community's resource tenure insecurity has paramount importance in the local adaptation studies.

This study contributed to research and policy on rural adaptation strategies. Future studies interested in appraising local adaptation strategies along agroecology and any development planning in areas like the Anger watershed ought to consider the following issues: First, local contexts of livelihood systems, and impacts of external processes such as climate variability and non-climate national/and global interventions on the local adaptation. Second, the concept of 'agroecology of adaptation strategies' has paramount importance in considering the simultaneous impacts of locally bolded processes because the adaptation situations have resulted from the combined effects of these processes. Thirdly, a much stronger emphasis should be given to the non-production aspects of agroecology for the analysis of local environmental change, and impacts resulted from external interventions mainly non-climate stressors. Lastly, understanding adaptation situations helpful in providing locally representative recommendations requires comprehending these issues through wide-ranging research methods applied in this study. The prior observations of the local contexts in the watershed, application of the case-study approach to capture data on these issues from multiple sources, and in-depth investigations of the adaptation situations for each case unit, and comparative analysis along with the case studies in this study helped us to comprehend the local adaptation situations.

Acknowledgements

This work was supported by Addis Ababa University, Ethiopia. We thank the university for providing financial support for the first author to undertake this study. We also thank zonal, districts, and *kebeles* administrators for their cooperation during data collection. We would like to appreciate all of the participants in this study for their time and patience in responding to our interview questionnaire and discussions in focused groups.

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CHAPTER SIX

SUMMARY AND CONCLUSION

Introduction

The general objective of the dissertation was to assess the global environmental change processes of climate variability, and land-use dynamics at the local level, explore the livelihood implications of these changes in combination and individually on small-scale farmers in the Anger watershed of southwestern Ethiopia. Although considerable progress has been made in understanding global environmental changes specifically, on the climate variability and land use and land cover changes in Ethiopia, there are still several important research issues on the human dimensions of these changes. In this section, the lesson learned and the contributions of this study, high-priority future research agenda that might yield valuable information, the policy implications and recommendations were provided.

Summary of key findings

The structural land-use changes, and associated LULC dynamics and its implication on small-scale farmers' access to land resources were examined in this study. The increase in LULC for agricultural land and settlements and decrease in grass/ and bushlands, forest lands, and wetlands were observed in the watershed. The comparative analyses along with case-studies show incredible LULC dynamics in the *kolla* mainly with the introduction of state farm, and the recent private agricultural investment. The differential change processes and unique impacts observed in the *kolla* was due to state interventions for 'development'. Therefore, investment activities and land deal processes intentioned for development has been implemented in a contrast manner with the investment initiative of the country, mainly in its effects to deny the local community's access to the land resources. The problem was emanated from immature investment policy, and associated defects from stakeholders in managing and implementing development interventions.

The processes pave the way for unfair resource exploitations at the expense of the local community and the physical environment, and threaten future environmental carrying capacity. These situations showed the tendency toward class formation and struggle between investors and small-scale farmers. Therefore, development policies, institutions and stakeholders in this aspect should be tracked in a path realistic for win-win relationships. The livelihood system referring to *kolla* should catch due attention, that it is impossible to achieve rural development in this agroecology denying their access to land and common-pool resources.

Moreover, the state of climate at local level were examined in this study as another aspect of global environmental change processes. The trends and variability in rainfall and temperature show a substantive difference along agroecology. The observed rainfall coefficient of variations, concentrations, and anomalies showed significance of persisting rainfall variability conditions in the watershed with a considerable spatial difference. The temperature trends show an increase in both maximum and minimum temperature in the watershed with remarkable spatiotemporal differences, that the condition was severe in *woinadega* agroecology. The unpredictability of rainfall time, concentrations, and unexpected rain during harvesting were major challenges in the watershed. These have multifaceted livelihood impacts such as reducing *belg* crops, soil degradation, crop destructions on plot and during harvestings.

This study contributed to fill the knowledge gap on climate states in southwestern Ethiopia at a small geographic region. The methods used in this study help to integrate this climate information at local level with another global environmental change processes. Particularly, findings in this study were integrated with the analysis of land-use dynamics, and applied for the assessment of local community's vulnerability and adaptation to the simultaneous effects of land-use change and climate variability.

Thirdly, this study examined the extent of small-scale farmers' vulnerability at a household level, illustrate the spatial variations and differential vulnerability, and characterize factors of vulnerability along with case studies. The small-scale farmers in the Anger watershed are vulnerable to the effects of global environmental change of climate variability and structural land use dynamics, and the magnitude, causality and subsequent livelihood outcomes are varied among households due to disparities in the identified vulnerability factors. Although, the effects of climate variability were practical in all agro-ecologies, deprived of access to land and natural resources due to historical state interventions in the *kolla* was unequivocal stressor triggered vulnerability of households. The land use process, policies, and institutions which facilitated these unsustainable interventions are relatively continuous and structured in the *kolla* in a manner to rebut local community's access. Consequently, these conditions have been shaped the vulnerability through altering ecological, economic, and social systems of the local community.

This study revealed that from both environmental change processes, the effects of structural land use dynamics overweighted the climate variability. Hence, future research in these contexts and policy toward development planning should not consider these processes in isolation, rather their combined effects mainly in areas like *kolla* of Anger watershed. The approaches and methodologies applied in the study have the potential to comprehend the simultaneous impacts of site-specific global change processes particularly, the spatial aspects of causalities and differential vulnerability.

Lastly, the small-scale farmers' adaptation strategies in the watershed were examined, and the spatial comparisons were made to explore the sustainability situations of the strategies along with agro-ecologies which have shown variations in exposure to the effects of these global environmental changes. Most of adaptation strategies identified in this study have been significantly practiced in sustainable manner in the highland than *kolla* agroecology. Although free strategies which are profoundly depend on natural environments in the past become unpractical and have been replaced by newly introduced strategies in the study area, the causal linkage in constraints of adaptation in the watershed shows remarkable difference along with case studies. Climate variability and socio-economic dynamics intentioned as internal to the community were the constraints in the highland, while the present-day strategies are forced by the valley's socio-economic externalities and perceived as maladaptive in the *kolla*. The land deal processes in the valley disrupted the free adaptation practices, and eventually stimulated the reframing of local adaptation and coping strategies to the impacts of large-scale agriculture on top of, and even rather than climate variability in the *kolla*. Moreover, the processes hindered their adaptive learning, enforced to adopt the strategies they explained as forced mal-adaptive such as practicing non-farm activities, seasonal migration, dependency on remittances, change in consumption, and dietary. The community's experiences in the human–environment co-existence and their ecological knowledge are hindered by the transformation of the rural landscape to stimulated large-scale agricultural investments.

In general, this study revealed that global environmental change of climate variability and land-use dynamics shows remarkable differences in their processes and effects at local level in the study area. The persistence and effects of structural land-use dynamics overweighted the climate variability factors. Thus, the difference observed in the magnitude of vulnerability to the changes along case studies in the watershed was significantly contributed by the factors' effects of structural land-use dynamics. Similarly, the status and sustainability situations of adaptation strategies were the reflections of these stressors. Thus, broad-spectrum policy and practices which recognize the adverse impacts of such site-specific processes are recommendable to stipulate sustainable livelihood system of local community.

Conclusions

The contributions of structural land use analysis for the LULC change research

The analysis of structural land use dynamics, and local implications noted in this thesis signifies the knowledge on how forces within and beyond the individual actor such as national and international development interventions are combined to upshot the dynamics and the effects on the local community's decisions on land use/and tenure conditions, and their access to land resources. Thus, the study has revitalized the overwhelming research of land use change basically to understand human-environment relationships. The forces of the dynamics were highly attributed to individuals, households and communities, and less associated with the national/and global level interventions for the dynamics, and impacts in the previous researches. However, this research provided thoughtful on the process as the driver of land use dynamics, and the trajectories that will be essential for local community vulnerability in phase of climate variability. It enabled to realize the links between political-economic changes induced land use dynamics, and households' access to land resources, decision on livelihood options, and adaptation strategies.

Thus, the causal attribution of the links between global economy, and actual changes in land use/and tenure systems and livelihood impacts at local level requires a place-based account on the history of the processes, model LULC change in the contexts and explore the implications on the local community. The applied context specific analysis was useful to understand the processes, and the impacts specifically, how national and global political economy alter environmental systems, and human vulnerability to the change through restructured land resources' property rights, and livelihood assets. It provides a number of illustrations on the power relations between local community and global/ and national actors on resources decisions, the implications for rapid LULC changes, and on the livelihood welfare of local community and ecosystems.

Micro-scale climate variability analysis, and livelihood impact assessment

One of the challenges in global climate change research is to make available the scientific information, such as climate analysis relevant to decision making at the local level. Hence, the analysis of climate variability in this study contributed for two basic purposes in this regard: First, it revealed the effects of climate variability on land resources and other resource bases of local community mainly by scrutinizing the difference in impact magnitude along agroecology.

Second, it is used to integrate this climate information with non-climate environmental change to understand local livelihood pathways. Thus, this study provides new insights in the by applying climate studies at local level considering unique features of an area, and convoluted concepts, and methodologies in integrating the knowledge with site specific non-climatic factors. Specifically, we have practiced context specific analysis of the trends and variability in elements of climate, and applied the findings in the studies of local vulnerability and adaptation strategies through integrating the results with other non-climate analysis.

The need for integrating non-climate processes and impacts with climate variability in the rural household's livelihood assessments

The study revealed the extra-ordinary importance of understanding the ways in which non-climate external forces are combined with climate factors to upshot major alterations in land and environmentally important natural resource endowments, heighten vulnerability and constrain adaptation strategies of local community. Such understanding could be helpful to identify the real and pressing change processes, identify causal linkage between livelihoods outcomes and the stressor/s, anticipate future impacts of the change/s and identify potentially useful interventions.

The study has contributed for rural development research in developing the approach for case-based, comparative and procedural investigations which ranges from examining local case-specific global environmental change processes to pinpoint spatiality of the processes, identifying the livelihood implications of the processes, and analysis of differential impacts (vulnerability and adaptation constraints), and the subsequent local livelihood pathways. Thus, the recommendation is toward the social-ecological experimentation of the local processes of global environmental changes and impacts through inductive observations of issues/ and problems, conceptualizing and contextualizing the processes, examination of the change processes and impacts within designed case-studies, and make comparisons to pinpoint the spatiality of the processes, causalities and impacts.

The applied methodology proved the importance of integrating spatial and social data from multiple sources, and miscellaneous analysis techniques to capture the situations of the households and cases as unit of analysis. Moreover, the livelihood data for households' vulnerability and adaptation studies were collected with due concern for research questions about the global environmental change processes. Likewise, the data were managed in a manner to address the geographic links between the change processes and household's livelihood situations. Furthermore, the multiplicity of data sources, and linkage of remote sense-based land use data, gridded climate data, household survey and participations of various stakeholders played crucial role to understand the processes and impacts. However, for the future research, an advance observational platforms and methodological improvement is of high demand. The global spatial data that serve the change impacts research should be improved to the way multilevel models and datasets are applied to incorporate with micro-scale survey from community, household, and individual factors for the same analyses.

In general, the study calls for the integrative assessments approach for the livelihood studies of small-scale farmers in areas like Anger watershed of southwestern Ethiopia. The approach qualifies to understand the spatio-temporal dynamics of the processes at local level, their interactive impacts to alter the biophysical, socioeconomic, and institutional settings, and create feedbacks on the local community's livelihood assets and strategies, and reshape the contextual livelihood systems and determine the livelihood pathways.

Spatial concerns in the household's vulnerability, and the situations of adaptation and coping strategies

Although the evidence from different parts of the world indicates that all of the environmentally significant kinds of local livelihood systems are determined by multiple factors. This research shows that the interactions are typically specific to the agroclimatic dynamics, socioeconomic situations of a community (livelihood strategies and assets), the knowledge/and interest of responsible decision makers, and the micro-scale sociopolitical contexts. Therefore, the spatial difference between *kolla* and highland parts of the watershed in household's vulnerability and situations of adaptation strategies were the result of the interactive effects of structural land-use dynamics and climate variability.

Unlike *kolla* agroecology that experienced the same agroclimatic and socioeconomic conditions in Ethiopia, households found in the *kolla* agroecology in the Anger watershed have been exposed to *kolla* based recurrent 'development' interventions, which denied their access to land resources, heightened their vulnerability to the impacts of global environmental change processes and constrained their adaptation strategies. Therefore, livelihood conditions across agro-ecologies are sociopolitical constructions produced through decision making power on, and access to land resources than the inherent biophysical and socioeconomic dynamics internal to local community. It witnessed the close relationship between agroecology and national/and global economic and political dynamics, and, therefore, the dynamics play a crucial role in the agroecological based constructions of household's vulnerability and sustainability of adaptation and coping strategies. Therefore, this study has contributed to advance in the understanding the spatial patterns of the global environmental change at local level as driving forces for livelihood systems by illuminating the operations effects on household's vulnerability and adaptations in particular contexts.

Relatively, overweighted impacts of the structural land-use dynamics than climate variability for the household's vulnerability, and the situations of adaptation and coping strategies in the kolla agroecology

The key findings in this study on the effects of climate variability and structural land-use dynamics imply that: First, the high magnitude of vulnerability and the constraints to adaptation and coping strategies observed in the *kolla* contrasts the household's resilience observed in a different part of the same agroecology in Ethiopia. The agroclimatic and associated livelihood strategies and assets in the *kolla* agroecology of Ethiopia have been recognized for the provisions of resilient livelihood systems mainly for the sustainability of the local adaptation strategies to the impacts of climate variability. Contrary, the households in the *kolla* of Anger watershed were more vulnerable and their adaptation and coping strategies were more unsustainable than their counter-highland part. The situations of livelihood outcomes in the *kolla* of Anger watershed are the reflections of persistent structural land-use dynamics than climate variability.

Second, previous research defined the socio-economic of access to land resources as internal to a community in explaining the vulnerability factors. These could be acceptable for areas without external interventions for land resource uses, and where the resource shortages are attributable to the community's internal socio-economic and demographic dynamics. However, in the *kolla* of Anger watershed, these processes that were significantly external to the community have affected their access to land and natural resources directly and degraded their social adaptability indirectly. The effects of the structural land-use changes have dominated the climate and biophysical factors in determining vulnerability pathways and constraining the adaptation strategies of the local farmers. Therefore, the livelihood outcomes in the *kolla* have resulted from mismanagements of the development interventions; where local livelihood systems were preserved poorly, indigenous resource tenure were not respected, and the balance of power and decision making between the local community and other stakeholders were not realized. Thus, considerations of such non-climate stressors have paramount importance for future research and policy aimed to improve the ability to anticipate and respond to the impacts of such global environmental changes in the phase of changing climate.

Policy implications of the study

The policy decisions on the global environmental change at the national and regional level require good analyses of the processes and impacts of the changes. Thus, this study provides an analysis for the policymakers on these processes and their livelihood impacts on the smallholder households at the local level. In this section, the policy implications in line with the objectives of this study and the imminent policy-related research issues are indicated.

The institutions and stakeholders' consensus and decision making on the land resources use and tenure conditions

The study revealed uncommon understandings, interests, concerns, and values among stakeholders (small-scale farmers, government officials, experts, and investors) and institutions (customary and government) regarding the natural resources, livelihood assets, environmental change processes, and impacts. Although the difference and dispute of interests are unavoidable, lack of knowledge on the local livelihood systems, values, and development policy objectives and strategies were the major problems hampering the relationships among stakeholders. These referred to the need for policy, and programs endorse strong regulations, legal norms, and specific decisions, and create awareness on contested issues. These provide an advance to reproduce the digestion on the interrelationships between the local community and the emerging stakeholders. The problems of stakeholders' perceptions and the decision-making processes in the study area require continuous assessment of the conditions at the local level and participatory stakeholder discussions.

Policy and institutions as the source of the compromised win-win relationship between the local community and investment activities

The wrong perceptions of institutions and officials on the investment goals deferred the win-win relationship among stakeholders (mainly between small-scale farmers and investors). Although the policy goals are not toward polarization of the sectors, the perceived role and efficiency of the sectors, lack of good governance, weakening of local institutions mired the developments in the watershed. These institutional defects have hindered the impact evaluation and monitoring on large-scale agricultural investments, facilitated misbehaved character of capitalists, and reversed the investment objectives, on top of compromising livelihoods system and development contributions of the small-scale farmers.

Moreover, the development policies and institutions have a lack spatial information on the local livelihood systems, physical environment, and their interrelationships. However, the consideration of this spatial knowledge has crucial roles in the informed decision-making. The detailed accounts of the local realities on the interactions between the environment and local livelihood systems have paramount importance for policy decisions in planning any development interventions. The observed contestable judgments and value disagreements between stakeholders in the study area were some of the reflections that resulted from a lack of this knowledge. Likewise, the analyzed policy documents and observed institutional situations for this study implied the need for more integrations of research-based spatial knowledge with the policy decisions on planning and implementing development activities. For this reason, that policy decisions informed by the research of the local context provide to enhance the government institutions, experts, and other stakeholders to focus on the local livelihoods opportunities. This knowledge provides information on the local sustainability, reduce the narrow concern on the viability of the sector on the limited aspects of development, enhance the beneficial co-existence between the local community and large-scale sector.

These lack of spatial information in the policy decision-making and the implementations problems at the institutions are not limited to the policy-research interface, but the researches are inadequate for Ethiopia in this aspect. Future research on the rural developments needs spatial orientations applicable for policy recommendations, mainly the agroecology-based livelihood assessments should consider the agroecology of interventions resulted by different processes (climate and non-climate external disturbances) exerted from various scales (global, national, local), and their implications on the agroecologically produced local natural resources for the livelihood sustainability of local community.

Re (thinking) of the small-scale farmers' livelihood sustainability, and rural development approach paying focus on the kolla agroecology

Although the state interventions for the large-scale agricultural developments have a long history in the *kolla* agroecology of Ethiopia, there are spatial differences based on the potentials of the areas for agricultural development. However, the current extensive intentions of agriculture-based development provide the highest precedence for the kolla. For instance, the development plan and program documents such as the Agricultural Growth Program and the government officials' speech on the investment have focused on the kolla land size and potential in Ethiopia. These future development intentions focused on the kolla exploitations have implications for further expansions in the other parts of the country. Therefore, the investment policies, strategies, and implementations should be taken to the appropriate track. If these conditions continued as exist in the Anger watershed, the geographic extent and a number of the local community exposed to the impacts of such land deals and resource tenure situations will increase and the processes continued to reverse the fate and potentials of the agroecology.

The need for policy initiatives that address the issues of the need for local livelihood resilience by integrating non-climate local processes of global environmental change impacts with climate emergency. The strategy and plan such as the Climate Resilient Green Economy (CRGE) Strategy, Growth and Transformation Plan, Ethiopia's National Adaptation Plan (NAP), and other development programs should consider confounding non-climate local specific global environmental change impacts on the local livelihood systems.

The local realities and experiences along with the agroecology (except for farms) were poorly understood and didn't link to the development planning. The government institutions fail to contemplate this context for the local human-environment interrelationships in the watershed, while the knowledge of the contexts and principles are vital for sustainable development planning and implementations. To this end, the government and relevant institutions should encourage the studies provide to understand the constructions of agroecology. These may be thoughtful to internalize the agroecological situations, touch with launching the stakeholders' discussions and dialogue, and plan towards enhancing opportunities and minimize the risks.

Implications for future studies

This study has provided important information on local processes of global environmental change processes focusing on the climate variability and land-use dynamics and their livelihood impacts on the local community in the Anger River watershed. In this regard, future research may offer more insights into such processes to understand the impacts on local livelihood resiliencies. Hence, the following issues which were not adequately investigated in this study need further studies:

- The analysis of structural land use dynamics in this study provides a number of illustrations on the spatial aspects of the process and effects on the livelihood welfare of local community focusing only on the current implications of the changes. However, the local implications of the global land-use changes particularly related to trade liberalization and resource privatization mainly the future impact scenarios on the environmental carrying capacity, and livelihood provisions needs farther studies.
- Future research on climate analysis should be relevant for the decision making at the local level. To this end, the study should be conducted at micro-scale in a manner to understand local climate variability situations and causal linkage within local contexts.
- The study implies for the importance of research on the national/and regional policy and institutional analysis on global environmental change processes and impacts focused on rural vulnerability and adaptations to the changes. The future research could focus among others, on the characteristics of effective institutions for managing global environmental changes, limits of policy instruments on the processes and local impacts, identification of conditions under which global economy influences national development policy to impede the local livelihood contexts.

- The future research which emphasis on the agroecology contexts in Ethiopia are crucial, mainly for environmental and local livelihood. The research conceptions for rural livelihood should consider non-production-functions changes unique to certain agroecology mainly resulted from global environmental changes, and express the processes beyond the inherent local causations. The concepts should be applied through the holistic view linking issues of the local livelihoods with agroecologically constructed inequality in access to land resources, and associated livelihood outcome.

Appendices

Appendix 1. Questionnaire

Dear respondent your household has been randomly selected to participate in the research entitled “Land-use Dynamics and Climate Variability: Local Processes, and Livelihood Implications on Small-scale Farmers in Anger watershed, southwestern Ethiopia”. The aim of this survey is to collect data on households’ socio-economic and demographic background, the trend and status of community access to land resource, impact perceptions and adaptation strategies to climate change and structural land use dynamics. Your genuine responses are extremely important for success of this research. I assure you that your answers will be completely confidential, summary information will be used for analysis, and no individual questionnaire will be made available to any authority.

Date of interview	____________________	Questionnaire No.	________________
District	____________________	Kebele	________________

Part I: Households Socioeconomic and Demographic Characteristics

1. Gender of the household head (1) Male (2) Female

2. Age of the household head (1) 18 – 30yrs (3) 46-65
   (2) 31 – 45yrs (4) 65+

3. How long have you lived in this kebele? (1) <5 years (3) 11-15 years
   (2) 5-10 years (4) Over 16 years

4. What is your household size? (1) < 4 persons (3) 8– 15 persons
   (2) 4– 7 persons (4) >16 persons

5. Highest level of education for the household head — (1) No formal education (2) Less than Grade 5 (3) Grade 5-8 (4) Secondary & above (> 9) (5) Tertiary level

6. What is your marital status? — (1) Single (2) Married (3) Divorced (4) Widowed

7. Of the household, the extent of dependence (number of persons below 15 years out of total house hold size) — (1) ≤ quarterly (2) nearly half (3) more than half

8. Do you have relatives in this area, how many? — (1) No (2) < 5 households (3)>5 households

9. Have you any socio-economic/ customary institutions? — (1) No (2) Yes

10. If yes on Q. 9, How many institutions? ----------

11. Do you have access to extension services? — (1) No (2) Yes

12. If 'yes' for Q.11, how did they visit you in a year? — (1) Once in a year (2) Every quarterly (3) Twice in a year (4) Every month in a year

13. How many years of experiences do you have on your main livelihoods? — (1) < 3 years (2) 3-10 years (3) > 10 years

14. Do you have access to land management and climate change information? — (1) No (2) Yes

15. What is your main source of income? — (1) farm based (2) off-farm (3) Non-farm (4) All

16. If you selected 1 on Q. 15, what type of farming system do you practice? (Select the most practiced) — (1) Cropping (2) Mixed farming (3) Beekeeping (4) Livestock

17. Numbers of livestock — Cattle — Sheep — Goats — Chicken — Others

18. Size of farm plot under perennial crops (1) No area 2) <0.5 hectare 3) 0.5-1 hectare 4) > 1 hectare

19. What type of non-farm/ and off-farm livelihood system

(1) Petty trade
(2) Daily labor
(3) Brewery
(4) Firewood selling
(5) Fixed job
(6) Charcoal making
(7) Carpentry
(8) Weaving
(9) Blacksmith
(10) If others -----

20. What are the main crops produced in this area?

----

21. How many crop types do you produce out of these crops

(1) ≤ quarter
(2) Nearly quarter
(3) Half
(4) > Half
(5) Nothing

22. On what extents of your crop land do you use artificial fertilizers? (1) No access at all (2) Less than half (3) Half (4) For entire crop land

23. On what extents of your crop land do yo1u use improved seeds? (1) No access at all (2) Less than half (3) Half (4) For entire crop land

24. Do you engage in small scale irrigation? (1) No access to irrigation at all (2) Yes, on < 0.5hectare (3) Yes, on 0.5-1 hectare (4) Yes, on > 1 hectare

25. Do you have access to credit services (1) No (2) Yes

26. If yes for Q.25, which of the followings credit institution/sources provide you a loan?

(1) Banks (2) Oromia Credit & Saving Institute

(3) Local saving and credit associations (4) Community based organizations such as *Ikub* and *Idir* (5) Informal financial sources

27. Do you have money deposit and food reserve for the time of recession? (1) No (2) Yes

28. If 'no' for Q. 27, in which season/months food insecurity prevail? How do you cope with it?

----

29. Do you practice soil and water conservation? (1) No (2) Yes

30. If Yes for Q. 29, on what extent of your land? (1) Small area (2) Half of the land (3) Total land

31. How is the steepness of the slope of your farm land? (1) >15% (Very steepy) (2) 10-15% (Moderate) (3) < 10% (Gentle) (4) 0% (flat)

32. How do you rate vegetation cover in your locality? (1) Bare land (2) Sparsely vegetated (3) Moderate coverage (4) Densely vegetated

33. How do you rate fertility level of your farm land?
(1) Poor (require heavy fertilizer)
(2) Moderate
(3) Fertile (require small fertilizer)
(4) Highly fertile (no additional fertilizer)

34. Did you experience any type of natural hazard such as drought, extreme temperature, flooding etc. in the last five years? (1) No (2) Yes

35. If Yes, for Q. 34, how often? (1) Rarely (<Once in 5years) (2) Sometimes (twice in 5years) (3) > twice in 5years (4) Frequently (every year)

36. How do you rate the occurrence, amount and duration of rainfall in your locality?
(1) Below average (decreasing)
(2) Uniform
(3) Above average (increasing)
(4) Undetermined

37. How do you rate the intensity of temperature in your locality?
(1) Below average (decreasing)
(2) Uniform
(3) Above average (increasing)
(4) Undetermined

38. How is the wind direction you have been experiencing? (10) significant change (2) moderately change (3) No change (4) Undetermined

39. Have you influenced socially by investment (your house and land are surrounded or within the area occupied by agricultural investment?) (1) No (2) Yes

40. Households denied access to other natural resource other than land for cultivation/grazing due to increased need of land for investment (1) No (2) Yes

41. Household denied access to near open natural resources due to continuous belt in investment holding system (1) No (2) Yes

42. Do you think that your livelihood is affected due to lack of capacity to compete for resource with investors (1) No (2) Yes

Part II: Access to Land Resources, Climate Variability and their Implications on Livelihood Systems of the Small-scale Farmers

43. Do you engage in agricultural activities? (1) No (2) Yes

44. If ‘yes’ on Q.39, do you own land? (1) No (2) Yes
45. If ‘yes’ on Q. 40, how do you get the land? (1) Inheritance (2) Resettlement program (3) lease/purchase (4) Transfer in the form of gift (5) other if any-----

46. If ‘yes’ on Q.39, What is the size of your farm land? (1) < 0.5 hectare (2) 0.5- 1 hectare (3) 1-2 hectares (4) >2 hectares

47. If ‘yes’ on Q.39, how many farm plots do you have? (1) Only one plot (2) two plots (3) three farm plots (4) > three plots

48. How did you engaged in agriculture, if you don’t have your own land? (1) Contract land (2) Entered sharecropping (3) Worker in investment (4) Other if--------

49. How do you become landless? (based on Q.44) --
----

50. Do you use all land for agriculture (cropping and livestock rearing)? (1) No (2) Yes
51. If “no” for Q.46, what do you do with the land you do not use for agriculture? -----------------
----
----
52. Describe the size and characteristics of land you own and use (in hectares)

Description	Plot 1	Plot 2	Plot 3	Describe if you own more plots	Total
Land size in hectare					

Land quality (a=fertile, b=medium, c=poor)					
Status: Rented (1=in 2= out)					

53. Has your landholding changed during the last 10-20 years? No (2) Yes

54. If 'yes' on Q.49, how did it change? (1) Decreased (2) Increased (3) undetermined

55. If 'yes', on Q. 49, why did it change? (1) Sale (2) Inheritance (3) Redistribution (4) Investment acquisition (5) Purchase (6) Others------------

56. For what purpose did you use the land before the acquisition? (If Q.51 is '4') (1) Grazing (2) Crop land (3) Source of firewood (4) Source of water

57. Were you consulted when the land deal was made? (If Q.51 is '4') 1. No 2. Yes

58. 11If 'yes' on Q.53, how did you participate? ---

----

59. Do you think that the land deal was made in transparent manner? 1. No 2. Yes

60. Why do you to think so? ---

----

61. Does the large-scale agricultural project have any direct impacts on your means of living? 1. No 2. Yes

62. If yes, how did it impacts you? (1) adversely (2) positively
how? --

63. List out the socioeconomic/livelihoods problems associated with the agricultural investment projects? --

64. Did you get any direct compensation for lost opportunities such as landlessness, lack of access to water and other resources? (If Q.51 is '4' or investment land acquisition) 1. No 2. Yes

65. If yes for Q.60, what kind of compensation did you receive?
(1) In kinds; describe --
(2) In cash payment; describe ---

66. If 'no' for Q.60, Why didn't paid?
    (1) The land perceived as open and common land?
    (2) Did not have" *ragaa*" (Holding certificate)?
    (3) The land was not mine for it belongs to the state?
    (4) Describe if any other reason/s---------------------------------------

67. What have you been doing to get the compensation? --
----

68. Have you benefited from the project in the form of technology transfer? (1) No (2) Yes

69. Has crop production and supply increased in your village as a result of the investment project? (1) No (2) Yes

70. Have you or other members of your family got any employment opportunity in the project? (1) No (2)Yes

71. If yes on Q. 66, what type? (1) Temporary (2) permanent.
Explain the condition of payment?--

72. Do you think that the introduction of agricultural investment projects resulted in infrastructure development in your locality? (1) No (2) Yes, modestly (3) Yes, very much

73. If 'yes' for Q.68, list the types and distributions of the infrastructures developed in the area and the role they played in connection with own livelihood ---

74. Do you think that the agricultural products of the investor accessed by (reach) local markets and satisfy grain need of the local community? (1) Not at all (2)Yes, modestly (3) Yes, to the level of local satisfaction

75. Do you think that the large-scale agricultural investment has significant adverse environmental impacts? (1) No (2) Yes

76. If 'yes' for Q.71, what are the main environmental impacts of the investments? (1) Water resource (2) Natural forest
(3) Wetlands (4) Soil degradations

77. On which of the following livelihood source did the environmental entity you have identified (on Q.72) has significant negative impacts?
    (1) Crop production

(2) Livestock

(3) forest related productivity

78. Explain how the identified environmental degradations are affected your livelihoods? -
----

----

79. How do you perceive the natural conservation practices or the harmony of large-scale investors with nature? (1) Poor (2) good (3) Very good (4) undetermined

80. Compare the level of environmentally friendly system of small-scale farmers and the large-scale investment ---
----

81. What happened to natural ecosystem of these areas with the introduction of both state farm and private agricultural investment? --
----
----

82. Have you felt climate change associated situation in the last 30 years (only for >45 years old)? (1) No at all (2) Yes, but very slight (3) Yes, modestly (4) Yes, very much

83. If ‘yes’ for Q. 82, what type of change do you felt among the following climate associated situation

    1) Extreme hot days in *bega* (dry) months
    2) Extreme cold nights in *bega* (dry) months
    3) Extreme dry condition in *bega* (dry) months
    4) Considerable decrease in amount and duration of *kiremt* rainfall
    5) Significant change in time of rainfall onset and cessation

6) Others (Specify)

84. If 'yes' for the above question (Q. 82), what are the impacts of these changes on your life?

(1) Agricultural crop productions are decreasing	(4) Agricultural practices are limited to some crop types
(2) Natural forest-based assets are deteriorated	(5) increase in epidemics such as malaria
(3) grazing land is diminished	(6) Water sources are decreasing

85. Have your livelihoods disturbed significantly in the last 10-20 years? (1) Not at all (2) Yes, modestly (3) Yes, very much

86. If 'yes' on (Q. 85), describe the biophysical and socioeconomic constraints undermine your livelihoods? --

87. To what change processes do you attribute the causes of these livelihood constraints more?

(1). climate changes and variabilities

(2) lack of access to land resources because of structural land use dynamics, and tenure insecurity

88. Why and how the cause you have selected above (Q.87) has been adversely affected your livelihood conditions? ---

89. The followings are the adaptation and coping mechanisms commonly practiced in Ethiopia to overcome livelihood constraints for small scale farmers. Thus, rank the strategies you have been practicing as '1,2,3,4' if you use the mechanism 'usually, sometimes, rarely and not practiced at all' respectively.

S. N	Adaptation strategies	Rank	Coping strategies	Rank
1.	Changing planting date		Change in consumption	
2.	Crop diversification		Receiving support through PSNP	
3.	Improved seed		Accessing credit	
4.	Non-farm activities		Selling livestock	
5.	Reducing stocking density		Renting out land	
6.	Improving livestock farm		Seasonal migration	
7.	Employed small scale irrigation		Remittance	
8.	Tree planting		Add others if any, and explain if among the first three ranks under both ‘adaptation’ and ‘coping’ separately ---------------------- -- -- ------------------------------------	
9.	Soil and water conservation			
10.	Soil fertility management			
11.	Drought-tolerant crops			
12.	Others, if any could be ranked as the first three			

90. Describe why you prefer to adopt the first three ranked strategies (depending on the question number 92) -- ----------------------------------

91. Explain the trends of adaptation and coping strategies you have been practicing (For example, a strategy commonly practiced before, its current status, and a new adoptions if any) -- --- ---

92. Identify the change process (either climate variability or structural land use dynamics) as the driver/s for the changing practicality of adaptation and coping strategies (depending on the question number 91) -- --

Appendix 2. Discussion Points for Small-scale Farmers (FGD for Elders and Local Customary Leaders)

1. Global environmental change processes and livelihood implications

i. Issues of land use land cover dynamics

- ✓ What is land and land resource for small-scale farmers in your area?
- ✓ Traces on land tenure system, drivers and impacts of land use dynamics
- ✓ Trends of small-scale farmers' access to land resource, local internal socio-economic and demographic dynamics, and external drivers in land use dynamics.
- ✓ Are there large-scale investment activities in your area? Who are investors in your area? What are the criteria to be investor? How do you evaluate their role and effects on local community and physical environment?
- ✓ How do you describe your relationships with investors and investment activities?
- ✓ Identify (list) down some of the main impacts of large-scale agriculture investment on your livelihoods?
    - It could be either negative or positive
    - Impacts difference among communities having different livelihood system (impacts on farmers, gatherers, hunters)
    - Displacement of people

ii. Issues of climate change and variability

- ✓ Trends and variability conditions of rainfall and temperature
- ✓ How do you describe the impact of climate change in your livelihoods? Particularly in terms of:
    - your agricultural productivity?
    - type of crop produced? Seasons of productions? Frequencies of production
    - Access to water and irrigation?
    - Natural resource degradation (vegetation, wild animals and other resources)

iii. Simultaneous processes and impacts

- How do you express climate change/variability and land use land cover dynamics in your area?
    - ✓ Causes of the changes
        - Natural increase (Rapid population growth and associate demand of land for agriculture, land fragmentation, overutilization of natural resources
        - Socio- economic and political factors
    - ✓ How do you express their impacts on small-scale farmers' livelihoods?
        - Are the impacts simultaneous and equal?
        - Which stressor is severe in context of your livelihoods and why?
        - How do you express the processes? Are they external or internal to local community? Why?

2. The current status and changing aspects in vulnerability of local community
    - Who are most vulnerable (area, household characteristics),
    - Causal linkage with dynamics in political and socio-economic situations, how and why?
    - Associations with dynamics in biophysical environment/and climate change.
3. The current status and changing aspects in adaptations strategies of the local community
    - Describe the trends of adaptation strategies;
    - compare the efficiency of past and present strategies
    - Causal linkage with dynamics in political and socio-economic situations and biophysical environment/and climate change.
    - Currently, what mechanisms are mostly adopted? and how do you describe the present adaptation strategies?
    - What are the implications of changes in the strategies on your livelihood system?

Appendix 2. Interview Protocols for Experts and Government Officials

1. How do you describe the situation of the present environmental change?

    - land use land cover dynamics
    - climate change
    - the impacts on local small-scale farmers and general environment?

2. How do you compare the role of investors and small-scale farmers in development?
    - Capital
    - Environment experience,
    - Technological knowhow, land use plan, agricultural input
    - Adaptability to climate change and land degradations
    - Level of environmentally friendly system
3. How do you describe the situations of large-scale agricultural investments and land use governance?

    - guidelines/and rule for land transfer to investors
    - check list for evaluating investors' application and business plan

4. How do you describe the opportunities, and constraints of large-scale investment on small-scale farmers' livelihood in relation to surrounding highland farmers?

Appendix 4. Land use land cover data of Anger watershed

Appendix 4.1. Results of the accuracy analysis error matrix for each land use land cover data (1976, 1991, 2001, and 2019)

Error matrix of 1991

Classified data	Reference Data						
	Forests	Wetlands	Grass/bush lands	Agricultural Land	Settlements	Row Total	User Accuracy
Forests	134	0	9	2	0	143	59%
Wetlands	0	86	2	38	7	133	95%
Grass/ bush lands	88	1	109	12	10	220	88%
Agricultural Land	5	3	0	96	2	106	57%
Settlements	1	1	4	20	123	149	87%
Column Total	228	91	124	168	142		
Producer Accuracy	92%	65%	50%	91%	83%		
Over all accuracy = diagonal/column total = 0.7277 = 0.73							**73%**

Error matrix of 1991

Classified data	Reference Data						
	Forests	Wetlands	Grass/bush lands	Agricultural Land	Settlements	Row Total	User Accuracy
Forests	23486	34	11	1	0	23532	99%
Wetlands	4439	948	41	9	1	5438	71%
Grass/ bush lands	4	28	1595	674	0	2301	70%
Agricultural Land	23	8	39	16731	131	16932	99%
Settlements	0	2	0	1198	10405	11605	90%
Column Total	27952	1020	1686	18613	10537		
Producer Accuracy	84%	93%	95%	90%	99%		
Over all accuracy = diagonal/column total = 0.8889 = 0.89							**89%**

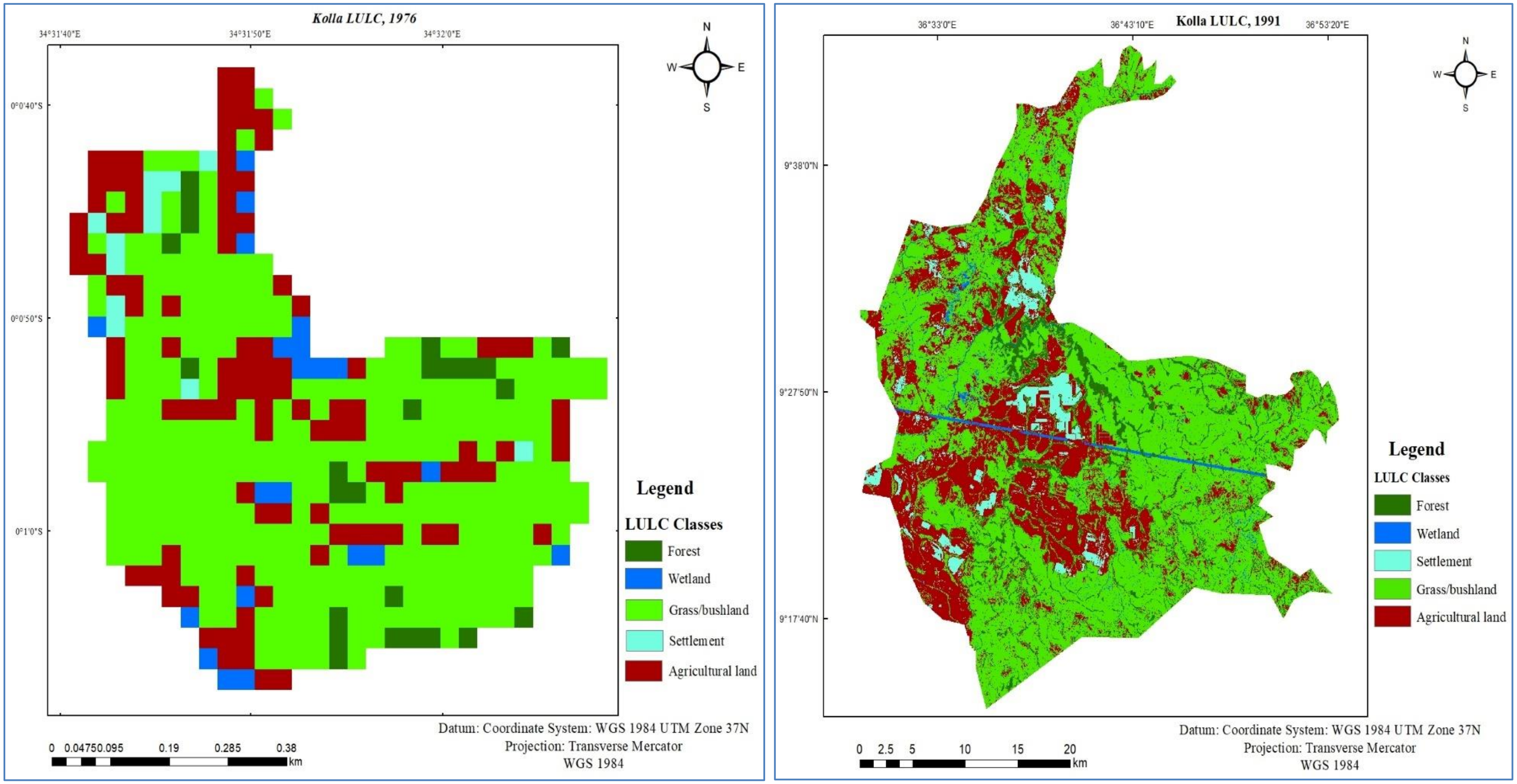
Continued……. Error matrix of 2001

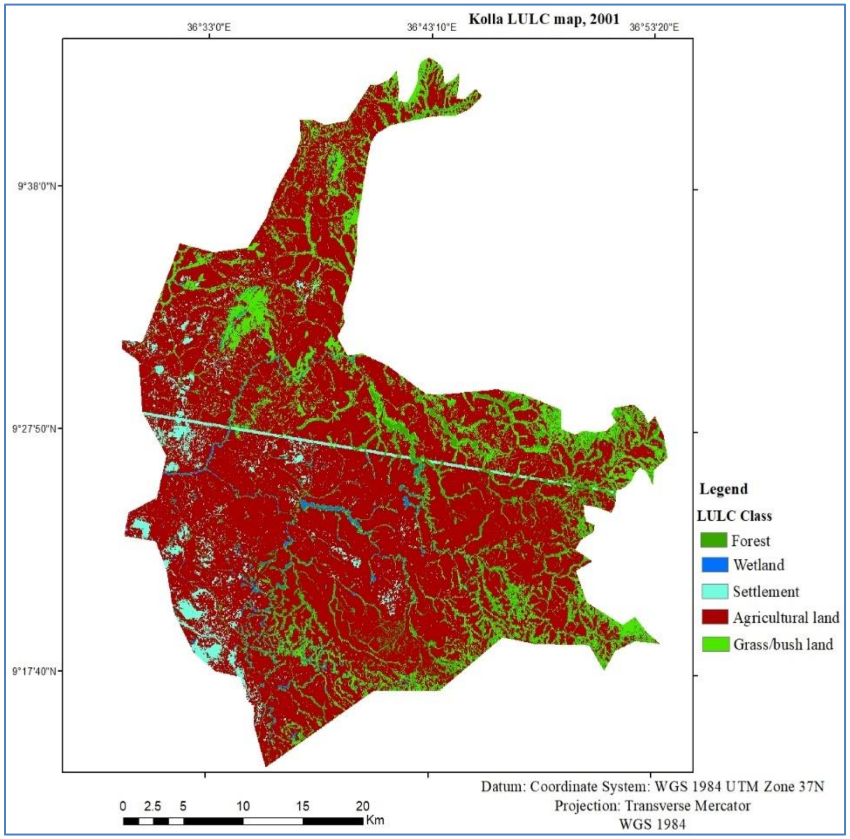
Classified data	Reference Data						
	Forests	Wetlands	Grass/bush lands	Agricultural Land	Settlements	Row Total	User Accuracy
Forests	32614	2	186	32	0	32834	99%
Wetlands	244	1674	927	1228	7	4080	41%
Grass/ bush lands	626	126	14014	5572	1	20339	69%
Agricultural Land	17	45	523	54247	398	55230	98%
Settlements	0	20	8	5480	12635	18143	70%
Column Total	33501	1867	15658	66559	13041		
Producer Accuracy	97%	90%	90%	82%	97%		
Over all accuracy = diagonal/column total = 0.88							**88%**

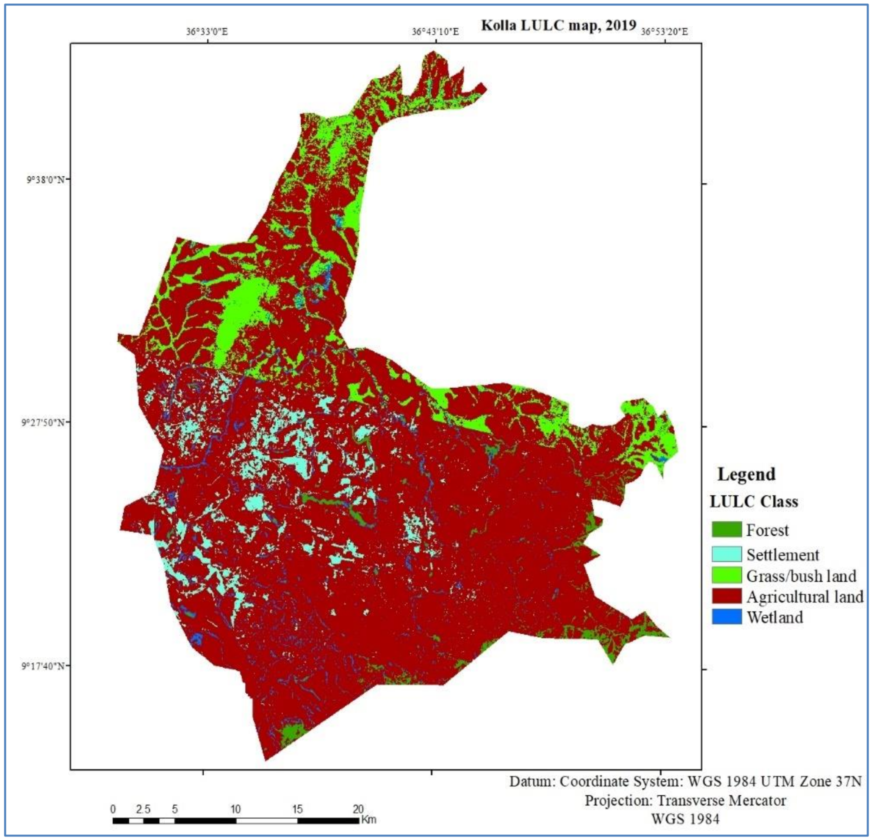
Error matrix of 2019

Classified data	Reference Data						
	Forests	Wetlands	Grass/bush lands	Agricultural Land	Settlements	Row Total	User Accuracy
Forests	171865	20	7	205	0	172097	99%
Wetlands	564	11096	404	9657	6	21727	51%
Grass/ bush lands	1043	5960	7191	2466	0	16660	43%
Agricultural Land	368	913	65	141169	955	143470	98%
Settlements	0	1	0	9117	25769	34887	74%
Column Total	173840	17990	7667	162614	26730		
Producer Accuracy	99%	62%	94%	87%	96%		
Over all accuracy = diagonal/column total = 0.92							**92%**

Appendix 4.2. LULC images in *kolla* agroecology (for 1976, 1991, 2001, and 2019 respectively) used for comparative change analysis with entire watershed in chapter 2




Kolla LULC map, 2001
36°33'0"E
36°43'10"E
36°53'20"E
9°38'0"N
9°27'50"N
9°17'40"N
Legend
LULC Class
Forest
Wetland
Settlement
Agricultural land
Grass/bush land
0 2.5 5 10 15 20 Km
Datum: Coordinate System: WGS 1984 UTM Zone 37N
Projection: Transverse Mercator
WGS 1984


Kolla LULC map, 2019
36°33'0"E
36°43'10"E
36°53'20"E
9°38'0"N
9°27'50"N
9°17'40"N
Legend
LULC Class
Forest
Settlement
Grass/bush land
Agricultural land
Wetland
0 2.5 5 10 15 20 Km
Datum: Coordinate System: WGS 1984 UTM Zone 37N
Projection: Transverse Mercator
WGS 1984

Appendix 5. Rainfall and temperature data of Anger watershed

Appendix 5.1. Mean Monthly rainfall measured from different sites in Anger watershed

Dega agroclimate zone												
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	oct	Nov	Dec
1983	0.0	26.7	44.5	15.0	165.1	217.3	354.2	260.6	148.0	150.0	50.7	0.0
1984	2.4	0.0	24.8	30.0	225.7	248.9	289.0	232.7	194.9	5.4	29.8	4.4
1985	15.2	0.0	32.2	91.2	154.7	210.0	238.2	295.5	180.2	73.1	14.9	7.7
1986	0.0	16.5	36.9	50.0	33.3	262.3	286.3	220.1	157.9	42.3	3.5	9.5
1987	0.0	3.7	110.6	65.8	187.6	254.5	264.6	228.0	166.7	113.6	21.5	12.7
1988	16.3	32.3	52.6	0.0	168.4	261.3	331.3	248.5	256.9	154.8	4.0	0.0
1989	0.0	5.4	143.6	55.4	124.0	212.7	294.7	241.6	177.1	53.3	6.5	122.7
1990	4.6	7.6	61.7	40.2	88.7	283.9	289.7	355.6	209.1	48.9	25.9	1.1
1991	0.0	20.1	21.7	67.1	136.3	304.3	399.3	368.2	230.8	56.2	2.9	6.2
1992	22.1	0.0	22.2	118.5	226.3	466.4	379.8	380.4	196.1	228.2	72.7	24.0
1993	0.0	22.2	53.1	184.8	225.2	340.2	407.5	368.5	154.7	212.2	5.9	0.0
1994	3.4	2.1	28.8	94.9	235.8	190.3	279.2	290.2	175.3	20.0	32.2	3.7
1995	1.0	6.5	81.5	71.3	156.1	223.6	261.1	352.9	167.2	36.1	30.6	25.7
1996	56.1	5.8	125.7	89.3	206.8	298.0	296.6	216.5	220.1	49.9	28.8	18.9
1997	16.0	0.0	38.5	160.0	208.8	230.9	283.5	180.9	127.7	174.3	67.1	9.3
1998	0.0	1.6	39.9	18.2	186.7	311.9	276.0	332.9	220.9	248.8	39.6	0.0
1999	19.4	0.0	4.0	58.9	225.9	240.1	185.0	223.4	194.1	247.8	10.2	10.8
2000	0.0	0.0	0.0	102.2	146.8	311.7	258.2	293.0	166.7	142.0	32.5	6.7
2001	0.0	25.5	60.6	63.8	201.4	223.8	233.1	308.5	146.6	127.7	2.3	17.0
2002	30.9	1.6	64.1	89.6	75.6	243.2	256.8	199.9	134.2	58.1	0.0	35.9
2003	0.0	62.4	58.6	36.9	24.8	312.6	331.8	345.5	180.8	4.8	27.3	26.0
2004	12.9	7.7	13.2	45.6	145.0	251.6	269.7	293.7	199.0	78.6	13.4	0.0
2005	12.1	0.0	92.8	46.5	120.1	317.6	314.4	303.0	222.0	83.9	61.7	0.0
2006	3.4	6.2	63.7	42.7	163.3	254.0	327.9	294.1	225.0	132.3	7.8	75.4
2007	6.2	18.4	54.0	111.2	155.9	313.6	237.6	267.5	199.3	57.5	0.0	0.0
2008	14.2	0.0	1.5	139.3	256.3	327.2	288.4	251.6	202.7	121.7	84.3	4.3
2009	0.0	20.3	56.6	115.8	48.1	269.3	256.6	339.5	214.1	167.8	4.2	20.2
2010	7.2	16.7	1.8	24.4	359.6	299.2	307.5	267.5	202.8	52.5	29.3	3.3
2011	26.1	4.0	46.8	60.1	235.9	246.3	215.1	307.1	197.1	51.1	44.7	0.0
2012	0.0	0.0	22.9	25.0	147.5	246.9	275.3	310.9	249.5	47.8	64.3	14.1
2013	17.6	0.0	20.0	4.6	232.9	283.9	266.6	264.6	215.6	94.4	41.6	0.0
2014	0.0	0.0	76.0	186.7	274.2	280.7	235.2	224.4	206.5	208.5	0.0	0.0
2015	11.2	7.4	37.6	83.6	91.1	287.7	256.4	286.6	209.4	111.6	32.4	10.5
2016	11.3	7.3	36.9	84.3	89.4	288.5	254.5	286.8	210.4	112.0	32.8	10.3
2017	11.4	7.2	36.2	85.0	87.8	289.4	252.7	287.0	211.5	112.4	33.1	10.1

***Continued…….Woinadega* agroclimate zone**												
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	oct	Nov	Dec
1983	1.3	9.1	15.4	5.2	196.5	245.2	369.0	329.4	342.1	164.7	34.2	0.0
1984	0.0	0.0	12.2	25.7	216.7	370.5	401.4	339.3	329.8	15.4	3.8	7.6
1985	2.1	0.0	15.9	69.6	250.5	286.4	382.1	439.5	268.9	80.3	24.0	5.0
1986	0.0	10.0	32.3	54.8	45.0	346.0	325.4	286.7	335.6	101.6	11.2	14.7
1987	2.1	0.0	68.0	65.1	305.4	307.9	427.6	246.8	227.9	177.7	42.3	8.2
1988	5.5	34.1	27.6	2.7	182.8	339.5	377.2	364.4	382.5	182.0	2.7	0.0
1989	0.0	0.0	95.9	56.2	193.0	243.0	364.4	382.2	353.5	90.4	12.9	48.7
1990	1.1	0.7	23.8	39.8	105.8	307.3	409.4	480.0	341.8	98.6	10.8	0.0
1991	0.1	9.0	15.4	141.2	194.1	314.9	300.7	380.1	216.5	62.0	2.7	6.0
1992	0.0	0.0	21.5	100.1	192.5	183.2	337.8	351.8	301.4	216.1	56.3	18.0
1993	0.0	6.5	39.1	127.5	243.8	286.4	336.3	378.8	386.3	185.3	18.4	0.0
1994	1.6	0.6	2.7	69.6	341.2	327.8	365.3	402.7	262.7	17.2	76.2	13.7
1995	0.0	0.0	43.9	124.5	229.7	222.2	346.7	321.9	327.1	47.6	8.1	27.9
1996	0.3	0.3	92.7	53.8	259.9	311.0	398.9	320.7	346.6	85.5	28.7	9.7
1997	2.9	0.0	43.1	91.0	293.0	343.0	332.0	299.8	306.3	191.7	81.2	4.2
1998	1.5	0.2	39.4	10.5	222.3	301.2	308.2	362.4	356.3	223.6	20.1	0.0
1999	23.3	0.0	0.0	71.1	235.9	331.1	312.8	323.2	318.9	273.5	31.3	17.6
2000	0.0	0.0	0.5	146.4	226.1	278.3	338.7	290.6	339.1	202.6	29.4	13.8
2001	0.0	9.0	19.9	16.1	254.2	264.5	359.5	317.6	298.7	174.4	14.9	9.2
2002	7.6	2.7	27.9	29.7	70.9	393.6	381.6	347.5	378.9	69.9	1.5	32.0
2003	0.0	38.4	30.5	10.1	12.7	394.0	360.2	482.9	445.8	28.1	17.7	3.0
2004	3.8	10.8	9.5	48.3	107.1	416.7	463.3	447.2	431.3	119.5	33.8	1.2
2005	0.0	0.0	101.8	10.5	101.1	319.2	368.9	363.6	387.2	141.6	31.4	0.0
2006	0.9	0.4	9.4	11.4	245.1	362.3	481.8	415.8	423.6	150.9	9.2	59.9
2007	0.0	21.8	20.5	91.6	309.0	437.1	395.9	382.8	369.6	95.0	6.5	0.0
2008	9.6	1.0	0.0	202.9	387.4	213.8	380.5	411.9	374.0	94.8	40.3	17.4
2009	0.3	12.5	17.2	21.2	47.0	312.0	354.0	445.4	251.0	141.7	9.6	0.5
2010	21.3	2.5	1.5	41.7	379.0	246.3	493.0	399.8	385.8	80.4	63.5	4.3
2011	13.7	7.3	20.7	13.8	279.2	338.1	337.0	334.4	392.8	52.6	29.7	0.0
2012	0.0	0.0	33.5	0.0	109.0	337.4	396.4	384.6	427.7	46.5	39.4	6.9
2013	6.4	2.3	24.9	16.0	319.8	310.9	404.0	363.1	313.6	136.4	56.9	0.0
2014	0.0	6.7	59.8	161.3	293.3	235.1	362.1	423.7	337.5	247.5	37.3	0.0
2015	6.4	6.5	25.8	60.4	237.6	322.6	392.8	398.8	383.0	128.8	36.0	8.3
2016	6.6	6.5	25.5	60.4	239.1	323.4	393.9	400.5	385.4	129.0	36.5	8.2
2017	6.8	6.6	25.2	60.4	240.5	324.1	395.1	402.3	387.9	129.2	37.0	8.1

Continued……Kolla **agroclimate zone**												
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	oct	Nov	Dec
1983	0.0	22.1	30.0	8.0	165.0	207.7	343.0	272.2	197.7	163.1	59.0	0.0
1984	0.3	0.0	15.2	26.7	216.7	269.4	326.5	273.8	216.8	5.1	18.9	3.3
1985	11.4	0.0	31.1	71.5	182.7	246.3	269.2	333.6	203.3	78.2	17.1	11.3
1986	0.0	9.7	27.9	54.1	37.7	252.0	293.7	237.0	200.7	78.5	0.3	7.8
1987	0.4	1.8	100.7	49.9	211.8	233.9	282.3	251.4	186.9	102.2	32.7	11.0
1988	12.9	19.0	19.8	0.0	147.8	251.9	330.6	263.6	298.0	157.3	3.8	0.0
1989	0.0	2.3	124.8	65.3	138.2	215.8	342.1	306.4	272.7	66.7	13.6	103.8
1990	2.6	6.5	43.8	35.1	111.4	285.0	355.4	408.4	233.3	52.0	24.7	0.0
1991	0.5	17.2	38.3	91.7	162.1	305.8	364.1	343.9	212.0	46.8	11.4	14.4
1992	11.4	1.9	43.7	103.3	191.8	285.2	324.2	329.9	207.0	236.8	58.5	18.1
1993	0.0	19.7	51.9	161.7	227.6	315.2	360.0	368.2	225.7	195.7	19.5	0.0
1994	4.6	2.4	17.2	87.2	243.7	231.8	306.6	315.2	191.8	25.6	47.3	6.1
1995	0.2	5.1	72.8	68.1	151.7	209.0	247.2	337.8	201.7	16.7	18.4	27.8
1996	32.1	4.2	121.8	72.3	219.5	275.4	322.7	246.5	231.0	51.3	33.8	19.2
1997	11.4	0.2	48.3	123.0	222.7	225.1	279.6	213.7	142.3	190.7	58.2	8.0
1998	4.3	1.3	29.8	26.3	200.1	299.0	269.7	319.3	242.3	245.7	35.8	0.1
1999	21.7	0.0	0.2	54.3	240.4	220.6	226.7	256.7	214.8	225.3	10.9	15.2
2000	0.0	0.0	0.4	105.2	187.3	282.7	257.5	293.7	215.0	147.6	28.6	5.2
2001	0.0	19.1	47.5	58.6	183.2	227.1	260.2	269.8	183.6	111.5	8.4	11.5
2002	13.9	7.3	59.5	73.6	75.6	271.4	278.5	225.3	171.4	48.1	1.5	31.4
2003	1.5	42.7	64.0	27.2	13.7	297.7	315.8	340.6	216.3	19.9	29.7	26.2
2004	6.8	9.1	19.8	61.6	123.1	288.3	310.6	286.5	222.1	96.2	15.3	1.0
2005	2.6	0.0	118.7	43.6	120.8	277.7	314.3	270.3	213.4	112.8	50.2	0.0
2006	1.4	3.8	42.9	21.8	156.4	260.6	344.9	289.3	229.5	100.1	19.1	65.5
2007	3.6	28.1	33.8	77.9	181.7	357.2	289.6	267.6	228.7	61.7	2.8	0.0
2008	8.8	0.1	2.3	138.4	290.5	299.5	322.2	258.8	209.4	105.1	57.5	13.4
2009	0.5	14.5	44.4	90.8	35.7	247.3	292.2	419.4	216.3	159.8	3.7	5.3
2010	7.9	20.7	18.7	40.6	299.3	259.8	354.0	265.2	240.3	41.0	29.2	3.5
2011	21.0	0.8	49.0	49.2	220.9	243.6	226.8	271.0	264.2	44.3	40.3	0.0
2012	0.0	0.0	27.1	18.5	125.5	277.8	314.2	313.0	279.1	50.7	51.1	4.4
2013	5.4	0.1	7.4	0.4	216.7	269.7	285.8	270.0	216.4	103.5	61.9	0.0
2014	0.9	2.9	72.0	155.3	267.6	259.0	256.3	271.3	257.0	194.5	8.1	0.0
2015	6.9	0.4	38.8	72.1	189.0	180.2	283.8	286.4	232.0	104.7	31.5	8.2
2016	7.0	2.5	38.4	72.6	189.9	181.2	282.7	286.0	232.7	104.8	31.7	8.0
2017	7.1	2.0	38.1	73.0	190.8	182.2	281.5	285.5	233.5	104.8	32.0	7.7

Appendix 5.2. Mean Monthly Minimum and Maximum temperatures measured from different sites in Anger watershed

***Dega* agroclimate**																								
	March		April		May		June		July		August		September		October		November		December		January		February	
Year	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1983	24.8	10.6	25.1	10.7	23.4	9.3	21.1	8.4	17.9	7.7	17.1	9.0	18.2	9.2	20.0	9.9	21.7	9.2	22.6	8.9	23.2	8.4	23.9	9.8
1984	25.1	10.2	26.9	11.9	23.0	9.2	18.3	7.4	17.2	8.4	17.4	8.0	18.2	8.0	21.7	8.5	22.4	8.9	23.0	11.0	23.8	7.9	24.9	10.0
1985	24.6	9.4	23.4	9.7	20.6	9.1	19.0	9.2	16.8	8.6	16.9	8.5	18.6	8.7	21.1	8.5	22.7	9.2	22.8	9.5	23.5	9.7	24.2	8.9
1986	25.2	10.9	24.1	10.5	26.1	10.8	19.5	9.7	17.7	9.3	18.4	9.5	19.1	8.2	22.0	8.7	24.2	8.7	24.3	8.8	24.3	9.7	23.9	10.6
1987	23.9	11.6	24.7	11.6	23.3	12.4	20.3	9.9	19.8	9.3	18.9	9.1	20.7	9.1	22.3	9.7	23.5	9.6	24.0	9.8	25.0	9.5	25.9	12.2
1988	26.6	11.8	26.6	12.3	23.7	10.7	19.6	9.9	17.0	9.3	17.4	9.8	18.9	9.8	20.6	9.7	21.7	8.5	22.2	8.1	25.1	10.1	24.8	11.0
1989	22.4	10.7	21.2	11.1	21.9	10.5	18.7	8.9	17.7	9.2	17.9	9.2	19.0	9.2	21.0	9.4	22.9	9.0	21.7	9.8	22.7	8.2	23.4	10.0
1990	24.3	10.6	24.4	11.6	23.1	11.1	19.4	9.4	17.8	9.3	18.2	8.9	18.5	8.9	22.0	8.9	22.9	9.7	23.8	9.0	23.4	9.5	23.5	10.4
1991	24.6	11.7	24.9	11.0	23.2	11.2	19.6	10.1	17.3	9.9	18.1	9.8	19.9	9.5	21.9	9.5	22.6	9.5	22.6	9.0	25.7	10.2	25.6	11.6
1992	25.6	12.2	24.7	10.7	22.8	10.4	19.5	8.5	16.6	8.6	16.9	9.7	18.9	9.2	19.9	9.7	21.1	9.1	23.2	9.6	22.6	10.2	24.1	11.1
1993	24.8	11.1	21.8	11.3	22.2	10.8	19.5	9.8	17.5	9.3	18.0	9.3	18.7	9.1	21.2	9.7	22.9	9.4	23.8	9.1	23.7	9.2	23.6	10.2
1994	26.5	12.1	25.7	12.4	22.4	10.6	19.1	9.9	17.2	9.7	17.3	10.0	19.7	9.4	23.4	8.8	23.3	10.3	24.8	9.2	24.6	10.3	26.4	11.0
1995	25.3	11.0	24.4	12.5	22.5	11.6	21.0	10.3	17.0	9.7	18.1	10.0	19.4	9.6	21.9	9.7	23.1	9.9	24.2	10.3	25.5	9.8	26.6	11.6
1996	25.3	12.1	23.8	11.6	22.0	10.5	19.1	9.4	18.2	9.4	18.2	9.1	19.8	9.2	22.6	8.8	23.2	9.2	23.4	9.0	24.1	10.6	26.9	11.4
1997	25.9	10.7	23.7	10.9	22.5	10.3	20.0	9.3	17.8	9.2	18.3	9.3	20.8	8.9	21.4	9.7	22.2	10.5	23.9	9.4	24.5	10.1	26.9	8.9
1998	26.1	12.5	27.1	12.9	23.2	12.0	20.4	9.6	17.2	9.5	18.2	10.0	19.7	9.9	20.7	10.3	22.4	8.0	23.6	7.8	24.7	10.1	26.1	10.5
1999	26.5	10.6	25.9	12.4	21.8	10.3	20.2	8.9	16.9	8.4	17.3	8.8	19.6	9.0	20.3	10.1	22.6	7.6	23.4	8.7	24.4	9.0	27.0	10.9
2000	27.5	12.0	23.5	11.2	23.0	11.0	20.1	9.2	17.6	8.5	17.5	9.2	19.8	9.8	21.4	11.0	22.2	9.9	23.0	9.4	25.6	9.8	27.0	10.7
2001	24.1	11.7	24.9	12.2	22.9	11.2	19.1	9.5	18.4	9.9	18.2	10.2	20.7	9.6	22.0	9.9	23.6	9.5	24.3	10.0	23.9	9.5	26.2	11.2
2002	25.8	12.1	25.3	12.1	24.9	12.0	20.8	10.1	19.7	10.0	18.6	10.0	20.6	9.7	23.2	9.9	24.3	9.7	24.2	9.7	24.9	10.4	26.7	11.6
2003	25.9	12.3	25.8	12.5	27.2	13.0	20.7	10.2	18.1	10.2	18.7	10.7	19.3	9.8	23.0	10.1	23.8	10.4	24.1	10.3	25.3	10.1	26.7	12.0
2004	26.3	12.2	25.4	12.5	25.1	12.1	19.6	10.0	18.8	9.7	19.1	10.2	20.1	10.1	21.6	9.7	23.7	10.2	24.0	10.2	25.7	12.0	26.3	11.0
2005	26.2	12.2	25.6	12.4	24.2	11.9	21.4	10.2	18.8	10.2	20.3	10.1	20.8	10.8	21.8	10.8	23.0	10.3	23.7	9.6	24.8	10.3	28.8	12.7
2006	26.1	12.0	25.7	12.6	23.6	11.3	20.5	9.8	18.3	10.3	17.8	9.8	19.7	10.0	22.3	11.0	22.6	10.6	23.0	10.2	26.0	10.5	26.9	12.6
2007	26.2	12.1	25.1	12.7	22.8	11.8	19.9	10.2	18.4	10.6	17.8	10.4	18.9	10.3	22.0	9.6	23.1	9.9	23.8	9.0	23.9	10.3	25.2	11.5
2008	26.8	12.2	24.2	11.9	21.2	10.6	19.9	9.5	17.5	9.2	17.3	9.4	19.3	9.9	21.4	10.2	21.7	10.1	22.5	10.0	25.1	10.1	26.2	11.2
2009	26.0	11.3	24.9	11.1	26.1	11.4	22.6	9.2	18.2	9.3	18.5	10.1	20.2	10.1	21.2	10.0	23.6	9.8	23.3	10.7	23.9	9.9	25.7	11.3
2010	26.0	11.0	25.0	11.8	22.8	10.9	20.6	9.7	18.5	9.4	18.7	9.6	19.6	9.7	22.5	10.1	22.9	10.3	23.6	10.2	24.6	10.2	26.3	11.0
2011	26.0	11.0	26.6	11.4	23.9	11.1	20.5	9.7	19.4	9.8	19.1	10.2	19.7	9.8	23.5	10.3	22.8	10.3	23.6	9.1	23.8	10.5	26.8	10.9
2012	27.7	10.9	26.9	11.5	25.7	10.6	21.4	9.6	20.4	9.8	18.8	10.2	19.3	10.0	22.8	8.3	23.4	10.2	23.6	8.3	25.7	9.9	27.8	10.2
2013	27.1	11.5	27.5	11.2	23.0	10.5	20.0	10.3	18.5	10.2	18.2	10.0	19.7	10.2	21.6	10.6	23.3	10.8	23.8	9.1	24.8	10.3	27.5	11.0
2014	25.9	10.7	24.8	10.4	23.4	10.3	21.2	10.5	18.7	10.4	18.4	9.7	19.2	9.8	21.9	10.3	23.3	10.6	23.6	7.2	25.0	10.1	26.3	10.1
2015	26.8	11.8	25.8	12.0	24.0	11.5	21.0	10.1	18.9	10.2	18.7	10.2	20.0	10.3	22.3	10.4	23.2	10.5	23.8	9.3	25.1	10.6	27.5	11.4
2016	26.9	11.8	25.9	12.0	24.1	11.5	21.0	10.1	19.0	10.2	18.7	10.3	20.0	10.3	22.4	10.4	23.2	10.5	23.8	9.3	25.1	10.6	27.6	11.4
2017	27.0	11.9	25.9	12.0	24.1	11.5	21.1	10.2	19.0	10.3	18.8	10.3	20.1	10.4	22.4	10.4	23.3	10.6	23.8	9.3	25.2	10.7	27.7	11.4

Continued…...*Woinadega* Agroclimatic zone																								
	March		April		May		June		July		August		September		October		November		ecember		January		February	
Year	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1983	27.5	12.7	27.7	13.4	25.8	13.4	22.9	12.9	21.2	11.9	20.7	12.3	22.0	11.4	22.3	11.9	23.6	11.5	24.6	11.2	24.7	10.6	26.6	12.0
1984	27.5	12.9	27.5	13.9	25.4	12.6	21.6	11.9	21.0	11.8	21.1	11.9	22.6	11.3	24.1	12.1	24.4	12.5	24.7	13.6	25.3	10.9	27.2	11.9
1985	26.3	13.7	25.1	13.4	23.3	12.7	21.6	13.1	19.9	12.4	20.2	12.5	21.7	12.5	22.9	12.2	24.2	12.1	24.2	12.5	25.0	12.7	25.5	12.4
1986	27.3	14.7	26.1	13.7	27.2	15.0	22.2	13.5	21.0	12.6	21.6	12.8	22.3	12.4	23.5	12.6	24.6	12.6	25.5	12.1	26.2	12.2	27.2	14.0
1987	27.0	14.8	26.8	15.2	24.8	14.6	23.0	13.6	22.7	12.8	22.1	12.8	23.6	12.6	23.9	13.2	24.8	13.2	25.4	12.8	26.1	12.7	27.5	14.6
1988	28.4	14.2	29.1	14.7	26.4	13.9	22.9	13.6	21.3	13.0	21.5	12.8	22.8	12.8	23.1	12.7	24.5	12.3	25.3	11.4	26.5	13.0	26.5	14.0
1989	26.4	13.5	25.7	13.4	24.5	12.9	22.8	12.8	21.4	12.0	21.0	12.1	22.6	12.5	23.0	12.6	24.4	12.4	24.1	12.2	25.6	10.6	26.6	12.5
1990	27.1	13.8	27.6	15.3	26.0	14.3	22.9	13.3	21.0	12.7	21.3	12.4	22.1	12.6	23.5	12.9	25.0	13.1	25.9	12.4	25.0	12.4	26.2	12.8
1991	27.5	14.8	26.4	14.2	25.6	14.0	22.8	13.1	21.1	12.4	21.7	12.2	23.2	12.2	23.8	12.3	24.7	12.7	24.8	11.8	26.5	12.7	27.8	13.9
1992	28.0	14.1	26.6	13.6	25.6	13.5	23.4	12.6	22.0	12.1	21.2	12.8	22.5	12.4	22.9	12.6	23.8	12.4	24.7	12.3	25.5	12.6	27.0	13.6
1993	27.5	14.4	24.9	13.8	24.5	14.0	22.9	13.6	21.4	13.0	21.6	13.0	21.9	12.5	23.2	13.1	24.6	13.3	25.9	12.5	25.0	11.4	25.8	12.3
1994	28.4	15.2	27.6	16.8	24.6	14.3	23.0	13.9	20.7	12.8	19.9	12.9	22.1	13.0	24.2	13.5	24.6	14.0	25.4	13.2	26.7	13.6	27.9	15.1
1995	28.0	14.3	27.7	15.9	25.6	15.6	23.6	13.4	21.2	13.2	21.5	13.2	23.1	13.3	24.3	13.6	24.6	13.5	25.2	13.2	26.6	12.2	27.4	14.6
1996	27.6	15.7	27.4	15.8	24.8	15.0	23.0	13.4	21.6	13.5	22.3	13.7	23.4	13.3	23.9	13.2	24.7	13.0	25.2	13.1	26.3	13.2	28.3	14.3
1997	28.9	14.5	26.9	15.0	24.7	14.2	22.7	13.5	21.4	13.1	21.6	13.3	23.1	13.0	24.1	14.4	24.8	14.4	25.8	13.9	26.3	12.8	27.9	11.9
1998	28.5	15.6	28.7	16.2	27.3	16.1	24.7	13.8	22.0	12.9	21.7	12.8	22.9	12.9	23.7	13.4	24.3	12.2	25.0	10.9	26.1	12.9	28.1	13.6
1999	28.6	13.9	28.2	15.3	25.8	14.0	23.9	12.9	22.1	12.5	22.4	13.1	23.5	13.3	23.7	13.8	24.8	12.2	25.9	13.0	25.2	11.6	28.2	13.9
2000	29.3	14.7	26.4	14.6	25.9	14.6	23.6	12.9	22.4	12.9	22.3	12.8	23.8	12.5	24.0	13.6	25.0	12.8	24.9	12.2	26.9	13.0	28.0	13.5
2001	27.2	14.3	27.2	15.0	26.9	14.7	22.9	13.5	21.8	13.0	21.5	13.4	23.4	12.8	23.6	13.3	24.4	12.7	25.1	12.8	26.1	11.9	27.7	13.7
2002	28.1	15.1	28.4	15.7	28.7	15.4	23.4	13.4	22.9	13.1	21.9	13.1	23.3	12.8	24.4	13.0	25.5	13.5	25.6	13.0	26.1	12.9	28.3	14.5
2003	28.6	15.8	28.8	15.9	30.1	16.9	23.6	13.7	21.4	13.2	21.5	13.3	22.7	13.0	24.2	13.5	25.1	13.7	25.7	12.5	27.3	13.1	28.3	14.5
2004	28.7	15.8	27.8	15.5	27.4	14.9	22.7	13.9	21.8	13.1	21.6	13.4	22.6	12.9	23.3	13.1	24.7	13.1	25.5	13.2	27.0	13.3	28.0	13.9
2005	28.5	14.8	28.3	16.4	26.7	15.4	23.7	14.2	21.4	13.6	22.2	13.3	23.7	12.6	23.9	11.8	25.1	12.9	26.3	11.9	26.4	12.9	29.3	14.5
2006	28.5	15.3	28.3	15.7	25.8	14.6	23.3	13.9	21.7	14.0	20.9	13.1	23.4	12.9	24.9	14.3	24.9	13.5	25.0	12.8	27.3	13.5	28.5	14.7
2007	28.8	15.0	27.1	15.3	25.5	15.0	22.8	14.1	20.7	13.6	21.4	13.2	22.6	13.6	23.2	12.8	24.7	13.3	25.4	13.0	26.2	12.2	27.4	14.4
2008	28.6	15.5	26.0	15.6	24.7	14.3	23.1	13.9	22.3	13.2	22.0	13.4	23.2	13.3	23.7	13.4	24.2	13.2	25.3	13.1	26.4	13.2	27.6	14.3
2009	28.9	15.7	27.8	15.2	27.6	15.7	25.4	14.2	22.6	13.3	22.8	13.3	23.5	13.1	24.0	13.0	25.0	12.8	25.6	13.0	26.3	13.4	27.4	15.0
2010	29.0	14.3	28.7	15.9	28.2	14.5	24.1	14.0	22.2	13.4	20.3	13.3	22.3	13.2	24.5	13.2	24.9	13.4	25.3	13.2	26.5	12.5	29.1	14.6
2011	28.2	14.5	28.5	15.2	26.7	14.8	23.9	13.6	22.9	13.0	21.7	13.0	23.3	12.9	24.9	13.3	23.8	14.7	25.9	13.5	26.1	12.2	28.3	13.6
2012	29.2	14.7	28.5	15.1	27.4	14.6	24.3	13.6	22.5	13.3	22.8	13.4	23.5	12.9	25.1	13.5	25.7	15.2	27.1	13.9	26.7	12.3	28.9	13.5
2013	28.3	15.9	28.5	15.4	26.5	14.6	23.2	13.9	20.5	13.5	20.9	13.3	22.8	13.2	23.2	13.4	24.3	13.6	25.2	12.0	26.2	13.4	28.1	14.8
2014	28.4	14.7	26.8	14.5	25.1	14.0	24.7	14.4	21.8	13.8	21.9	12.9	23.8	13.4	24.0	14.1	25.2	13.6	25.4	13.0	26.4	12.6	28.1	13.3
2015	29.1	15.5	28.2	15.9	27.1	15.3	24.2	14.1	22.2	13.7	29.0	13.5	23.4	13.4	24.4	13.7	25.0	13.9	25.8	13.1	26.8	13.1	28.7	14.5
2016	29.1	15.6	28.3	16.0	27.2	15.3	24.3	14.2	22.2	13.7	29.2	13.5	23.5	13.5	24.4	13.7	25.0	14.0	25.9	13.2	26.8	13.2	28.8	14.6
2017	29.2	15.6	28.3	16.0	27.2	15.4	24.3	14.2	22.2	13.8	29.5	13.5	23.5	13.5	24.4	13.8	25.0	14.0	25.9	13.2	26.8	13.2	28.8	14.6

Continued…....... *Kolla* Agroclimatic zone

	March		April		May		June		July		August		September		October		November		December		January		February	
Year	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1983	30.8	14.2	31.2	14.9	28.7	14.0	26.4	13.8	24.1	13.4	23.4	14.1	24.7	13.5	25.7	13.9	27.0	12.5	28.0	12.7	28.3	11.9	29.8	12.8
1984	30.9	14.4	31.4	15.9	27.9	13.5	24.4	13.1	23.7	13.7	24.5	13.7	24.9	13.2	27.4	13.6	27.9	13.0	27.9	14.7	28.7	11.8	30.4	13.4
1985	30.0	14.0	28.0	14.1	25.5	13.7	24.4	14.5	22.7	13.8	23.2	13.8	24.4	13.8	26.1	13.3	27.3	13.3	27.9	13.6	28.4	13.3	29.1	12.6
1986	30.8	15.7	29.5	15.6	30.9	16.3	24.7	15.1	23.6	14.5	24.3	14.9	25.0	13.7	26.9	13.6	28.7	13.1	28.8	12.5	29.3	13.2	29.8	14.5
1987	29.7	15.7	30.1	16.5	27.6	16.3	25.3	15.1	25.4	14.6	24.5	14.4	26.4	14.1	26.8	14.3	27.8	14.3	28.7	13.9	29.8	13.1	30.9	15.2
1988	31.8	15.6	32.4	16.1	28.8	15.4	25.3	15.3	22.8	14.5	23.5	14.7	24.9	14.7	26.1	14.3	27.7	13.4	28.9	12.7	29.7	13.8	29.9	14.9
1989	29.0	14.6	28.4	14.8	27.2	14.9	25.1	14.2	24.0	14.4	24.0	14.3	25.3	14.3	26.3	14.0	28.0	13.2	27.3	13.7	28.7	11.6	29.6	13.4
1990	29.6	15.0	30.2	16.4	28.9	16.3	25.6	15.3	23.8	14.7	24.7	14.4	25.3	14.3	27.3	14.0	28.6	14.3	29.5	13.8	28.5	13.7	28.9	14.2
1991	30.4	16.0	29.2	14.9	27.7	14.9	25.2	14.7	23.6	14.6	24.5	14.3	26.4	14.4	27.3	13.9	28.2	13.6	27.8	13.0	29.8	13.7	31.0	14.9
1992	31.0	16.1	29.8	15.7	28.0	15.6	25.7	14.7	23.9	14.4	23.2	14.8	25.1	14.3	25.6	14.6	26.8	13.5	28.0	13.5	28.1	13.5	29.6	14.5
1993	30.6	15.5	27.4	15.3	26.9	15.5	25.1	15.2	23.8	14.7	24.8	14.8	25.4	14.3	26.9	14.5	28.3	13.9	29.1	13.8	28.4	12.7	29.1	14.0
1994	31.6	15.7	31.0	17.4	27.0	15.4	25.3	15.3	23.5	15.0	23.3	14.9	25.5	14.5	28.3	13.6	28.0	14.3	29.2	13.3	30.0	14.0	31.1	14.7
1995	31.1	15.0	30.4	17.0	28.2	16.3	26.7	15.3	23.8	15.0	24.5	15.0	26.1	14.6	27.8	14.4	28.3	14.0	28.9	14.1	30.1	13.1	31.1	15.0
1996	30.3	15.7	29.6	16.1	26.6	15.0	25.2	14.6	24.8	14.7	24.5	14.1	25.9	14.1	27.6	13.8	28.3	13.3	28.9	13.2	29.1	13.7	31.4	14.9
1997	31.2	14.9	28.9	15.2	26.9	14.5	25.8	14.6	24.7	14.5	24.9	14.7	27.0	14.1	27.2	14.5	27.4	14.4	28.6	13.4	29.8	13.3	31.4	12.5
1998	31.5	16.2	32.5	17.1	29.1	16.6	26.4	15.2	23.9	15.1	24.2	15.1	25.7	14.9	26.2	15.0	27.8	12.6	28.9	12.0	29.0	12.9	31.0	13.6
1999	31.7	14.0	31.0	16.4	27.5	15.0	26.1	14.6	23.9	14.4	24.1	14.6	25.7	14.5	25.8	14.9	28.0	12.3	29.0	13.3	29.1	12.6	31.9	14.3
2000	32.2	15.4	29.0	15.7	28.5	15.5	26.0	14.5	24.6	14.6	24.5	14.7	26.4	14.8	26.6	15.1	27.7	13.9	28.1	13.4	30.2	13.4	31.3	14.2
2001	30.1	15.5	30.6	16.5	29.0	16.0	25.3	14.9	24.4	14.8	23.9	15.0	26.2	14.7	27.0	14.3	28.2	13.7	29.0	14.2	29.2	12.7	30.9	14.6
2002	31.2	16.0	31.3	16.5	31.1	16.5	26.7	15.0	25.8	15.0	24.4	15.0	26.1	14.5	28.0	14.6	29.0	14.1	29.2	13.5	29.3	13.7	31.3	15.1
2003	31.3	16.3	31.5	16.6	32.4	17.5	26.0	15.1	23.8	14.9	24.0	15.1	25.5	14.6	27.8	14.8	28.7	14.4	28.9	14.2	30.5	13.5	31.5	15.1
2004	31.8	16.5	30.8	16.6	30.5	16.5	25.4	15.2	24.7	14.7	24.8	15.1	25.9	14.8	26.7	14.2	28.3	14.1	28.6	13.9	30.2	15.0	30.9	14.4
2005	31.8	16.1	31.2	17.1	29.2	16.2	26.6	15.3	24.4	15.4	25.8	15.0	26.5	15.4	27.3	15.2	28.1	14.3	29.3	14.0	29.3	13.6	33.3	16.3
2006	31.6	15.9	31.0	16.6	28.3	15.7	26.1	15.1	24.4	15.5	23.7	14.4	25.6	14.7	27.3	15.2	27.5	14.2	27.6	13.8	30.9	14.0	32.0	15.8
2007	31.4	15.6	30.1	16.7	28.2	16.3	25.6	15.4	23.9	15.3	24.0	15.2	25.3	15.3	27.0	14.2	28.2	13.8	28.8	13.4	28.6	13.2	30.1	14.3
2008	32.1	16.3	28.6	16.3	27.0	15.2	25.9	14.9	24.4	14.5	24.5	14.9	25.8	14.8	26.5	14.5	26.9	14.0	28.1	14.3	29.7	13.4	30.8	14.6
2009	30.8	15.3	30.2	15.6	30.8	16.1	28.1	14.8	25.1	14.9	25.6	15.4	26.7	15.3	27.1	14.5	28.8	13.8	28.6	14.5	29.1	13.8	30.3	15.2
2010	31.3	14.8	30.4	16.2	29.1	15.3	26.9	14.8	25.0	14.5	24.4	14.2	25.8	14.1	28.0	14.1	28.4	14.1	28.6	14.2	29.8	13.5	31.8	14.5
2011	31.2	14.7	31.9	15.6	29.2	15.4	26.4	14.8	25.7	15.0	25.1	14.9	26.4	14.6	28.4	14.4	27.6	14.6	28.9	13.3	28.5	13.1	31.4	13.8
2012	32.6	15.2	32.3	15.9	30.7	15.3	27.3	14.9	26.0	14.8	25.1	15.1	25.9	14.9	28.1	14.7	28.5	14.6	29.4	13.1	29.9	13.0	32.5	14.1
2013	32.1	15.3	32.6	15.2	28.8	15.0	26.1	15.5	24.9	15.3	24.4	15.0	26.0	15.0	27.0	14.8	28.2	14.3	28.9	13.0	29.2	13.6	32.1	14.6
2014	30.9	14.4	30.0	14.4	28.6	14.6	27.4	15.4	25.3	15.4	24.7	14.6	25.4	14.6	26.8	14.8	28.3	14.2	29.1	13.3	29.8	13.0	31.1	13.3
2015	31.9	15.6	31.1	16.2	29.6	15.9	26.9	15.3	31.8	15.3	24.9	15.1	26.3	15.1	27.5	14.9	28.3	14.4	29.0	13.7	29.8	13.7	32.0	14.8
2016	31.9	15.6	31.1	16.2	29.7	16.0	27.0	15.3	31.9	15.3	24.9	15.1	26.3	15.1	27.6	14.9	28.3	14.4	29.0	13.7	29.8	13.7	32.1	14.8
2017	32.0	15.6	31.2	16.2	29.7	16.0	27.1	15.3	32.0	15.3	24.9	15.1	26.3	15.1	27.6	14.9	28.3	14.5	29.0	13.7	29.8	13.7	32.1	14.8