# CLIMATE ADAPTATION SERVICES: INTEGRATING LAND INFORMATION TO SUPPORT MOUNTAIN COMMUNITIES

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This research was conducted under the auspices of the Graduate School for Socio-Economic and Natural Sciences of the Environment (SENSE)

ITC dissertation number 332
ITC, P.O. Box 217, 7500 AE Enschede, The Netherlands

ISBN 978-90-365-4622-5
DOI 10.3990/1.9789036546225

Cover designed by Job Duim
Printed by ITC Printing Department


UNIVERSITY OF TWENTE.
ITC
FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

# CLIMATE ADAPTATION SERVICES: INTEGRATING LAND INFORMATION TO SUPPORT MOUNTAIN COMMUNITIES

DISSERTATION

to obtain
the degree of doctor at the University of Twente,
on the authority of the rector magnificus,
prof.dr. T.T.M. Palstra,
on account of the decision of the graduation committee,
to be publicly defended
on Friday 5 October 2018 at 16:45 hrs

by

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born on 16 August 1973
in Shiraz, Iran

This thesis has been approved by
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**Dr. R.M. Bennett**, co-supervisor

*To Communities*

# *Acknowledgements*

This journey began due to my curiosity and my ambition, where I decided to pursue a Ph.D.. I feel grateful to be selected as a Ph.D. candidate at the University of Twente, ITC Faculty, PGM department. I would like to acknowledge the Erasmus Mundus Action 2 Project SALAM, International Scholarship of the European Commission 2013 that arranged the funding for me to pursue my study. Also, I would like to thank ITC for financially supporting my research budget and granting me the ITC Fellowship Program (IFP).

Throughout my Ph.D., I have received support from many people, without which this thesis would have never been achieved. First and foremost, I wish to express my gratitude to my promoter, Prof. Jaap Zevenbergen, for accepting me to be a part of the land administration team and providing me with guidance and support. With him and my two supervisors, I have been encouraged by an outstanding team. I am equally indebted to Dr. Rohan Bennett, who became my supervisor after the retirement of Dr. Arbind Tuladhar, for all the discussions that continued over Skype after he moved to Australia. Thank you for your invaluable constructive feedback, scientific suggestions and the freedom and trust that you offered me, all of which have shaped my Ph.D., my work and beyond. You read my numerous drafts and despite all my efforts continued to find grammar mistakes and typos. Thank you for your immense patience, aspiring guidance, priceless critical insights and friendly advice during my Ph.D. It makes me think time and time again about what research and English mean.

When I was in Nepal for my case study, I met and worked with many amazing people. I take this opportunity to acknowledge all the people and organizations for their immense support and valuable contribution throughout my research. Especial thanks to Tuladhars' family, Ganesh Prasad Bhatta, Rabindra Maharjan and Govinda Joshi for supporting me during my fieldwork in Nepal. Thanks to Swikriti Amatya, my Nepali translator and Pawan Thapa, my information system developer. I would also like to thank my MSc students Malihe, Arshad, Prakash, and Pawan. I had a great time working with all of you, and your study contributed to my Ph.D. as well. My Ph.D. would not have reached this stage without them. I got an ample opportunity to be involved in exploring mountain communities' livelihood.

I also much appreciate that I have been In Enschede, surrounded by so many great people. It is a pleasant place to study in due to its international atmosphere. Lydia, Petra, Stephan, Sara, Razieh, Mitra, Parinaz, Elnaz, Mila, Liza, Richard, Reshma, Rehana, Divyani, Monica, Dimitrios, Eduardo, Kwabena, Dimo, Rosa, Paul, Shima, Theresa and other ITC colleagues, thank you for making me feel at home and sharing your life experiences. My special appreciation goes to Milad, Sue, Gert, and Anica for making my time more enjoyable with traveling, cooking, baking and our nice conversations of scientific and non-scientific topics. I am happy that we are still friends. I am also very grateful to my graduation committee. Thank you very much for your willingness to be committee members and taking your time to review my Ph.D. thesis. Special thanks to my para nymphs; Lydia Prieto Leon and Sara Mehryar. I appreciate your company throughout my Ph.D. defence.

I had a pleasant experience being involved in the establishment of ITC Ph.D. community (pITCom.), cultural activities of the international food festival, international evening and Iranian new year. I extend my special thanks to ITC staff, Tom, Evelien, Milad, Harm-Jan, Haidi, Manuel and the rest from the different communities for sharing lots of memorable moments during my study period. Furthermore, I would like to extend my sincere gratitude to Zbig, Luuk, Michel, and Cheryl for their unconditional support and encouragements. You offered me ways to find my future path. I am grateful to get to know you in my life. Friends all over the world, Mahshid, Jila, Lars, Mark, Mahmoud, Ahmad, Janusz, Mahsa, Mojdeh, Juan, Shahin, Ezzat thank you for your friendship and care.

I am incredibly grateful for working with many amazing people in the Netherlands, Vietnam, and Ghana due to Geodata for Water and Agriculture (G4AW) projects. My sincere gratitude goes to Harry Derksen and Ad Bastiaansen for accepting me to be a part of their team. I would also take this opportunity to thank Andre for sharing his knowledge and experiences in the projects with me.

Finally, I am profoundly grateful to my parents and my siblings for their precious love, support, and encouragements. I am equally thankful to Farrokh for understanding me over the past years. Thank you for giving me the freedom to

find my own way. Last but not least, my sincerest thanks and immense love to my daughter, Shahrzad who is always supporting and inspiring me to find myself in my life, mainly in difficulties. I never forget the lessons, experiences, and stories that you share with me to comfort me and your rigorous effort in proofreading my writings. I am proud of you.

At the end of my Ph.D. journey, I take this opportunity to express my experiences during my Ph.D. journey. Besides scientific research and development, I learned time and budget management, planning, projecting, coordinating, convincing people with different backgrounds, working in an international and interdisciplinary environment, life and personal development. I always travelled with hopes and dreams to explore the islands of my life journey. From now onwards, I would like to continue with enlightenment.

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## *List of abbreviations*

| | |
|---|---|
| AFOLUL | Agriculture, Forestry and Other Land Use |
| ALM | Adaptation Learning Mechanism |
| API | Application Programing Interface |
| CAC | Citizen Awareness Centers |
| CAP | Community Adaptation Programs |
| CBA | Community-Based Adaptation |
| CBO | Community-Based Organizations |
| CCP | Climate Change Policy |
| CDM | Clean Development Mechanism |
| CFG | Community Forest user Group |
| COP | Conference of the Parties |
| CRiSTAL | Risk Screening Tool-Adaptation and Livelihoods |
| CSO | Civil Society Organizations |
| DADO | District Agriculture Development Office |
| DDC | District Development Committee |
| DFO | District Forest Office |
| DHM | Department of Hydrology and Meteorology |
| DLO | District Livestock Office |
| DPO | District Planning Office |
| DSO | District Survey Office |
| ECARDS | Environment, Culture, Agriculture, Research, and Development Society |
| FAO | Food and Agriculture Organization |
| FECOFUN | Federation of Community Forestry Users Nepal |
| FFP LA | Fit-For-Purpose Land Administration |
| FGI | Focus Group Interview |
| FIG | International Federation of Surveyors |
| FUG | Forest User Group |
| GDP | Gross Domestic Product |
| GeoJSON | Geographic JavaScript Object Notation |
| GHG | Greenhouse Gases Emission |
| GIS | Geographic Information System |
| GLOF | Glacial Lake Outburst Flood |
| GLTN | Global Land Tool Network |
| GtG | Gigatonnes Greenhous |
| HKH | Hindu Kush Himalayan |
| ICIMOD | International Centre for Integrated Mountain Development |
| ICRAF | World Agro-forestry Centre |
| ICT | Information and Communication Technologies |

| | |
|---|---|
| IDEAM | Institute for Hydrology, Meteorology and Environmental Studies in Colombia |
| IFAD | International Fund for Agricultural Development |
| IPCC | Intergovernmental Panel on Climate Change |
| IS | Information Systems |
| IT | Information Technology |
| KU | Kathmandu University |
| LA | Land Administration |
| LADM | Land Administration Domain Model |
| LAPA | Local Adaptation Plans for Action |
| LIS | Land Information System |
| LULUCF | Land Use, Land Use Change and Forestry |
| LUP | Land Use Policy |
| LVI | Livelihood Vulnerability Index |
| MCAS | Mountain Community Adaptive System |
| MENRIS | Mountain Environment Regional Information System |
| MoAD | Ministry of Agriculture and Development |
| MoFSC | Ministry of Forest and Soil Conservation |
| MoLRM | Ministry of Land Reform and Management |
| MoST | Ministry of Science and Technology |
| MWIS | The Mountain Weather Information Service |
| NAP | National Adaptation Plans |
| NAP | National Agriculture Policy |
| NAPA | National Adaptation Plan of Action |
| NCT | Noticing things, Collecting things and Thinking about things |
| ND-GAIN | University of Notre Dame Global Adaptation Initiative |
| NGO | Non-Governmental Organization |
| PC | Personal Computer |
| PES | Payments for Environmental Services |
| PPCR | Pilot Project for Climate Resilience |
| QGIS | Quantum GIS |
| REDD+ | Reducing Emissions from Deforestation and Forest Degradation |
| RUPES | Pro-poor Environmental Services |
| SDG | Sustainable Development Goals |
| SDI | Shack/Slum Dwellers International |
| SFM | Sustainable Forest Management |
| SMS | Short Message Service |
| TWG | Thematic Working Groups |
| UN/ECE | United Nations Economic Commission for Europe |
| UNCED | United Nations Conference on Environment and Development |

| | |
|---|---|
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UN-GGIM | United Nations Statistics Division |
| UN-HABITAT | United Nations Human Settlements Programme |
| UN | United Nations General Assembly |
| VDC | Village Development Committee |
| VGGT | Voluntary Guidelines on the Responsible Governance of Tenure of land, fisheries and forests in the Context of national food security |
| WUPAP | Western Uplands Poverty Alleviation Programme |

# Chapter 1 : Introduction

## *1.1 Background and problem definition*

Climate change is recognized as a seminal global challenge of the contemporary era. All aspects of human life and nature are potentially affected by climate change, with impacts being amplified in mountainous regions. Climate change in mountainous areas affects various activities including agriculture, food availability, water resources, energy infrastructure, ecosystem services and human health, among others (Kohler & Maselli, 2009). Climate change is demonstrated to increase poverty and brings about environmental and socio-economic problems in mountainous regions. For the vast majority of mountain communities, climate change means reduced land security leading to increased risks of losing shelter and livelihood. The most vulnerable mountain people are low-income people, women, disabled people and children as they are mainly dependent on agriculture. Decision makers often ignore mountain communities (Blaikie & Sadeque, 2001) (IPCC, 1997).

> *"Two years ago, spring rivers caused landslides. Many individual lands were demolished. 22 people died, and 10 people were injured. We are panicked, and we are committed to doing something as a community. The problem is that we do not know what to do and how to do it"* Study participant of Focus Group Interview (FGI) in Charikot, Nepal.

Mountains are the living space of about 12% of the world's population, and it is estimated that 40% of people worldwide depend on mountains for some form of service or good including fresh water, hydroelectricity, timber, biodiversity, minerals, and recreation (e.g., tourist destination). Mountains display a diversity of climate that challenges the human capacity to respond to environmental degradation. Mountains are places where frequent natural disasters occur, including avalanches, wildfires, deforestation, changes in biodiversity, temperature and rainfall patterns (Zhelezov, 2011). *"Mountains are the first indicator of climate change"* (UN, 2013): the fragility of the ecosystems in mountains mean that the effects in those areas are some of the most visible indicators of climate change in any context. The increase in the vulnerability of those living in high-risk mountain areas, and the observed changes in loss of livestock and agricultural productivity, are taking place rapidly in mountain regions across the globe (Kohler et al., 2014).

The abovementioned issues result in mountain areas being a key focus for developing appropriate responses to climate change. The Kyoto Protocol (UN, 1998) and Conference of the Parties (COPs) – as seen in Paris (2015), Marrakesh (2016), Bonne (2017) are the fundaments of these responses. In COPs development, adaptation is introduced as a potential solution to reduce the impacts of climate change. It involves coping with the current situation that is a result of climate change (IPCC, 2014a). Climate change that finds its root both in natural causes, such as solar radiation, and humankind activities, including burning fossil fuels, deforestation, and land use change, leads to an increase in the earth surface temperature and Greenhouse Gases Emission (GHG), respectively (IPCC, 2007a). Deforestation and land use change are mainly taking place in forests and mountain regions through economic investments in industry, agriculture, tourism, hydropower, and communication routes. The competition for land and rural market-oriented agriculture, forestry, mineral extraction and recreation development increases land use change (Kohler & Maselli, 2009). Climate change further influences land and land use systems in mountain areas, leading to the displacement of mountain people. Deforestation and cultivation of marginal soils (Beniston et al., 1996) lead to debris-flows, agricultural disruption, and decreases available land and its usability for mountain communities. Consequently, competition to access resources increases (Dodman & IIED, 2012). The mountain communities/individuals who are already vulnerable are the most affected by these interferences.

> *"We have less paddy and potato productions. It directly affects our lives. Fewer crops mean less food for us."* Study participants of FGI in Charikot, Nepal.
> *"First, we had landslides, then heavy rainfall and now three months of the monsoon! I am a victim of landslide, and I am trying to migrate to Katmandu. I have no place to stay in my mountain community."* Female study participant of FGI in Charikot, Nepal.

With regards to mountainous areas and climate change adaptation, Agenda 21 – Chapter 13 – specifically focuses on *"Managing fragile ecosystems: sustainable mountain development"* and calls for the generation and strengthening of knowledge for the sustainable development of mountain people. An important part of achieving this objective appears to be the establishment of accessible information systems in these regions. These would *"facilitate integrated* *management of mountain ecosystems"* and capacity building of local communities by disseminating information (UN, 1992a). The mountain communities/individuals as mentioned before are more vulnerable due to a lack of information about available resources. FAO, UN-HABITAT, and GLTN identified the significant gaps related to land and climate change on land tenure to natural resources, land and property rights, land scarcity and land conversion (UN-HABITAT & GLTN, 2010). Filling these gaps is fundamental to increasing the effectiveness of climate change adaptation schemes (Arial et al., 2011) (Otto et al., 2017).

Secured access to land and resources is a fundamental human need and facilitates shelter, food security, housing, and properties to reach an acceptable living standard (FAO, 2009). Land tenure defines one's right to land and resources (Munro-Faure et al., 2002). Land and natural resources play essential roles in economic development since they supply goods and give services to humankind. Forces of supply and demand (Tuladhar, 2004) and climate change (IPCC, 2014a) (FAO, 2009) affect land and natural resources. Considering the effect of climate change as disadvantageous, strategic modelling is required to facilitate the participation of vulnerable communities in adaptation programs and protection of their tenure rights (FAO, 2012). A number of authors addressed land rights, security of tenure and existing institutional capacity in this vein. Barnes & Quail (2011) considered the cadastre as an alternative for identifying carbon property rights, in the context of climate change mitigation and adaptation. Knox et al.( 2011) assessed tenure challenges and the effectiveness of a clear and secure land tenure regime that could lead to successful climate change mitigation activities. Karsenty & Assembé (2011) emphasized *"reforms to adapt land tenure systems to international agendas"* in central Africa. Worliczek & Allenbach (2011) discovered the potential of existing tenure systems in Wallis Island in the South Pacific for climate change adaptation. Therefore, for the implementation of adaptation programs, particularly in mountainous areas, appropriate policy and institutional arrangement are required.

Increasing knowledge, use of available spatial information and new technology are essential for mountain communities to know how to better manage land and natural resources and tackle the impacts of climate change. In the interim, to increase mountain communities' resilience to the impacts of climate change, collaborative international working groups including World Bank, UNESCO, European Union's Alpine Space Program and ICIMOD initiated various studies, research, training and Community Adaptation Programs (CAPs) in different mountainous regions. The IPCC highlighted the need for climate information and services worldwide to facilitate adaptation to climate change (Visbeck, 2008). Climate information provides details of temperature and rainfall data. Climate services enable users to have access to and to understand the information and the impacts of climate change on their environment (WMO, 2011a).

> *"We are convinced that TV Programs for Sustainable Forest Management and radio broadcast programs on climate change are the main sources of information on community forest management, land use management and how to diversify our livelihood. Our preference is radio programs as we can listen to them on our FM radio mobile."* Study participants of FGI in Bocha, Nepal mentioned.

However, mountain communities are a unique case, and so far these sorts of services and related Information Systems (IS) do no reach the users. Therefore, it is important to improve existing IS or to develop a new generation that can support the unique community needs. Different mountain information systems are being developed worldwide based on these global challenges, government mandates, technological support, IT infrastructure and use of information in various sectors and levels. They all aim at providing versatile services to decision and policy makers at international, national and local levels. For instance, mobile technology already underpins a forest fire alarm system and flood alert system in Himalaya region. Mountain communities receive Short Message Service (SMS) at the time of risk. Integration of an IS, and geo-visualization is shown to facilitate the decision-makers' access to the relevant information and natural resources in mountain regions (Murthy et al., 2014). The Mountain Weather Information Service (MWIS) provides another example. It provides forecasts of temperature, rainfall, wind, cloud, sunshine and air quality to mountain users in Scotland, England and Wales. The MWIS' aim is to aid mountain safety for the trekkers and mountain inhabitants. The users can use the forecast app or the MWIS website directly to access the detailed weather forecasts, synoptic charts and installed webcams in the mentioned mountain regions (Geoff Monk & Associates, 2017). A further possible solution to facilitate mountain communities' adaptation to climate change is the socio-technological processes of mapping, cadastral surveying and land registration: these lead to integration, use and facilitated delivery of land management functions (Williamson et al., 2005). Mitchell & Zevenbergen (2011) indicate that the incorporation of carbon rights into IS strengthens Payments for Environmental Services (PES) to reduce GHG.

Responding to the challenges and opportunities above, this research aims to investigate the relevance of integrated land and climate change IS in the form of a Land Information System (LIS) for vulnerable mountain communities; a LIS that provides climate adaptation services to reduce the vulnerability of those communities. LIS has the potential for spatial enablement of land administration (Rajabifard et al., 2002) since it facilitates data sharing in a network of heterogeneous geospatial data (Groot & McLaughlin, 2000). LIS assists service delivery amongst isolated and stand-alone stakeholders of a system, and this could include mountain communities and organizations. Technological advances including Geo-ICT support integration, management and dissemination of land and climate change information (Adinarayana et al., 2008) (J. A. Zevenbergen et al., 2014) create the potential for a service-oriented LIS to contribute to adaptation to climate change.

## 1.2 Knowledge gap

Taking all the aforementioned points into account, a clear need is evident for further action in the area of technology-supported and land-related climate change adaptation. However, whilst good examples of IS at international, national, local and community levels are already evident, as described above, SMS does not provide climate adaptation services and MWIS is developed based on international and national commitment - and not on communities and individuals needs regarding climate adaptation services. The 2030 Agenda addresses capacity-building in climate change adaptation (United Nations, 2015). The Paris Agreement on Climate Change calls for engaging vulnerable people and communities in adaptation planning processes as a country-driven and participatory approach (UNFCCC, 2015). The Cancun Adaptation Framework emphasizes strengthening IS to provide decision-makers with *"improved climate-related data and information"* (UNFCCC, 2011). The Voluntary Guidelines on the Responsible Governance of Tenure (VGGT) express the need to address land tenure in the context of climate change (FAO, 2012). A holistic appraisal of these developments suggests there is a renewed need for a) identification and linkage of land tenure security in adaptation to climate change, b) integrated land policies, institutions and services for stakeholders at local and national levels, c) developing a service-oriented climate adaptation IS based on communities and individuals needs and d) the incremental use of Geo-ICT by communities and individuals to assist them in adapting in a better way. Figure 1 conceptualizes these gaps graphically. This research is trying to address the existing shortcomings to increase the effectiveness of mountain communities' adaptation to climate change.

> *"We are learning how to adapt to the current situation by practice. Due to the pressure in our living and livelihood, we would like to know about the alternative ways of climate change adaptation. We share our problems with researchers, but we never hear back! Many adaptation programs are not designed based on our needs! Our priority is having an information center about the available and potential resources to sustain and optimize ourselves and our next generation regarding forest management and private land and climate change adaptation."*
> Study participant of FGI of Charikot, Nepal.

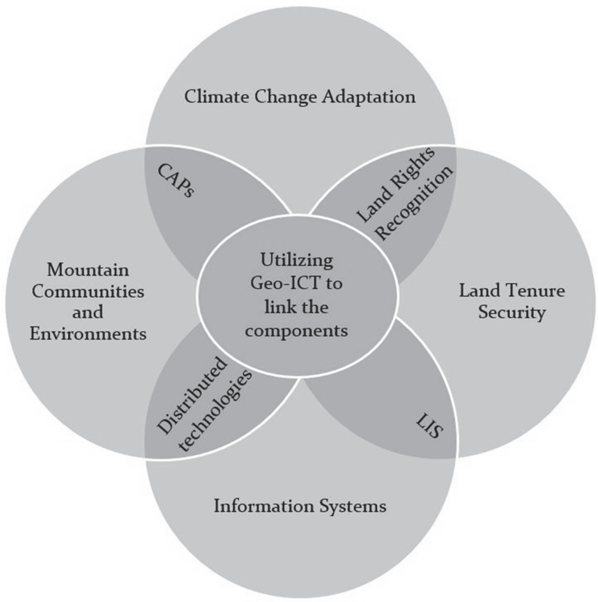



**Figure 1– Overarching research gap**

## 1.3 Research objectives

To address the knowledge gap of land-related climate change adaptation, specifically regarding the lack of knowledge and information of mountain communities, this thesis seeks to explore the contribution a LIS might make to facilitating mountain communities in adapting to climate change. The following overall objective and four sub-objectives are formulated to achieve the primary goal of this research.

**The overall objective:** to develop the concept of an integrated IS that provides mountain communities with accessible climate adaptation services. This includes understanding the role of all stakeholders in the process of how further cooperation and integration strengthen mountain communities, to what extent they see IS as a useful tool, and what their requirements would be.

**Sub-objective 1:** to identify the socio-technical limitations of existing mountain Community-Based Adaptation (CBA) in response to the effects of climate change.
**Sub-objective 2:** to develop a strategic model that enables integration of policies and institutional arrangements from different sectoral levels and to consider its implementation for CBA services.
**Sub-objective 3:** to define how an integrated IS can be designed and implemented for mountain CBA and specifically focus on what requirements, including spatial data and climate services, are needed.
**Sub-objective 4:** to evaluate the integrated IS by exploring its effectiveness in regards to promoting CBA.

## 1.4 Conceptual framework

To support achievement of the overall objective and sub-objectives, the conceptual framework of systems thinking, and more specifically soft-systems thinking, is applied (Çağdaş & Stubkjær, 2011). Soft systems thinking manages complex systems considering human activities and their perspectives in an iterative process (Nidumolu et al., 2006). This means considering the problem space and objectives as a collection of parts: the small parts of the systems interact together (Patel & Mehta, 2017). The conceptual framework – (Figure 2) – resembles the concept of systems thinking that consists of sub-systems or components, interactions, and the purpose of a system (Arnold & Wade, 2015).

Figure 2 sketches the process diagram and identifies a visual overview of the necessary components put together in this research. LIS involves interactions of different conceptual components that affect the quality of its services (Alemie, 2015). Understanding how various components of a system interact is needed in a complex system such as climate change (Waste & Zazueta, 2017) (IPCC, 2014a). The conceptual framework incorporates systems thinking to expand an IS view on larger numbers of components and interactions in the development of the integrated IS.

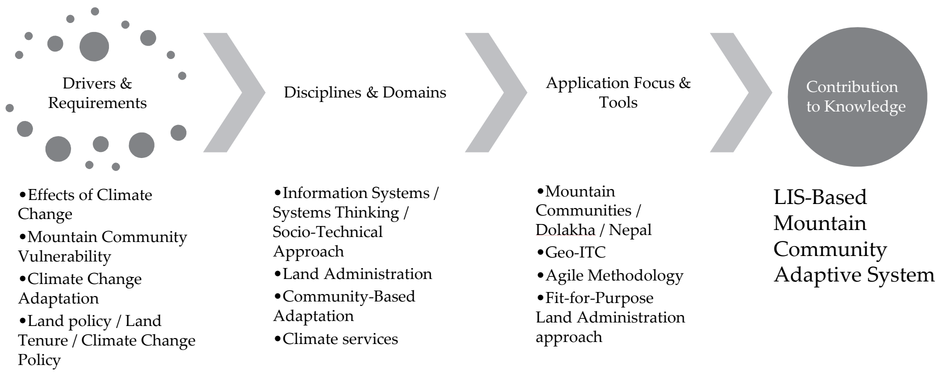



**Figure 2– Conceptual framework**

## *1.5 Research methods*

Fundamentally, the research is design oriented with systems development informing the scientific process. In such an approach, it is critical to periodically review the research to keep it up-to-date as new concepts and updates are continually arriving. Iterative phases can be distinguished including conceptualizing, identifying requirements, developing, and testing the IS. The research method begins with a literature review to conceptualize the essential elements, followed by a case study to identify the requirements and components of the IS. Qualitative data analysis reveals requirements including policy, stakeholders, data, and services. An Agile-inspired approach is utilized in the software development process (design and development of IS). The specific research design steps are discussed as follows:

– **Conceptualizing**

**Literature review:** desktop research is conducted and considers climate change and its impacts. This includes reviews of pertinent literature relating to land tenure, land administration and related functionalities; information systems trends, technologies and their requirements; and adaptation policies and options for mountain communities. Secondary sources including *"earlier research, government or semi-government publications"* (R. Kumar, 2005), journal papers and books are an inseparable source of knowledge for understanding methodological gaps in IS and adaptation to climate change. In this regard, conventions, policies, guidelines, and reports from active international and national climate change organizations are included. The stakeholders of adaptation to climate change at different administrative levels and the limitations of existing mountain CBA are identified to support sub-objective 1.

– **Requirements analysis and modeling**

**Case study:** After several iterations in decision making, Nepal is identified as the appropriate case study: the jurisdiction, place, and people are predominantly mountain oriented. In addition, it is recognized globally as being a location impacted by climate change. Nepal's forest area has increased 25.5% through mitigation efforts between 1978-1992, with Community Forest user Group (CFG) playing an important role in that matter (Gautam et al., 2002). To verify what is done regarding climate change adaptation in Nepal, climate policies and options are considered for this research.

**Data collection:** An inductive approach is applied to collect the data since it provides a more in-depth understanding of the research topic to uncover the pattern in the collected data (Preston, Westaway, et al., 2011). Stakeholders have already been identified in the literature review that included persons, groups and organizations who either influenced or were impacted by action/activities or the outcome of processes in adaptation to climate change (Çağdaş & Stubkjær, 2011). In-depth interviews, Focus Group Interviews (FGI) and household surveys were conducted using different sets of questionnaires. The questionnaires are designed considering climate change, land administration, information systems, and adaptation - to identify the role of stakeholders in adaptation to climate change, vulnerabilities, and their recommendations. Additionally, land and climate change data are collected from active international, national and district organizations involved in climate change. These data are used to populate the integrated IS.

**Data analysis:** In-depth interviews and FGI are the conventional methods of collecting data in qualitative research (Gill et al., 2008). ATLAS.ti was applied to handle qualitative data used for data analysis. To achieve sub-objective 2, different Nepalese policy documents are analysed using ATLAS.ti and SWOT analyses that lead to building and adopting a strategic model as a base for the IS. The vulnerable stakeholders, their level of vulnerability, IS requirements and prioritized services are identified to achieve sub-objective 3. The *"Noticing things, Collecting things and Thinking about things"* (NCT) approach of ATLAS.ti is used for qualitative data analysis. Noticing things is the process of marking interesting things in the collected data based on the sub-objectives. Collecting things or coding is used to create keywords to manage the quotations. Coding provides a path to bring the findings together in a structured way of making networks out of things. Thinking about things looks at the qualitative data again from the perspective of sub-objectives 2 and 3 to find data patterns and their relations, using the different analytical tools that the software offers. In this regard, network analysis is used for sub-objective 2 and query tools are used to aggregate data for sub-objective 3. Graphical representations of the network analysis and query tools are available in the Appendices.

– **Analysis and design**

**System analysis:** A theoretical framework is developed based on the analysis of detailed information on services for adaptation to climate change. This theoretical framework involves possible land administration functionalities and land-related policies for adaptation to climate change along with service-oriented IS. The elements of Fit-For-Purpose Land Administration (FFP LA) are used as criteria to analyse the system.

**System design:** An Agile-inspired approach is used in design and development of the integrated IS. An Agile-inspired approach is an incremental and iterative work sequence in the development of a Service-Oriented IS. A core team of three consisting of a system developer, a system analyst, and a critical scientific support expert start the Mountain Community Adaptive System (MCAS) development. This approach uses a cloud-based infrastructure, incorporates web-services, and open-source software to prepare for sub-objective 4.

**System testing:** Actual users with different backgrounds test the prototype to explore to what extent it can provide climate adaptation services. Actual users are selected for the system testing, due to the direct contact of the service developer with potential users. The participants have used desktop computers at Kathmandu University (KU), Dhulikhel, Nepal to test the prototype.

**System validation:** This aspect is performed in parallel with system development and system testing to check if the required components of the prototype are fully integrated, and Fit-For-Purpose. An Agile-inspired approach provides the opportunity to validate the system during each incremental and iterative development process. System testing with the actual users contributes to further findings and enhancements.

## *1.6 Structure of thesis*

The results of this research are presented in six chapters. This chapter discussed the introduction, background of the research and associated fundamental concepts that support the other chapters of the research. Chapters 2 to 5 address one of the research sub-objectives presented in section 1.3. Chapter 6 synthesizes the findings of the research, reflection and outlook and further research directions. The structure of the thesis is presented in figure 3.

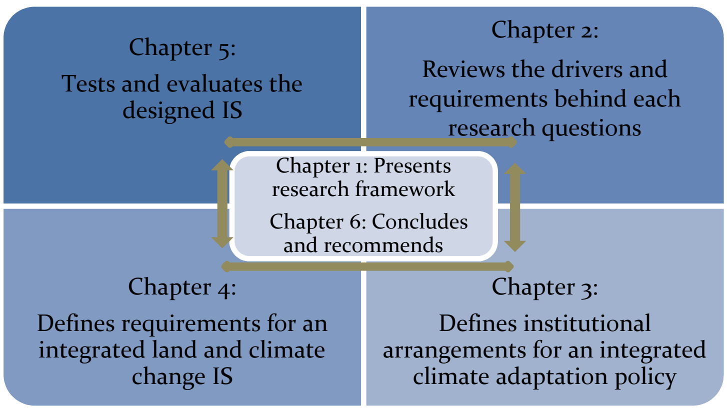



**Figure 3– Structure of the thesis**

**Chapter 2: Utilizing Geo-information for Mountain Community Adaptation -** Presents the development of a theoretical framework, using literature review, to support the subsequent work. It covers community vulnerability, adaptation factors, geo-information for mountain communities, adaptation strategies, and plans at the community level. Three case studies are presented to identify stakeholders and their roles: i) the community experienced impacts; ii) community responses; and iii) community limitations to tackle the impacts of climate change. A hypothetical IS – dubbed MCAS - is suggested and it is argued that the approach could potentially provide climate adaptation services to facilitate mountain communities.

**Chapter 3: A Land-Based Strategic Model by Integrating Diverse Policies for Climate Change Adaptation in Nepal –** Explains how institutional fragmentation in the implementation of integrated climate adaptation policy is challenging. This creates a gap in the implementation of an integrated policy both in climate information supply and in the delivery of climate services at community and individual levels. Qualitative data analysis in ATLAS.ti is used to identify what adaptation options and key climate services are needed. SWOT analysis identifies the gap relating to climate adaptation services. A land information based model for climate change adaptation services is introduced. Land administration as an institutional approach for dealing with land related challenges is suggested in the implementation of the model as a service to strengthen district and community institutions.

**Chapter 4: Defining the Requirements of an Information System for Climate Change Adaptation in the Mountain Community of Dolakha, Nepal –** Outlines the possibility of using an integrated IS, or so-called MCAS, to support mountain communities in CBA. Adaptation initiatives, tools, and options are presented to explore their limitations and potentials in facilitating CAP. Details of the study area (Dolakha, Nepal) and reasons for its selection are provided. NCT is adapted for data analysis to address MCAS requirements and its services based on mountain community vulnerability. The MCAS set-up- with the ability to integrate and provide land and climate services - is introduced. Required data and its providers are identified. The data can support MCAS in CBA service delivery and assist policy and institutional arrangements.

**Chapter 5: Evaluating a Fit-For-Purpose Integrated Service-oriented Information System for Mountain Community-Based Adaptation –** Focuses on testing a developed web-based integrated IS interface, an implementation of MCAS, to promote Community-Based Adaptation. It presents integrated land and climate change data as climate adaptation services. This chapter also reviews some of the current web-based and mobile applications as supporting tools for mountain communities and the concept of Fit-For-Purpose (FFP) of Land Administration (LA). The outcomes of the Agile-inspired development process is presented. The system is tested, and the results of the test are evaluated against the adapted elements of FFP LA approach.

**Chapter 6: Concluding Remarks and Recommendations –** Consolidates the findings and conclusions of the entire research. It addresses the research's contribution to knowledge, policymakers and mountain communities. It also provides a set of recommendations for future work.

# Chapter 2 Utilizing Geo-information for Mountain Community Adaptation[*]


* Published as Khezri, A., Tuladhar, A., & Zevenbergen, J. (2017). Utilizing Geo-information for Mountain Community Adaptation. *Nepalese Journal on Geoinformatics*, *16*, 24–39.

# Abstract

Mountain communities are vulnerable to diseases, malnutrition, and insecurity of land, which may lead to losing shelter and livelihood. This paper reveals that the current way of living of the mountain communities is unsustainable and vulnerable, and there is a lack in improving their adaptive ability for climate change adaptation. In order to understand how to improve the adaptive ability of the mountain community, this research makes a critical analysis of three case studies in Nepal, Indonesia and Peru. The results indicate the importance of geo-information as services or products at each scale ranging from global, regional, national, state/province, community to individual. The aim is to emphasize on access to geo-information that helps reduce the community vulnerability by providing a more effective adaptation program. Here we propose a framework for a Mountain Community Adaptive System (MCAS) which establishes the relationships between the vulnerability, livelihood and climate change adaptation.


**Key words:** Adaptation, Geo-information, Mountain Community Adaptive System (MCAS).

# 2 *Introduction*

Climate extremes and changes in temperature or rainfall disrupt water supply, infrastructure and settlements. People often re-settle in a safe place where land plays a vital role to safeguard their shelter and livelihood in a sustainable way. Currently there has been very little attention to vulnerability of mountain people and their roles in the process of adaptation to action have been largely neglected (Gentle & Maraseni, 2012) (Bajracharya et al., 2011). We argue from both theory and case studies that participation of mountain communities in Community-Based Adaptation (CBA) strategy and plan requires effective management of geo-information for vulnerability reduction, livelihood improvement and land tenure security.

FAO (2012) defines land tenure as *"Who can use What resources for How Long and under What Condition?"* Who, what resources, where, how long and what conditions are information that exist at different scales from global, regional, national, state/provincial, local/community to individual. There is a need of reliable and timely access to structural climate change data as well as livelihood information and activities, and regions of interest for environmental conservation and economic development. Here emphasis is on the participation of the mountain community and the individual in the implementation of adaptation (FAO, 2012) by giving information about their environment including the effects of climate change, what and where the available resources are, how to access the assets and increase their livelihood choices, under what conditions they can experience economic benefits and what the potential adaptation actions are in their regions.

This paper explores access to geo-information that helps reduce mountain communities vulnerability. First, the methodology has been explained in section 2.1. Second, the components of vulnerability in general, community livelihood vulnerability in practical and geo-information to support communities have been discussed. Specifically, we propose a model for adaptation factors at community level and the potential role that geo-information plays. Third, climate change adaptation strategies and plans at community level are described, and the needs are identified at community level with the implications for the mountain communities. Fourth, three case studies derived from secondary sources

(Maharjan & Joshi, 2013) (Macchi et al., 2011) (Torres & Frías, 2012), representing mountain community climate change perception in Nepal, mountain community conditional land tenure system in Indonesia and mountain community value chain in Peru. Then, a Mountain Community Adaptive System (MCAS) is developed based on a conceptual framework at different scales. The potential ability of MCAS in geo-information services delivery to improve the adaptive capacity of the mountain community are finally presented.

## 2.1 Materials and methods

The research method used first is literature review of the components of the vulnerability based on IPCC (2014) and Watts and Bohle 's (1993) vulnerability model. Based on that, community livelihood vulnerability is explained. Adaptation factors and the role that geo-information plays in a CBA are derived from integrating the components of vulnerability and is represented in table 1. Next, climate change adaptation strategies and plans, and relevancy to mountains communities are analyzed.

Three case studies have been selected from secondary sources (Maharjan & Joshi, 2013) (Torres & Frías, 2012) (Gentle & Maraseni, 2012) (Kerr et al., 2006), representing mountain communities' livelihood and vulnerabilities to climate change, land tenure security and whether there is any adaptation plan. We assessed each case study to identify the stakeholders, the experienced impact for each stakeholders such as the impact of climate change on the communities and their environment and the experienced impact in the adaptation process, the roles each stakeholder played, the stakeholders' responses to and their limitations in the process of adaptation to climate change. This assessment is presented in table 2.

The methodology followed for each case study is based on adaptation factors which are identified in Table 1. As such, an inductive research approach was taken, as the vulnerability aspects have been identified. In doing so, we attempted to understand the needs of mountain communities in climate change adaptation. Next, a Mountain Community Adaptive System (MCAS), its functionalities and its framework are proposed. A MCAS is a geo-information tool which will be able to supply information in terms of services at different spatial scales (Table 3) that address the needs of communities in adaptation to climate change.

## 2.2 Community vulnerability

The term *"Community"* is defined as a group of people with backgrounds that have the same characteristics. A community is involved in common actions in a geographic space and ties up together socially (MacQueen et al., 2001). Literature shows that climatic events and environmental changes cause losing lives and livelihood of mountain community. This section reviews the components of vulnerability including adaptive capacity, sensitivity and exposure, community livelihood vulnerability and its components and then the role that geo-information plays for the communities.

### 2.2.1 Components of vulnerability

According to IPCC (2014), vulnerability is *"lack of capacity to cope and adapt"* and includes three components: adaptive capacity, sensitivity and exposure.

***Adaptive capacity*** as the ability of stakeholders is *"a function of wealth, technology, education, information, skills, infrastructure, access to resources, and stability and management capabilities"* (McCarty et al., 2001). Capacity depends on *"capitals"* (Hinkel, 2011) consisting of the following aspects:

- *Social capital* which relates to the stability of relationships among communities and their management capabilities to deal with climate change.
- *Human capitals* related to access to education, availability of information and skills for a community.
- *Natural and financial capitals* are about accessibility to resources and finance/wealth respectfully.
- *Physical capitals* on the availabilities of infrastructure and technology.

Since climate events take place on land either through natural or anthropogenic activities, the authors argue that these issues should be directed towards the better use of land. Combining land issues and capitals as a function of adaptive capacity would bring benefits to a community to adapt to climate change. If a community is aware of information on land and capitals, it is likely to increase community adaptive capacity.

***Sensitivity*** is the way a community has access to available resources that are directly or indirectly influenced by climate change. Resource for a community is the level of access to and use of information about their environment to achieve the aim of vulnerability reduction. For instance, floods and droughts have an impact on communities sensitive to agriculture. They have lower agricultural production and that means less accessibility to resources or natural capitals. Therefore, they need to invest in crop diversity or change to other sources of food for their survival. They have fewer financial capitals since they spent their money previously on agricultural products. Moreover, they have fewer human capitals as they do not have enough skills on how to grow new crops or how to find the best way of accessing to resources. It is important to reduce community sensitivity by enhancing their human capitals. In this way they are well-prepared to tackle the impacts of climate change.

***Exposure*** is the stress or difficulty a community faces to cope with climate variability and disasters. Exposure as the level of a community interaction with climate events is location-based. For instance, one community is endangered by drought while another community in a different location is at the risk of falling rocks. A community's knowledge on the type of climate events that happen in their region is necessary. A community's exposure to the effects of climate change increases if they do not have reliable information on climate variability and climatic events. However, their actions to reduce the effects of climate change depend on physical capitals including infrastructure such as type of roads, buildings and the level of access to and use of technology like agro-forestry or smart-agriculture.

Watts and Bohle (1993) define two sides (figure 4) for vulnerability which the relationship between them is usually established through the political economy approach in terms of social inequalities, crisis and conflict resolution, capacity to take actions and manage emergency situations of climate events. Thus, the external side of vulnerability or exposure is influenced by:

– Human-Ecology perspective: community capacities to manage environment.
– Entitlement theory: inability of people in a community to access or manage assets.

The internal side of vulnerability or coping side is influenced by:

– Action theory approach that allows space for people to act.

– Models of access to assets for mitigating vulnerability.

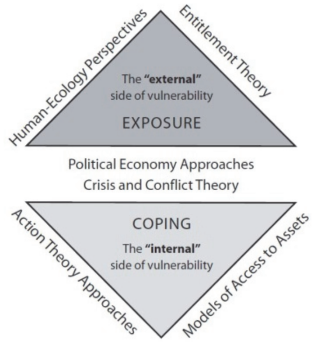



**Figure 4– The two sides of vulnerability according to the Bohle model** (Watts & Bohle, 1993)

Thus the model (figure 4) suggests vulnerability largely depends on people's assets management and control mechanism (Villagrán de León, 2006). UN/ECE (1996) defines vulnerability as results from the impacts of climate change on community and land as a basis of human activities, natural resources and source of life and wealth. We argue that vulnerable communities require knowledge on the best way of using and protecting their lands from climate variability and climate events. Currently they mostly depend on their local knowledge rarely assisted by local experts on their livelihood.

### 2.2.2 *Community livelihood vulnerability*

A community always has interaction with available resources including access to land in their environment as a means of securing their livelihood (Ingold, 2000). A livelihood is determined by *"the activities, the assets, and the access that jointly determine the living gained by an individual or household"* (Ellis, 1999). A social-ecological system like a community is vulnerable when it experiences shocks and stresses (Adger, 2006).

Hahn et al. (2009) developed the Livelihood Vulnerability Index (LVI) for assessing the impacts of climate change on the communities. It consists of:

– Socio-demographic profile, livelihood strategies (type of work) and social networks (lending or borrowing loans, getting support from the government, non-government agencies and family members).
– Availabilities of health centers, food (availability of food type, crop diversity production) and water (water sources and their accessibilities).

– Natural disasters and climate variability.

In addition to the above components Shah et al. ( 2013) added *"housing and land tenure"* elements, addressing the sensitivity as explained in section 2.2.1. These were directly related to the type of material used to construct houses and the right holders of the houses that are living there. It further emphasizes on participation of local and indigenous people in planning and management of climate change. The study concluded that a community is more vulnerable if it does not have access to secured housing and land tenure.

### 2.2.3 Geo-information for communities

Geo-information consists of any information related to a specific location. It facilitates communities with access to resources needed on climate change adaptation from stakeholders of different scales of global, regional, national, provincial, community and individual, contributing toward community sustainable development. The factors and the role that geo-information play in a community adaptation are derived from integrating components of vulnerability. Based on the above we developed a model which is depicted in table 1 on adaptation factors and geo-information needs at community level. Based on that, community and livelihood vulnerability consist of external and internal aspects.

**Table 1– Adaptation factors and geo-information at community level**

| Vulnerability aspects | Adaptation factors | Geo-information types |
|---|---|---|
| Internal | Access to resources (Sensitivity) | Socio-economic data, health facilities, educational facilities, crop diversity, forest, water resources |
| | Capitals (Adaptive capacity) | Land right , land use, land value |
| | Access to assets | Loan, credit, social services, governmental aids |
| | Exposure to external shocks and stresses | Hazard map, risk and crisis maps |
| | Access to Geo-information | Meta-data on geo-information |
| | Space for community to act | Local policies and plans |
| | Capacity to manage in emergency situations | Administrative jurisdiction, topography, road/transportation |
| External | Governance | Interaction forums between state, Non-Governmental Organization (NGO) and private market sector |
| | Institution | Legal acts |
| | Integrated policies and plans | National policies, strategies and plans |
| | Spatio-temporal changes | Climate variability (snow, temperature, rainfall) |

***Internal aspects*** refer to the factors that make a community vulnerable to climate events and variability. Access to resources, assets and their use for a community livelihood are mostly affected by shocks like droughts, floods and climate variability events due to vulnerability components as mentioned in section 2.2.1. Generally, a community does not have the capacity to manage in an emergency situation because:

– The type of threat is not known.
– They are not ready for the threat.
– They do not have plan for a climate change threat.

Therefore, a community needs to have information on environment like topography and transportation to enhance its capacity and to get the maximum benefits in climate change adaptation. Moreover, community access to geo-information creates a space to act, to enhance their capitals and adjust their plans according to their needs, to improve their livelihood and to reduce their vulnerability. Integration of capitals increases interaction among them. For instance, human capitals such as education and skills facilitate management of natural capitals like natural resources to strengthen financial capitals such as the economy of an individual or a community.

***External aspects*** refer to the external community factors that cause threats to a community. Spatio-temporal changes have negative effects on community livelihood. Whereas a community is expecting a rainy year for crops to grow, they are faced with a dry year. They do not know how to adjust themselves to the new situation. Rapid changes of natural events and exposure to external shocks and stresses like forest fires, land and mud slides are external threats. For a community that uses land for their livelihood, changes in the natural system and ecosystems become unpredictable. Geo-information facilitates producing natural disasters and hazard maps of the area by combining spatially referenced data. It supports a community and higher administrative levels by providing information on the climate change hazard zones and the natural disasters that they are faced with.

The external aspects highlight other important factors such as institutions, policies, strategies and plans. Institutions like political and economic institutions need to establish a legal framework for a community as regards access to assets and their needs to improve their livelihood. Policies, strategies and plans in terms of national and local climate policies accelerate the objectives of adaptation to climate change and community participation. Governance concept increases interactions among climate change stakeholders i.e. state, private sector and Civil Society Organizations (CSOs), including communities in the areas.

## *2.3 Climate change adaptation strategies and plans at community level*

Adaptation is about stakeholder actions from a local to a national level (Klein et al., 2014) to reduce the impacts of climate change. IPCC (2007) indicates that different adaptation strategies and plans are made considering various adaptation dimensions consisting of spatial scale, sector, type of action, actor, climatic zones and development. Adaptation strategy has a spatial dimension

(Biesbroek et al., 2009) in different sectors like land, water resources, agriculture, infrastructure and settlement, human health, transport and energy.

Climate change effects such as landslides, severe droughts and floods lead to displacement and forced migration of people from their original places at community level. The competition for fertile land and natural resources increased by climate change impacts over time. It directly influences vulnerable and marginalized groups. In many instances vulnerable individuals and communities are trying to adapt themselves by learning to practice (Banjade et al., 2006) with the available resources. Lack of information hinders communities in accessing potential resources available around them. They do not have information on adaptation strategy and plan, policy and finance.

### *2.3.1 Policy, strategy and plan at community level*

Availability of information and participation increase the effectiveness of CBA activities and communications with districts and national levels. Implementation of local adaptation plans at community level mostly depends upon strategies and plans of national governments with regional and global inputs about climate extremes data and information in terms of scale. The knowledge needed for activities on their lands and livelihood means that communities need a supply of information by geo-information to act on and to adapt to climate change. It is necessary for national and state/provincial levels to inform vulnerable individuals and communities about global, regional and national climate change strategic adaptation plans. For instance, Nepal developed National Adaptation Plan of Action (NAPA) based on national needs to support mountain people in adaptation to change. The Local Adaptation Plans for Action (LAPA) framework has been prepared as a bottom-up approach to implement NAPA and facilitate adaptation services for mountain communities. LAPA emphasizes on participation of local bodies and vulnerable people to provide information on their needs and prioritize adaptation activities for decision makers (GoN, 2011a).

### *2.3.2 Relevancy to mountain communities*

The United Nations General Assembly (2013) recognizes that mountain regions are highly vulnerable to the negative impacts of climate change including deforestation, a changing pattern of agriculture, land use change and land degradation. Chapter 13 of agenda 21 of the United Nations Conference on Environment & Development (UNCED) highlighted managing fragile ecosystems and strongly recommends involvement of relevant stakeholders including local authorities, civil society, local people and the private sector in mountain development activities.

Communities play a key role in the adaptation to climate change. When there is a policy, strategy and action plan, they combat impacts of climate change and also improve their lives and livelihood, leading to economic development. There is a need to inform the community about the potential resources and events that are taking place regarding climate change to create a better adaptation action.

## 2.4 Case studies

This section presents three case studies from Nepal, Indonesia and Peru. These case studies have been chosen from mountainous countries which are climate change (Byrne et al., 2014) and/or land hotspots.

### 2.4.1 Community vulnerability due to climate change variability in Nepal

Two cases from Nepal are presented to study the effects of climate change variability. The first case is about the Chepang community of indigenous people in rural Mid-hills of Nepal for community perceptions about climate change and its impacts, while the second case study, located in eastern and western Nepal, demonstrates impacts due to climate variability.

***Chepang community:*** the Chepang community is categorized as a highly marginalized indigenous people of Nepal living in hilly villages of the Chitwan, Makwanpur, Dhading and Gurkha districts. This case study discusses if the households of Chepang community perceived any changes in climate, the impacts on crop production and livelihood assets, and if adaptation strategies are adopted. Since agriculture is the main activity for this community, many forests are cleared for cultivation. But due to the nature of the topography and the unsuitability of lands for agriculture, the community mainly depends on livestock, labor working, getting loans and paying them back by their livestock and collecting wood from the forests.

This case shows that the majority of people in the Chepang community experience dramatic changes in the rainfall patterns, late monsoon, longer and hotter summers and frequent hailstorms. The experiences on increased summer temperature and less amount of rainfall are in line with the climate data of the Department of Hydrology and Meteorology (DHM) in Kathmandu. It further reports about problems on drying crops, human health, less livestock productivity and the death of small livestock as the result of climate change. The case does not indicate if the Chepang community implemented any adaptation strategy and plan, as they did not have any information about the possible strategies and plans for climate changes (Maharjan & Joshi, 2013).

***Bajhang and Terhathum communities:*** this case is about responses of the communities to climate change in the rural villages of west and east Nepal, namely Bajhang and Terhathum, where the effects of climate change have largely damaged agricultural productions, and brought the communities poverty and insufficient food. The communities are mostly involved in agricultural labour on low salaries. The communities are often faced with warm summers and cold winters, changes in rainfall patterns and monsoon, food spoiling and a growing number of mosquitoes and pests.

The study reveals that the communities respond to the changes by (a) deforestation to gain more land for cultivation and agriculture; (b) crop diversity; (c) selling assets and taking loans to cope with food insecurity; (d) building canals to divert water from soil erosion and control floods and (e) migration to other cities and countries for paid work. A number of Community-Based Organizations (CBOs) are involved in providing loans with interest to the communities and to have the forest areas protected by local people. Governmental institutions are responsible for building infrastructure, support agro-forestry and provide fruit trees for the farmers.

The Western Uplands Poverty Alleviation Programme (WUPAP) and Environment, Culture, Agriculture, Research, and Development Society, Nepal (ECARDS) collaborate with the International Fund for Agricultural Development (IFAD) and the Nepal National Government. They interact among communities, government and non-governmental institutions to train farmers and distribute the seeds (Macchi et al., 2011). Now, communities know what type of seeds are needed; how, when and where to plant the seeds; therefore they are not faced with a shortage of agricultural products. Food security strengthens the livelihood of the communities.

### *2.4.2 Community conditional land tenure system in Indonesia*

Sumberjaya is a sub-district of Lampung province in Sumatra, Indonesia. The study area includes private land, protected forest (governmental land) and a national park where rice and coffee farming are two major agricultural activities on private land. The case study describes the forced eviction of farmers, local people and communities based on the government perception that coffee farming on slopes causes soil erosion and is harmful for the operation of the hydropower dam (Catacutan, 2011). Forced eviction has created violence and conflicts over lands and has led to forests being burnt by the evicted people. Consequently, the government's efforts of planting trees in forests did not produce a sustainable forest management (Kerr et al., 2006).

The studies by the World Agro-forestry Centre (ICRAF) showed that coffee farms in those areas were the main sources of income for the communities and they also prevented soil erosion of the natural forest (Catacutan, 2011). Later on, the government transferred the forest land to the evicted communities with conditional land tenure (Kerr et al., 2006). Then ICRAF and IFAD funded the Rewards for Use of and shared investment in Pro-poor Environmental Services programme (RUPES) to bring multiple stakeholders together for forest protection and watershed management at both pilot and implementation levels.

The first program is the Community Forestry Program implemented by the Local Forestry Department under supervision of the National Government's Community Forestry Program. It provides coffee farmers and local communities with a five-year conditional land tenure to avoid eviction. In return coffee farmers committed themselves to the protection of forests by agro-forestry and coffee plants for coffee production. There is an opportunity of 25 years extension of land use right if the local people achieve a sustainable forest management (Porras & Neves, 2006). The second program is the River Care Program, which removes sediments from hydropower reservoir in a sub-catchment through Payment for Environmental Services (PES) for community to practice soil and water conservation. This is an ongoing agreement on the condition of the removal of sediments by the community. Lastly, there is the Soil Conservation Program, a reward scheme for soil conservation, which stimulates the farmers to control erosion and reduce sediments from their farms by *"terracing, sediment pit and strip weeding techniques"*, for which farmers receive cash payments based on their progress (Catacutan, 2011).

### *2.4.3 Community Value Chain in Peru*

This case is about community mountain adaptation in Peru where communities implement a program on adaptation to climate change as an opportunity to expand their economy. Cajamarca is located in the Andean highlands of northern Peru and is one of the poorest and highly-populated areas. Productivity level of coffee and cocoa are low due to poor soil fertilization and lack of knowledge amongst the farmers. Deforestation and land degradation are caused by farmers since they need more agricultural lands to cultivate corn and cotton as the sources of their income. As a result, the risk of natural disasters and loss of biodiversity has increased. Subsequently the lives and livelihood of farmers are exposed to the dangers of climatic events.

This project was initiated through collaboration of the Food and Agriculture Organization (FAO) and the Institute for Hydrology, Meteorology and Environmental Studies in Colombia (IDEAM) with the objective to implement sustainable agricultural practices in mountains. NGOs introduce natural forest environment into the local production system by agro-forestry. They design farm management plans by using farmers' information on local biodiversity and the production methods of different native forest species and motivate farmers to use fertilizer for higher quality products. NGOs also establish local committees, where farmers share their knowledge and sell their products to national level and international social enterprises that search for high-quality cocoa and coffee productions in mountainous areas (Torres & Frías, 2012).

## *2.5 Discussion*

Table 2 presents findings of the case studies based on five components: (a) stakeholders; (b) experienced impacts; (c) role of stakeholders, (d) responses and (e) limitations. The adaptation factors that are given in section 2.2.3 are discussed for each case study.

***Community vulnerability in Nepal:*** access to resources and assets such as land, crops, forest products and income generation are difficult for the Chepang community as the main stakeholder of climate change effects. Chepang's responses are deforestation that bring flood, erosion and no forest products to use or to sell. Therefore, the community's adaptive capacity decreases because they are more exposed and sensitive to climate change events. Since they do not have a concrete role in climate change adaptation, they do not have the space to act and to adapt themselves to the effects of climate change. The Chepang community does not have the knowledge about managing their environment due to lack of information about on-going changes in climate and limited access to land and income. Since external adaptation factors did not play any role, they became more vulnerable to climate change.

As stakeholders the Bajhang and Terhathum communities, CBOs, government and non-governmental institutions and international organizations experience different climate change impacts. Therefore, their responses vary from one scale to another. While the communities' responses like selling assets and migration increase their exposure, their sensitivity affect crop diversity, erosion control and floods. The communities try to improve their adaptive capacity by doing and learning. However, their limitations in access to agricultural land, shortage of income and unsecured land tenure stop them from having an effective adaptation programme. The CBOs provide training for farmers and communities on how to conserve their environment and how to increase their income. Thus communities have more space to act, and the communities' adaptive capacity increase because they have information about their environment through the training program. This case study also reveals that though government and non-governmental institutions collaborate with international organizations, CBOs do not interact with higher levels and this limits giving information to the communities on accessing resources. There is a need of a strong network in which different stakeholders participate, particularly communities at all scales.

***Community conditional land tenure system in Indonesia:*** different stakeholders had been identified at three scales of communities, NGOs and government. The communities' lives and livelihood are endangered because they do not have land tenure security, access to resources, assets and capacity to manage in conflicts due to forced eviction. Consequently, the communities' sensitivity and exposure are high. However, NGOs mediate among stakeholders to bring capitals to the communities by implementing community forest protection and watershed management program. This case also shows that having access to information is one of the best ways for communities to increase their adaptive capacity themselves. Forced evicted communities did not have information on how to preserve their environment by means of agro-forestry. They did not know that the forest is a resource that generates income through forest products and a market-based mechanism like PES.

Since NGOs bring different adaptation programs that are implemented by communities, each adaptation program covers one of the adaptation factors that identified in table 1, section 2.2.3. Firstly, conditional land tenure brings capitals to the communities as they have right to use the land as a shelter and a source of food. Secondly, agro-forestry gives the communities access to resources, for example diverse forest products such as coffee and crop diversity. Lastly, soil conservation program support communities financially which is access to assets because communities are getting paid cash money. The Government uses the conditional land tenure as a policy to manage the environment in the communities, which means that the government has more information about the communities' requirements to prioritize the policy. Consequently, it gives the communities more space to act, as the government, through its legal framework, hands over the implementation of adaptation to the communities. It improves the link between stakeholders, which facilitates the design and implementation of adaptation programs. This case includes all adaptation factors that are necessary to overcome internal vulnerability aspects as well as some of adaptation factors regarding external vulnerability aspects, based on the proposed model in table 1.

***Community value chain in Peru:*** three scales are involved in the climate change adaptation plan. The communities do not have access to resources and capitals such as agricultural lands, farm products and land management technical skills which would make them more sensitive and exposed to the effects of climate change. There is no place for the communities to get information about the consequences of their activities on the environment and climate change events. Each community tries to provide for its basic needs, which are shelter and income.

The national strategy for climate change of Peru supports the community adaptation to climate change to act through agro-forestry and access to local, national and international marketing. First the NGOs give information about the role of agro-forestry and its benefits to the communities, then the NGOs create a network among farmers to manage their environment better and transfer agro-forestry skills to other communities. Farmers have more information, skill management and access to resources, which gives them space to act. Consequently, the market expands to international level because the communities produce high-quality cocoa and coffee. Networking gives the communities more knowledge on climate change as it links them with the national level where they explain their needs and their vulnerability due to climate change.

The above three case studies show a hierarchical level of stakeholders ranging from international, regional, national, state/provisional, community and individual levels where each scale has different level of plan, policy, authority, knowledge and ability to act respectively. These case studies highlight the importance of access to information at each scale. It reduces the community vulnerability and transforms adaptation program to an economy platform. Therefore, it is necessary to consider the adaptation factors in table 1, section 2.2.3 in designing an adaptation programme.

Case studies show that communities are mostly vulnerable to climate change. They also suggest that vulnerability aspects and adaptation factors (indicated in table 1) largely depend on the development and implementation of local adaptation plans so that communities have more space to act according to their needs. The strong need for the supply of information through geo-information for climate change adaptation at community level can be concluded from the above case studies. Timely available reliable geo-information creates a platform to link different scales for the development and design of an adaptation policy and plan based on the stakeholders' requirements. This, in turn, improves the community knowledge and information on managing the environment and raises the awareness of the communities about the impacts of climate change. Nevertheless, case studies indicate ongoing debates at different scales particularly international, regional and national levels to establish constant contacts among them. While regional levels collaborate with national levels to strengthen the communities' adaptive capacity by developing different strategies related to climate change and its impact, national level are involved with designing climate policy and adaptation plans such as NAPA and LAPA to reduce the effects of climate change on the communities. The information on climate data including temperature and precipitation, changing rainfall patterns and monsoon, duration of floods, droughts and landslides, crop types and land use among other spatial data are important for the communities, so they can prepare themselves for possible changes.

This paper emphasizes a need of supplying information by geo-information and climate change service delivery through a system by involving different scales, particularly individuals and the community. Such a system provides an ability for decision makers and the chance to monitor climate change interaction, leading to design a better adaptation strategy and policy. The Mountain Community Adaptive System (MCAS) will be introduced in the next section which allows the communities access to information and services including geo-information to reduce vulnerability of the communities.

**Table 2– Findings of the case studies**

| Cases | | Stakeholder | Experienced impact | Role of stakeholder | Response | Limitation |
|---|---|---|---|---|---|---|
| **Community vulnerability due to climate change variability in Nepal** | **Chepang community** | Community | Changes in the rainfall patterns, late monsoon, longer and hotter summers, frequent hailstorms, drying crops, health problems | No concrete role in climate change adaptation | Deforestation, labor working, get loans and pay them back by their livestock and forest products | Limited knowledge and information in climate change, limited access to agricultural land, shortage of income |
| | **Bajhang and Terhathum communities** | Community | Agricultural production failure, poverty, food insecurity, crop pests and mosquitoes | Practicing by learning in climate change adaptation | Deforestation, crops diversity, selling assets, taking loans, control erosion and floods, migration | Limited information on climate change and access to agricultural land, shortage of income, insecure land tenure |
| | | Community-Based Organizations | Difficulty in interaction | Interacting with communities | Facilitate farmers to take loans, protection of forest areas by local people | Weak institution |
| | | Government and non-governmental institution | Difficulty to identify community need in adaptation plan | Collaboration with international and national organizations | Building infrastructure, agro-forestry, provide fruit trees for the farmers | Weak institution, adaptation of policy and plans |
| | | International organization | Top-down approach | Strengthening the livelihood systems of local people | Seed distribution, training of farmers | Weak interaction |
| **Community conditional land tenure system in Indonesia** | | Farmers, local people and communities | Forced eviction | Implementation of adaptation program | Forest protection, agro-forestry, coffee production, soil conservation, watershed management | Land tenure insecurity, lack of information on how to increase adaptive capacity |
| | | NGOs | Monitoring | Bring multiple stakeholders together | Mediation | Weak institution |
| | | Government | Violence, conflicts over lands and forest fires | Forming a national level network to incorporate different stakeholders | Providing five year conditional land tenure with the possibility to extend to 25 years | Weak institution, adaptation of policy and plans |
| **Community Value Chain in Peru** | | Communities | Low productivity of coffee and cocoa, natural disasters | Implement adaptation program | Deforestation | Lack of information on tropical rainforest ecosystem and agricultural techniques |
| | | Local NGO, social enterprise | Market | Strengthening of social organization, products improvement, commercialization, | Capacity building by agro-forestry | Pilot project |
| | | Government | National/international market | Project design | Capacity building by giving access to land and international marketing | Pilot project |

## 2.6 *Mountain Community Adaptive System (MCAS)*

The aim of a Mountain Community Adaptive System (MCAS) is to strengthen the communities and/or the individual to climate change adaptation. It provides reliable information to communities so that their actions are timely and correctly taken. A MCAS needs an information system that consists of different components that work together for the predefined purposes or services. It has characteristics including system components, interrelationships, boundary, purpose, environment, system interfaces, inputs, outputs and constraints (Norman, 1996).

The main functions of the proposed MCAS are given below:

- It provides access to all available data of different scales at global, regional, national, state/provincial and community levels.
- It maintains these data and processes them to make suitable geo-information for climate change adaptation at community level.
- It disseminates geo-information as a service to the community and/or the individual for their timely actions via web services on smart mobiles.

Table 1 shows adaptation factors and geo-information for climate change adaptation in view of a community's vulnerability and livelihood. These services or products are derived from the data of different scales by MCAS. A MCAS allows members of the community to participate and make decisions in the appropriate adaptation actions with the aim of reducing the community's vulnerability and improving the community's resilience to climate change. Consequently, MCAS improves the adaptive capacity of the mountain communities.

### *2.6.1 Geo-information services for climate change adaptation*

Sections 2.2, 2.3 and 2.4 highlighted the role of land and land tenure security including geo-information as services for the community and/or the individual. The proposed MCAS as a service-oriented system interlinks land administration services on land rights, restrictions and responsibilities at individual level. Such interlink strategies provide opportunities for better services via available land administration services. Geo-information services at different scales are presented in table 3. Based on table 3 each scale is able to provide or use different geo-information services. A service that is provided by a scale can be used at the same scale or at higher and lower scales. For instance, in the case of the community value chain in Peru district and national levels expand marketing while communities increase their adaptive capacity and income by agro-forestry. Here, communities are both a service provider and user at community level whereas the national level is just a service user.

**Table 3- Geo-information services at different spatial scales**

| Geo-information services (maintenance and dissemination) | Spatial scale | | | | |
|---|---|---|---|---|---|
| | Global | Regional | National | District | Community |
| Climate information (temperature, rainfall and snow,) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Climatic zone (Tropical wet/wet-dry, monsoon, steppe, desert, dryland, floodplain, mountain, marine, tundra, arctic/subarctic) | ✓ | ✓ | | | |
| Information on type and frequency of natural disasters | ✓ | ✓ | ✓ | ✓ | ✓ |
| Locational information of districts, and local village offices, community offices, NGOs involved | | | ✓ | ✓ | ✓ |
| Information about the impacts of climate change on humans, livestock and their environment | | | ✓ | ✓ | ✓ |
| Information on land rights,, cadastral data, land use and land value | | | ✓ | ✓ | ✓ |
| Information on transportation | | | ✓ | ✓ | ✓ |
| Information on water resources | | | ✓ | ✓ | ✓ |
| Energy (Water, electricity, windmill, solar panels, gas and oil) | | | ✓ | ✓ | ✓ |
| Ecosystem zone, forest zone, protected areas | | | ✓ | ✓ | ✓ |
| Infrastructure (buildings and settlements) | | | ✓ | ✓ | ✓ |
| Topography, administrative jurisdiction, geographic area boundaries, elevation model | | | ✓ | ✓ | ✓ |
| Information about forest products | | | ✓ | ✓ | ✓ |
| Marketing | | ✓ | ✓ | ✓ | ✓ |
| Integrated climate and land policy | | | ✓ | ✓ | ✓ |
| Legal framework | | | ✓ | | |
| Farm and non-farm training | | | | ✓ | ✓ |
| Health centers and educational facilities | | | ✓ | ✓ | ✓ |
| Natural disaster and hazard map | ✓ | ✓ | ✓ | ✓ | ✓ |
| Adaptation plans and actions | | | ✓ | ✓ | ✓ |

### *2.6.2 Framework for a MCAS*

MCAS's framework consists of users, spatial data, data providers and web-based services to clients at community level. The objective is to connect land-based community service providers together. See figure 5 for overall framework.

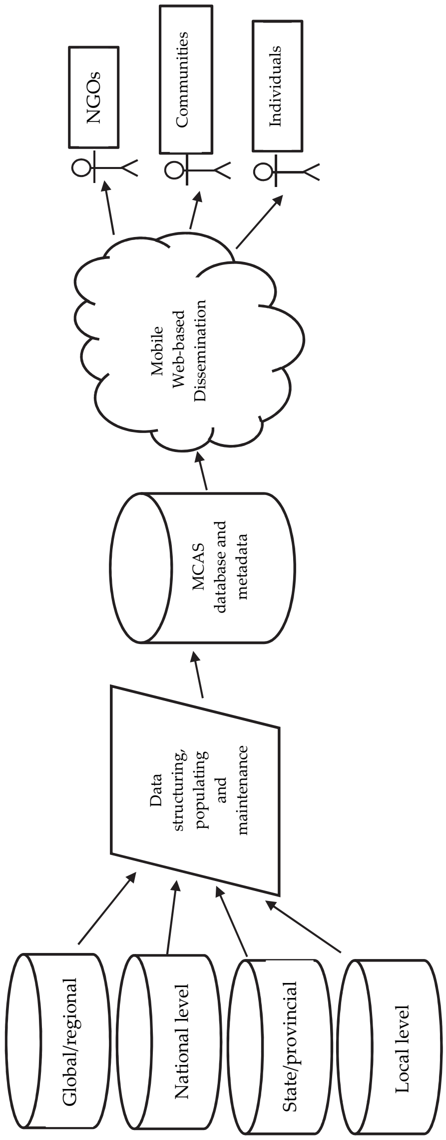



**Figure 5– MCAS overall framework**

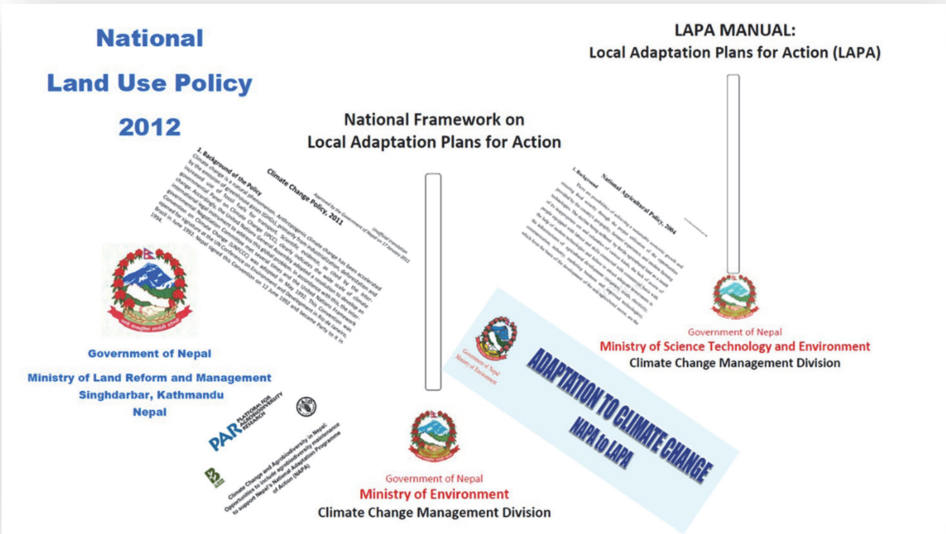
Users at different levels, also at the local level, including NGOs, community groups and individuals can have access to the MCAS's services because it is based on a mobile/web-based system. As shown in figure 5, spatial data sets from global/regional, national, state/provincial and local level organizations are structured and brought to the MCAS database to populate and maintain it.

Spatial data sets and data sources at different scales will be defined after further research on the MCAS requirements.

## 2.7 Conclusion

Climate change and its effects can be found worldwide, particularly in mountainous areas because of their fragile nature. While mountain communities are struggling to have their basic needs, which are shelter and income, they are trying to cope with their climate variability. Climate change policy together with NAPA and LAPA are parts of UNFCCC's and IPCC's concerns about climate change and related issues. IPCC as a knowledge sharing panel produces reports at international level to understand the causes and effects of climate change in the best way at regional and national levels. This is a top-down approach and is not sufficient for lower scales. It is fact that community and individuals are mostly endangered by climate change effects because even though climate change is a global phenomenon, the concrete events are happening at community level. Moreover, climate change events are different region by region and they change over time and space. In the three case studies mentioned, we identified that adaptation strategies and plans are not functioning well when there is not a sharing platform to raise awareness of provincial, community and individual levels constantly. However, the community and the individual are participating actively in the climate change adaptation programme. CBA requires more information and land services. The flow of information enhances the individual's and/or community's knowledge on the current adaptation programmes and plans. A MCAS as a service-oriented system was introduced to raise awareness of community and individual by providing geo-information services to improve their adaptive capacity. It consists of interrelated components or subsystems with various kinds of well-organized geospatial data (of land and climate) and integrated services that give national, provincial, community and individual levels the potential for an efficient and effective community adaptation. MCAS raises the awareness of a community about community vulnerability and the possible way to protect livelihood from climate change.

# Chapter 3: Land-Based Strategic Model by Integrating Diverse Policies for Climate Change Adaptation in Nepal*




* Published as Khezri, A., Tuladhar, A. M., & Zevenbergen, J. (2018). Land-Based Strategic Model by Integrating Diverse Policies for Climate Change Adaptation in Nepal, Limits to climate change adaptation / edited by W.L. Filho and J. Nalau. Cham: Springer, 2018. ISBN: 978-3-319-64599-5. (Earth and Environmental Science). 41–57. https://doi.org/10.1007/978-3-319-64599-5_4

# 3 Introduction

Climate change is an important item on the agenda since the rate of Greenhouse Gas emission (GHG) is increasing globally. Despite a number of mitigation policies, anthropogenic influences have led to increasing GHG emission over the last 40 years, particularly between 2000 and 2010. Nowadays almost all sectors and regions aim to reduce the risk of climate change through adaptation, via place and context specific solutions which reduces climate vulnerability. Integration of adaptation into policy design is required as *"population size, economic activity, lifestyle, energy use, land use patterns, technology and climate policy"* are the main drivers of climate change. Institutional arrangements include adaptation in economic options (insurance), laws and regulations (land tenure security and property right), and national and government policies and programs (sub-national and local adaptation plans and community-based adaptation) (Dasgupta et al., 2014).

This paper focuses mainly on adaptation in national policies and programs in Nepal, a mountain country that faces the adverse effects of climate change. Effectiveness of adaptation depends on policies and interaction across all scales. Lack of co-ordination in climate policies has been shown to make farmers suffer in the case of West African farmers since there are different stakeholders taking adaptation action individually or not focusing precisely on adverse effects of climate change (Moumouni & Idrissou, 2013). Therefore, adaptation requires co-ordination to manage these interactions, limit overlapping adaptation options and consider priority adaptation actions for different sectors. The Cancun Adaptation Framework includes institutions at the national level for *"strengthening and, where necessary, establishing and/or designation of national-level institutional arrangements"* (UNFCCC, 2011). Literature reveals that only 6 out of 99 countries have an adaptation framework to address adaptation and this is often a single policy or separate laws. Nepal also has no adaptation framework (Nachmany et al., 2015).

Land is an inseparable part of human activities and natural resources plus it is a source of life and wealth (UN/ECE, 1996). The purpose of this paper is to explores if the role of land is considered in adaptation plans and programs and it revealed that it is not. Therefore, this paper introduces a land-based strategic model for climate change adaptation services by integrating a variety of plans of action from the sectoral national policies related to land, environment, agriculture, forestry, meteorology and hydrology. Then, an institutional approach suggests towards the implementation of the land-based strategic model as part of land administration services which include geo-information to strengthen local and community institutions. As such, adaptation strategies at national and sub-national levels plus adaptation policies in different sectors have been reviewed in section *"Adaptation Strategies"*. The methodology has been explained in section *"Materials and Methods"*. Analysis of in-depth interview with the key experts at national level, a series of Nepal policy documents, in-depth interview with key experts at district and international levels, and focus group interviews have been presented in section *"Analysis"*. The result of the analysis has been discussed in section *"Towards strategies"*. SWOT analysis has been used to identify an adaptation intervention strategy in section *"Analysis Using SWOT Technique"*. Finally, a land-based strategic model has been proposed to fill in the fragmented adaptation structure. Land Administration (LA) will be introduced as a tool for the implementation of this land-based model.

## 3.1 Adaptation Strategies

Adaptation is a series of strategies that responds to the needs of national and sub-national levels, sectors, communities and individuals facing climate change (Lim et al., 2005). Different strategies are introduced to tackle the impacts of climate change. They include local responses from farmers such as diversifying crops and livestock (Morton, 2007), food preservation and storage, water harvesting, integrating farming activities with livestock or fisheries and cropping time alteration (Howden et al., 2007), micro-insurance mechanism for crops and livestock (Biener & Eling, 2012), saving, loan and credit systems (Andersson & Gabrielsson, 2012) and development of adaptation policy for different zones and resources (Pielke et al., 2007).

The IPCC report 2014, working group II, consists of part A: Global and sectoral aspects, and part B: Regional aspects, which shows the different impacts of climate change across the world. The components of climate change risk, including exposure, vulnerability and physical hazards (Burkett et al., 2014) happen at different spatio-temporal scales because of various climate variables, resources, people's perceptions, infrastructure, ecology, environment and economy. Therefore, adaptation came into action on different scales and sectorial levels which are supported by their policies. Studies reveal that adaptation has positive effects on reducing poverty, improving livelihood and reducing vulnerability when supported by a policy (Stringer et al., 2009). UNFCCC, international organizations and NGOs support adaptation. Multiple guidelines, strategies, policies and documents encourage adaptation planning (USAID, 2007) (World Bank, 2009) (Dodman & IIED, 2012).

## *3.2 National and Sub-national Adaptation Initiative*

Countries take national initiatives to fill the gap between international negotiations and nations by developing adaptation plan through NAPAs and National Adaptation Plans (NAPs) (Mimura et al., 2014). Adaptation integrates adjusting to and coping with the current changes (Stringer et al., 2009). Therefore, it requires information about causes of risks and vulnerabilities that people and environment undergo (Füssel, 2007).

The national level provides policies and plans, and performs networking and coordination between states, local levels, communities, civil societies and NGOs. It involves vulnerability reduction and capacity building for different states, cities, communities, and individuals. Laws and regulations plus government policies and programs are institutional instruments to accelerate adaptation (Noble et al., 2014b). Local authorities contribute to adaptation through their governance structure, utilizing local knowledge to adaptation planning and their roles in the implementation of community-based adaptation (Mimura et al., 2014).

## *3.3 Adaptation Policies in Different Sectors*

Different opportunities for adaptation have been identified across various sectors including water resources, terrestrial eco-systems, marine and coastal systems, food security and food production systems, urban and rural areas. Key economic and service sectors include human health and security, livelihood and poverty (IPCC, 2014b). Countries take effort to develop different policies to manage their resources. This section reviews the key climate-sensitive sectors policies including agriculture, water, forest and land.

***Agriculture policy*** encourages agricultural development and removes barriers to ensure food security. Macroeconomic, tax and market management are among existing agricultural policies (Demeke et al., 2014). Land is necessary for agriculture and to sustain rural livelihood. Land distribution and land titling as land-related agriculture policies improve farmers' access to land and tenure security. Climate-smart agriculture and agro-ecology are introduced to overcome food insecurity (Demeke et al., 2014). Agriculture adaptation to climate change includes crop management at farm level.

***Water policy*** responses to urgent water management need. The major adaptation strategies to improve water management are:

- Investment in water infrastructure (irrigation and drainage systems),
- Monitoring existing water systems (water pollution control),
- Water infrastructure engineering (dams and pumps),
- Control water supply and demand (pricing and legislation),
- Utilizing new technology (water recycling).

Water is consumed at different scales and various sectors including industry, energy, food production and health. The water adaptation policies mentioned facilitate resolving water and land conflicts because they improve water security, which is access to healthy water in terms of quantity and quality (UN WATER, 2011). Forest management policy is a thematic element of Sustainable Forest Management (SFM) to manage all types of forest and to meet climate change challenges. REDD+ and voluntary carbon markets are introduced at national and sub-national levels as a part of mitigation strategy. Changing land use such as deforestation has direct and indirect effects on forest biodiversity, forest products and ecosystem services. Land use, land use change and forestry (LULUCF) plays an important role in climate change mitigation. Many land-related adaptation options including soil preparation, forest risk minimization of erosion by diversification of forest products and avoiding landscape fragmentation contribute to carbon sequestration (FAO, 2011). Therefore, land use related activities should be integrated in forest management practices.

***Land policy*** is a set of action plans to manage complex legal and socioeconomic activities (Smith et al., 2014). It is a tool for land use, land management, land tenure security and property rights (USAID, 2008). Agriculture, Forestry and

Other Land Use (AFOLUL) is an important sector contribute to climate change mitigation including energetic agriculture waste and forest monitoring (Shubert, R., Schellnhuber, H.J., Buchmann, 2009).

Land use planning minimizes risks by hazard zoning, limit urban and rural development in disaster-prone areas and control population and infrastructure density (Bajracharya et al., 2011). Land use, land use change and forestry (LULUCF) has been recognized as part of a mitigation strategy in *"forest management, cropland management, grazing land management and revegetation"* (UNFCCC, 2014a) to decrease human-induced activities related to land.

In this paper we focus on an integration of these varied adaptation strategies that are land-based. However, there are also other adaptation strategies that are taking place by different ministries, NGOs and civil society groups that were not included in this paper. Furthermore, we focus on a land-based integration whereas other integration attempts can also be made (e.g. climate change adaptation and disaster risk reduction).

## 3.4 Materials and Methods

This paper focuses on Nepal since it ranked 7 in Climate Risk Index, 2014 (Kreft et al., 2017) as one of the most vulnerable countries to the impacts of climate change. Nepal has a variation of climatic conditions from sub-tropical to temperate to alpine mountains because of its specific rise of topography from some meters up to 4000 m. Maximum summer temperatures range from 28 to 40 °C and minimum winter temperatures from 7 to 23 °C. The monsoon is from mid-June to mid-September with about 80% of rainfall. Nepal's annual average rainfall is 1500–2500 mm with the maximum of 4500 mm. Landslides and floods are frequent natural hazards which damage people and their livelihood (UNDP, 2009). Annually, it has the increase rate of 0.025% of GHG emissions and the annual average maximum temperature increase of 0.06 °C (GoN, 2011b).

Adaptation is necessary since the best mitigation strategies do not stop further climate change impacts (Burkett et al., 2014) in the short/medium term. Based on UNFCCC (2014b), adaptation consists of *"observation of climatic and non-climatic variables; assessment of climate impacts and vulnerability; planning; implementation;*

*and monitoring and evaluation of adaptation actions".* Each component of adaptation involves different stakeholders who play roles at different scales. 84% of the people in Nepal live in mountain rural areas and their major source of livelihood is agriculture (UNDP, 2009). Effective adaptation provides opportunities for mountain communities and increase their resilience to tackle their needs and priorities.

The research method used here is the analysis of a series of qualitative interviews that were held with the key experts of Ministry of Land Reform and Management (MoLRM), Ministry of Agriculture and Development (MoAD), Ministry of Forest and Soil Conservation (MoFSC) and Ministry of Science and Technology (MoST) on their roles and responsibilities mainly related to adaptation. Next, Nepal's policy documents of CCP, NAPA, LAPA, NAP and LUP are selected to identify if they considered adaptation and in-land perspective. For validation of the policies and plans of action, the in-depth interviews with the regional key experts at ICIMOD are analyzed. Furthermore, the in-depth interviews with local key experts at district level and focus group interviews at community level are analyzed to explore if they are involved in any land-related adaptation program. In-depth interviews had been conducted with two key experts at each ministry but one key expert at each district office and different thematic areas of ICIMOD.

It is because the key expert at both district office and ICIMOD are involved in adaptation implementation but not adaptation policy development. Focus group interviews had been conducted with two mountain communities which were involved in adaptation implementation (two other remote communities were too difficult to reach). Different sets of questionnaires were designed for each in-depth interview and focus group interview related to climate change, land and livelihood, adaptation planning, policy and implementation. For this paper, we only analyzed the questions related to adaptation policy.

The ministries, policy documents and ICIMOD have been selected because of the important role they play in national adaptation policy to climate change and reduction of mountain people's vulnerability, respectively. Furthermore, other ministries, NGOs and civil society groups which are mainly involved in adaptation implementation have been left out. Even thought, they might have interesting outcomes in their works.

*"Computer-assisted NCT analysis"* was used as a method for qualitative data analysis in ATLAS.ti. NCT consists of three connected steps of Noticing Things (quotation), Collecting Things (coding) and Thinking about Things (finding patterns and relation in data). Interviews and documents have been coded in the light of adaptation to climate change. The methodology followed for each document is based on an analytical framework to search for a proposed adaptation option considering land. As such, an inductive research approach is taken, as the objectives and drivers of policy development, level of involvement and adaptation strategies have been identified. An approach was taken based on a grounded theory which emphasizes on how often a code is repeated (Kaplan & Maxwell, 2005) in order to draw up the key services that each organization needs and can provide and that can be placed in the adaptation. Then the main findings of the analysis are discussed using the SWOT matrix to identify the gap on climate information and services.

Finally, a land-based strategic model is proposed and LA has been introduced as an implementation tool that covers both the spatial and social aspects of land.

## 3.5 Analysis

This section explains the analysis of in-depth interviews with the key experts at ministry level, policy documents, in-depth interviews with the key experts at international level, district offices and focus group interviews at local level.

### 3.5.1 Analysis of in-Depth Interview with Key Experts at National Level

The Ministry of Land Reform and Management (MoLRM) developed a LUP, 2012 and is not involved in adaptation. However, the LUP, 2012 indirectly addresses the most frequent impacts of climate change on land. The ministry is able to support policy makers by producing land-related data from land measurement and cadastral data to mapping at different scales. For instance, land experts combine different data types including topographic maps, land type, crop type, soil type and soil capacity to provide land use map for the maximum benefit of farmers. There is no level of involvement with the adaptation program but the ministry is involved on a national, district, community and individual level because of its roles and responsibilities.

***The Ministry of Agriculture Development (MoAD)*** developed NAP, 2004 and is not involved directly in adaptation. It conducted a Pilot Project for Climate Resilience (PPCR) for community poverty reduction. This ministry responds to agricultural development. It focuses on agro-business for communities, farmer training, distributing seed and fertilizer, financing small agriculture enterprises and micro-insurance schemes. The involvement of MoAD is the same as that of MoLRM.

***The Ministry of Forest and Soil Conservation (MoFSC)*** is not involved in adaptation. The ministry contributes to the mitigation of climate change through community forest management. Conserving forest contributes to some extent to adaptation since the communities use forest products. The ministry is involved on a national, district and community level because of its roles and responsibilities in the mitigation of climate change.

***The Ministry of Science, Technology (MoST)*** is involved in adaptation policy development such as NAPA, LAPA, low carbon strategy and climate change budget code. They allocate 80% of the budget for vulnerability reduction of local people. This budget mainly comes from mitigation such as REDD+. The ministry requested collaboration from different ministries, district and local levels for NAPA and LAPA development. The level of involvement with adaptation is limited to raising public awareness by organizing workshops, public discussions and seminars from time to time.

### *3.5.2 Analysis of Nepal Policy Documents*

***CCP, 2011***

***Objective*** To engage Nepal internationally in minimizing the effects of climate change and as an urgent need for the development of mountain people, livelihood and eco-system (GoN, 2011c).

***Driver of Development*** Impacts of climate change on mountainous areas, people, livelihood and ecosystem; changing rainfall and temperature patterns.

***Level of Involvement*** International (UNFCCC) and national (ministry of environment).

***Adaptation Strategies*** Preparation of NAPA and LAPA, adopting promotion of development of Clean Development Mechanism (CDM), renewable energy and raising public awareness.

*NAPA, 2010*

***Objective*** To be used as a strategic tool for vulnerability assessment and prioritizing adaptation actions (Ministry of Environment, 2010a).

***Driver of Development*** Changing rainfall and temperature patterns, poverty.

***Level of Involvement*** National and Village Development Committee (VDC) levels.

***Adaptation Strategies*** Climate change vulnerability assessment; identification of six climate-sensitive areas including:

– Agriculture and food security,
– Water resources and energy,
– Climate-induced disasters,
– Forest and biodiversity,
– Public health,
– Urban settlement and infrastructure.

Identification of adaptation priority activities including:

– Promoting community-based adaptation through integrated management of climate-sensitive sectors,
– Building and enhancing adaptive capacity of vulnerable communities through agricultural development,
– Community-based disaster management,
– GLOF monitoring and disaster risk reduction,
– Forest and ecosystem management,
– Adaptation to climate change in public health,
– Ecosystem management,
– Sustainable management of water resources and clean energy supply,
– Promoting climate smart urban settlement.

*LAPA, 2011*

***Objective*** To fill the gap of adaptation implementation and support vulnerable groups (GoN, 2011b).

***Driver of Development*** Impacts of climate change on agriculture, forestry, public health, water and sanitation, watersheds and micro-finance.

***Level of Involvement*** National, VDC, Municipality, District Development Committee (DDC), ward, community and household levels. LAPA has been developed and piloted in 10 Nepal districts.

***Adaptation Strategies*** No adaptation strategies. LAPA as a bottom-up approach introduced different steps and many different core tools for *"integrating climate change resilience into local-to-national planning processes"* (GoN, 2011b) but there is no core tool on how to implement an adaptation plan.

***NAP, 2004***

***Objective*** To reduce poverty and ensure food security through agricultural development (GoN, 2004).

***Driver of Development*** Decreasing fertile agricultural land, lack of access of farmers to resources including skills, labor and commercial bases, lack of infrastructure for agricultural development (roads, industry, communication, marketing), food insecurity and poverty.

***Level of Involvement*** National, villages and household levels.

***Adaptive Strategies*** No adaptation strategies.

***LUP, 2012***

***Objective*** To achieve land use planning and sharing land resources benefits to mountain people (GoN, 2012a).

***Driver of Development*** Unmanaged use of land, inequality in access to land, government and public land violation, land fragmentation, food insecurity and poverty.

***Level of Involvement*** International (UN, 1992b), national, VDC, Municipality, DDC, ward, community and household levels.

***Adaptation Strategies*** No adaptation strategies.

### *3.5.3 Analysis of In-depth Interview with Key Experts at International Level (ICIMOD)*

This section presents analysis of in-depth interviews at ICIMOD conducted in different thematic areas. ICIMOD is a knowledge-sharing center based in Kathmandu with the aim of facilitating mountain people to adapt to change and sustainable mountain ecosystems.

***Ecosystem Services*** is mainly responsible for support and implementation of REDD+ and it is not involved in adaptation.

***Adaptation to Change*** keeps track of climate and non-climate changes. This thematic area facilitates ministry offices and DDCs in pilot adaptation activities by providing information about changes in the specific area.

***Livelihood*** works closely with mountain communities to improve their adaptive capacity. This thematic area facilitates communities by alternative livelihood options such as stitching, planting fruits and vegetables, farm bees and collecting herbal medicine and aromatics.

***Mountain Environment Regional Information System (MENRIS)*** supports both adaptation and mitigation indirectly by providing data and information to decision makers and district level.

***Geospatial Solution*** supports adaptation by providing different thematic data such as forest type, forest fires, forest productivity and evapotranspiration. The thematic area integrates technology and adaptation since it provides more options to stakeholders of adaptation.

### *3.5.4 Analysis of In-Depth Interviews with Local Key Experts at District Level*

***District livestock office*** gives advice to the community on how to treat animals.

***District agriculture development office*** distributes seeds and fertilizers and trains farmers in vegetable cultivation and small irrigation schemes.

***District forest office*** is not involved in adaptation but mitigation through REDD+ and community forest management.

***District survey office*** is not involved in adaptation.

***District planning office*** raises community awareness through Citizen Awareness Centers (CACs) in all VDCs, supports vulnerable groups through social security programs, rural micro hydro-plan and facilitates the installation of hydropower and early warning systems.

### *3.5.5 Analysis of Focus Group Interview at the Community Level*

Two focus groups interviews were conducted with the communities in Bocha and Cherikot in the Dolkha district. Dolkha district is selected because of frequent landslides and floods.

***The Cherikot and Bocha communities*** are mainly involved in the mitigation of climate change through REDD+. They get fertilizer and seeds from the district agriculture office to speed up their agriculture products. District livestock office facilitates Bocha communities with animal treatment since livestock is a source of their livelihood.

## 3.6 Towards Strategies

From the policies mentioned in Adaptation strategies it can be concluded that land plays a role in all socioeconomic and environmental activities which are climate-sensitive and are confronted with *"environmental, social, economic and political stressors"* (Olsson et al., 2014). Land is a basis for housing, agriculture, infrastructure, water, forest and livelihood among others. Annually 1.6 GtG carbon is emitted from both changes in land use (forest conversation to agricultural land) and land use (respiration of vegetation and organic materials). Land is a source of carbon removal/emission by its forest, cropland, wetlands, grassland and settlement categories (UNFCCC, 2014b) and needs to be considered in each adaptation policy, strategy, plan and program.

The roles and responsibilities of MoLRM, MoAD, MoFSC and MoST have been analyzed with regard to land. The MoLRM does not participate in any adaptation plans and programs. However, it has the ability to produce any land-related data on demand for the whole of Nepal, having offices in all 75 districts. The MoAD is involved in a series of small-scale farmers' capacity building programs. The MoFSC engages communities in forest management as part of mitigation. The MoST developed a CCP, a NAPA and LAPAs to address adaptation and to fill in the fragmentation between different scales of national, district and community.

Nepal policy documents had been reviewed to explore the consideration of an adaptation program with land perspective in their plans. CCP is a law (Nachmany et al., 2015), executive with a mitigation framework (LSE, 2011) and does not mention which organization(s) should be involved in the process. NAPA was developed in six basic themes, introducing a list of priority adaptation options. LAPA, an executive law, has an adaptation framework that supports identification of climate-vulnerable areas and prioritizes community-adaptation action. NAP focuses mainly on its responsibilities in agriculture sector. LUP does not consider adaptation and only mentions classifying climate change prone-areas in forestry zones. None of these policy documents consider land-based services as an adaptation option.

Analysis of the in-depth interview with the key experts at regional level revealed that ICIMOD focuses on both adaptation and mitigation at regional level and do not consider specifically land. Analysis of the in-depth interviews with the key experts at district level and focus group interviews at community level revealed that there is no land-based adaptation foreseen for communities. The analysis of the in-depth interviews at international, national, district and community levels plus policy documents lead to the identification of the important factors including land, policy, coordination and implementation tools. Presence of these factors make communities adapt better to climate change.

## 3.7 Analysis Using SWOT Technique

SWOT analysis is a strategic tool to harmonize intervention strategies and to make improvement in complex strategic situations (Helms & Nixon, 2010), such as adaptation to climate change. SWOT as a matrix is used to analyze the current situation of adaptation. It is influenced by internal factors in terms of strength and weakness of policies and ministries in carrying out adaptation activities, while external factors determine if adaptation can take advantages of opportunities optimizing institutional arrangements and adaptation (Table 4).

**Table 4– SWOT Matrix of adaptation strategy in land perspective**

| **Internal factors** | **External factors** | |
|---|---|---|
| | *Opportunity (O)*<br>1. Clear mandates and roles/responsibilities of each organization<br>2. Existing climate change policies<br>3. Identification of climate-sensitive sectors<br>4. Prioritization of adaptation action<br>5. Availability of different tools to promote adaptation | *Threat (T)*<br>1. No appropriate policy for adaptation<br>2. Lack of coordination among ministries for adaptation<br>3. No tool for adaptation implementation<br>4. Services of one ministry not available for other ministries<br>5. Adoption of adaptation<br>6. LAPA only for 10 districts |
| *Strength (S)*<br>1. Ministerial understanding and awareness of the importance of adaptation<br>2. Ministerial provision of different services to citizens<br>3. Different scales participation<br>4. Different scales experiences with adaptation | *SO strategies*<br>– Definition of roles and responsibilities of stakeholders<br>– Availability of diverse services<br>– Stakeholders' involvement in adaptation at all scales<br>– Use of potential tools in adaptation | *ST strategies*<br>– Development of new adaptation strategy<br>– Start and improvement of coordination at different scales<br>– Sharing of different services, knowledge and experiences |
| *Weakness (W)*<br>1. Overlapping adaptation action<br>2. Same adaptation options for different districts and communities<br>3. No idea of communities' expectations<br>4. No improvement in community resilience<br>5. No consideration of the role of land as a basis for adaptation | *WO strategies*<br>– Defining appropriate adaptation policy<br>– Introducing new adaptation strategy<br>– Applying new concepts and tools to adaptation<br>– More adaptation options | *WT strategies*<br>– Utilizing land-based strategy<br>– Improving coordination among adaptation stakeholders<br>– Improving climate information and services<br>– Finding potential tools to implement adaptation<br>– Developing adaptation framework<br>– Improving communities resilience |

The SWOT analysis reveals 19 strategies which are required to improve adaptation from a land perspective. Land relates to structural and non-structural measures: infrastructure and policy (Charoenkalunyuta et al., 2011). *"Integrated management of agriculture, water, forest and biodiversity"* has been proposed by NAPA. Moreover, one of the concepts that LAPA purposes is *"integrated approaches between various sectors and sub-sectors"* to inform different stakeholders on their sectoral programs (GoN, 2012b). *"Coordinating climate change related activities at the local level"* and *"enhanced coordination at the technical level"* at national level has been recommended after analysis of climate change institutions of Nepal (CPEIR, 2011). Coordination adds value to what needs to be done in adaptation.

## 3.8 *Integrated Land-Based Strategy*

People, waterbodies, agriculture and forest areas, urban and rural areas, mountain and all natural and man-made structures are connected or attached to land or a specific location. As mentioned earlier, all are affected directly or indirectly by the impacts of climate change. Therefore, an integrated land-based strategy is required in adaptation to climate change. Different policies which were analyzed and introduced in this paper are related to the land sector and linked to the impact of climate change. The strategic model is shown in Fig. 6. Please note that the letter *"S"* stands for service.

Figure 6 shows how these institutions can be linked in providing services for mountain people building their resilience. Analyses of policy documents and in-depth interviews revealed that each ministry provides service(s) to the mountain people. The services are the result of their institutional roles and responsibilities and not directly because of adaptation. The services considering land are fragmented in their contribution to adaptation. Furthermore, the policy documents mentioned adopt policies related to their institutional arrangements. These are the services which LA is able to provide. Table 5 lists these services with respect to land. Some of the services are not the responsibility of MoLRM but they can be integrated with land administration.

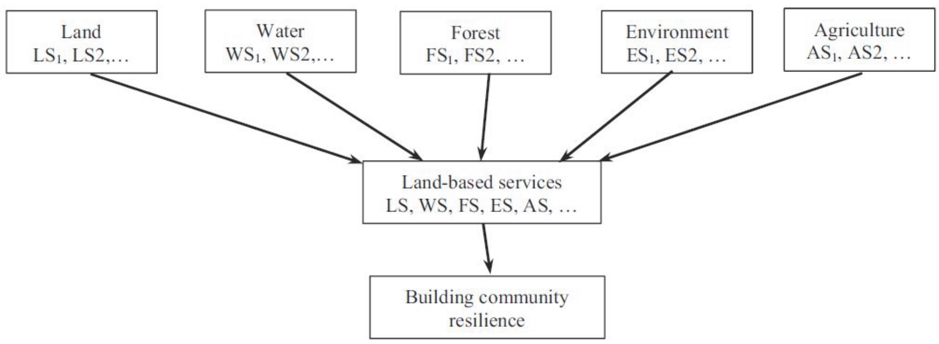



**Figure 6– Land-based strategic model**

**Table 5– Land information service(s) needed by policies**

| Policy document | Land information services |
|---|---|
| Climate Change Policy (CCP)<br>National Adaptation Program of Action (NAPA)<br>Local Adaptation Plans for Action (LAPA) | Administrative boundary level, vulnerable area, vulnerable group, hazard zone, natural disaster, land type, land management, land tax, land distribution, land registration, land measurement, land tenure, infrastructure, current adaptation and mitigation plan, land administration, carbon map, identification of land and water conflict areas |
| National Adaptation Plans (NAP) | Administrative boundary level, soil type, land type, land consolidation, land use, land cover, hazard zone, natural disaster, infrastructure, identification of land and water conflict areas, land distribution, land registration, land measurement, land tenure, |

There is a need of implementing a land-based strategy to provide services to the mountain people. LA with its functionalities including land use, land tenure, land value and land development, is a tool. It has the ability to provide access to resources, use of resources and control over them in terms of information and services. LA is country specific and can be adapted to support rules and regulations related to climate change policy and adaptation in any country. LA is able to collect, manage and disseminate land-related data mainly geo-information. Successful adaptation needs to consider the interest(s) of different stakeholders and resources available which are manageable through land administration.

Land governance, land policy, land management, land use planning, land tenure security, cadastral maps, carbon maps and transparency are a few of examples of land administration services in adaptation (FIG, 2014).

## *3.9 Conclusion*

Countries put effort into collaborating on an international level in adaptation to climate change. There are different adaptation strategies at national and sub-national levels because of the direct and indirect effects of climate change on different sectors. Institutional arrangements support adaptation by policy intervention to enable adaptation planning and implementation which is ad hoc and sporadic. Since land is a specific entity and source of natural, societal and environmental development, an integrated land-based strategic model is able to overcome these fragmented adaptation approach. The model integrates various services from different service providers to improve specifically mountain community resilience. Land administration as a tool supports the provision, integration, management and implementation of services from different sectors since it has the ability to engage multiple stakeholders at both policy and technical level across environmental, societal and economic sectors at different scales and time frames.

# Chapter 4: Defining the Requirements of an Information System for Climate Change Adaptation in Mountain Communities of Dolakha, Nepal*

* Published as Khezri, A., Bennett, R., & Zevenbergen, J. (2018). Defining the Requirements of an Information System for Climate Change Adaptation in the Mountain Communities of Dolakha, Nepal. *MDPI-Climate*, *6*(2), 47. https://doi.org/10.3390/cli6020047

# Abstract

Community-based Adaptation Programs (CAPs) that involve the participation of communities are being actively promoted in mountainous areas. These areas are climate sensitive and are often heavily influenced by landslides, floods, and drought. This research indicates that designers of adaptation programs seek to develop and implement CAPs based on international viewpoint and their obligations, but not community requirements. Such CAPs create uneven access to information resources for communities and do not implicitly reduce community vulnerability. In response, the research proposes the establishment of an Information System (IS) to support delivery of reliable climate adaptation services to mountain communities. This research uses Nepal as a case study that experiences a lack of effective adaptation programs due to its varied topography, prevalent climate-related disasters, and barriers in capacity building and institutional development. The results of the analyses indicate that the national level focuses on preparing adaptation action plans, whilst district levels and Non-Governmental Organization (NGO) focus on facilitating adaptation implementation for community and individuals. Additionally, the results reveal that an IS can enhance the design and implementation of CAP. Finally, the results are used to articulate prioritized services for an IS to assist communities who are in the greatest need of climate service delivery.


**Keywords:** information system; information system requirements; community-based adaptation program; mountain communities; climate change

# 4 Introduction

The Community-based Adaptation Program (CAP) is an emerging concept that can play a key role in responding to climate change. At the international level, there are many policy solutions and top-down implementations that emphasize the importance of CAP (Wilbanks & Kates, 1999). A growing number of National Adaptation Programs of Action (NAPA) and Local Adaptation Plans for Action (LAPA) also focus on CAP. Many mountain communities participate in CAPs: the *"small-scale, place-based, grassroots-driven and lesson-based approach"* (Schipper et al., 2014) aligns with the prevailing livelihoods and vulnerabilities in those locations. Mountainous areas are fragile ecosystems defined as including a general prevalence of natural disasters (UNEP-WCMC, 2002), less human capacity to respond to environmental degradation threats (Messerli, 2012) and an early indicator of climate change (Castellari, 2008). They are sources of water, energy, biodiversity, forest and agricultural products amongst others. This remarkable combination of resources makes them susceptible to environmental and economic breakdown (UN, 1992a). Mountain CAPs tend to focus on community vulnerability reduction and emphasize the need for collective action by focusing on community adaptation efforts—ones that bring the benefits directly to the members of the communities and thereby facilitate rural development (Dodman & Mitlin, 2013).

A variety of actors and funding mechanisms at various levels are involved in the development and implementation of CAPs for mountainous areas. Mountain individuals and communities are at the front line and react to the adverse effects of climate events, based on the resources available. The local level acts as a mediator between national and community levels for CAP budget allocation. Meanwhile, the national level develops the climate-related policies that are implemented lower down. The international level focuses on climate change negotiations and increasingly distributes funds to facilitate CAPs (Adger, 2003). Therefore, CAPs involve the complex and interdependent hierarchy of actors: identifying an adaptation programs' needs and requirements, especially for mountain communities and individuals, is a complicated activity: the local level is often considered the last component of this hierarchy and the final operational level of a CAP.

Successful mountain CAP implementation requires local governments to take responsibility in translating top-down national or regional adaptation policies and financing communities and households in bottom-up adaptation actions. Experiences from adaptation programs reveal that local government is a key actor; however, these organizations often experience difficulty accessing resources and have the limited capacity (Hardoy & Romero Lankao, 2011). Moreover, they face challenges in gaining the support of national and international levels—especially in more inaccessible and less developed countries (Noble et al., 2014a).

In resolving some of the above-mentioned problems much work in the sector has focused on developing plans and policies, climate change modeling and monitoring tools, spatially integrated tools and information tools. In this regard, the interdisciplinary area of Information Systems (IS) (Lockemann, 1975) appears to be a promising domain to a supportive socio-technical framework for integrating *"hardware, software, data, people, and procedures"* (Silver et al., 1995). IS cuts across almost all sectors including tourism (Buhalis, 1998), economics, natural sciences, computer science, communications (Boell, 2017) and complex systems such as climate change (Ai et al., 2015). Its core describes the exchange of information and availability of service/s based on user requirement/s.

The United Nations Framework Convention on Climate Change (UNFCCC) endorses community access to climate information and services through the development of technical tools and methodologies. Climate services refer to information about climate change and its impacts (Goosen et al., 2013). This information has the potential to enable mountain communities to prepare themselves for climate change events. Communities require information on past, present, and future of climate variables. Improvements in agriculture, water availability, and sustainable land use are directly related to information about land and climate. The UNFCCC acknowledges the importance of climate information and demands climate services mainly related to adaptation activities (WMO, 2011b). This paper focuses on limitations in existing land and climate change services that support mountain communities for CAP initiatives and seeks to identify areas for improvement, primarily based around appropriate information provision and IS application. Therefore, land and climate change IS are needed to supply the required information and data services, based on mountain communities' needs, to increase their adaptive capacity. This paper also explores if the potential role of IS is appropriately considered in CAP theories and practice (using Nepal as an area of focus) and its requirements. As such, Section 4.1 reviews adaptation initiatives, adaptation needs, and options—including existing tools. Section 4.4 explains the materials and methods including a description of criteria for study area selection, the study area itself, data collection activities including the questionnaire developed, and the subsequent data analysis. Section 4.8 presents the analysis of the in-depth interviews undertaken with key experts from NGO, local and national levels, Focus Group Interviews (FGI) and household surveys.

## *4.1 Adaptation Initiatives*

There are many policy statements—and top-down approaches at international level—that emphasize the need for CAP (Wilbanks & Kates, 1999). The UNFCCC suggests the development of adaptation programs should be action-oriented and country-driven. In response, nations make efforts to develop different adaptation tools and methods to deal with climate change problems (Paul & Rashid, 2016) (Klein R.J.T. et al., 2014) (Mallick & Vogt, 2015). Specific to mountainous countries, NAPA, LAPA and climate change policy have been developed as strategic adaptation tools.

CAP is discussed as a participatory and coordinated approach where government agencies, ministries, local municipalities, NGOs, communities and the private sectors are all stakeholders—and involved in development (Noble et al., 2014a) (Klein R.J.T. et al., 2014).

## *4.2 Adaptation Needs and Options*

Adaptation needs arise when the impacts of climate change require action to safeguard populations, assets, ecosystem and their services (Mallick & Vogt, 2015). Adaptation focuses on environment and society. Climate change potentially alters ecosystem services and biodiversity (Hoegh-Guldberg, 2011) and reduces access of marginalized people to basic services (Skoufias, 2013). Sound adaptation relies upon networks of actors at international, national and local levels to provide guidelines, regulations, and policies (Agrawal et al., 2009). Institutions support adaptation funding and promote the design and implementation of adaptation (Mertz et al., 2009). Technology and information can provide more accurate observations regarding climate variables (UKCIP, 2011). Information sharing can support making sound decision/s in promoting vulnerability and impact assessments. It can enhance a communities' adaptive capacity (UNFCCC/SBSTA, 2007). Information sharing defines where and why communities are involved, what role they are playing, what resources they are using, and for how long. The information enables improvements of community capacity, and identifying available resources and adjusting to new situations.

Identification of adaptation needs is usually based on impact assessments (Finzi Hart et al., 2012) and/or resilience assessments (Preston, Yuen, et al., 2011). Over time, adaptation needs tend to have moved from focusing on environmental, social and economic drivers of vulnerability, to underlying causes of vulnerability including *"informational, capacity, financial, institutional, and technological needs"* (Burton et al., 2006).

A wide range of adaptation options is identified in the literature. Engineering solutions such as building codes and seawalls (Eisenack et al., 2012), floating gardens (Irfanullah et al., 2011), ecosystem services (Pramova et al., 2012), alerting systems (van Aalst et al., 2008), incentives such as taxes, subsidies and Payment for Environmental Services (PES) (De Bruin et al., 2009), amongst others (Sultana & Mallick, 2015), are some of the actions by means of adaptation options. Most adaptation options are *"discrete activities"* and have *"concrete outcomes"* that are defined in *"scope, scale and time"* (Adaptation Fund Board, 2013). On these initiatives, Noble et al.(2014a) argue that most adaptation programs are overlapping, need prerequisites, do not meet adaptation needs, are impossible to implement or poorly developed—particularly in the least developed countries. In addition, existing adaptation options are said to be mostly sector-specific or location-specific. Having said this, CAPs for mountain areas are probably most useful when they are tailored to meet mountain communities' (user) need/s. This is more likely to increase community involvement, add value to community achievements, and makes adaptation successful.

## 4.3 Adaptation Tools

Adaptation tools and methods, a specific type of adaption option, are defined as adaptation strategies and/or as plans of action (Lim et al., 2005). *"Sector-specific"* tools include agriculture (smart agriculture), water (watershed management), coastal resources (shoreline management), human health (mapping disease) and terrestrial vegetation (agro-ecological zones) (UNFCCC, 2004).

Interactive geo-design tools can be applied to support decision-makers at the local level (Eikelboom & Janssen, 2015). Decision support tools screen risks and support adaptation strategies such as Community-based Risk Screening Tool-Adaptation and Livelihoods (CRiSTAL) (IISD, 2012). Planning tools monitor and model climate change and its impacts: SERVIR provides a prime example. It is a spatially integrated tool that detects changes in land, forest and water resources at regional levels (SERVIR, 2015). There are also examples of innovative information dissemination tools at different administrative levels. weADAPT is an *"open space"* climate adaptation platform. It connects researchers, policy makers and active adaptation practitioners on a global scale to learn and share adaptation case studies. weADAPT consists of searchable adaptation layers (weADAPT, 2016). The Adaptation Learning Mechanism (ALM) is another adaptation knowledge-sharing information platform to exchange adaptation experiences on a global level (ALM, 2017). AfricaAdapt is a network that focuses solely on Africa about *"the flow of climate change adaptation knowledge for sustainable livelihoods"* between policy makers and civil society groups. It is a web-based application that includes videos, offline activities such as radio programs in local languages and face-to-face interactions and represents climate variability (AfricaAdapt, 2015).

IS as a generalized concept, looks promising with regards to CAP implementation. It has the capability of information retrieval and information management (Castro et al., 2002), promoting sharing and exchange of information (Westerhoff et al., 2011) and translating information (Noble et al., 2014a). Geographic Information System (GIS) applications and Information and Communication Technologies (ICTs) tools are popular to facilitate communities preparedness for climate change related events (AfricaAdapt, 2015) (Castro et al., 2002).

In summary, a wide array of adaptation tools is available (Preston, Westaway, et al., 2011). However, there are limits, barriers, and costs associated with each. Sector-specific tools only cover the common sectors. Decision support tools are usually focused on one-way communication and are product-focused (Weaver et al., 2013). Planning tools are generally designed by multiple stakeholders, and although not specifically focused on climate change (Pensa et al., 2013), they are suitable to assist data and information for adaptation. Most innovative information dissemination tools are designed on global and regional scales: they are not simple and/or useful for communities to perceive. Also, the tools that are emerging remain geared towards scientific communities and present information from/for scientific perspectives (Kirchhoff et al., 2013) and not necessarily fit with the on the ground community needs (Lemos et al., 2012). These tools introduce different adaptation actions that require various tools, resources, skills, scientific and comprehensive experiences: they do not necessarily bring benefits for communities/individuals concerning development as a goal of CAP. Literature reveals that decision makers in practice are the ones that are actually seeking climate information to support the environment and plan strategies at their level of interest (Kirchhoff et al., 2013).

## *4.4 Materials and Methods*

This paper explores the limitations of existing climate change adaptation tools. It investigates the possibility and need for an Information System (IS) through evidence-based design and implementation of CAPs based on relevant and highly granular spatial data and services. Specifically, the paper focuses on mountain communities' requirements that are relevant for prioritizing services required for Mountain Community Adaptive System (MCAS). In response, the exploratory case study approach was identified as being commensurate to the fulfilment of the aims. A case study can *"contribute to our knowledge of individual, group, organizational, social, political and related phenomena"* (Yin et al., 2014), such as a mountain community. The use of the exploratory case study, involving primary research, enabled focusing on a specific unit of analysis and a particular location. It enabled the capture and assessment of qualitative data, concerning understanding the limitations of existing tools and potential enhancements enabled by IS. Figure 7 presents the overview of the research methodology conceptually.

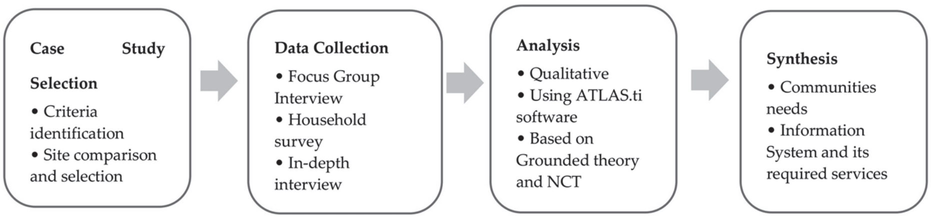



**Figure 7- Overview of research methodology**

## *4.5 Case Study Selection and Criteria Identification*

From an initial subset of countries with known predomination of mountainous communities, Nepal was selected. Key criteria for selection included its engagement (or lack thereof) in existing CAP initiatives, adequate levels of safety and security, large sample selections regarding numbers and diversity of mountainous communities, and proximity and availability to the research team. Nepal has climate change policies, NAPA, LAPA and laws specifically focused on adaptation. This compares favorably to the other member countries of the Hindu Kush Himalayan (HKH) region—Afghanistan, Bangladesh, Bhutan, India, Myanmar, and Pakistan. These legal instruments support plans and programs for mountains' people resilience (GLOBE International, 2013). Nepal ranked 120 amongst 181 countries based on The University of Notre Dame Global Adaptation Initiative (ND-GAIN) Index. This rank represents a combination of Nepal's vulnerability to climate change and its readiness (ability to convert the investment to adaptation). Nepal ranked 24 in Climate Risk Index for 1996–2015 (Kreft et al., 2017) and 71 in the least ready country (ND-GAIN, 2015) for adaptation to climate change. Nepal's high vulnerability (rank 129) and high readiness (115) of ND-GAIN Matrix Index emphasizes that it is responding to the effect of climate change, but it needs urgent and greater adaptation actions (ND-GAIN, 2015). Rural mountain communities face poverty which is increased through factors such as *"remoteness, poor accessibility, the fragility of the ecosystems, and marginalization"* (Hunzai et al., 2010). About 80% of Nepal's population resides in rural areas (DataUN, 2015) that hampers them in climate change adaptation. It is difficult to inform and train rural mountain communities about adaptation programs, design and implementation of CAP because of lack of infrastructure such as roads, power and energy lines. Therefore, many of them are not involved in CAP.

***Specific Study Area Selection***

The Dolakha district of Nepal with Charikot as its district headquarters was selected for data collection. The specific case helps to bridge the gap between the literature review and the real world (Maw et al., 2011). The area is ranked: (a) very highly vulnerable in overall Vulnerability Index of Nepal, (b) highly vulnerable in Combined Risk Index including flood, drought, landslide, ecological, temperature, rainfall and Glacier Lake Outburst Flood (GLOF) and (c) prioritized district for adaptation planning (Ministry of Environment, 2010b). Dolakha district with an altitude of 2088 m and a population of 186,557 (GoN, 2014) is located in latitude 27◦46′42.24″ N and longitude 86◦10′30.72″ E in central development region, Janakpur zone, mountain physiographic area, in the central east part of Nepal (OpenNepal, 2015). Dolakha's average temperature was 14 ◦C, and its average rainfall was 324 mm between 2009 to 2016 (WorldWeatherOnline, 2017).

Three Village Development Committees (VDCs), Charikot (Bhimeshwar municipality), Susma chhemawati and Bocha were selected based on the following criteria: (a) accessibility—easy to access rural, remote mountainous areas, (b) scale of the field work support, (c) highly susceptible to extreme drought and rainfall. The total number of households is 6076 in Charikot, 775 in Bocha and 864 in Susma chhemawati. The average household sizes in the selected VDCs are 3.71, 3.61 and 3.98, respectively. In the three mentioned VDCs: firewood is the primary fuel used for cooking, electricity is the source of light, tap water is the source of drinking water, radio, mobile phone, and television are the main communication facilities, the major casts are Chetree in Charikot and Bocha, and Thami in Susma chhemawati, the dominant language is Nepali in Charikot and Bocha, and Thami in Susma chhemawati, and more than half of the population living in the three VDCs are literate (HDX, 2015). Figure 8 presents Dolakha district in Nepal.

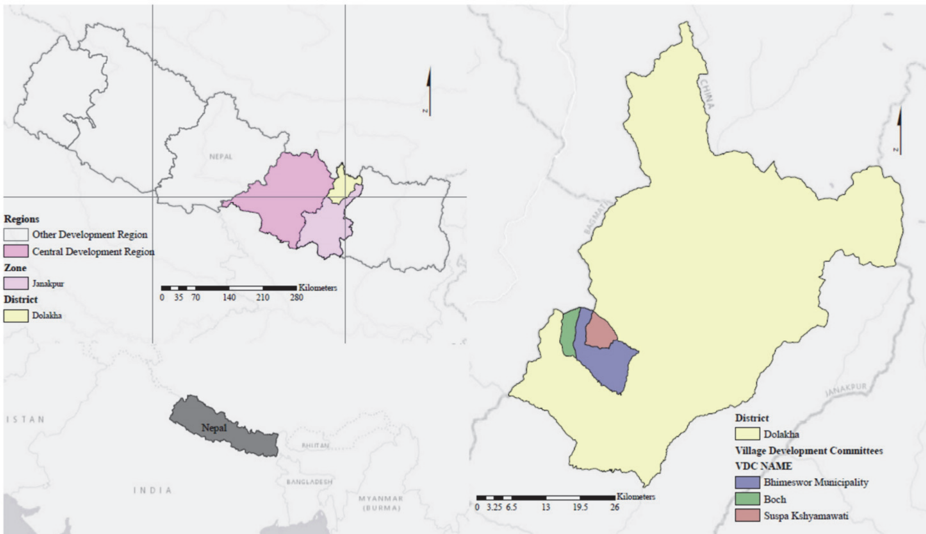



**Figure 8- Dolakha district, Nepal**

## *4.6 Data Collection*

The research method applied consists of FGI with local communities and a household survey with local residents to identify if and how they are involved in CAP. Additionally, a series of qualitative in-depth interviews were carried out with key local experts of the district offices and an NGO at Charikot, Dolakha district headquarters. For validation of CAP and its services, key national experts of the sectoral ministries and departments were interviewed in Kathmandu, Nepal.

### *4.6.1 Focus Group Interview and Household Survey*

FGIs with the local communities of Bocha (n = 21) and Charikot (n = 19) coupled with 29 household surveys with local residents of the three selected VDCs were carried out to explore their involvement in CAPs and adaptation service/s delivery. The NGO recommended the three VDCs on account of them being closely involved in the implementation of climate adaptation activities. In addition, it was easier accessing them with due consideration to the road system in Dolakha district. The selection of household survey was based on one household per a community: during conducting fieldwork it was confirmed that each community consisted of eight to thirteen households. Prior to data collection, different sets of open-ended questionnaires were designed based on secondary data sources for each level of national, district, community and individual. These questionnaires focused on various aspects including adaptation programs, climate change evidence/policy, land policy/tenure, community life and livelihood/vulnerability, adaptive capacity and data and information system. A literature review, desk research and the theoretical background of each level revealed the different stakeholders and their roles and responsibilities relative to CAP. These were used to map the understanding of the interviewee(s). Prior to FGI, being a member and non-member of the Forest User Group (FUG), number of participants (between 6 to 10) (Bryman, 2016), gender-issues (equality in male and female participants), participants professions (farmer, housewife, teacher, seller and worker) and their ages (youth, adults and senior) were taken into consideration. For this paper, we only analyzed the questions related to the impacts of climate change, mountain community vulnerability, and roles and responsibilities in the design and implementation of CAP; all, to explore if current CAP/s were in line with mountain communities' needs and requirements.

### *4.6.2 In-Depth Interview*

In-depth interviews, the ministries, the district offices, and an NGO were undertaken because they play an essential role in CAP and increasing mountain community adaptive capacity. The Ministry of Science and Technology (MoST, Katmandu, Nepal) was chosen as the developer of NAPA (Ministry of Environment, 2010a). The Ministry of Agriculture and Development (MoAD, Katmandu, Nepal) and the Ministry of Forest and Soil Conservation (MoFSC, Katmandu, Nepal) are the key stakeholders of Thematic Working Groups (TWG, Katmandu, Nepal) of NAPA. The Department of Hydrology and Meteorology (DHM), under the Ministry of Environment and Government (MoEG, Katmandu, Nepal), provides data and information about rainfall and temperature. The Ministry of Land Reform and Management (MoLRM, Katmandu, Nepal) was selected since climate change is happening on land and land is the unique source of life (UN/ECE, 1996). The district offices create links between community and national level. The District Planning Office (DPO) is the head of all district offices. The District Forest Office (DFO) and the District Agriculture Development Office (DADO) were selected as forest, and agriculture products are influenced by the impacts of climate change. Community forest management is quite successful in

Nepal (Niraula et al., 2013) and agriculture provides 33% of Gross Domestic Product (GDP) in Nepal (Government of Nepal, 2011). The District Livestock Office (DLO) was chosen as climate change has an impact on livestock. The District Survey Office (DSO) provides cadastral and land use maps that play a vital role in the design and implementation of adaptation programs. The Federation of Community Forestry Users Nepal (FECOFUN) is an active NGO in Dolakha for poverty reduction and provides opportunities for communities through REDD+.

## *4.7 Qualitative Data Analysis and Synthesis*

The qualitative interviews were analyzed using ATLAS.ti. to address the issues related to development and implementation of CAP/s and MCAS requirements. The relevant data was collected and organized for a comprehensive analysis of specific details (R. Kumar, 2014). Data entry processes were undertaken and intended to ensure data accuracy and to remove the incompleteness of collected data during the fieldwork. Collected data from the fieldwork were qualitative. NCT was utilized as a method for qualitative data analysis and research software in ATLAS.ti. NCT stands for Noticing (quotation), Collecting (coding) and Thinking (finding patterns in data). Qualitative data analysis requires extensive data-visiting and code-defining, re-visiting and revising coded-data or re-analyzing. The steps to analyze narrative descriptions are: coding that is labeling segments of transcriptions based on a specific objective, conceptualizing that refers to the named themes in the research study, the categorization that are classified codes and Grounded theory. Transcriptions of in-depth interviews, FGIs and household surveys were coded in line with CAP. The methodology followed for each transcription was based on an analytical framework to search for CAP considering IS and its requirement/s. Therefore, an inductive research approach was taken to identify the impacts of climate change, community vulnerability, CAP strategy, stakeholders' roles and responsibilities, and their recommendation/s to improve the design and implementation of CAP. Grounded theory was taken as an approach to identify the code frequency (Friese, 2014) and to find the key adaptation services that the communities and individual/s need to place in CAP.

It is possible to integrate data segmentations during the process of data analysis in ATLAS.ti. to make a *"system of linkages"* (Friese, 2014). The linkages are a holistic approach toward the understanding of the qualitative data. The linkages display network views that allow the analyzer to find the relationships among data segments. To create a network view, first, the documents of FGI, in-depth interview of NGO, district and national key experts were grouped according to a shared code of recommendations. Therefore, it was possible to associate all recommendations to one recommendation code. Next, the recommendations were linked together if they were similar, support or contradict each other. Accordingly, a convenient cluster of recommendations was created rather than being distributed among the documents that made finding the results easier. The network view and clustering also applied to current CAP strategy. Next, the main findings of the analysis were revisited, and the concept of an integrated land and climate change IS was hypothesized and conceptualized, based on communities requirements.

## 4.8 Results and Discussion

This section presents the results of the summarized analysis of FGI with communities, the household survey and in depth-interview with NGO, district, and national key experts. Recommendations and CAP strategies are presented separately or as a group in each section based on the criteria mentioned in qualitative data analysis and synthesis.

### 4.8.1 Results of Focus Group Interview with the Communities

**Charikot**

***Impacts of climate change:*** shorter rainy seasons and less paddy production, less amount of rain compare to the past and no snow in the winter.

***Community vulnerability:*** power struggle promotes inequality in getting high-quality seeds, lack of pasture land for their cattle due to community forest management, harder grass (cannot be eaten by cattle) and difficulty in tilling soil due to chemical fertilizers.

***Existing CAP involvement:*** utilizing chemical fertilizer and modified seeds, harvesting water in small tanks, taking part in raising awareness programs to improve their knowledge about climate change.

***Bocha***

***Impacts of climate change:*** inconsistency in rainfall, rising temperature, changes in monsoon time, melting snow, water deficit, landslides, and erosion.

***Community vulnerability:*** human health problems including difficulty in breathing due to dust and pollution, less animal productivity including cow and buffalo, more livestock miscarriage, unexpected trees blooming, increasing mosquitos and diseases in crops, soil degradation, lack of infrastructure including road and proper market to sell their agricultural products.

***Existing CAP involvement:*** livestock treatment, using organic fertilizer and hybrid seeds, bio-engineering (bamboo and cardamom) to stop erosion, soil treatment, building fences to prevent landslides, poultry and goat farming, listening to TV and FM radio mobile programs about climate change.

### *4.8.2 Results of the Household Survey in Three VDCs*

***Susma Chhemawati (n = 11)***

***Impacts of climate change:*** landslide, water deficit, drought, heavy rainfall during monsoon and shorter rainy seasons compare to past.

***Community vulnerability:*** livestock disease including Blackwater fever (n = 2), loss of land (n = 8), damage in crops including potato (n = 4) and farm fruits such as apple (n = 1), less agricultural products including paddy, millet and maize (n = 11), no information about the effects of climate change (n = 6).

***Bocha (n = 8)***

***Impacts of climate change:*** heavy snow compare to previous years, shorter rainy season, landslides because of heavy rainfall, less visibility due to the increasing amount of fog and dust.

***Community vulnerability:*** livestock disease including Blackwater fever (n = 1), damage in crops including potato and cauliflower (n = 4), no information about the effects of climate change (n = 4).

***Charikot (n = 10)***

***Impacts of climate change:*** frequent rainstorm, rising temperature, cold seasons, flood, drought, landslides, and air pollution due to dust.

***Community vulnerability:*** livestock disease including Blackwater fever (n = 3), failure in paddy (n = 7), no information about the effects of climate change (n = 6).

Only 6 out of 29 respondents are involved in bio-engineering and building fences as a part of CAP involvement.

#### 4.8.3 Results of the In-Depth Interview with FECOFUN (An NGO)

***Impacts of climate change:*** less rainfall pattern compare to baselines, erosion, and landslides, low rate of fertility both in agriculture and livestock, increasing numbers of pests and weed.

***Community vulnerability:*** insufficient agricultural products, lack of planning and implementation of adaptation by the government or the civil society.
***Existing CAP involvement:*** raising community awareness on carbon reduction, forest fire, and overgrazing, conducting bio-engineering (bamboo and cardamom), renovating communities stove, using bio-fuel and biogas.

#### 4.8.4 Results of the In-Depth Interview with District Key Experts

***DLO*** is involved in livestock treatment, training farmers on keeping their livestock safe and passing livestock problems to MoAD through the regional directorate.
***DADO*** is involved in mandatory programs—providing seeds, training farmers in a technical way regarding cultivating vegetable and small irrigation schemes.
***DFO*** is responsible for Reducing Emissions from Deforestation and forest Degradation (REDD+) and directing communities on harvesting forest products.
***DSO*** supplies cadastral maps and land-related data.
***DPO*** is an entry point for district offices to prioritize plans and programs. This office trains mountain communities in improving their livelihood through Citizen Awareness Center (CAC), supports mountain community through social security programs, crops and fruits planting.

#### 4.8.5 Results of In-Depth Interview with National Key Experts

***MoSTE*** contributes to the development of climate change policy, NAPA, LAPA, low carbon strategy and allocating a budget for mountain community vulnerability reduction.
***MoFSC*** is responsible for mitigation policy development.
***MoAD*** developed National Agriculture Policy (NAP). This office is involved in agro-business, micro-insurance schemes, goat, and vegetable farming.

***MoLRM*** is responsible for the development of Land Use Policy (LUP), producing topographic maps and cadastral data, and management of LIS.
***DHM*** provides rainfall and temperature, wind, solar radiation and evapotranspiration data.

It became clear that except NGO, MoAD, and DADO, there are no CAP strategies at district and national level. MoAD and DADO have an indirect involvement with current CAPs as a part of their responsibilities. Additionally, almost every source recommended the need of a system for instant communication of information such as potential resources. The system facilities communities to diversify their livelihood to ensure their income generation. NGO, several national and district offices highlighted the need of practicing land and forest use rights/lease to make access to suitable land easier. Communities can expand agro-business and manage vacant lands this way. Different types of weather, climate change data, CAP policies, plans, and programs were mentioned as crucial information for increasing local awareness and building mountain communities' capacity.

## *4.9 Key Findings*

Results of the in-depth interviews at national offices revealed that ministries are not involved in CAP: they focus mostly on the development of different climate-related policies—based on their roles and responsibilities. These policies do not necessarily cover communities' needs in CAP. For instance, Nepal climate change policies were developed to implement the provisions of Kyoto Protocol (GoN, 2011c).

The objectives of Nepal's NAPA are reducing poverty in mountainous regions and progressing the Nepal development process (Government of Nepal, 2011). The experts suggested that climate-related policy development needs the results of vulnerability assessment, climate disaster management, and risk information. The national key experts at MoSTE mentioned that 80% of the total climate change fund is allocated to the implementation of programs at the community level. They added that LAPA is also developed to support CAP and delivery of adaptation services to mountain communities. These findings highlight that there are no budget or policy barriers to the involvement of district offices in CAP.

However, the results of the in-depth interviews at district offices and NGO revealed that only DADO (as its responsibility) and the NGO were involved in CAP. Importantly, of the two, neither consider or utilize IS in CAP implementation.

Results of FGI showed that communities are involved in some pre-defined CAPs based on their needs and the resources available. NGO is more active in Bocha than its headquarters (Charikot). Therefore, Bocha community gets more information on accessing resources and using them better. It reduces climate vulnerability and the risks they face. The Bocha community generates money using poultry and goat farming, by selling chickens, goats and their products. This cash income enables communities to insulate their houses against heat and cold, to add facilities to them including bio-stove/electrical stoves and water tanks that support their health and water deficit, respectively. The communities indicated that information about adaptation strategies and climate change policy add value to their life. For instance, this information ensures improvement in communities' agricultural products. They can identify better places to cultivate what products and when to invest in different agricultural products and the best time and ways of harvesting forest and agricultural products. Results of the household survey showed that a minority of individuals are involved in some of CAP offered by an NGO—36% in Susma chhemawati, 12.5% in Bocha and 40% in Charikot. Membership is necessary to be involved in CAP/s. Lack of money to become a member and not having information on adaptation activities hamper individuals in CAP implementation. Since people are engaged in income generation business in Charikot, they are reluctant to participate in CAP. Individuals proposed to identify information on how to participate in CAP and the potential roles of CAP. Table 6 presents limitations of current CAPs based on the analysis of all the results at the different levels.

**Table 6- Limitations of current Community-based Adaptation Programs (CAPs)**

| | |
|---|---|
| **Policy Issues** | – Unclear operation of adaptation program at multiple levels of national, district, community and individual.<br>– Development of Nepal's climate policy is based on the Kyoto protocol rather than local communities' requirements.<br>– Uncertainty in how to involve mountain communities in CAP. |
| **Legal Issues** | – CAP is not a legal instrument yet.<br>– No direct communication between communities and responsible organizations for CAP. |
| **Economic/Finance Issues** | – Limitation of livelihood options and access to productive assets.<br>– No specific tools to identify the economic development of CAP.<br>– Difficulty in identifying vulnerable mountain communities.<br>– Inequality in conducting the social security program. |
| **Technology/Information Issues** | – Lack of infrastructure to expand telecommunication channels.<br>– Focus is on disseminating general information on climate change and not specific adaptation practices for the local context.<br>– No evidence on facilitating mountain communities in using IS. |
| **Social Issues** | – Existing power relations promote inequality in accessing resources.<br>– Conducting CAPs without looking at communities prerequisites (what is needed), potentials (knowledge, capacity, asset, resources, information) and societal variables (gender, cast, and ethnicity). |

Overall, all results confirmed that IS and its requirements were not considered in CAP/s. Information on climate change risks from stakeholders and organizations is vital for adaptation planning (Mimura et al., 2014). Key experts at district offices, NGO, and national level recommended the need for disseminating information. Access to information (DLO, DFO, and DPO), raising awareness (DADO), having a source of weather data and information (DSO), establishing an information center (NGO, MoAD) and integration of climate change information with land data (MoLRM) are emphasized. The ministries need information about climate change and adaptation activities in the development of climate-related policies from other ministries and district offices. Furthermore, both communities and individuals mentioned the need for efficient and effective ways of communicating regarding climate change information and adaptation. Figure 9 represents categories of the services that the communities need to be shared or reported to the government, NGOs or other communities.

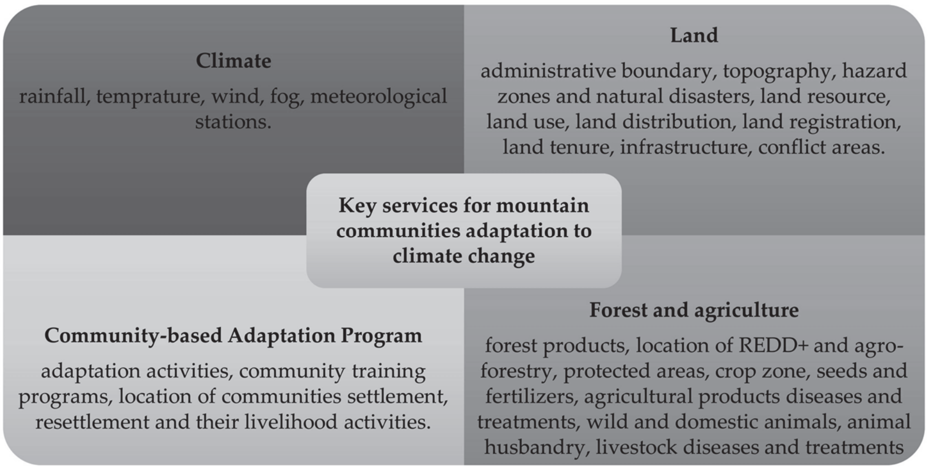



**Figure 9- Key needed services**

## *4.10 Conceptualizing MCAS*

Amongst the many issues raised, lack of information and information sharing stands out as a cross-cutting theme. The results of the analysis suggest the need for the introduction of an intervention strategy that increases access to climate information, addresses the resources available, identifies CAP and facilitates participation in CAP. These are the types of information that communities need to determine the potentials, improve their capacities, and adjust to the current/new situations. Furthermore, policymakers and CAP planners are concerned to know about the socio-economic impacts of climate change on a community to increase community adaptive capacity. Information is an influential factor regarding the effectiveness of both policymakers' choices in adaptation planning and communities in implementing CAPs. Information addresses the needs of a nation, an organization, a community and/or an individual. The flow of information adjusts the needs of stakeholders of CAP/s since it answers *"what, who, when, why and how"* questions. A system creating and sharing such information could translate and disseminate this information to each stakeholder especially at the community level.

Land Information System (LIS), a subset of an information system, appear more suitable for managing the needs of users since they link an activity/s to a specific position (Wallace et al., 2010). LIS can collect, store, manage and disseminate spatial and non-spatial information regarding services to citizens. Integrating LIS with the emerging technologies including mobile and web-based tools support chances for sharing information (Williamson et al., 2010). It appears, LIS are highly suitable for application into CAPs: adaptation activities can be seen as a service for responding to the impacts of climate change, which fundamentally have a spatial extent. However, issues of security and data privacy, along with data and system maintenance must be considered in the context of any system development deemed sustainable. Moreover, the ability of mountain communities to access and use such an IS requires more thorough investigation. Dealing with obstacles and the digital divide is an inseparable part of any IS development initiative, particularly for the vulnerable people who are in the greatest need of help.

Going beyond the general notion of LIS and CAP, climate services address climate variability and climate events. A climate service is efficient when it is based on the users' need (Hewitt et al., 2012). The concept of a Mountain Community Adaptive System (MCAS), an integrated land and climate change IS, that contributes to the service delivery of CAP/s is a possible response. Impacts of climate change cause or contribute to mountain communities/individuals vulnerability as they were identified in Sections 4.8. This is where we find the link to identify the needs of mountain communities as prioritized services in MCAS. Figure 10 presents the overview of MCAS. It shows how MCAS can contribute to providing land and climate change services to support mountain communities/individuals. It has the potential to assign rights to store, view, access, share and report information in CAP/s.


**Figure 10- The overview of Mountain Community Adaptive System (MCAS)**

The ministries provide data and services based on their institutional responsibilities and not because of CAP. MCAS can integrate these data and services to contribute to CAP. LIS allows different datasets *"to be organized using geographic coordinates"* and *"to be grouped according to locations"* (Bennett et al., 2008). Figure 9 presents key services for mountain communities. The prioritized climate services in the line of CAP were identified, based on the analysis of the field work. Not all of these services are crucial or used for MCAS. Some of the services require sponsors or customization for a specific activity/reason.

Rain and temperature are two critical factors that influence agriculture. Meeting this need is to make these variables accessible in a meaningful way called climate services. It provides essential climate information such as annual rain and temperature. They improve communities/individuals needs and/or interests. Mountain communities can identify wet/dry and/or warm/cool year/period to adjust their agricultural activities. DHM is observing this information so the closest meteorological station/s can be placed in MCAS.

Other certain requirements for the mountain communities/individuals include: (a) infrastructure such as road networks, water reservoirs, and hydro lines are important as they facilitate them in overcoming water deficit and quick access to the market, (b) land use category to identify forest land from agriculture and pasture lands, (c) information about villages, administrative boundaries and municipalities enable them to share their activities and problems with the relevant district offices, and (d) other CAP activities in the area which inspire them and allow exploring the possibilities of doing the same CAP. Furthermore, it connects them to the resources available in the closest area to overcome their shortage efficiently. MoFSC, MoAD, and MoLRM can share and combine their data to support these services to the mountain communities/individuals. A base map is necessary to locate all these spatial and non-spatial data. MoLRM is capable of providing a base map.

## *4.11 Conclusions*

CAP is a popular approach for adaptation at local level, especially in climate-sensitive areas including mountains. Different adaptation options and tools are identified to assist communities/individuals in development and implementation of CAPs. The purpose of the CAP is to strengthen mountain communities' adaptive capacity. The study reveals that many CAPs are developed based on national level commitments that do not include necessary communities' requirements. Communities then remain vulnerable since they are still experiencing difficulty in accessing information about available resources and CAP. Information is an important factor to overcome communities' limitation. An Information System, particularly Land Information System (LIS), can deliver climate change adaptation service to communities. Mountain Community Adaptive System (MCAS) can integrate climate variable and prioritized services from different data and service providers to foster communities' abilities in CAP. The data and services to be included will be targeted to reduce the mountain communities' vulnerability.

# Chapter 5: Evaluating a Fit-For-Purpose Integrated Service-Oriented Land and Climate Change Information System for Mountain Community Adaptation*

* Published as Khezri, A.; Bennett, R.; Zevenbergen, J. Evaluating a Fit-For-Purpose Integrated Service-Oriented Land and Climate Change Information System for Mountain Community Adaptation. *ISPRS Int. J. Geo-Inf.* 2018, *7*, 343.

# *Abstract*

Climate change challenges mountain communities to prepare themselves via Community-Based Adaptation (CBA) plans that reduce vulnerability. This paper outlines the evaluation of a developed web-based information system to support CBA, referred to as a Mountain Community Adaptive System (MCAS). The web-based user interface visualizes collated data from data providers, integrating it with near real-time climate and weather datasets. The interface provides more up-to-date information than was previously available on the environment, particularly on land and climate. MCAS, a cloud-based Land Information System (LIS), was developed using an Agile-inspired approach offering system creation based on bare minimum system requirements and iterative development. The system was tested against Fit-For-Purpose Land Administration (FFP LA) criteria to assess the effectiveness in a case from Nepal. The results illustrate that an MCAS-style system can provide useful information such as land use status, adaptation options, near real-time rainfall and temperature details, amongst others, to enable services that can enhance CBA activities. The information can facilitate improved CBA planning and implementation at the mountain community level. Despite the mentioned benefits of MCAS, ensuring system access was identified as a key limitation: smartphones and mobile technologies still remain prohibitively expensive for members of mountain communities, and underlying information communication technology (ICT) infrastructures remain under-developed in the assessed mountain communities. The results of the evaluation further suggest that the land-related aspects of climate change should be added to CBA initiatives. Similarly, existing LIS could have functionalities extended to include climate-related variables that impact on land use, tenure, and development.


**Keywords:** Integrated Land Information System, climate adaptation services, mountain community, Agile-inspired approach, Fit-For-Purpose Land Administration.

## 5.1 Introduction

Community-Based Adaptations (CBA) are policy driven interventions, focused on agricultural investment (Zheng & Dallimer, 2015), via community-based activities (Ayers & Forsyth, 2009). CBA faces several challenges being often project-based and small-scale in nature (Sarzynski, 2015), power relations at the community level can impede success (Pörtner et al., 2014), and there can be a general *"lack of support from the government"* (Syomiti et al., 2014). Moreover, culture can create social barriers, and the role of institutions can impede information availability (Regmi, 2012), and the supportive information that is available to assist the CBA is often incomplete, unavailable, or out-of-date (Heltberg et al., 2012)(King, 2014).

The lack of supportive information to promote CBA is the focus of this study. Effective CBA demands that communities are equipped with the relevant information about land and climate. This enables engagement and assists decision-making at the local level to realize the true benefits of CBA. Decision-making might involve selecting between the range of adaptation options including crop diversity plans, soil conservation, and tree planting, among others (Berrang-Ford et al., 2011). Currently, communities are not able to maximize full understanding of the available resources, risks, and vulnerabilities at a high level of detail. If community stakeholders are uncertain about the goals and objectives of CBA, it can cause competition or opposition (Lieske, 2015).

In response, the purpose of this study is to evaluate whether a developed web-based Land Information System LIS tool can support and enhance CBA activities. The planned tool could integrate a variety of land information, including administrative boundaries, roads, land use, cadastre, topography, hydro lines as well as climate change data - including rainfall and temperature - for rural mountain communities. To present the evaluation, first the background, the materials and the methods for development and evaluation of a web-based LIS tool are explained in sections 5.2 and 5.3. Evaluation of the system, against adapted Fit-For-Purpose Land Administration (FFP LA) criteria, is then presented in section 5.4. The purpose of the evaluation is to identify whether the designed system (MCAS) supports climate adaptation services for CBA. The critical findings based on the evaluation are discussed in section 5.5.

The conclusion is presented in section 5.6.

## 5.2 Background

Mountainous zones have specific contextual challenges including high altitude, dense fog, heavy rain and snow, potential avalanches and falling rocks amongst others: technology applications may require adaptation or extensions beyond those applied in other contexts. Often, power lines and cables hardly reach such communities, leading to lack of electricity, internet, and mobile network coverage. Communities are scattered in small populations and may be skipped over in programs aimed at enabling technology update and dissemination. In these areas installation, repair, and maintenance of any old and new information communication technology (ICT) infrastructure is more challenging than in other contexts. It is more complicated and time-consuming to transfer the required personnel and materials to such places as supportive infrastructure, for example, roads and transport infrastructure, are often weaker or damaged. Whilst geospatial data including satellite images, surveying and cartography facilitate information provision about mountainous areas, issues of excessive terrain relief (Gruen & Murai, 2002), atmospheric errors, shadow effects in satellite images (Veregin, 2005)(Sjoberg & Horn, 1983), human resource limitations (in surveying), also lead to incomplete spatial information coverage of mountainous areas (Fassnacht et al., 2006).

Despite the challenges in mountainous areas, the potential for ICT to support management of mountainous areas cannot be denied: ICT can play a substantial role in strengthening community adaptive capacity (Ospina & Heeks, 2011). Communication and information infrastructures are increasingly providing better services to users, even in remote locations. ICT tools such as mobile and web-based information interfaces can present a wide variety of information about the current status of land and climate—but, also historical and predicted scenarios. Such information can facilitate the engagement of rural mountain communities in CBA to better respond to relevant needs. ICT applications such as integrated land and climate change data, known as LIS, can enable mountain communities to become principal actors and decision-makers in CBA.

Developments are occurring rapidly in this space. New information channels including online groups and digital forums are developed to improve the exchange of knowledge related to community adaptation. For instance, Shack/Slum Dwellers International (SDI) provides information on community risk reduction in 33 countries in Africa, Asia, and Latin America (Wamsler & Brink, 2014). There exists mountain-based IS tools that are dedicated to providing alarm and warning services in high mountains: GeoAvalanche crowdsources snow avalanche information to support tourist safety and resource management in the European Alps. It shares avalanche data and maps of risk zones via a website, accessible via smartphones. Users subscribe to geo-portals communicate 2-way on alerts about avalanche incidents and snow conditions. It creates a regional interoperable network to contribute to avalanche bulletin maps (Bartoli & Medaglia, 2012). Geopraevent operates alarm and monitoring systems for natural hazards and displays the results online to experts, local authorities, and people in different mountainous in China and the European Alps, amongst others. Different sensors, including people radar, a rock fall radar, webcams, and infrared cameras, plus geophones and weather stations, are combined to supply data within the data portal. Information about glacial lakes, permafrost, and flood waves, among others, are available on all devices (Geopraevent AG, 2017).

Despite these developments, further investigation reveals that an integrated land and climate change IS has not been developed for CBA initiatives, particularly in developing contexts. Table 7 presents some web-based and mobile applications that provide different services to support citizens directly. Only Fog Watch application can be considered a climate change relevant mountain IS application: it provides information about fog density in *'Indo-Gangetic Plain and Brahmaputra Basin'* (ICIMOD, 2016). The other apps (marked * in Table 7) provide information in all European countries, but, not necessarily on land and climate change. Most of the applications are specifically for experts or specialists working within scientific fields or sectors, such as MySeason, an app not intended for local participants. It is also worth mentioning the listed applications do not support the crowdsourcing concept that enables broader and richer information to be included in the system.

**Table 7- Web-based and mobile applications that provide services to citizen**

| App Name | App Domain | App Information | Webpage ** | Open Source Software |
|---|---|---|---|---|
| MySeasons * | Biodiversity | Monitoring vegetation phenology | http://myseasons.eu/ | CITnet |
| Atmos * | Weather | Providing short-term predictions on current meteorological conditions | http://beja.m-iti.org/web// | GitHUb CITnet |
| Protar.org * | Land cover | Providing land cover change in protected areas across Europe | http://www.protar.org/ | GitHUb CITnet |
| Geoss2go * | Mapping | Digital field mapping of tourism, agriculture and risk management | http://moovida.github.io/geoss2go/ | GitHUb CITnet |
| CALIOPE EU * | Air quality, air pollution | Forecasting 48-h air quality over Europe | http://www.bsc.es/caliope/en?language=en | CITnet |
| Fog Watch | Weather | Presenting the presence and intensity of fog | http://www.icimod.org/?q=22713 | NA |

**Access date to all web pages is 8-8-2017.

In this study, a web-based information system referred to as Mountain Community Adaptive System (MCAS) is developed to promote CBA. MCAS is intended to provide near-real-time information on temperature and rainfall, along with other localized data, provided by local communities via crowdsourcing, about land use and land holdings, including imagery that could act as an enabler and enhancer of existing CBA initiatives. Importantly, it is necessary to verify whether MCAS is capable of providing information services that support CBA. On this, growing from part 6 section 23 of the Voluntary Guidelines on the Responsible Governance of Tenure of land, fisheries and forests in the Context of national food security (VGGTs) (FAO, 2012), where participation and consultation with communities and individuals are recommended for land tenure security programs, the World Bank and the International Federation of Surveyors (FIG) developed the FFP LA framework, including a set of design principles, to simplify providing tenure security, control of land use and natural resources for all, particularly in less developed countries. The FFP approach seeks to bypass establishment of costly, time-consuming and sophisticated LA systems that demand professional personnel to work. The FFP LA approach *"allows a system to be incrementally improved over time."*(Mitchell et al., 2015). This means FFP LA is a flexible and affordable approach focusing on the quality of the services to satisfy users' needs.

Analysis of the FFP approach shows that LIS underpins global issues including climate change (Enemark, Keith Clifford, et al., 2015). International organizations such as FAO and UN-GGIM support LA projects that are designed closely to FFP principals since it identifies the purpose/s of a system and decides on what to include in the system to improve (FIG, 2014). The FFP LA frameworks – spatial, legal, and institutional – need to interact to support delivery of fundamental data for geospatial information management, protect the tenure security of local people from risks of climate change and natural disasters and manage lands in rapid urbanization and land conflicts (Enemark, McLaren, et al., 2015). Mitchell et al.(2015) also indicate that the FFP LA concepts and tools can support the enhancement of adaptation to climate change. In this vein, the FFP LA frameworks appear to be suitable for evaluating MCAS: MCAS seeks a flexible and low-cost approach for creating and sharing the land and climate data amongst community stakeholders, one that enhances CBA-related decision making. The objectives of FFP LA and MCAS are closely aligned.

## 5.3 *Materials and Methods*

In this section the criteria for case selection and data collection processes are discussed first. The MCAS development process is then explained, as are the system architecture and evaluation criteria based on FFP LA, and subsequently the test plan.

### 5.3.1 *Study Area and Its Context*

Within Nepal, one of the most climate affected countries (Eckstein et al., 2017) Dolakha district is selected since it is ranked very low on combined/multiple adaptation capability indices, which include socio-economic, technologic (irrigation system), and infrastructural (road and communication) adaptation capability (Ministry of Environment, 2010b). Figure 11 presents Dolakha district, Nepal. Dolakha faces many challenges regarding CBA. In response, this study proposed the establishment of an LIS to support evidence-based design and implementation of CBA – based on relevant and highly granular spatial data and services (Khezri, Bennett, et al., 2018). The data requirements for the intended LIS were collected in Dolakha district.

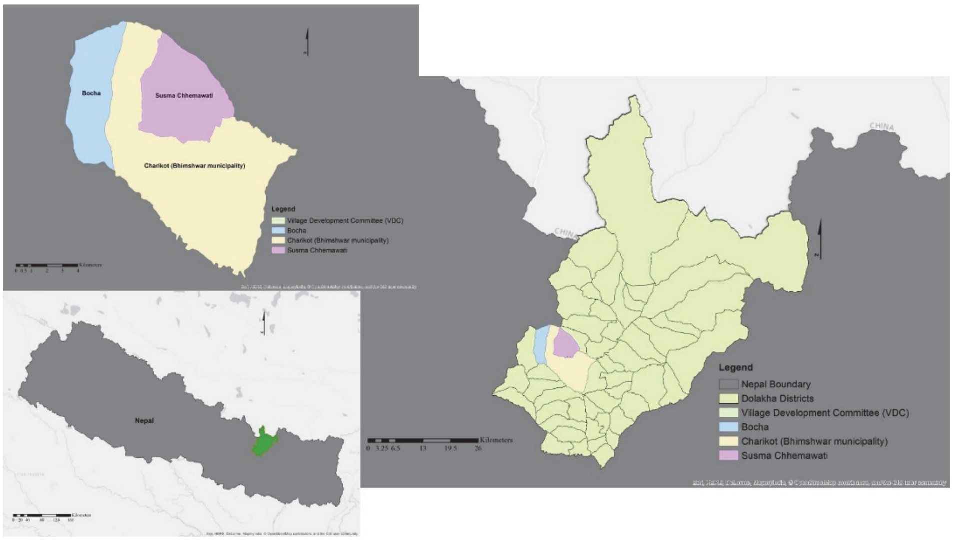



**Figure 11- Case study location**

Land and climate data were necessary to populate the system. CBA data were derived from analysis of in-depth interviews with the district key experts, an NGO, Focus Group Interview (FGI) of two communities in two Village Development Committees (VDCs, the lowest administrative unit of Nepal), individual household surveys, and the personal observations of the first author of this paper during research. Specifics on the data collection, analysis, and requirement synthesis activities are available in (Khezri, Bennett, et al., 2018). The process included coverage of fieldwork activities, FGI and household surveys, in-depth interviews with the district key experts, data analysis, and synthesis. Individual household surveys were conducted in three VDCs including Susma Chhemawati (n = 11), Bocha (n = 8) and Charikot (n = 10), coupled with FGIs with the local communities of Bocha (n = 21) and Charikot (n = 19), in-depth interviews of district offices (n = 5), an NGO, and participants at the national level (n = 5). Spatial and non-spatial data collected from the International Centre for Integrated Mountain Development (ICIMOD), the District Forest Office (DFO), the District Survey Office (DSO) and the Department of Hydrology and Meteorology (DHM) populated the LIS. These organizations are selected because ICIMOD is an active knowledge sharing center that assists mountain people to understand climate change and its impacts. DFO and DSO are involved with forest and agriculture land-based activities amongst others. DHM provides temperature and rainfall data.

### *5.3.2 Agile-Inspired Development Process*

The development of any IS requires the utilization of a development methodology. Agile development is increasingly identified as a suitable method that receives interest in the process of IS development. Every iteration of Agile development includes planning, analysis, design, and testing; allowing an IS to change and develop gradually over time (Dennis et al., 2012). The literature shows the nature and use of Agile in IS development occurs in diverse fields and has theoretical linkages to socio-technical approaches (Johannessen & Ellingsen, 2009), teamwork models (Moe et al., 2010), complex adaptive systems (Meso & Jain, 2006) and knowledge management (Dingsøyr et al., 2012). Since Agile development simplifies the development process (Dennis et al., 2012), an Agile-inspired approach was applied in this study for the prototype development of MCAS.

In the Agile Manifesto, the 7th principal is *"Working software is the primary measure of progress"* (Schwaber, 2004). In the Agile method, the focus is not on long-term planning or documentation nor the developer or client contract (Dingsøyr et al., 2012). The system starts working with the minimum system requirements. The developers and client/s take feedback from each other at pre-defined time intervals to sustain client/s needs with the system (Barton et al., 2015). It is an interactive and iterative model that has been used to develop and refine MCAS. *"Short time development, implementation and testing"* during six months (May-October 2016) were defined because of the research time constraints. In May 2016, a core team of three consisting of a system developer (technical IS), a system analyst (technical IS and land and climate change researcher) and a scientific project adviser (technical IS, land informatics and project advisor) started the MCAS development. The team was kept small: it was easy to communicate, and only the required people were included. The system developer was a Nepalese national with connections to the mountain communities. In addition, the system analyst spent over one month embedded with specific mountain communities in order to be sensitized with conditions, livelihoods, and environments. Although not ideal (This limitation and potential responses is covered in more depth under *'5.5 Discussion'*), both the system developer and the system analyst acted as the users of MCAS at the time of its prototype development and implementation to put the work well into the desired context.

Face-to-face communication was performed between the system developer and the system analyst every two weeks and with the team every month for six months to complete the project. This iterative communication was focused on the prototype development of MCAS, its implementation, and testing, providing technical and scientific feedback from the team members to improve MCAS. The prototype development was separated from the core users, meaning it diverged from a more purist Agile approach. An Agile-inspired approach emphasizes teamwork and user satisfaction (Beck, 2000). Although incorporating users is an efficient way to capture user requirements in an Agile approach, too little contribution from end-user is often reported as a weakness in system development (Misra, 2008). Due to the limited capacity of the system analyst including time and cost, and lack of direct and indirect contact with the mountain communities, which is something that needs to be noted for any future scaling or implementation work, the team simulated receiving input from the communities: the system developer and the system analyst tried to act as much as possible as the users, based on the earlier findings regarding the requirements (see section 5.3.1). Every two weeks, the testing of MCAS provided feedback from the developer and the analyst to consider required changes in MCAS—requirements including technology, types of services and system performance were considered. To grasp the needs concerning land and climate change services, the system requirements came from Section 5.3.1 and the system developer. Figure 12 presents the Agile-inspired approach of the MCAS prototype development and how all the tasks fit together.

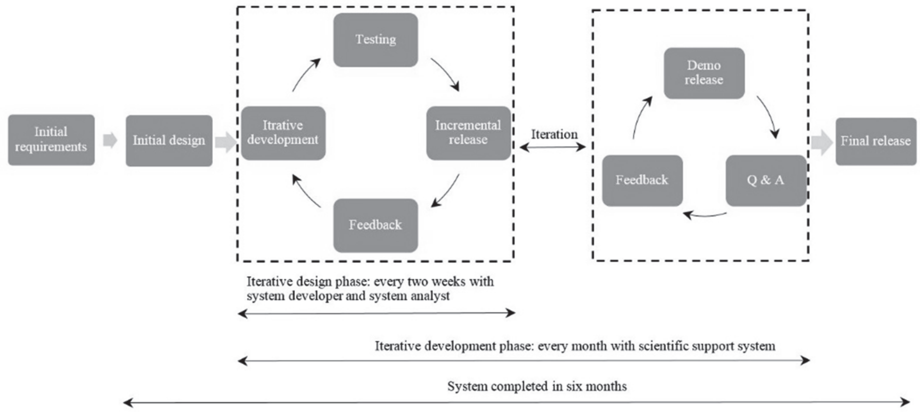



**Figure 12- MCAS development process**

### *5.3.3 Information System Architecture*

MCAS needed both hardware and software for data processing. The hardware for data repository and visualization needed to be able to remain consistent with both pull and push mechanisms in the system. In addition, the land and climate change data and web-services in the MCAS included raster and vector data, images and geo-location points. The system was also considered to need to incorporate desktop PC, laptop and smartphones compatibility. Open-source software including Quantum GIS (QGIS) - enabling the sharing, viewing, editing, and analysis of spatial data - along with Geographic JavaScript Object Notation (GeoJSON) that enabled text-based data interchange formatting to present geographic features – were coupled with Leaflet, Bootstrap, JavaScript/jQuery - to enable MCAS interoperability, credibility and reliability. Table 8 represents the open source tools used for the development of MCAS.

**Table 8- Open source tools used for the development of MCAS**

| Open Source Tools | Version | Function | Source |
|---|---|---|---|
| Quantum GIS (QGIS) | 2.18.3 | Create, edit, visualize, analyze and publish spatial data | http://www.qgis.org/en/site/ |
| Geographic JavaScript Object Notation (GeoJSON) | RFC 7946 | Encoding geographic data feature | http://geojson.org/geojson-spec.html#introduction |
| Leaflet | 0.7.7 | JavaScript library | http://leafletjs.com/ |
| Bootstrap | 3.3.7 | HTML, CSS, and JS framework | http://getbootstrap.com/ |
| JavaScript | ECMAScript | Coding language | https://www.javascript.com/ |
| jQuery | Core 3.0 | Feature-rich JavaScript library | https://jquery.com/ |

Ultimately, MCAS was compiled as a four-tier architecture including: i) data tier that represented the required data, ii) application tier consisting of process, service interface and webserver components, iii) presentation tier enabling visualization of the data layers in terms of services and iv) communication tier presenting the push information from the system through search and querying - and the system pull information as data layers, graphs, maps and images (Figure 13 presents the MCAS system architecture.)

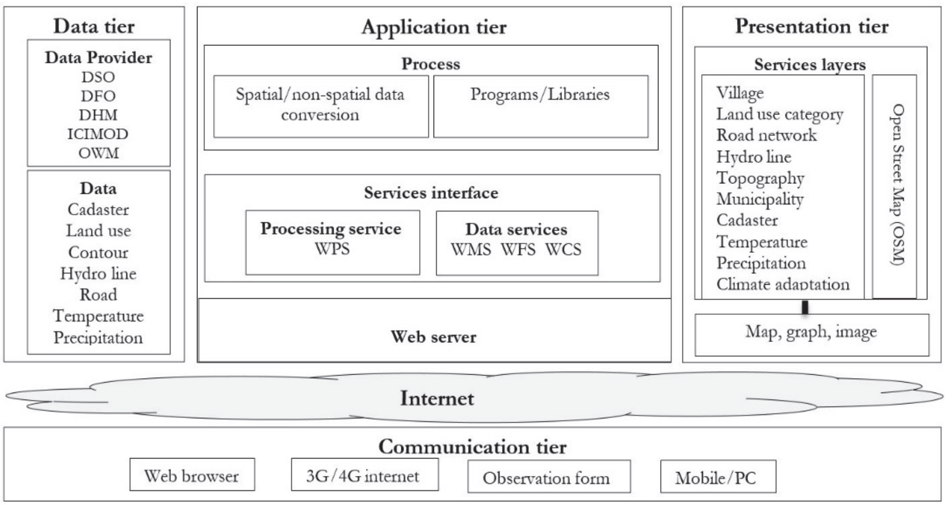



**Figure 13- MCAS system architecture**

### 5.3.4 Information System Evaluation Criteria

IS evaluation is mostly *"context and user specific"* (DeLone & Mclean, 2003). Likewise, several countries implement specific elements of FFP LA to revise their legal and institutional framework such as registration of land tenure in Rwanda, registration of communal land in Namibia and rural land registration of Ethiopia (Bennett & Alemie, 2016). The FFP approach supports building a viable LIS and making incremental change/s in LIS based on social needs, in a short timeframe. Additionally, LA provides a platform for the development and delivery of geospatial information. Therefore, the frameworks of FFP LA have the potential to support CBA in line with the VGGTs. For this specific study, FFP LA elements including *"flexible", "inclusive", "participatory", "affordable", "reliable", "attainable" and "upgradable"* were used as evaluation criteria to assess MCAS (Reasons for selecting FFP LA are justified and explained in detail in Section 5.2 of this article). Utilizing FFP LA in the assessment of MCAS identifies if it is designed based on community needs, is accessible to mountain communities and individuals, includes all FFP LA elements, and can be incrementally improved to enhance CBA experiences. The reliability and interrelated frameworks of FFP LA are considered to coincide with the areas of constraints for change in adaptation services. The definition of FFP LA's elements as adapted in this study are presented in table 9.

**Table 9- Adapted elements of FFP LA to MCAS**

| Elements of FFP LA | Adapted to MCAS |
|---|---|
| 'Flexible in capturing the spatial data. | Flexible in capturing spatial and non-spatial land and climate change data. |
| Inclusive in scope to cover all tenure and all land. | Inclusive of all types of land tenure that are relevant to Community-Based Adaptations (CBAs). |
| Participatory in approach to data capture and use to ensure community support. | Participatory in sharing information about the effects of climate change on their land and livelihoods, and implementation of current CBA. |
| Affordable for the government to establish and operate, and for society to use. | Affordable for the community/individual to invest in relevant technology devices and supportive infrastructure to access the provided services. |
| Reliable in terms of information that is authoritative and up-to-date. | Reliable not only regarding cadastral data, but also for climate adaptation services. |
| Attainable in relation to establishing the system within a short timeframe and within available resources. | Attainable to provide climate adaptation services in short time. |
| Upgradeable with regards to incremental upgrading and improvement over time in response to social and legal needs and emerging economic opportunities.'(Enemark, Keith Clifford, et al., 2015). | Upgradable regarding the community/individual's needs to facilitate CBA. |

The methodology followed for the evaluation of MCAS is based on participant observation that derives qualitative data (Bryman, 2016). In the approach, participant observation is used across multiple phases of the research including prototype use test (Guest et al., 2013). Table 9 was used to assess the results of the user's test to see whether MCAS included all the elements of FFP LA.

### *5.3.5 Test Plan*

Due to time constraints and limitations in the access to mountain communities the system developer held a workshop at Kathmandu University (KU), Dhulikhel, Nepal on 5 September 2016, to evaluate the MCAS prototype. KU supported the test with the Internet connection, space, and PCs. The participants for the user test came from within KU—which is made up of people with diverse backgrounds: gender, educational level, age, and profession were all considered in selecting the users of MCAS. The system developer invited potential users to join the user testing utilizing a word-of-mouth approach, and seeking to maximize diversity within testers. Finally, 12 participants were chosen randomly from the volunteer population—including students, farmers, a businessman, and a housewife. The farmer category included actual mountain community members, currently based in Dhulikhel and supporting campus construction work. To ensure up to 85% that the problems in a system are found, the participation of 5–8 people in the user tests is sufficient (Bugs et al., 2010). The Participants' attributes are presented in table 10.

**Table 10- Participation statistics**

| Place | Profession | Age | Education | Gender |
|---|---|---|---|---|
| Rural area 7<br>Urban area 2<br>City 3 | Farmer 4<br>Student 6<br>Businessman 1<br>Housewife 1 | Average 27<br>Maximum 38<br>Minimum 21 | Literate 6<br>Illiterate 6 | Male 6<br>Female 6 |

Each user was given a computer with access to the MCAS prototype, via the Internet. The test started with an introduction to the purpose of the test and a short demo of MCAS. Then, participants were encouraged to use MCAS. The participants interacted with MCAS using prepared guidelines and carried out pre-defined tasks relating to FFP elements. For instance, the participants were asked to identify system functions, capture land information and climate change information, and identify climate adaptation services. The instructor facilitated the illiterate participants in reading the guidelines and writing down observations without any interference of the work, although, this is recognized as a limitation of both the evaluation and MCAS itself and as covered later, requires further research. Literate persons used the user guide included in the user guide that is available in the Appendices of this research.

Qualitative data analysis was conducted to identify the user evaluation results. To facilitate data analysis, the results of the user test were coded based on the adapted elements of FFP LA (column II of Table 9) which involved comparing the results found with the adapted definition of each component. Coding requires reviewing the output of the user test so that the data can be continuously compared and conceptualized (Bryman, 2016). The coding process in this study created categories of the elements of FFP LA, which enhanced the formulation of the results. After that, all the coded user tests were merged to manage the categories with ease, and to maintain consistency in code handling. The codes were shown in a single environment, to allow exploring the data as a whole.

## 5.4 *User Evaluation Results*

The results of the analysis of the user test are presented as follows:

### 5.4.1 *Flexible*

The users selected a specific layer and extracted information from its sub-layers. Turning on the sub-layers, land and climate data were presented on the base map. The participants could make queries by clicking on the map. A pop-up window showed information about the clicked point on the base map (Figure 14). When the participants selected a meteorological station, a ten year (2000-2010) rainfall and temperature graph appeared in MCAS (Figure 15). Land layers were interactive. The participants could combine different land layers and make queries about their desired location/s, zoom in/out, and apply pan functions to explore MCAS from parcel to Village Development Committee (VDC) to district levels. The advantage of combining land layers in an interactive environment and getting query compared to a static map was having an overview of the whole area to identify the information one needs. Moreover, the pop-up window of the spatial query contained detailed information of each location in a map layer.

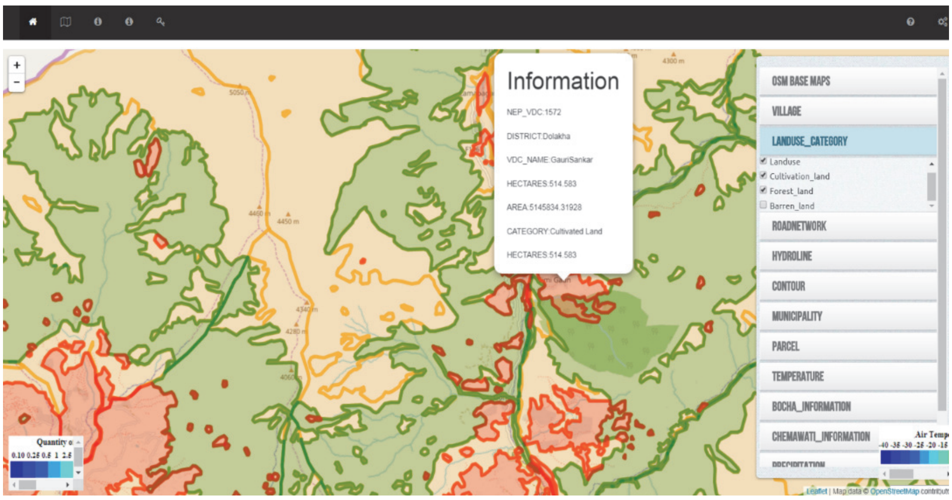



**Figure 14- Selected layer and result of a query.**

A user could select the desired layer from the right panel that included base-map, villages and municipalities and their administrative boundaries, land-use category (land use, cultivation, forest, and barren areas), road network, hydro lines, contour or topographic map, land parcels, information about three Village Development Committees (VDCs), adaptation options and rainfall and temperature data. The user could zoom in/out on the map via the +/− buttons located at the top left-hand side (this function also applies to other figures that were presented in this study). In this figure, a user already selected sub-layers of the land-use category that were shown on the map in red, green, and orange colors. Since a user could make a query by clicking on the map, the pop-up window revealed information about the clicked location including the name of the district, name of the VDCs and its assigned code, land use category and its area in hectares.

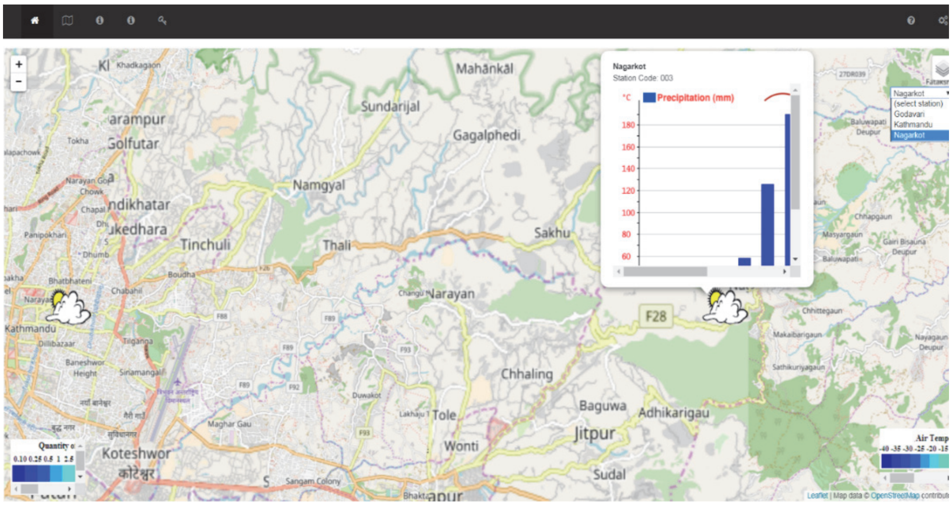



**Figure 15- Rainfall and temperature graph.**

A user could select the desired meteorology station from the top right-side panel that included the three meteorology stations of Godavari, Kathmandu, and Nagarkot. In this figure, a user selected the Nagarkot station. A pop-up window displayed information about the temperature and rainfall of 10 years. Both the temperature and the rainfall information were shown in one graph. The Y-axis illustrated annual temperature in °C, and the X-axis visualized yearly rainfall in mm for the selected location. It displayed climate information related to that particular meteorology station. Based on the aforementioned information in this paragraph, it is concluded that the system exhibited a level of flexibility.

### 5.4.2 Inclusive

The adapted definition of Inclusive for MCAS indicated *"including all types of land tenure that are relevant to CBA."* Analysis of the user evaluation results did not reveal any code specifically related to inclusiveness. Furthermore, there was no evidence of types of land tenure in the system (Figure 16). The populated parcel maps in MCAS were collected from the DSO of Dolakha. *"The cadastral based-map is sometimes incomplete"* due to the technical problem including vectorization (Hammoudi et al., 2010) but the data may include *"size, value and legal rights"* related to the parcel (J. Zevenbergen, 2004). However, there may be other reasons including privacy to protect land information, and particularly tenure rights that remained uncovered. It was beyond this study to check this further and subsequently requires further research. The intention was to explore whether any land tenure was included as an attribute of a parcel that was relevant to CBA, for instance: tenancy. Therefore based on the results of the user test the system is not yet considered to be inclusive. However, it is inclusive regarding the ability to provide a cross-cutting suit of datasets relevant to CBA, even if all tenures are not provided.

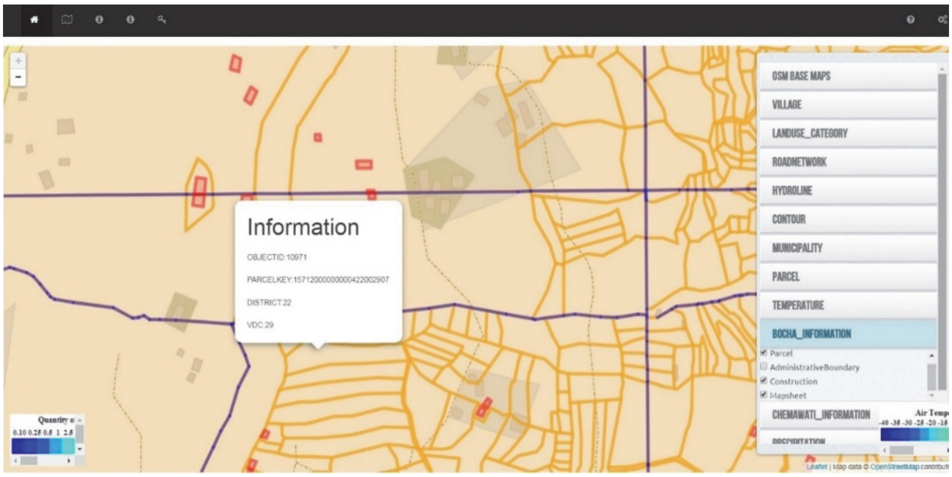



**Figure 16- Parcel information layer.**

A user could select the information about a VDC from the top right-side panel. In this figure, a user selected sub-layers of the Bocah information layer that consisted of the parcel (orange lines), construction area (red blocks) and map sheet (purple lines). The user made a query by clicking on the map. The pop-up window revealed information about the parcel including object ID, parcel key, district and VDC code. The displayed information provided parcel attributes, but no layered information about land tenure.

### 5.4.3 *Participatory*

Two of the participants could fill in the observation form that was designed for the communities/individuals to share their experience about the impacts of climate change, time and the location of climate change events and their needs. The climate-adaptation layer created the opportunity for mountain communities/individuals to share a CBA option with an image as a *"bottom-up"* approach to support *"crowdsourcing."* The system developer had already populated the climate-adaptation layer with some photos of adaptation options for the purposes of testing. Figure 17 represents the climate-adaptation layer. The climate-adaptation layer supports community/individual to be visible. The shared photos of climate-adaptation experiences provide information about the available resources and how to conduct a CBA to other communities/individuals. Based on the results, it is concluded that the system exhibits an ability to support *"participation"*, however, ideally the evaluation would be extended to include a field-based test enabling contribution of data by real community members. This represents an area for further inquiry.


**Figure 17- Climate-adaptation layer.**

A user could select the climate-adaptation layer from the right panel and overlay it with other layers. The climate-adaptation layer consisted of different adaptation options (CBA) that the user could choose from. This figure shows how the user overlaid an adaptation option (gabion) from the climate-adaptation layer with the municipality layer. Gabion is an iron-made basket that is filled with sand and soil to protect and to stabilize slopes from erosion (Campelo et al., 2018). Bocha communities installed gabion walls as a climate adaptation option to protect roads and buildings from landslides. A user takes advantage by seeing CBAs in other places. This layer can provide information about who is doing what regarding CBA, where, and how, it can be combined with other land layers. Furthermore, a user can compare different CBAs to see if any of them align with the available resources or skills in the current location. The layer was already populated with some adaptation option photos for the user test, and enabled a user to upload and share their CBA options in MCAS. The climate-adaptation layer overall facilitates the implementation of an adaptation option in other locations and hence is concluded to be participatory.

### *5.4.4 Affordable*

MCAS is developed as a research prototype using open-source software and with minimum available resources of system requirements and experts. All of the participants had free access to the data of meteorological stations, ten year rainfall, and temperature graph and layers in MCAS. The users needed a smartphone/laptop to retrieve information from MCAS. The MoLR as a governmental body has already established a LIS and has the capacity of incorporating different data and information from other organizations or agencies including DHM. Technical experts from diverse backgrounds are available for further development and operation of an LIS such as MCAS. However, since open data was used for MCAS prototyping, the feasibility of existing open data in scaling or implementation of the system should be considered. Besides, assuming that all users in remote areas have devices available to access MCAS, the cost of providing internet infrastructure across the country is high and this is a broader contextual limitation of the system. From all the points raised, MCAS can be considered somewhat affordable in the short term, and potentially affordable in the medium to long-term.

### 5.4.5 Reliable

An LIS is reliable when it represents its data through the spatial framework of FFP LA that requires the four principals of (1) having visible boundary; (2) using satellite images; (3) being accurate in the way of fulfilling the purpose of the system and (4) authorizing update and improvement of an LIS (Enemark, McLaren, et al., 2015). MCAS provides reliable land and climate information by following these principals. MCAS used Open Street Map as a base map that enabled embedding data layers in the system. Open Street Map is using satellite navigation system in providing geospatial data (OpenStreetMap, 2017). Furthermore, data layers visualized general boundaries of the study area and this qualifies for most LIS purposes, particularly in rural areas (Enemark, Keith Clifford, et al., 2015). The displayed land and climate data in MCAS were accurate enough to fulfill the need of the users in identifying spatial objects, including land parcels and non-spatial objects such as rainfall and temperature graphs. MCAS could record changes of adaptation options through the sharing of images that update MCAS and provide incremental improvement in adaptation activities. According to all the aforementioned points MCAS can be considered to exhibit an inherent level of reliability.

### 5.4.6 Attainable

A mixture of an Agile-inspired approach and open-source software were put to use in MCAS development. A system runs with the minimum requirements in an Agile approach. Open-source software is usually available for IS development at limited or less time and cost. The implementation of Geo-ICT projects necessitates Internet access and installing its infrastructure. Also, Nepal mountain communities/individuals require PCs, laptops, or smartphones to access climate adaptation services as Geo-ICT services. In the absence of Internet service providers in Nepal's rural areas, with existing telecenters only concentrated in places with high population—mostly in Katmandu (Thapa & Sæbø, 2011). MCAS is currently not attainable in the study area. However, if a telecenter was to be set up in the study area—as would be expected in the medium term—MCAS could be considered attainable.

### 5.4.7 Upgradeable

MCAS was developed based on an Agile-inspired approach. This approach uses incremental development, based on the users' feedback to improve the system. The component based nature of the design of any IS creates the possibility of utilizing plug-ins and tools as needed. For instance, adding a specific feature and customization to make IS more versatile. The climate-adaptation layer has the potential to assist the government in developing its climate change policies, both the Local Adaptation Plans for Action (LAPA) and National Adaptation Program of Action (NAPA), since it presents facts and evidence of a CBA. MCAS as a communication channel connects communities/individuals and the government to experience climate adaptation services. Overall MCAS is considered to exhibit levels of upgradability.

In summary, some of the FFP LA elements have not been fully satisfied in this study, but they have the potential to be achieved with further research and development.

## 5.5 Discussion

The development and evaluation results revealed much about current CBA implementation, the potential utility of MCAS, drawbacks and challenges for its actual implementation and scalability. This section focuses on three critical areas deemed the most important learnings from the study.

### 5.5.1 Lessons from the design process

Initially, the Agile-inspired approach was not considered for the work, however, its adoption is considered to have enhanced the final outcomes. The nature of the project appears to have fit well with the Agile philosophy: a minimum set of requirements, established from the analysis of FGI and the household survey among individuals, coupled with an experimental mindset meant the first iteration of the system was available within two weeks, and iterations thereof became available at a repeating two week increment. During the ongoing system development, a core team consisting of a IS technical developer, a land and climate change researcher, and a project advisor tested and simulated MCAS repeatedly. This enabled rapid and incremental improvements.

However, a key concern was that the feedback was simulated from the project team. That is, it was not possible to incorporate the feedback from the actual users during system development. The team members were not working directly at the test location due to their workload, schedule overlaps, and the time and cost involved with traveling to reach mountain communities and there was no direct or indirect contact with them. The distance between the development location and the actual test location and the lack of any ability to co-develop MCAS was a major drawback, although perhaps to be expected in this small-scale testbed environment. At any rate, any efforts to replicate or scale the design process used here would need to take this issue into account.

Also, on the design process, the use of online open data and open-source software was thought to have accelerated the development. Extensive coding and programming were not needed, and neither was going through the bureaucracy of collecting data from multiple organizations. For instance, rainfall and temperature data were collected from the DHM website, and Open Street Map was used as the base map. A base map is a crucial component—no LIS such as MCAS can function without it.

Another issue emerging during the development process related to the challenges of working in multi-disciplinary and multi-cultural research environments. As a base level differences in language and culture continually impacted upon decision making. Moreover, during the trials of MCAS, the priorities of each user were different based on their backgrounds and their objectives. The difference between scientific language among disciplines (e.g., IS vs. LA vs. climate change experts) in the development team is thought to have also delayed several advancements in the software. The costs and challenges of miscommunication and the translation efforts in working in this multi-national and multi-disciplinary context (e.g., translating CAPs language into IS requirements and Geo-ICT demands) were neither factored not costed in during the design process, but, need to be highlighter as a major challenge for future work.

Finally, whilst the Agile approach seeks to enable adding new features and functionality, the actual implementation of these changes was considered highly challenging. Adding new features to make the system flexible, and adding data layers or making spatial queries accessible were challenging aspects to incorporate. It is important to consider who would deliver these updates in a practical setting. Most likely there is a need for external support outside communities and government to do such maintenance, and this potentially undermines the community-orientation of the tool.

### *5.5.2 Remaining challenges for the tool*

First, regarding content, the most requested layers and information included land-related layers, adaptation options, the location of meteorology stations and the rainfall and temperature graphs. As explained, these were certainly incorporated into MCAS, however, it is believed MCAS could be further developed to incorporate other datasets based on the feedback from the test users. However, this should be considered no small challenge: data acquisition and entry was more challenging than initially expected. Some of the collected data from different organizations, excluding open data, were defined in different coordinate systems, and needed transformation to be displayed correctly in the system. It was a challenging task to identify the proper coordinate system and to avoid parallax problems. Despite advances in automation and simplification of software tools, understanding and resolving this still demands a relatively high level of training and digital acumen. Further simplifying the process for adding new layers should be a future focus.

In terms of usability functionality, users tended to interact easily, if not seamlessly, with combined layers, a major challenge was loading the near-real time online climate data: processing and distributing the weather data points every second is only possible with a high-speed connection and most likely not realistic in the case location at the current time (OpenWeatherMap, 2017). Additionally, the loaded near-online climate data layer covered the base map entirely, and since the layer was not visually transparent, the underlying layers became invisible: this was considered a major usability flaw, but one that could be easily overcome with further development. Another identified issue was that users could not retrieve the exact value of the rainfall or the temperature from either the static graph or the near-online climate data due to the nature of the data being vector and raster respectively. Solving this would need specific knowledge of coding or specialized software and tools (Li et al., 2016) (V. Kumar et al., 2012). Furthermore, the use of the English language embedded into MCAS, was recognized as a barrier of both the development and evaluation of system itself. Language is an issue that demands further thought and research with regards to MCAS. Whilst digital translation tools have rapidly matured and are more readily available for implementation in such web service oriented systems, the issue of dealing with mountain community members who are not proficient in English certainly demands more consideration. Overall, the prototype emphasis on a single language limited the use and users of MCAS, by excluding the users who are not proficient in English. Overall, the prototype emphasis on single language limited the use and users of MCAS, by excluding the users who are not proficient in English.

In terms of functionality, and specifically crowdsourcing interactions, the climate-adaptation layer was already populated with photos for system simulation as preparation for the actual user test. Therefore, the idea of the community uploading CBA photo was not really explored and implemented in a satisfactory manner and demands the contribution of data by real community members (Figure 17 – Climate adaptation layer). In addition, MCAS was mainly tested on a desktop, and it is not clear whether some of the system functionalities including zoom in/out, pan and visualization of layers would work properly on a mobile device/smaller screen.

On affordability, developing MCAS was affordable as only a team of three experts was involved for two weeks to get the initial IS working. Simple functionalities were available early on in MCAS because it was designed and developed in the context of running an existing LIS. It was an ideal approach to facilitate and demonstrate proof of concept. The visual proof of concept represented the capability of the system. For instance, the climate-adaptation option layer provided specific information about CBA, the land-use category illustrated land information and the static climate graphs supplied information about rainfall and temperature. An Application Programing Interface (API) removed the challenges of translating the near-online temperature and rainfall data and embedding Open Street Map in MCAS. However, as already noted, to ensure that the design approach and developed system are scalable requires further investigation.

### 5.5.3 *Institutional opportunities and challenges*

Considering MCAS more broadly, in terms of institutional and policy implications, it is worth recalling that CBA is being integrated into National Adaptation Plans (NAPs) and sectoral policies, budgets, and planning frameworks to enhance community adaptive capacity (Cimato & Mullan, 2010): tracking CBA is increasingly essential for identifying whether adaptation actions are achieving the desired results and whether to continue adaptation implementation. An LIS like MCAS can share local contributions with the national level regarding the goals defined by NAPs, NAPAs, and LAPAs in adaptation. The climate adaptation experiences shared via MCAS at the local level could aid tracking and measurement of adaptation activities. It could facilitate policy-makers in choosing adaptation policies and strategies, in addition to helping the national level in management and financial support of adaptation actions and reinforcing communities in learning about the implementation of various adaptation options.

Maintaining LIS components and contents considered one of the major challenges with regards to technical infrastructure in developing countries (Simbizi, 2016). Formulation and implementation of LIS is often challenged due to political instability and motivation, capacity, financial resources and data availability (Furuholt et al., 2015). Capacity constraints related to the development of IT experts and equipment, Geo-ICT infrastructure, update and system maintenance should also be considered in the implementation of any LIS including MCAS. Each CBA is conducted by an individual or a community in a specific place, and thus the particular parcel may be transacted or inherited to other person/s. It is complicated to identify when and how that happened and whether the new owner would like to continue conducting that particular CBA.

Evaluation results of MCAS show that mountain communities/individuals could get more from a LIS generally: a type of service that benefits both mountain communities/individuals and the government, rather than climate information services alone. Indeed, it can be considered a disappointment that the communities for which MCAS is intended do not have readily available access to land tenure security, let alone land tenure data, and even more so relevant climate change information. This is where demonstrators like MCAS provide opportunity: as a driver for climate change adaptation and as a supportive tool for enhancing land tenure security.

## 5.6 Conclusion

This paper assumes that MCAS as a LIS is a comprehensive way to provide information for CBA in rural mountain areas. An Agile-inspired approach was used to develop MCAS. The developed web-based LIS demonstrated the ability to integrate a variety of spatial and non-spatial information including land and climate change variables. User testing was firstly conducted by the development team and later with the actual users because of time limitation, budget, and resources. The FFP LA approach was used to evaluate MCAS. The result of the user test revealed the importance of MCAS in supporting climate adaptation services. It indicated that MCAS could provide land and climate change information together with various experiences of CBAs. The spatial side of LIS allowed users to explore their location in the context of land use, infrastructure, and available resources that can enhance CBA activities. Climate change data demonstrated changes in climate variables. The evaluation identified the potential ability of MCAS to be fit-for-purpose with respect to the climate change adaptation needs within a community. This new service has the potential to provide an incentive for communities/individuals that are at the frontier in implementing CBA. The limitations related to the implementation of the new services were identified particularly the lack of Geo-ICT infrastructure in the case area. Regardless of the aforementioned limitations, MCAS can still be considered as a factor in supporting development in rural mountain communities/individuals. It is further suggested that the land aspects of climate change should be added more explicitly to CBA initiatives.

# Chapter 6: Synthesis

# 6 Introduction

The primary goal of this thesis was to explore the necessity, opportunities, and challenges of an integrated LIS aimed at enhancing climate adaptation services for mountain communities. In this regard, the study was driven by four research sub-objectives, each presented and answered in the chapters of this thesis. The following sections summarize the findings related to each sub-objective to inform an overarching synthesis and set of concluding remarks.

## 6.1 Main findings

**Sub-objective 1: To identify the socio-technical limitations of existing Community-Based Adaptation (CBA) programs in mountain areas aimed at responding to climate change.**

This research sub-objective was formulated to understand mountain communities' vulnerability and CBA options, in order to better identify the gaps in response to climate change. This research sub-objective is addressed in Chapter 2 utilizing four steps to identify the components informing the sub-objective.

In the first step, definitions are concentrated upon: the term *"community"* were defined as *"a group of people with backgrounds that have the same characteristics"* (Khezri et al., 2017); and vulnerability is explained to include adaptive capacity, sensitivity, and exposure (IPCC, 2014b). These definitions are extended to explore community livelihood vulnerability, and the critical elements that influence communities' adaptive capacity, namely - adaptation factors and geo-information. Consequently, a model to understand the interactions was developed: adaptation factors, geo-information, and vulnerability aspects were integrated. The model outlines the potential role geo-information can play in enhancing adaptation factors. Various types of geo-information such as hazard maps and topography maps, resource areas, administrative boundaries and transportation links, adaptation policies and plans, and climate variables are available to enhance adaptation factors and reduce communities' vulnerability. Each of the adaptation policies and plans can be considered as a type of geo-information since adaptation options include location and sector-specific policies (Khezri, Bennett, et al., 2018).

In the second step, climate adaptation strategies were explained to enable linkage of national and local adaptation plans-of-action to communities, particularly in mountainous regions. The United Nations General Assembly (2013) emphasizes on the vulnerability of mountainous areas because of changing climate patterns. In addition, Chapter 13 of Agenda 21 of the United Nations Conference on Environment and Development (UNCED) endorses the involvement of mountain communities in mountain development activities. The implementation of an adaptation option requires communities to take part. It needs the flow of information about potential resources, climate variables and adaptation policy to engage both ways in order to achieve an optimum result from implementation.

In the third step, case studies on how mountainous countries are advancing in CBA were explored. This enables examination of how the above definitions, model, and agendas play out in a practical setting. To this end, three case studies derived from secondary data sources were presented: i) mountain community's climate change perceptions in Nepal (Maharjan & Joshi, 2013); ii) mountain community conditional land tenure systems in Indonesia (Macchi et al., 2011); and iii) mountain community value chains in Peru (Torres & Frías, 2012). The results indicated the importance of information to strengthen mountain communities and to support climate adaptation services. For instance, the involvement of communities in agro-forestry showed how access to information about improved products created in Peru resulted in the transformation of CBA to an economic outcome. An information system can assist mountain communities in providing reliable information on climate change variables, lessons and best practices of CBA.

In the fourth step, a service-oriented information system, termed the Mountain Community Adaptive System (MCAS), was proposed. A conceptual framework was developed to connect different components of the system to provide climate adaptation services via web services. The objective of this framework was to integrate different geo-information (e.g., land and climate) and to enhance the link between communities and implementation of CBA.

Overall, the chapter showed the need for the two-way flow of information, supported by appropriate technology and infrastructure, to support climate adaptation services in vulnerable mountain communities. It also revealed that more specific definitions of system requirements including technology and policy were required.

**Sub-objective 2: To develop a strategic model that enables the integration of policies and institutional arrangements from different sectoral levels and to consider its implementation for CBA services.**

Ensuring access to geo-information as part of climate adaptation services is recognized to improve implementation of mountain communities' adaptation options. In this regard, re-envisioning institutional arrangements to better supply information to an integrated climate adaptation policy was addressed by sub-objective 2 in chapter 3. Literature revealed the lack of coordination in climate policy creation and implementation (Moumouni & Idrissou, 2013) - and this included the institutional framework (UNFCCC, 2011). Analysis of climate policies, focus group interviews with target communities, and individual in-depth interviews with key experts at international, national and local levels, highlighted the fragmentation in adaptation to climate change. Land and information about land, being a somewhat standalone entity, was identified as integral to both societal and environmental development: it provided the ideal base for modelling the required integration - using a Land Administration (LA) perspective. Responsible and accessible LA is known to provide a basis for effective adaptation options that are needed for communities and the government to improve access to and control over the use of resources. LA as a country-specific and context-specific tool can enable collection, management and provision of information services. Table 11 lists land information services needed by policies.

**Table 11- Land information services needed by policies**

| Policy document | Land information services |
|---|---|
| CCP<br>NAPA<br>LAPA | Administrative boundary level, vulnerable area, vulnerable group, hazard zone, natural disaster, land type, land management, land tax, land distribution, land registration, land measurement, land tenure, infrastructure, current adaptation and mitigation plan, land administration, carbon map, identification of land and water conflict areas |
| NAP | Administrative boundary level, soil type, land type, land consolidation, land use, land cover, hazard zone, natural disaster, infrastructure, identification of land and water conflict areas, land distribution, land registration, land measurement, land tenure, |

LA can support the cross-sectoral integration and implementation of these services. LA has the potential to handle both policy and technical issues related to adaptation to climate change. Therefore, the establishment of a Land Information System (LIS) was identified to enable overcoming the limitations of existing climate change adaptation tools in supporting climate adaptation services in mountain communities/individuals.

**Sub-objective 3: To define how an integrated IS can be designed and implemented for mountain CBA and specifically focus on what the requirements, including spatial data and climate services, are.**

Following the above-mentioned recognition that a supportive IS could be put in place to assist policy and institutional arrangements relating to climate adaptation services, a socio-technological approach was suggested in response to sub-objective 3. The results of the investigative work indicated that in the case context, the different levels of national, district, NGO, community and individual were involved in adaptation programs. Diverse aims and focus were also evident amongst the stakeholders, varying from preparing climate-related polices down to implementing pre-defined adaptation options at individual and community level. However, further results revealed that communities and individuals were reluctant to implement Community Adaptation Plans (CAPs) since these are not designed based on their needs and requirements. Table 12 presents limitations of existing CAPs.

**Table 12- The limitations of current Community-based Adaptation Programs (CAPs)**

| | |
|---|---|
| **Policy Issues** | – Unclear operation of adaptation program at multiple levels of national, district, community and individual.<br>– Development of Nepal's climate policy is based on the Kyoto protocol rather than local communities' requirements.<br>– Uncertainty in how to involve mountain communities in CAP. |
| **Legal Issues** | – CAP is not a legal instrument yet.<br>– No direct communication between communities and responsible organizations for CAP. |
| **Economic/Finance Issues** | – Limitation of livelihood options and access to productive assets.<br>– No specific tools to identify the economic development of CAP.<br>– Difficulty in identifying vulnerable mountain communities.<br>– Inequality in conducting the social security program. |
| **Technology/ Information Issues** | – Lack of infrastructure to expand telecommunication channels.<br>– Focus is on disseminating general information on climate change and not specific adaptation practices for the local context.<br>– No evidence on facilitating mountain communities in using IS. |
| **Social Issues** | – Existing power relations promote inequality in accessing resources.<br>– Conducting CAPs without looking at communities prerequisites (what is needed), potentials (knowledge, capacity, asset, resources, information) and societal variables (gender, cast, and ethnicity). |

Table 12 confirmed that IS requirements were not considered in existing CAPs. However, it was evident that some form of IS would be beneficial, if not essential, to realize suitable climate adaptation planning. Following on, the key services for mountain communities were identified (see Figure 18). These services were the types of information that a Land Information System (LIS), a subset of LA, usually collects, stores, manages and disseminates as IS to citizens. Emerging technologies including mobile and web-based tools were confirmed as being able to support sharing spatial and non-spatial information (Williamson et al., 2010). Therefore, the concept of an integrated land and climate change IS, or a Mountain Community Adaptive System (MCAS), that contributes to adaptation to climate change was identified as a possible response. An MCAS could contribute to providing land and climate change services to support mountain communities/individuals. The importance of assessing the effectiveness of MCAS, as an integrated IS, regarding how it supports and enhances CBA initiatives was subsequently argued. On this, Christiansen et al. (Christiansen et al., 2016) reported on the lack of applicable indicator/s due to the multifaceted nature of adaptation: much of what is considered as CBA is not focused on climate change adaptation options. There is no *"one size fits all"* (Christiansen et al., 2016) solution to assess the type of CBA or to identify whether CBA contributes to better management of the effects of climate change.

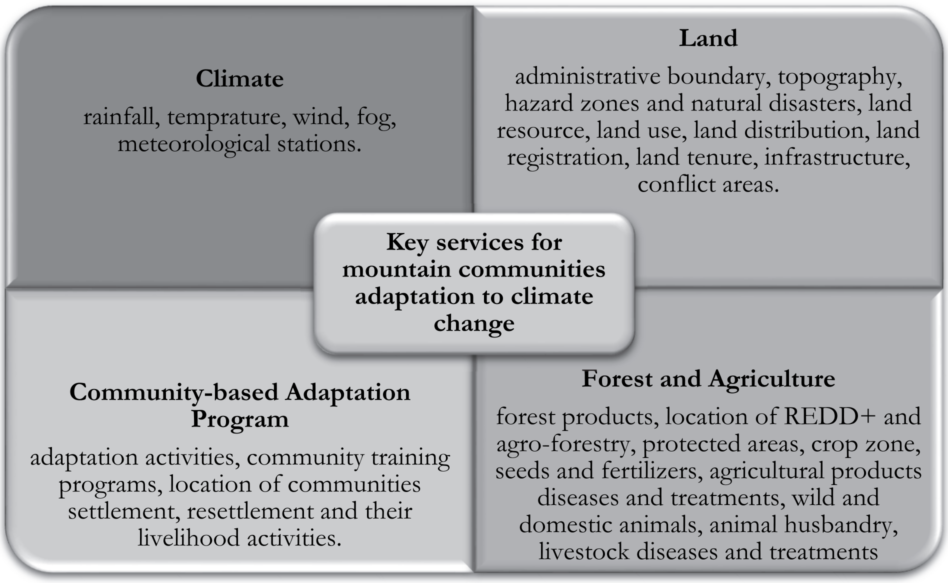



**Figure 18- Key needed services**

**Sub-objective 4: To evaluate the integrated IS by exploring its effectiveness in regards to promoting CBA.**

IS evaluation is mostly *"context and user specific"* (DeLone & Mclean, 2003). It is also recognized that evaluation of CBA needs indicators. A number of studies indicated that FFP LA concepts and tools can support the improvement of adaptation to climate change (Enemark, Keith Clifford, et al., 2015) (Mitchell et al., 2015). Therefore, the FFP LA framework was adapted to answer this sub-objective. Amongst other characteristics aligned to this work, the FFP LA approach improves a system incrementally over time (Mitchell et al., 2015). Furthermore, the Voluntary Guidelines on the Responsible Governance of Tenure of land, fisheries and forests in the Context of national food security (VGGTs), from which FFP LA stems, recommends participation of communities and individuals in responses to the impacts of climate change (FAO, 2012).

In this vein, a demonstrator MCAS was developed and was sought to be a flexible and low-cost approach to creating and sharing the land and climate change information amongst community stakeholders; focusing on the services that satisfy users' needs: the objectives of FFP LA and MCAS were therefore closely aligned. The elements of the FFP LA framework including *"flexible"*, *"inclusive"*, *"participatory"*, *"affordable"*, *"reliable"*, *"attainable" and "upgradable"* were adapted for the specific research to identify the constraints for change in adaptation services. The demonstrator MCAS was developed using an Agile-inspired approach offering system creation based on minimum system requirements and iterative development.

Evaluation results indicated that an MCAS-style system could provide useful land and climate change information such as land use status, adaptation options, near real-time rainfall and temperature details, climate change variables, amongst others, as services that can enhance CBA initiatives. The spatial side of MCAS allowed users the exploration of their location in the context of land use, infrastructure, and available resources. This information can improve CBA planning and implementation at the mountain community level. Despite the mentioned benefits of MCAS, key limitations to access the system were identified: lack of funding and low salaries of mountain communities made it difficult to pay for smartphones and internet packages, and the underlying requisite ICT infrastructures was under-developed in the assessed mountain communities. The results of the evaluation further suggested that finding out who is using which kind of adaption option and where, how and how long it is being applied are of more significant interest to both mountain communities/individuals and the government than climate adaptation services alone.

## 6.2 *Reflection, Contribution, and Outlook*

Advances in geo-information, integrated with internet, web and mobile technologies offer solutions to tackle challenges and impacts of climate change at global, national, local and community levels – as well as enhance the relationships between those levels. The advancement of Geo-ICT tools, including wireless sensor networks, web-based tools, and location-based services, provides significant potential for adaptation planning activities to increase local awareness about risks and impacts of climatic events. This section reflects on crucial aspects of the research and its contributions.

### 6.2.1 *Integrating Research, Policy and Technology*

As discussed in the previous chapters, national and local levels are all involved in the planning and design of adaptation – yet it is largely the community level that is the major stakeholder group involved in the implementation of CBA options. For each level, Geo-ICT tools can be widely used in supporting elements of adaptation including observation, assessment, planning, implementation, and monitoring and evaluation (UNFCCC, 2014b). However, there is limited literature on how best to utilize and implement Geo-ICT tools to link stakeholder adaptation steps across different governance levels. This research brought issues of LIS and integration into the climate change adaptation discourse.

Hadorn et al. (2008) revealed that integrated approaches facilitate cooperation between *"disciplines and with actors and participants outside science."* This research contributes to the integration of climate adaptation policy and utilizing technology to support i) communities, ii) policy makers and iii) scientific researches. The development of climate adaptation solutions can be policy-driven, technology-driven and socially-driven: LIS has the potential to play a vital role in these policy, technology and social dimensions. This research developed a socio-technological approach to the best of the researcher's knowledge has not been applied in the field of climate change adaptation previously. In this regard, this research contributes to utilizing LIS in climate change adaptation scientific researchers, for the interplay between social and technological dimensions to policymakers, and by providing climate adaptation services to communities. It further links stakeholders of adaptation steps across different levels.

### 6.2.2 *Developing and Evaluating Systems and Infrastructure*

Literature reveals the importance of climate services in increasing adaptive capacity and decreasing vulnerability of the people who are the frontier in climate events (Goosen et al., 2013) (Fünfgeld et al., 2013) (IPCC, 2014c). This research utilized LIS, a subset of LA, as a suitable tool to provide climate adaptation services to mountain communities. LIS as a country-specific tool has the potential to provide access to information and use of available resources as services (Khezri, Tuladhar, et al., 2018). Furthermore, this research utilized an incremental and iterative approach in both system development and system evaluation. Applying an Agile-inspired approach arguably could accelerate the process of aligning the LIS for the mountain community. The elements of FFP LA including *"flexible", "inclusive", "participatory", "affordable", "reliable", "attainable" and "upgradable"* were adapted and applied to revise the system and its services incrementally. Since the elements of FFP LA support the spatial, legal and institutional framework of an LIS, incremental changes can be adapted to any of them. For instance: incremental changes in adding different data or changes in climate adaptation policy. In addition, this research utilized distributed/cloud infrastructure in data storage and processing needs of climate adaptation services.

### 6.2.3 Co-Creating CAPs with an Interdisciplinary Team

Community-based Adaptation Plans have been defined as *"a community-led process, based on communities' priorities, needs, knowledge, and capacities, which should empower people to plan for and cope with the impacts of climate change."* (Gray et al., 2016). This research revealed that it is better to consider an interdisciplinary team of policy makers, governmental organizations, research centers and researchers, NGOs, local key adaptation experts, communities and individuals who need to work together in the process of developing CAPs. Forming an interdisciplinary team in developing CAPs creates an integrated understanding that facilitates the process of planning, designing and implementation of CAPs. This research supported the involvement of communities in co-development of CAPs that can lead into producing community-driven adaptation options.

### 6.2.4 Intersecting CAPs and Tenure Security

LIS is a tool that has the potential to address the changes and the activities in a system or context. CAPs are specific to actors and places: they are conducted by communities or individuals – potentially with the support of higher levels of governance. LIS can record and document the attributes of an object including *"objective, action, spatial extent, duration and people impacted"* (Bennett et al., 2008). These attributes can provide information about CAPs, and the involved people. LIS tracks the changes in different places and sectors that generate an evidence-base about people-to-land relationship particularly land tenure. Policy makers are interested in improving tenure security of rural communities that are confronting climate change. An LIS addresses the changes in the use of land, natural resource or conflicts over access to valuable areas that support policy makers in understanding the complexities of the communities' landscape and livelihood situations. Therefore, policy makers could include new rules on recognizing the rights of communities and individuals about using and gaining access to resources in the areas affected by climate change. This is a step towards creating tenure security, strengthening property rights and building community climate resilience.

### *6.2.5 Contributing to Socio-Technical Knowledge on Nepal*

This research examined the needs and requirements of an IS to provide climate adaptation services for mountain communities in Nepal. Chapter three considered Nepal's climate policy, while chapter four focused on CAPs in Nepal and chapter five revealed the results of the developed IS based on mountain communities' requirements. This implies that the case studies on Nepal's mountain communities can apply the results in this thesis to assist local climate policy and institutional arrangements. Furthermore, this research can be extended to other mountainous countries. Chapters three to five sought to emphasize that climate adaptation services require the integration of policies and socio-technological approaches to follow incremental solutions of providing climate adaptation services at community/individual level. This research demonstrates that the climate adaptation services needed in Nepal represent a complex and interlinked mix of environmental aspects, economic development objectives, and social contexts.

Overall, the concepts and tools applied in this research could facilitate mountain communities to be more aware of key issues related to climate change and to adjust better to climate change. Adaptation opens the dialogue on the people-to-land relationship. Mountain communities need to be more prepared to respond the challenges of resource management and move towards a shared problem-solving approach that increases the possibilities to participate in climate change policy and to enhance land tenure security.

## 6.3 Future research recommendations

This research showed the potential added values of utilizing LIS in adaptation to climate change for all levels of governance, be they national, local, community and individual. LIS as a management tool could integrate both policy and technology to deliver climate adaptation services. Further research should focus on forming policies to promote adaptation plans and programs, policies that could better consider land tenure security and seek to harmonize national laws and international climate change frameworks. Moreover, other subjects including scalability, transferability, financial and business models, and capacity requirements related to the outlined IS for mountain communities also need to be explored to ensure long-term and sustainable CAPs.

For any further progress, it is crucial to be able to apply the way CAPs function within a framework of multi-level governance, at scale. CAPs need legitimate support, collaboration and cooperation from the governance structures. Therefore, more research is needed to explore governance issues for planning and implementation of CAPs including land tenure security, continuous communities/individuals engagements, community capacity building development and scaling up to the national scale. Nevertheless, the actual progress of CAPs relies on interdisciplinary research involving experts from IS, LA, CAPs, Local Adaptation Plan of Action (LAPA) and National Adaptation Plan (NAP) that include different stakeholders engaged in such processes. In addition, future works should focus on applying land tools to adaptation to climate change such as the Land Administration Domain Model (LADM) to understand if this emerging global standard might contribute to improving climate adaptation services. It is essential to identify whether LADM can provide a standard data model that includes the necessary land and climate information-related components that support climate adaptation services.

This research has demonstrated the concept of integration and its benefits to mountain communities and individuals. However, policy and technology are changing independently. Technology is advancing rapidly in comparison to changes in institutional and organizational frameworks in climate change adaptation. Due to this division, less developed countries appear to be more vulnerable: most often there is no policy for adaptation plans and programs. This disconnects less developed countries from linking international climate change framework to a national level. Thus, further research should focus on how to deal with issues of providing climate adaptation services under a convenient policy and institutional framework.

Finally, the work undertaken here ultimately seeks to support achievement of the global development agenda and related programs including the Sustainable Development Goals (SDGs). In this vein it is hoped this work contributes to the growing discourse on land administration, good land governance and FFP LA in support of climate change and SDGs achievement (Mitchell et al., 2015) (Enemark, McLaren, et al., 2015) (Eckstein et al., 2017). The land component is mentioned in no less than six goals of SDGs including Goal 1: ending poverty, Goal 2: ending hunger, Goal 5: gender equity, Goal 11: sustainable cities and communities, Goal 15: life on land and Goal 16: peace, justice, and strong institution. A practical understanding of land components including land management, land governance, land policy and land information is needed to be considered in each dimension of the SDGs to support CAPs. The work at hand has further shown how climate adaptation services delivered with LIS support can enhance the sustainability of CAPs and the livelihoods, landscapes and relationships CAPs seek to improve.

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# *Summary*

Mountains are the living space of about 12% of the world's population, and it is estimated that 40% of people worldwide depend on mountains for some form of service or good including fresh water, hydroelectricity, timber, biodiversity, minerals, and recreation (e.g., tourist destination). Mountains display a diversity of climate that challenges the human capacity to respond to environmental degradation. The fragility of the ecosystems in mountains means that the effects in those areas are some of the most visible indicators of climate change in any context. For the vast majority of mountain people, climate change means reduced access to land leading to increasing risk of losing home, land or livelihood.

The abovementioned issues result in mountain areas being a key focus for developing appropriate responses to climate change. Conference of the Parties (CoPs) introduced adaptation as a potential solution to reduce the impacts of climate change. Adaptation involves coping with the changes caused by climate change. According to the Intergovernmental Panel on Climate Change (IPCC) working group 2, 2014, 95% of climate change finds its root in humankind activities, including burning fossil fuels, deforestation, and land use change. Economic investments in industry, agriculture, tourism, hydropower, and communication routes cause deforestation and land use change that are mainly taking place in forests and mountainous regions. Climate change further influences land and land use systems in mountain areas and decreases available land and its usability for mountain communities, leading to the displacement of mountain people. Consequently, the mountain communities and individuals who are already vulnerable are the most affected by these developments and changes.

Agenda 21 – Chapter 13 – specifically focuses on *"Managing fragile ecosystems: sustainable mountain development"* and calls for the generation and strengthening of knowledge for the sustainable development of mountain people. It appears that the establishment of accessible information systems in these regions is important to achieve mountain communities' adaptation to climate change. Increasing knowledge, use of available spatial information and new technology are essential for mountain communities to know how to better manage land and natural resources and tackle the impacts of climate change. The IPCC highlighted the need for climate information and services to facilitate adaptation to climate change. Different mountain information systems are being developed worldwide based on these global challenges, government mandates, technological supports, IT infrastructures and the drive to use information in various sectors and levels. The initiatives aim at providing versatile services to decision and policy makers at international, national and local levels. Mountain communities are a unique case, and so far these sorts of services and related Information Systems (IS) do no reach these users. Therefore, it is important to improve existing IS or to develop a new generation that can support the unique community needs.

The general objective of this research was to develop the concept of an integrated IS that provides mountain communities with accessible climate adaptation services. Under the umbrella of this overarching objective, four sub-objectives were attempted: (1) identify the socio-technical limitations of existing mountain Community-Based Adaptation (CBA) in response to the effects of climate change, (2) develop a strategic model that enables integration of policies and institutional arrangements from different sectoral levels and to consider its implementation for CBA services, (3) define how an integrated IS can be designed and implemented for mountain CBA and specifically focus on what requirements, including spatial information and climate services, are needed, and (4) evaluate the integrated IS by exploring its effectiveness in regards to promoting CBA. The conceptual framework of systems thinking and more specifically soft-systems thinking was applied to address the four research sub-objectives. The four sub-objectives can be viewed as components of the system interacting together to expand an IS view in the development of the integrated IS. Iterative phases were distinguished including conceptualizing, identifying requirements, developing, and testing the IS to periodically review the research to keep it up-to-date as new concepts and updates are continually arriving.

The research began with a literature review to develop a theoretical framework, and to support the subsequent work. It covered community vulnerability, adaptation factors, geo-information for mountain communities, adaptation strategies, and plans at the community level. Three case studies were presented to identify stakeholders and their roles: i) the community experienced impacts; ii) community responses; and iii) community limitations to tackle the impacts of climate change. From the results, an hypothetical IS – dubbed Mountain

Community Adaptive System (MCAS) - was conceived and argued as an approach for potentially providing climate adaptation services to facilitate mountain communities.

The research continued with a case study (Dolakha, Nepal) to identify the requirements and components of the IS. The research found that institutional fragmentation makes the implementation of integrated climate adaptation policy challenging. This created a gap in the implementation of an integrated policy both in climate information supply and in the delivery of climate services at community and individual levels. Qualitative data analysis in ATLAS.ti identified what adaptation options and key climate services were needed. SWOT analysis identified the gap relating to climate adaptation services. A land information model for climate change adaptation services was introduced. Land administration as an institutional approach for dealing with land related challenges was suggested in the implementation of the model, as a service to strengthen district and community institutions.

The results from the previous findings outlined the possibility of using an integrated IS, or MCAS, to support mountain communities in CBA. Adaptation initiatives, tools, and options were presented to explore their limitations and potentials in facilitating CAP. The reasons for the selection the study area (Dolakha, Nepal) and its details were provided. The methodology of Noticing things, Collecting things and Thinking about things (NCT) was adapted for data analysis to address MCAS requirements and its services based on mountain community vulnerability. The MCAS set-up, with the ability to integrate and provide land and climate services, was introduced. Required data and those agencies able to provide it were identified. The results defined how an integrated IS can be designed and implemented for mountain CBA with special focus on what requirements, including spatial information and climate services, are needed in CBA service delivery, and assisting policy and institutional arrangements.

Qualitative data analysis revealed IS requirements including policy, stakeholders, data, and service needs. An Agile-inspired approach was utilized in the software development process (design and development of IS) offering system creation based on minimum system requirements and iterative development. The forth sub-objective focused on evaluating a developed web-based integrated IS interface, an implementation of MCAS, to promote CBA. It was recognized that evaluation of CBA needs indicators. Therefore, the Fit-For-Purpose Land Administration (FFP LA) framework was adapted to evaluate MCAS. The elements of the FFP LA framework including *"flexible"*, *"inclusive"*, *"participatory"*, *"affordable"*, *"reliable"*, *"attainable"* and "*upgradable*" were adapted for this specific context to identify the constraints for change in adaptation services. Evaluation results indicated that an MCAS-style system could provide useful land and climate change information such as land use status, adaptation options, near real-time rainfall and temperature details, climate change variables, amongst others, as services that can enhance CBA initiatives. The information could facilitate improved CBA planning and implementation at the mountain community level. Despite the mentioned benefits of MCAS, ensuring system access was identified as a key limitation: smartphones and mobile technologies still remain prohibitively expensive for members of mountain communities, and underlying ICT infrastructures remain under-developed in the assessed mountain communities. Regardless of the aforementioned limitations, MCAS can still be considered as a factor in supporting the development in mountain communities and individuals. It was suggested that the land aspects of climate change should be added more explicitly to CBA initiatives.

The results in this research have contribution to: (1) integrating research, policy and technology, (2) developing and evaluating systems and infrastructure, (3) co-creating CAPs within an interdisciplinary team, (4) intersecting CAPs and tenure security, and (5) contributing to socio-technical knowledge on Nepal.

Overall, the concepts and tools applied in this research could facilitate mountain communities to be more aware of key issues related to climate change and to adjust better to climate change. Adaptation opens the dialogue on the people-to-land relationship. Mountain communities need to be more prepared to respond to challenges of resource management and move towards a shared problem-solving approach, one that increases the possibilities to participate in climate change policy and to enhance land tenure security.

# *Samenvatting*

Ongeveer 12% van de wereldbevolking woont in een bergachtige omgeving. Naar schatting 40% van de mensen is wereldwijd afhankelijk van berggebieden voor natuurlijke hulpbronnen en gerelateerde diensten of goederen zoals vers water, energie uit waterkracht, hout, biodiversiteit, mineralen en recreatie (als toeristische bestemming). Berggebieden vertonen een grote verscheidenheid aan klimaat hetgeen een uitdaging vormt voor de menselijke capaciteit om te reageren op verslechterende omstandigheden. Vanwege de kwetsbaarheid van de ecosystemen in deze gebieden zijn de effecten van klimaatverandering daar het meest zichtbaar. Voor de meeste bewoners van deze gebieden leidt klimaatverandering tot verminderde mogelijkheden om land te verkrijgen en het risico van verlies van huis, grond of levensonderhoud.

Als gevolg daarvan zijn berggebieden een prioriteitsgebied geworden voor het ontwikkelen van toepasselijke maatregelen op de gevolgen van klimaatverandering. De COP's (Conference of the Parties) introduceerden adaptatie als een mogelijke oplossing voor het verminderen van de effecten van klimaatverandering. Adaptatie omvat het omgaan met de veranderingen veroorzaakt door de klimaatverandering. In 2014 stelde werkgroep 2 van het IPCC (Intergovernmental Panel on Climate Change) dat 95% van de klimaatverandering zijn oorsprong vindt in menselijk handelen, waaronder het gebruik van fossiele brandstoffen, ontbossing en verandering van grondgebruik. Economische investeringen in industrie, landbouw, toerisme, waterkracht en communicatieverbindingen veroorzaken ontbossing en verandering van grondgebruik, waarvan een groot deel plaatsvindt in bosrijke en berggebieden. Klimaatverandering beïnvloedt verder de systemen inzake bezit en gebruik van grond in deze gebieden en vermindert de beschikbare hoeveelheid land en de bruikbaarheid daarvan voor de gemeenschappen, die in deze gebieden leven. Dit leidt tot (gedwongen) verhuizing van de bevolking in die gebieden. Gevolg is dat deze gemeenschappen en personen die al kwetsbaar waren, de grootste gevolgen van deze ontwikkelingen en veranderingen moeten dragen.

Wat betreft adaptatie aan klimaatverandering in berggebieden, benadrukt Agenda 21 – hoofdstuk 13 –specifiek het managen van kwetsbare ecosystemen door duurzame ontwikkeling van berggebieden en roept op tot het maken en versterken van kennis over de duurzame ontwikkeling ten behoeve van de bewoners. Het lijkt er op dat het opzetten van toegankelijke informatiesystemen in deze gebieden belangrijk is voor het bereiken van klimaatadaptatie door de bewoners. Toenemende kennis, gebruik van beschikbare ruimtelijke informatie en nieuwe technologie zijn essentieel voor deze gemeenschappen om te weten hoe beter met het land en de natuurlijke hulpbronnen om te kunnen gaan en de gevolgen van klimaatverandering aan te pakken. De IPCC benadrukt de noodzaak van klimaatinformatie en diensten die klimaatadaptie faciliteren. Uiteenlopende informatiesystemen voor bergachtige omgevingen zijn en worden in de wereld ontwikkeld gebaseerd op deze wereldwijde uitdagingen, overheidshandelen, technologische ondersteuning, IT infrastructuur en gebruik van informatie voor verschillende sectoren en niveaus. Ze zijn allen gericht op het aanbieden van veelzijdige diensten voor beslissers en beleidsmakers op internationaal, nationaal en lokaal niveau. Gemeenschappen uit berggebieden vormen een unieke casus, en tot nu toe bereiken dit soort diensten en gerelateerde Informatie Systemen (IS) deze gebruikers niet. Daarom is het belangrijk bestaande IS te verbeteren of een nieuwe generatie te ontwikkelen die de unieke noden van deze gemeenschappen ondersteunt.

Het hoofddoel van dit onderzoek was om een concept te ontwikkelen voor een geïntegreerd IS dat gemeenschappen in berggebieden voorziet van toegang tot klimaatadaptatie-diensten. Onder dit overkoepelende doel zijn vier deeldoelen gedefinieerd: (1) het identificeren van de socio-technische beperkingen van de bestaande CBA (gemeenschap-gebaseerde adaptatie) in berggebieden als reactie op de gevolgen van klimaatverandering, (2) het ontwikkelen van een strategisch model dat de integratie van beleid en institutionele arrangementen mogelijk maakt tussen verschillende sectorale niveaus en na te gaan hoe die in te voeren zijn voor CBA diensten, (3) definiëren hoe een geïntegreerd IS kan worden ontwikkeld en geïmplementeerd voor CBA in berggebieden, met speciale nadruk op wat voor vereisten, inclusief ruimtelijke informatie en klimaatdiensten, nodig zijn, en (4) evalueren van het geïntegreerd IS door de effectiviteit te onderzoeken aangaande het bevorderen van CBA. Systeemdenken, en in het bijzonder de zachte variant – het zogenaamde *soft-systems thinking*, is gebruikt als conceptueel raamwerk voor het aanpakken van de vier deeldoelen. Deze deeldoelen zijn te beschouwen als de componenten van het IS die als samenwerkende onderdelen bijdragen aan de visie voor de ontwikkeling van een geïntegreerd IS. Door interactieve fasen te onderscheiden, waaronder conceptualisatie, identificatie van vereisten, ontwikkeling en testen van het IS, kon het onderzoek periodiek herijkt worden en zo steeds actueel blijven ondanks het steeds opduiken van nieuwe concepten en inzichten.

Het onderzoek begon met een literatuurstudie om tot een theoretisch kader te komen, en het vervolg te ondersteunen. Het omvatte de begrippen kwetsbaarheid van gemeenschappen, adaptatiefactoren, geo-informatie voor gemeenschappen in berggebieden, adaptatiestrategieën en plannen op gemeenschapsniveau. Drie gevalstudies zijn gepresenteerd om de belangengroepen en hun rollen te identificeren: i) gevolgen die de gemeenschap ervaart; ii) reacties van de gemeenschap; en iii) beperkingen binnen de gemeenschap om de gevolgen van klimaatverandering aan te pakken. Een hypothetisch IS – MCAS (Mountain Community Adaptive System) genaamd– is gesuggereerd en argumenten zijn aangevoerd dat die aanpak potentieel klimaatadaptatie-diensten kan aanbieden ter ondersteuning van de beoogde gemeenschappen. Het onderzoek is vervolgd met een gevalstudie (Dolakha, Nepal) om de vereisten en componenten van het IS te bepalen. Dit onderzoek stelde vast dat institutionele fragmentatie een uitdaging vormt voor de implementatie van een geïntegreerd klimaat adaptatie beleid. Het nu nog ontbreken hiervan veroorzaakt een omissie in de uitvoering van een geïntegreerd beleid zowel voor de klimaatinformatievoorziening als in het aanbieden van klimaatdiensten op het niveau van gemeenschap en individuele bewoner. Kwalitatieve data analyse in ATLAS.ti liet zien welke adaptatie oplossingen en fundamentele klimaatdiensten nodig waren. Een SWOT analyse (analyse van sterktes, zwaktes, kansen en bedreigingen) identificeerde de omissie aangaande de klimaatadaptatiediensten. Een op land informatie gebaseerd model voor klimaatverandering-adaptatiediensten is geïntroduceerd. Land administratie als institutionele aanpak voor het omgaan met land-gerelateerde uitdagingen is voorgesteld ter uitvoering van het model als dienst om op districts- en gemeenschapsniveau de instituties te versterken.

Bovengenoemde uitkomsten lieten de mogelijkheden zien van het gebruik van een geïntegreerd IS, of MCAS, om de beoogde gemeenschappen te ondersteunen bij CBA. Adaptatie-initiatieven, instrumenten en opties zijn gepresenteerd om de beperkingen en mogelijkheden van het faciliteren van CAP's te verkennen. De reden voor de selectie van het studiegebied (Dolakha, Nepal) en de details daarvan zijn uitgewerkt. NCT (dingen opmerken, dingen verzamelen en over dingen nadenken) is toegepast voor de data analyse om de vereisten van het MCAS en diens diensten te bepalen, gebaseerd op de kwetsbaarheid van de gemeenschappen in berggebieden. De opzet van het MCAS is geïntroduceerd met de mogelijkheid tot integratie en levering van land- en klimaatdiensten. De vereiste data en de bronhouders daarvan zijn geïdentificeerd. De uitkomsten geven aan hoe een geïntegreerd IS voor CBA in berggebieden kan worden ontworpen en geïmplementeerd, met speciale aandacht voor welke vereisten, inclusief ruimtelijke data en klimaatdiensten, nodig zijn voor het leveren van diensten voor CBA, en welk ondersteunend beleid en institutionele arrangementen daarbij horen.

De IS vereisten, waaronder beleid, belanghebbenden, data en diensten, zijn voortgekomen uit de kwalitatieve data analyse. Een op Agile geïnspireerde aanpak is toegepast in het software-ontwikkelingsproces (ontwerp en ontwikkeling van het IS), hetgeen systeembouw mogelijk maakte op basis van minimale systeemvereisten en middels iteratieve ontwikkeling. Het vierde deeldoel richtte zich op het evalueren van een web-gebaseerde geïntegreerde IS interface - een implementatie van het MCAS - om CBA te bevorderen. Het was duidelijk dat voor de evaluatie van CBA indicatoren benodigd zijn. Daarom is het raamwerk van 'doelgerichte land administratie' *Fit-For-Purpose Land Administration* (FFP LA) aangepast ten behoeve van de evaluatie van het MCAS. De elementen van het FFP LA raamwerk, waaronder flexibel, inclusief, participatief, betaalbaar, betrouwbaar, haalbaar en verbeterbaar zijn aangepast aan de specifieke context om de beperkingen van veranderingen in de adaptatiediensten vast te stellen. De uitkomsten van de evaluatie lieten zien dat een MCAS-achtig system in staat is om nuttige land- en klimaat-gerelateerde data, waaronder grondgebruiksstatus, adaptatie-opties, vrijwel actuele regenval- en temperatuurdetails en klimaatveranderingsvariabelen, als diensten te verstrekken om CBA initiatieven te laten toenemen. De informatie kan bijdragen aan een betere CBA planning en uitvoering op het niveau van gemeenschappen in berggebieden. Ondanks genoemde voordelen van het MCAS, blijft het realiseren van toegang tot het systeem een grote beperking: smartphones en mobiele technologieën zijn nog steeds extreem duur voor de beoogde bewoners, en de onderliggende ICT infrastructuur blijft onderontwikkeld in de bezochte gemeenschappen in berggebieden. Ondanks voornoemde beperkingen, kan het MCAS toch gezien worden als een factor in het bevorderen van de ontwikkeling van de berggebieden en haar bewoners. Verder is aanbevolen om meer expliciet aandacht te geven aan de grond-gerelateerde aspecten van klimaatveranderingen bij CBA initiatieven.

De resultaten van dit onderzoek dragen bij aan: (1) het integreren van onderzoek, beleid en technologie, (2) het ontwikkelen en evalueren van systemen en infrastructuur, (3) het co-creëren van CAP's door een interdisciplinair team, (4) het kruisbestuiven van CAP's en rechtszekerheid inzake landrechten en (5) het bijdragen aan de socio-technische kennis over Nepal.

De concepten en instrumenten die in dit onderzoek zijn toegepast kunnen in brede zin gemeenschappen in berggebieden ondersteunen bij het meer bewust zijn van de kernaspecten inzake klimaatverandering en bij het zich beter aanpassen aan klimaatverandering. Adaptatie vraagt ook om een dialoog inzake de mens-grond relatie. De betreffende gemeenschappen dienen beter voorbereid te zijn om te kunnen reageren op de uitdagingen die het beheer van natuurlijke hulpbronnen met zich meebrengen en naar een meer gemeenschappelijke aanpak van problemen te bewegen die de mogelijkheden van participatie inzake klimaatveranderingsbeleid vergroot en de rechtszekerheid inzake landrechten versterkt.

# Appendices

## Questionnaire for Focus Group Interview

1. Have you ever heard of climate change and its effect on your country?
2. What is the meaning of climate change in your view?
3. Do you have any experience of change in your environment?
4. Do you consider climate change as a threat to you and your family? In what way?
5. Do you have any information and education about climate change? In what way?
6. Have you ever participate in climate change event preparedness program?
7. How do you adapt climate change effects?
8. How do you communicate with responsible adaption program organization? How often do you contact them?
9. What kind of adaptation options are you involved in?
10. Who is responsible for planning and implementation of adaptation options?
11. How do you plan/manage your livelihood?
12. How do you like to make a good commitment to protect your region?
13. Do you know how often climatic events are taking place in your region?
14. Any comment to reflect on my research?

| **No.** | **Respondent name** | **Type of work** | **Signature** |
|---|---|---|---|
| **1** | | | |
| **2** | | | |
| **3** | | | |
| **4** | | | |
| **5** | | | |
| **6** | | | |
| **7** | | | |
| **8** | | | |
| **9** | | | |
| **10** | | | |

## *Questionnaire for household survey*

| Respondent Information | Questionnaire number: |
|---|---|
| Household address | |
| Name of household head | |
| Email | |
| Telephone | |
| Mobile | |
| Type of work | |
| Date | |
| Signature | |
| Coordinate | |

1. Are you immigrated to this place? If "yes", please specify why did you immigrate here?
2. Do you know why and how climate change is taking place?
3. In case of climate change events, what is your reaction?
4. Have you ever participated in any climate change event preparedness program?
5. Who do you provide the information regarding climate change effects?
6. Are you a member of any adaptation program?
7. Did you face any major or unexpected problems during the past year?
    - Serious crop failure
    - Loss of land
    - Major livestock loss
    - Loss of waged employment
    - Climate change/drought/flood
8. Please list the most important crops that your household is producing?
9. How often do you experience climate change effects?
10. Do you have any individual/community effort to reduce the impacts of climate change in your region? Please specify.
11. Do you have natural/physical structure to protect your community from the impacts of climate change?
12. Do you have any problems that limit your livestock production?

## *Questionnaire for NGO/District level*

| Respondent Information | Questionnaire number: |
|---|---|
| Name | |
| Thematic areas | |
| Email | |
| Telephone | |
| Role/involvement in sector/s | |
| Date | |
| Signature | |

1. Is there a need for individual action regarding reducing emission action?
2. How do local people understand climate change?
3. How does climate change interact with community livelihood activities?
4. Do adaptation policies and related projects address the local requirements?
5. Which factor/s should be considered more in climate change policy?
6. What is the impact of climate change in your region?
7. Who are the most affected stakeholders of the impacts of climate change?
8. Is there any need to plan support for the following groups? If "Yes", please indicate the plan/s?

| Groups | Need support? | Specify plan |
|---|---|---|
| Forest institutions | | |
| Forest owners | | |
| Community and local level | | |
| Individual level | | |

9. What are the key vulnerabilities/impacts for your region?
10. Is the government involved in reducing the impacts of climate change?
11. What are the main adaptation options of your region?
12. Who is implementing adaptation options?
13. Which barriers have been identified in planning and implementation of adaptation?
14. Have the adaptation strategies been embedded within existing policy?
15. If you would like to add extra information regarding climate change adaptation.

## *Questionnaire for National level*

***Ministry of science, and technology environment, climate change section, sustainable development and adaptation section***

| Respondent Information | Questionnaire number: |
|---|---|
| Name | |
| Thematic areas | |
| Email | |
| Telephone | |
| Role/involvement in sector/s | |
| Date | |
| Signature | |

1. What is the element of climate change policy?
2. How do you implement climate change policy at community level?
3. What kind of data and information do you provide? What are the data format and scale?
4. Is land tenure security of community people considered in climate policy?
5. Is there any link between the government and communities?
6. Do you incorporate climate change data into current climate policies, regulations and decision process?
7. Who are the main agent/s of planning and implementation climate change policy at national level, and adaptation options at district and community level?
8. Do you consider any spatial information such as topography, water bodies, in designing climate policy and its process?
9. Do you use spatial information for climate change adaptation strategies?
10. What do you think of government interventions regarding reducing impacts of climate change, is it mostly top-down or bottom-up approach?
11. How do you create and raise the awareness of climate change impacts of the local stakeholders at household, community and VDC, DDC and national levels?
12. What is the criteria to qualify effective integration and implementation of adaptation activities at different levels of community/individual?
13. What other information or opinion you would like to add?

***Ministry of land reform and management, topographical and cadastral surveys, revenue and land information and archive departments***

| Respondent Information | Questionnaire number: |
|---|---|
| Name | |
| Thematic areas | |
| Email | |
| Telephone | |
| Role/involvement in sector/s | |
| Date | |
| Signature | |

1. Does climate change information integrated with cadastral and land maps?
2. Do you consider land tenure security to design land policy?
3. Is there any resettlement plan for community before/after climatic events?
4. In Government of Nepal (GoN, 2012), it is mentioned that citizens have a right to adaptation and should be compensated for the losses and damages caused by climate related disasters, How do/did you compensate such community/individual?
5. How do you share information about land and climate change among communities?
6. Is there any interaction among communities, district level and policy makers?
7. What kind of data and information do you provide? What are the data format and scale?
8. How do/can you support climate change policy makers and community by the data and information that you provide?
9. What is the key land policy issue to be addressed in relation to adaptation to climate change?
10. Do you use any climate policy instrument like building regulation, land use zone, pollution control, etc.?
11. Any other information you would like to add?

***Ministry of Forestry and Soil Conservation, Department of Forest Research and Survey, and Forest Department***

| **Respondent Information** | **Questionnaire number:** |
|---|---|
| Name | |
| Thematic areas | |
| Email | |
| Telephone | |
| Role/involvement in sector/s | |
| Date | |
| Signature | |

1. What kind of data and information do you provide? What are the data format and scale?
2. What is the key policy issue to be addressed in relation to adaptation to climate change?
3. How do you improve forest density, biodiversity and reduce the rate of deforestation?
4. How do you make a good commitment for forest protection? Any mechanism/criteria/elements?
5. What kind of service/s community/individuals can get from forest protection?
6. What kind of information do you incorporate with forest boundary?
7. Do you use any climate policy instrument like building regulation, land use zone, pollution control, etc.?
8. What other information you would like to add?

***Ministry of Agriculture***

| **Respondent Information** | **Questionnaire number:** |
|---|---|
| Name | |
| Thematic areas | |
| Email | |
| Telephone | |
| Role/involvement in sector/s | |
| Date | |
| Signature | |

1. What kind of data and information do you provide? What are the data format and scale?

2. What information is included in agricultural land? (if any)
3. Do you consider any other strategies beyond agriculture-base activities? If yes, please specify how or in what way. If not please specify the barriers.
4. Do you provide incentives for the farmers to implement environmentally sustainable practices?
5. What is the key policy issue to be addressed in relation to climate change?
6. Do you use any climate policy instrument like building regulation, land use zone, pollution control, etc.?
7. What other information you would like to add?

***Department of Hydrology and Meteorology***

| **Respondent Information** | **Questionnaire number:** |
|---|---|
| Name | |
| Thematic areas | |
| Email | |
| Telephone | |
| Role/involvement in sector/s | |
| Date | |
| Signature | |

1. What kind of data and information do you provide? What are the data format and scale?
2. What is the key policy issue to be addressed in relation to adaptation to climate change? for instance not to change the land use, not to concentrate the people in hazard-prone areas
3. What other information you would like to add?

## *Questionnaire for International level (ICIMOD)*

***Thematic area: Adaptation to Change***

| **Respondent Information** |
|---|
| **Full name** |
| **Email** |
| **Telephone** |
| **Role/involvement in sector/s** |
| **Date** |
| **Signature** |

1. What is the key policy issue for adaptation to be addressed in relation to climate change adaptation?
2. Is there any mechanism for coordinating in different levels for implementing of the climate change program?
3. What are the criteria to prioritize adaptation plans and options?
4. Is there an interaction between adaptation planning and design mechanism?
5. Do local institutions play role in planning and implementation of adaptation program?
6. Do you consider/incorporate climate change data and information like frequency, intensity, spatial extent, duration and timing of extreme weather and climate events in adaptation and mitigation strategies?
7. What other information or opinion you would like to add?

*Thematic area: Ecosystems*

| Respondent Information |
|---|
| **Full name** |
| **Email** |
| **Telephone** |
| **Role/involvement in sector/s** |
| **Date** |
| **Signature** |

1. Who is responsible for coordination across adaptation policy, planning and actors like donors, different climate change projects? (in Nepal, Dolakha).
2. What adaptation activities do provide benefits for communities?
3. What are the roles and responsibilities of community in implementation of adaptation options?
4. How do you identify, assess and manage vulnerable communities in relation to the interaction of climate change, ecosystem and degradation?
5. What services do you provide for community-based natural resource management?
6. What is the key policy issue for ecosystem to be addressed in relation to climate change?
7. What other information or opinion you would like to add?

*Thematic area: Geospatial Solutions*

| **Respondent Information** |
|---|
| **Full name** |
| **Email** |
| **Telephone** |
| **Role/involvement in sector/s** |
| **Date** |
| **Signature** |

1. What kind of technology are you using for adaptation measures?
2. How do you transfer the technology to community level?
3. Is there any institutional capacity building for planning and implementation of climate change adaptation program at district and VDC level, considering geo-information?
4. What kind of land and climate change data do you provide?
5. What other information do you provide? What are the data format and scale? Like soil types, use of land, or any data that facilitate adaptation?
6. What kind of services do you provide to facilitate climate change policy and land information system?
7. What kind of data and information do you need to enhance the system?
8. Do you consider/incorporate climate change data and information like frequency, intensity, spatial extent, duration and timing of extreme weather and climate events in your system?
9. How often do you update the data and information in the system?
10. What other information or opinion you would like to add?

*Thematic area: Livelihoods*

| **Respondent Information** |
|---|
| **Full name** |
| **Email** |
| **Telephone** |
| **Role/involvement in sector/s** |
| **Date** |
| **Signature** |

1. What is the criteria to identify vulnerable communities?
2. How vulnerable are the communities in terms of exposure, sensitivity and adaptive capacity?

3. Is there any institutional capacity for planning and implementation of climate change adaptation program at district and VDC level?
4. How do you facilitate community regarding impacts of climate change?
5. Do you think implemented adaptation options reduced vulnerability of community?
6. How do you enhance adaptive capacity of community?
7. What is the key policy issue for livelihood to be addressed in relation to climate change?
8. What other information or opinion you would like to add?

***Thematic area: Mountain Environment Regional Information System(MENRIS)***

| Respondent Information |
|---|
| Full name |
| Email |
| Telephone |
| Role/involvement in sector/s |
| Date |
| Signature |

1. What technology are you using for adaptation measures?
2. What kind of data and information do you provide? What are the data format and scale?
3. What kind of data and information do you need to enhance the system for adaptation options?
4. What kind of climate change data and information do you provide?
5. How do you share scientific information on climate change across sectors particularly at community level? Is there any feedback from community/individual?
6. What other information or opinion you would like to add?

## *Graphical representations of data analysis*

| Spatial scale | Sector | Number of Interviewee | Focus of the questionnaire | Data collection method |
|---|---|---|---|---|
| Regional level (ICIMOD) | Mountain Environmental Regional Information System (MENRIS) | 1 | Data, information and system design | In-depth interviews |
| | Adaptation to Change | 1 | | |
| | Geo-spatial Solution | 1 | | |
| | Livelihood | 2 | Adaptation programme, climate change policy, land tenure, land policy, REDD+ | |
| | Ecosystem | 1 | | |
| National level | Ministry of Agriculture | 1 | Adaptation programme, climate change policy, land tenure, land policy, REDD+, data and information system, resettlement, land allocation, risk management, adaptive capacity | |
| | Ministry of Forestry and Soil conservation-REDD Implementation Center | 2 | | |
| | Ministry of Climatology | 1 | | |
| | Ministry of Land Reform and Management | 3 | | |
| | Ministry of Science, Technology and Environment - Climate Change Section | 2 | | |
| District level | Livestock Office | 1 | Adaptation programme, community vulnerability, land tenure, land policy, resettlement, land allocation, risk management, data, information system, REDD+, resettlement, adaptive capacity | |
| | Survey Office | 1 | | |
| | Forest Office | 1 | | |
| | Agriculture Office | 2 | | |
| | Planning Office | 2 | | |
| NGO | FECOFUN Office | 1 | Adaptation programme, REDD+, Forest User Group, land tenure, community vulnerability, adaptive capacity | |
| Community level | Cherikot | 19 | Adaptation programme, REDD+, community vulnerability, livelihood, land tenure, climate change evidence, Forest User Group | Focus Group Interview |
| | Bocha | 21 | | |
| Individual level | Susma Chhemawati | 11 | Climate change evidence, adaptation programme, REDD+, Forest User Group, vulnerability, livelihood | Household Survey |
| | Charikot | 10 | | |
| | Bocha | 8 | | |

**Figure 19- Overview of interviews at different levels**

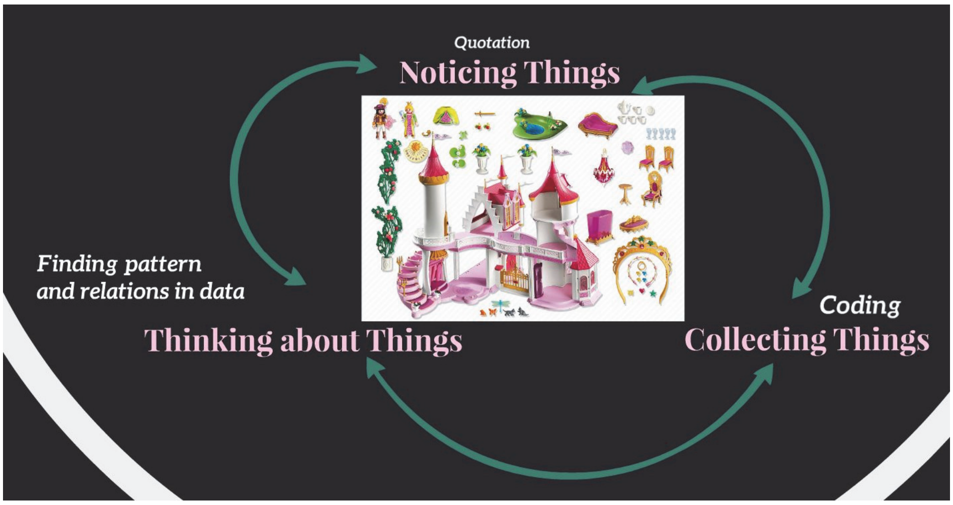



**Figure 20- Concept of NCT**

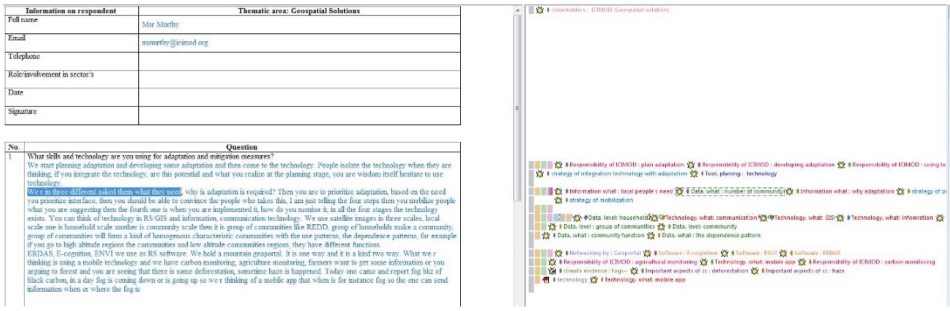


**Figure 21- Noticing and Collecting things from a document, quoting and coding**

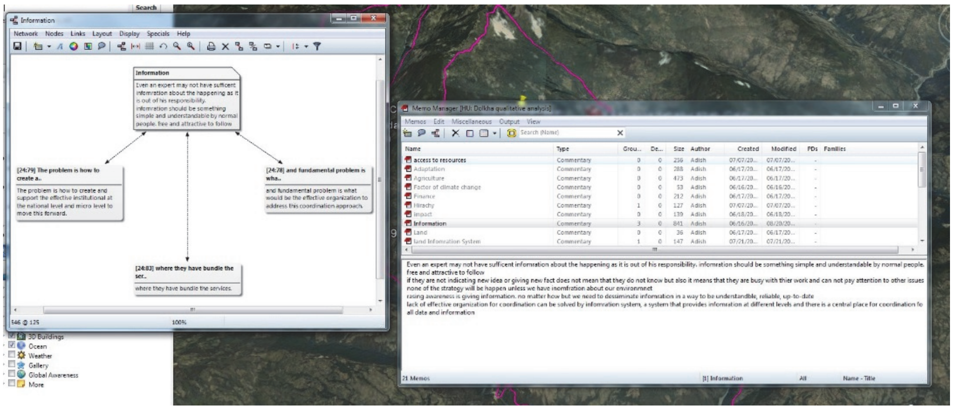


**Figure 22- Finding patterns in a document**

**Figure 23- Finding relations between the collected things**

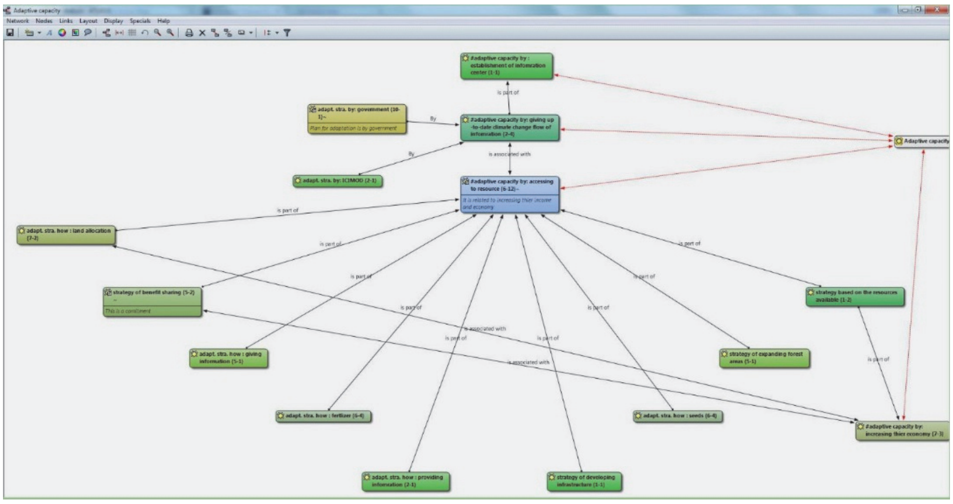



**Figure 24- Network analysis**

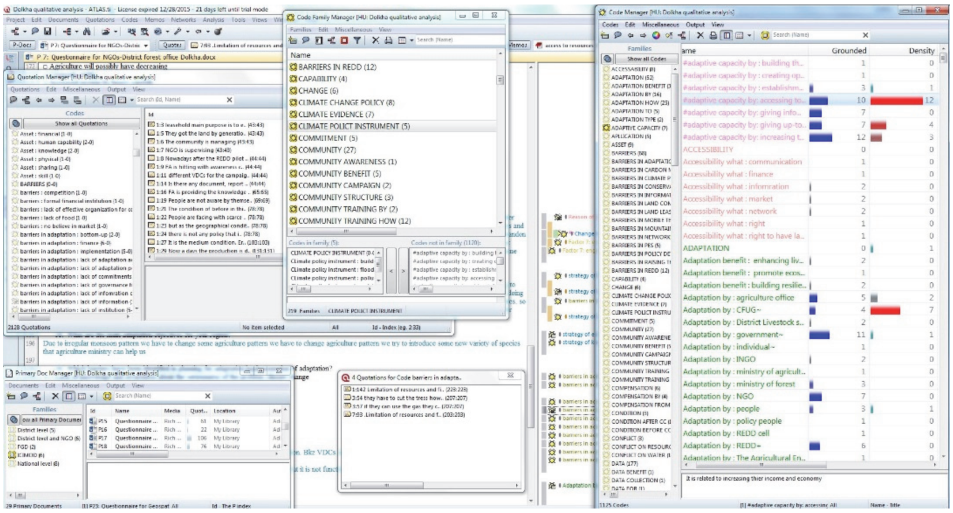


**Figure 25- Management of analyzed data**

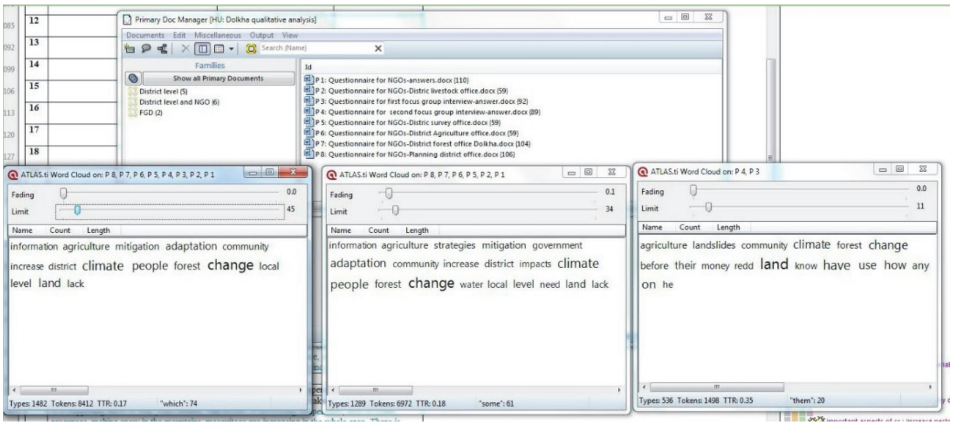
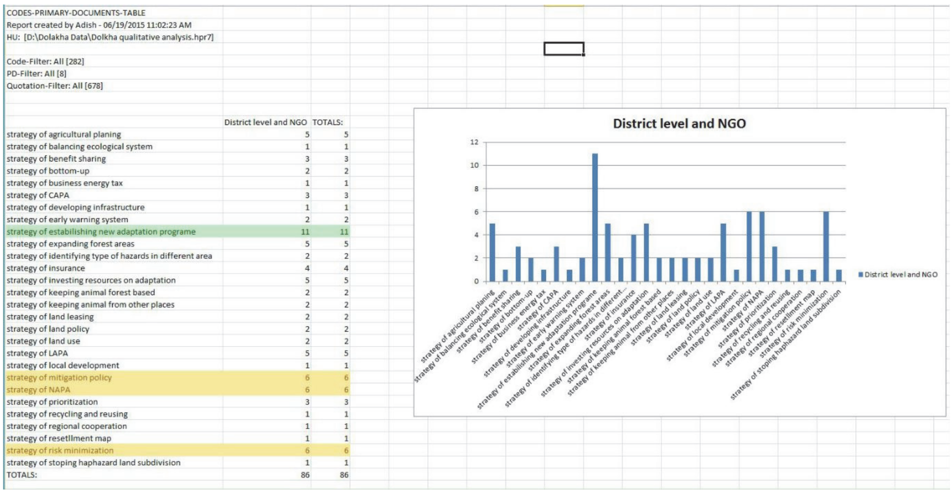



**Figure 26- Word cloud or word frequencies in a document**



CODES-PRIMARY-DOCUMENTS-TABLE
Report created by Adish - 06/19/2015 11:02:23 AM
HU: [D:\Dolakha Data\Dolkha qualitative analysis.hpr7]

Code-Filter: All [282]
PD-Filter: All [8]
Quotation-Filter: All [678]

| | District level and NGO | TOTALS: |
|---|---|---|
| strategy of agricultural planing | 5 | 5 |
| strategy of balancing ecological system | 1 | 1 |
| strategy of benefit sharing | 3 | 3 |
| strategy of bottom-up | 2 | 2 |
| strategy of business energy tax | 1 | 1 |
| strategy of CAPA | 3 | 3 |
| strategy of developing infrastructure | 1 | 1 |
| strategy of early warning system | 2 | 2 |
| strategy of estabilishing new adaptation programe | 11 | 11 |
| strategy of expanding forest areas | 5 | 5 |
| strategy of identifying type of hazards in different area | 2 | 2 |
| strategy of insurance | 4 | 4 |
| strategy of investing resources on adaptation | 5 | 5 |
| strategy of keeping animal forest based | 2 | 2 |
| strategy of keeping animal from other places | 2 | 2 |
| strategy of land leasing | 2 | 2 |
| strategy of land policy | 2 | 2 |
| strategy of land use | 2 | 2 |
| strategy of LAPA | 5 | 5 |
| strategy of local development | 1 | 1 |
| strategy of mitigation policy | 6 | 6 |
| strategy of NAPA | 6 | 6 |
| strategy of prioritization | 3 | 3 |
| strategy of recycling and reusing | 1 | 1 |
| strategy of regional cooperation | 1 | 1 |
| strategy of resetllment map | 1 | 1 |
| strategy of risk minimization | 6 | 6 |
| strategy of stoping haphazard land subdivision | 1 | 1 |
| TOTALS: | 86 | 86 |



**Figure 27- From qualitative data analysis to quantitative data analysis**

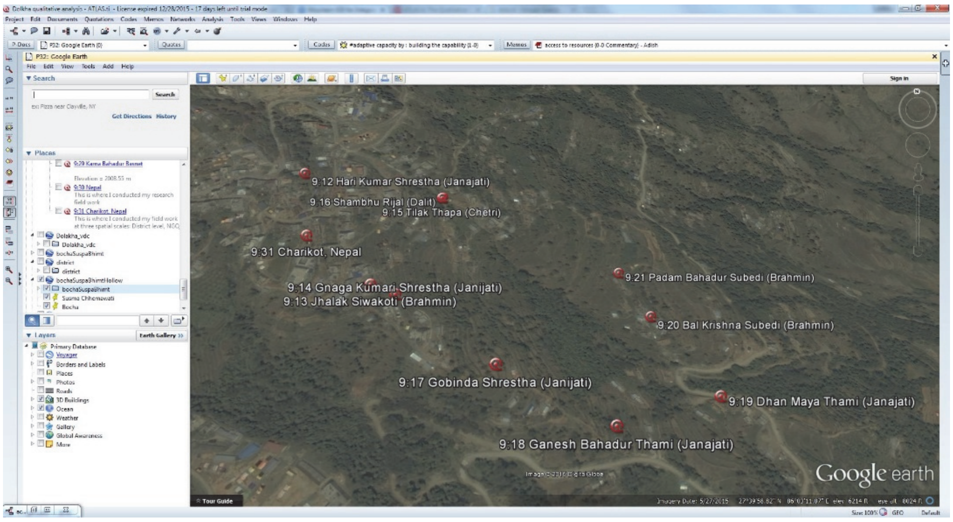



**Figure 28- Geo-coding documents**


**Figure 29- Triangulating geo-data with other collected data to enriching data analysis**

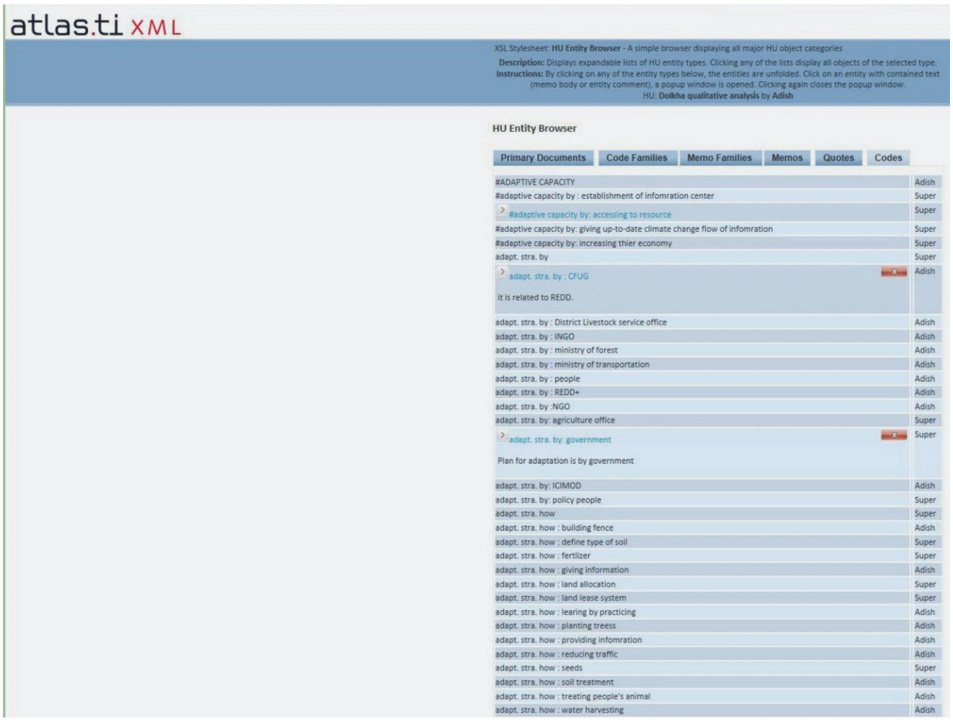



**Figure 30- Exporting codes in XML**

## *MCAS User Guide*

### *Introduction*

A mobile and web applications were built with the aim of providing information for the district, VDCs, NGOs, communities, and individuals. This system includes information about land and climate change, such as land use, administrative boundary, contour, hydro line, Cadastre, road network, near real-time temperature and precipitation, which support communities and individuals to access, visualize, and query information in a simple, easy and better approaches.

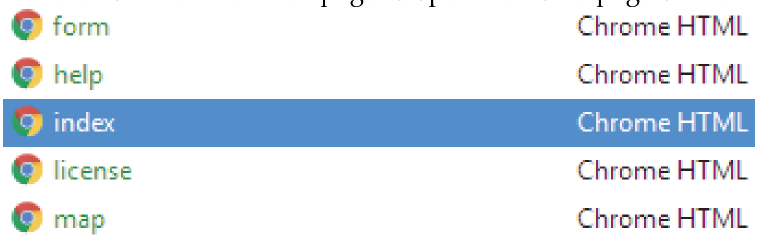
### *Process/Workflow*

1. Double-click on the index web page for opening the home page on the browser.
2. There is title bar on the top with the symbol, and name you can select map, license, home, help, and about us.
3. Click on the top left button zoom in/out, even you can scroll mouse for zooming in and out.

4. Click on the top right button  for selecting layers such as land use categories, village, contour, Cadastre, administrative boundaries, temperature and precipitation.
5. You can switch layers, overlay layers and click for the popup that contains attribute.
6. Click on the button name, select, station for selecting three meteorological stations.
7. Click on the layer name, select, temperature and precipitation for knowing up-to-date temperature and precipitation.

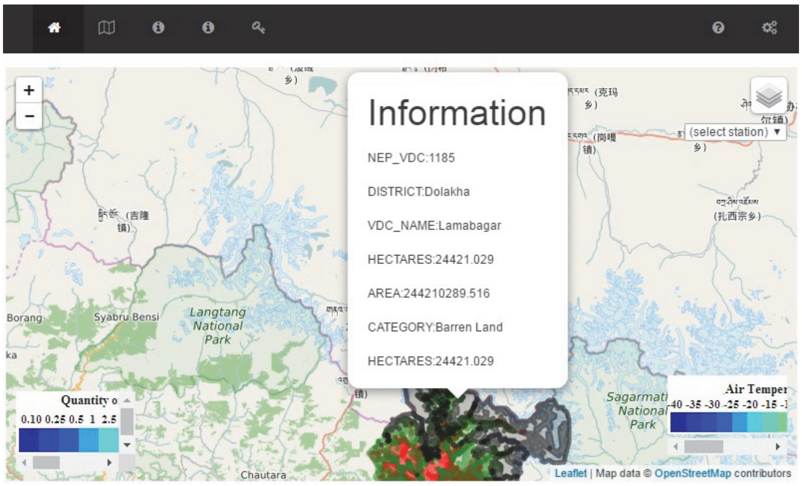
***Examples***

1. Double-click on the index web page to open the home page on the browser.



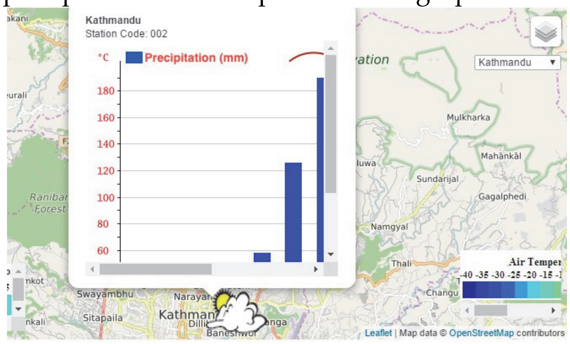

2. There is a title bar on the top with the symbols. You can select map, license, home, help, and about us.

3. You can switch layers, overlay layers and click for the popup that contains attribute.




4. Click on the button name, select, station to select each of the three meteorological stations.


5. When you click on the meteorological station such as Kathmandu, you can see monthly precipitation and temperature in a graph format.




6. Click on the top right button for selecting layers such as land use categories, village, contour, cadastre, administrative boundaries, temperature, and precipitation.

# *Biography*

Adish Khezri was born in Shiraz, Iran, on August 16th, 1973. After a BSc in Geology, she worked as a geologist with a private consulting company for seven years. She pursued her MSc in Geoinformatics with JKIP, a joint master program between KNTUT/Iran and ITC/The Netherlands. Afterwards she became a lecturer in GIS/RS at various universities for four years and eventually joined the office of census and information of Shiraz/Iran under the ministry of budget and planning. She was the GIS coordinator for updating the census and population maps, census agricultural maps and advisor in optimizing geospatial applications at the provincial level. During her Ph.D., she was a member of SENSE Ph.D. council, Research School for Socio-Economic and Natural Sciences of the Environment, and the educational member of ITC Ph.D. Community (pITCom.)

***Publications***

Khezri, A.; Bennett, R.; Zevenbergen, J. Evaluating a Fit-For-Purpose Integrated Service-Oriented Land and Climate Change Information System for Mountain Community Adaptation. *ISPRS Int. J. Geo-Inf.* 2018, *7*, 343. https://doi.org/10.3390/ijgi7090343

Khezri, A., Bennett, R., & Zevenbergen, J. (2018). Defining the Requirements of an Information System for Climate Change Adaptation in the Mountain Communities of Dolakha, Nepal. MDPI-Climate, 6(2), 47. https://doi.org/10.3390/cli6020047

Khezri, A., Tuladhar, A. M., & Zevenbergen, J. (2018). Land-Based Strategic Model by Integrating Diverse Policies for Climate Change Adaptation in Nepal, Limits to climate change adaptation / edited by W.L. Filho and J. Nalau. Cham: Springer, 2018. ISBN: 978-3-319-64599-5. (Earth and Environmental Science). 41–57. https://doi.org/10.1007/978-3-319-64599-5_4

Khezri, A., Tuladhar, A., & Zevenbergen, J. (2017). Utilizing Geo-information for Mountain Community Adaptation. Nepalese Journal on Geoinformatics, 16, 24–39.

Khezri, A., Tuladhar. A. M, & Zevenbergen, J. (2016). Geo-information for Strengthening Mountain Community in Climate Change Adaptation. In Centro de Investigação de Montanha (CIMO) (Ed.), Mountains 2016 : 1st International conference on research for sustainable development in mountain regions. Bragança: Instituto Politécnico Bragança.

Khezri, A., Bennett, R., & Zevenbergen, J. (2016). Combating Climate Change with Geospatial Data Infrastructure : a Platform for Facilitating Community Adaptive Capacity. In Climate change interventions as a source of conflict, competing claims and new mobilities. Utrecht, The Netherlands: LANDac Conference.

Khezri, A., & Tuladhar. A. M. (2014). Responding to Climate Change : Carbon Rights and Data Sharing Within Land Administration. Kuala Lumpur, Malaysia: XXV FIG Congress.

Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment

# DIPLOMA

**For specialised PhD training**

The Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment
(SENSE) declares that

## Adish Khezri

born on 16 August 1973 in Shiraz, Iran

has successfully fulfilled all requirements of the
Educational Programme of SENSE.

Enschede, 5 October 2018

| On behalf of the SENSE board | the SENSE Director of Education |
|---|---|
| Prof. dr. Huub Rijnaarts | Dr. Ad van Dommelen |

*The SENSE Research School has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW)*

KONINKLIJKE NEDERLANDSE
AKADEMIE VAN WETENSCHAPPEN

The SENSE Research School declares that **Adish Khezri** has successfully fulfilled all requirements of the Educational PhD Programme of SENSE with a work load of 67.2 EC, including the following activities:

**SENSE PhD Courses**

- SENSE writing week (2013)
- Environmental research in context (2014)
- Research in context activity: 'Initiating and organizing workshop focusing on qualitative data analysis which contributed to the course PLUS Research Methods and Techniques at the Faculty ITC of University of Twente (25 August 2016)'

**Selection of other PhD courses**

- EntrepreneurialU, CuriousU summer school, University of Twente 2015)
- English for lecturers, University of Twente (2014-2015)
- Technical writing class , University of Twente (2015)

**Selection of Advanced MSc Courses and MOOCs**

- Land information systems, ITC, University of Twente (2014)
- Land governance, ITC, University of Twente (2014)
- 'Going place with spatial analysis', 'Location advantages' & 'Earth imagery at work', ESRI, (2014, 2015 & 2017)
- Land tenure and property rights 1.0, 2.0& 3.0, USAID (2016)

**External training at a foreign research institute**

- Contributing analysis to Government review of the IPCC AR5 SYR report under coordination of the Netherlands Environmental Assessment Agency (PBL) in 2014

**Selection of Management and Didactic Skills Training**

- Supervising three MSc students at ITC (2015-2016)
- Supervising three MSc students and an intern at ITC (2015-2017)
- Member of (SENSE) PhD council (2013-2018)
- Organising PhD day ITC faculty, University of Twente (2017)
- Lecturing MSc students on 'Emerging issues: climate change impacts, adaptation strategies and policies for mountain communities', Kathmandu University, Nepal and ITC Faculty, University of Twente (2014-2017)

**Oral Presentation**

- Geo-information for Strengthening Mountain Community in Climate Change Adaptation. MOUNTAINS2016, 7 November 2016, Bragança, Portugal

SENSE Coordinator PhD Education

Dr. Peter Vermeulen