

Utilizing Geo-information for Mountain Community Adaptation

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KEYWORDS

Adaptation, Geo-information, Mountain Community Adaptive System (MCAS).

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.

1. 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 and Maraseni 2012; Bajracharya, Furley, and Newton 2006). 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 (2002) 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 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; Kerr et al., 2006; Torres, 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. 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; Macchi et al., 2011; Kerr et al., 2006; Torres, 2012), 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.

3. 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.

3.1 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 1) 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.

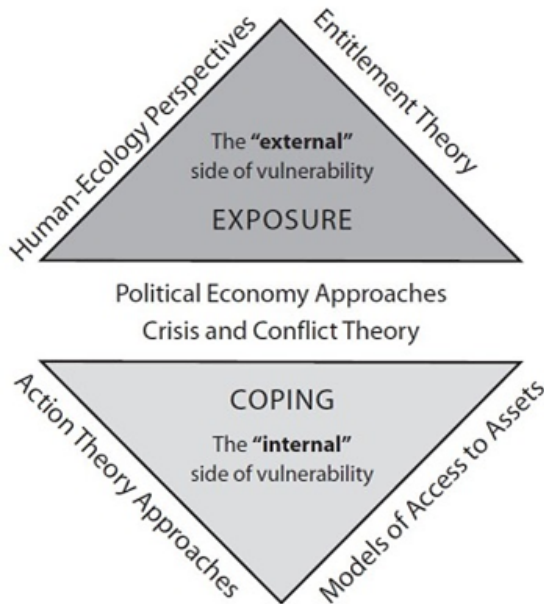


Figure 1- The two sides of vulnerability according to the Bohle model (Watts and Bohle 1993)

Thus the model (figure 1) 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.

3.2 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 2.1. 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.

3.3 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 2.1. 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.

4. 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, Swart, and van der Knaap 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 practise (Banjade, Schanz, and Leeuwis 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.

4.1 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 emphasises on participation of local bodies and vulnerable people to provide information on their needs and prioritize adaptation activities for decision makers (GoN 2011).

4.2 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.

5. 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.

5.1 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 and 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.

5.2 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, Pender, and Suyanto 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, Pender, and Suyanto 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 (Porrás and 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 practise 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).

5.3 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 and Frías 2012).

6. 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 2.3 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 2.3. 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 2.3 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	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
	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
Bajhang and Terhathum communities	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 institutional organization	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

7. 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.

7.1 Geo-information services for climate change adaptation

Sections 2.1 and 2.2 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

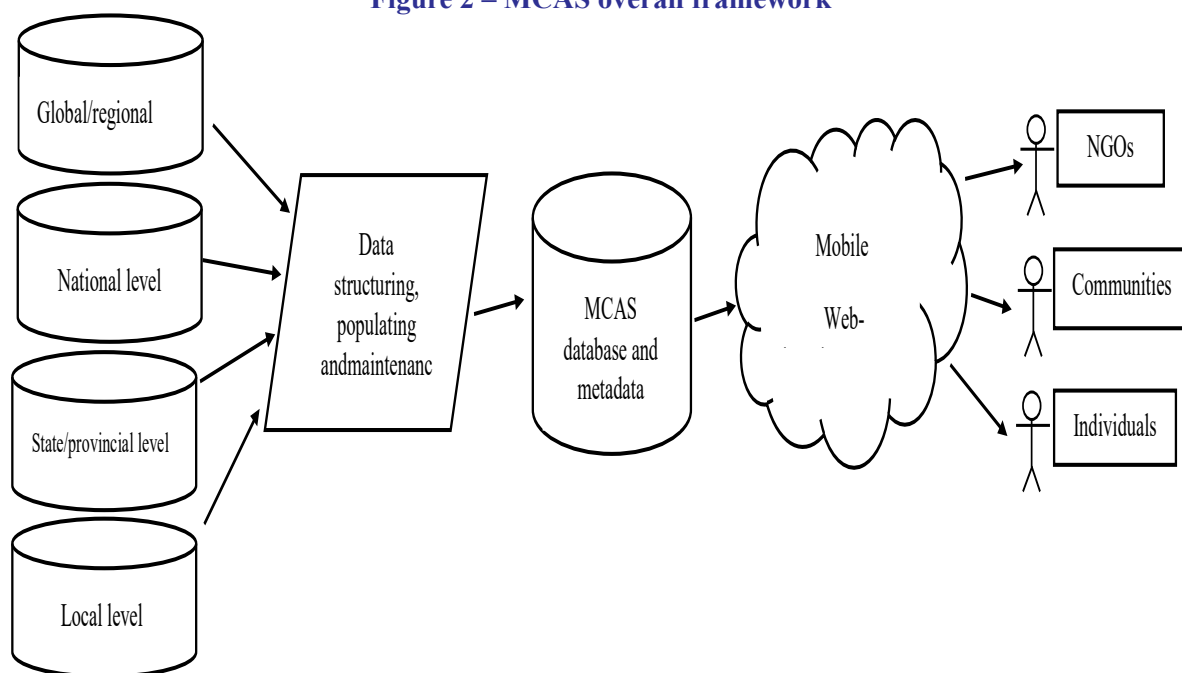
Geo-information services (maintenance and dissemination)	Spatial scale				
	Global	Regional	National	District	Community
Climate information (temperature, rainfall and snow,)	✓	✓	✓	✓	✓
Climatic zone (Tropical wet/wet-dry, monsoon, steppe, desert, dryland, floodplain, mountain, marine, tundra, arctic/subarctic)	✓	✓			
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			✓	✓	✓

Geo-information services (maintenance and dissemination)	Spatial scale				
	Global	Regional	National	District	Community
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			✓	✓	✓

7.2 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 2 for overall framework.

Figure 2 – 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 2, 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.

8. 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.

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