HI-AWARE Working Paper 6

HI-AWARE
Himalayan Adaptation, Water and Resilience Research

CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia

Classification of Adaptation Measures and Criteria for Evaluation: Case Studies in the Gandaki River Basin, Nepal

Consortium members

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About HI-AWARE Working Papers

This series is based on the work of the Himalayan Adaptation, Water and Resilience (HI-AWARE) consortium under the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) with financial support from the UK Government's Department for International Development and the International Development Research Centre, Ottawa, Canada. CARIAA aims to build the resilience of vulnerable populations and their livelihoods in three climate change hot spots in Africa and Asia. The programme supports collaborative research to inform adaptation policy and practice.

HI-AWARE aims to enhance the adaptive capacities and climate resilience of the poor and vulnerable women, men, and children living in the mountains and flood plains of the Indus, Ganges, and Brahmaputra river basins. It seeks to do this through the development of robust evidence to inform people-centred and gender-inclusive climate change adaptation policies and practices for improving livelihoods.

The HI-AWARE consortium is led by the International Centre for Integrated Mountain Development (ICIMOD). The other consortium members are the Bangladesh Centre for Advanced Studies (BCAS), The Energy and Resources Institute (TERI), the Climate Change, Alternative Energy, and Water Resources Institute of the Pakistan Agricultural Research Council (CAEWRI-PARC) and Alterra-Wageningen University and Research Centre (Alterra-WUR). For more details see www.hi-aware.org.

Titles in this series are intended to share initial findings and lessons from research studies commissioned by HI-AWARE. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the HI-AWARE consortium, they have only undergone an internal review process.

Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

About the Authors:

Bimal Raj Regmi, ICIMOD

Anju Pandit, ICIMOD

Corresponding Author: Bimal Raj Regmi, bimal.regmi@icimod.org

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Authors
Bimal Raj Regmi
Anju Pandit

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Production team

Doris Canter Vischer (Editor)
Debabrat Sukla (Communication Officer, HI-AWARE)
Dharma R Maharjan (Graphic designer)
Asha Kaji Thaku (Editorial assistant)

Photos: Bimal Raj Regmi - pp17, 19, 25; Anju Pandit - pp 23

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Executive Summary

Climate change adaptation practices constitute local knowledge and practices as well as autonomous and planned interventions targeted at reducing risk and enhancing the resilience of vulnerable households and communities with respect to their livelihoods and the economic sector they depend on for their well-being. The main purpose of this paper is to report on an assessment and documentation of adaptation strategies followed in policy and practice to address risk and vulnerabilities of communities living in the Gandaki River-basin. It is expected that understanding of existing adaptation options will help tailor effective responses for them in the Gandaki River-basin and beyond.

Climate-change adaptation literature on the Gandaki River-basin in Nepal was reviewed to identify adaptation options. These included actual and potential components of successful adaptation regarding the effects of heat, drought, flood, and rainfall variability across sectors in the plains, hills, and mountains. Climate change adaptation measures for a variety of sectors and hazard types were assessed. Case studies and multi-criteria analysis were used to understand as well as assess adaptation strategies and options in the study areas to determine the effectiveness of such strategies. The collection of data for these assessments was based on extensive literature review, project websites, and personal communication with all partner organizations. Semi-structured interviews with local communities were also conducted.

The study shows that people in the Gandaki River-basin are already experiencing climate change and its effect on their livelihoods. Major climate-change risks and hazards in the basin include flash floods, landslides, drought, Glacier Lake Outburst Flood (GLOF), water shortage, and the outbreak of the pest and other diseases. Since most farmers in the River-basin depend on agriculture, critical moments and stress periods are mostly linked with crop cycles and the livelihood system they depend on. Looking at the climate risk and vulnerability, adaptation is already felt necessary as people's lives and livelihoods are facing an increasing burden of shocks and stresses from climate change.

In this paper, local practices and on-the-ground planned and autonomous adaptation innovations are identified and analysed. The findings show that communities have been using traditional knowledge, practices, and technologies already for quite some time to cope with adverse climatic stresses in the short run. Adaptation and coping mechanisms include the conservation and sustainable use of important plant species, the use of different soil and water conservation methods such as drip irrigation and technologies to retain soil moisture, and changing cropping patterns and crop composition.

The review of autonomous adaptation reveals that most households cope with these changes through short-term and reactive solutions. We also found that autonomous adaptations deal with more climate variability and critical stresses over the year. In many areas such autonomous adaptation has failed to address the scale and intensity of climate change effect, though. These practices were inadequate to deal with additional risks and effects of climate change, because they lacked technical knowledge, financial support, and the right climate-change information.

The study also documented planned adaptation strategies. Common planned adaptation measures include local and community-based adaptation planning, climate-smart farming, improved irrigation, soil, and nutrient management techniques, improved access to climate resilient seed and technologies, improved marketing and strengthening community-based institutions including community-based insurance systems, and diversification of agriculture with focus on localized climate and nutrition-sensitive farming.

The case studies indicate that planned adaptation practices were effective in addressing climate risk and vulnerability of communities in the targeted villages. The planned adaptation strategies further helped to sensitize communities on the negative effects of climate change and relevance of development adaptation strategies to deal with climate risk and effect. Yet, planned adaptation practices faced several challenges. These included sustainability of such adaptation practices due to financial constraints as much as the very nature of these

adaptation strategies, because they were more oriented to addressing development issues than actual climate risks and effects.

The analysis of autonomous and planned adaptation in The Gandaki River-basin suggests that adaptation has to be viewed as a continuum. Since autonomous adaptation deals more with short-term coping and planned adaptation looks beyond coping and tries to address both observed and future adaptation needs, these two are inter-linked. Combining both strategies while fostering autonomous adaptation through scientific and local knowledge can help ensure the effectiveness of adaptation strategies in the region.

The study also indicates the need for a shift to a more multi-institutional adaptive governance mechanism. This will contribute to a recognition of the role of multi-stakeholders. Besides, a flexible governance arrangement can facilitate more transformative adaptation options and strategies at various levels.

Acronyms and Abbreviations

AIWRM	Adaptive Integrated Water Resource Management
BCDC	Biodiversity Conservation and Development Committee
CAP	Community Adaptation Plan
CARIAA	Collaborative Adaptation Research Initiative in Africa and Asia
CSB	Community Seed Bank
CCA	Climate Change Adaptation
CFUG	Community Forestry User Group
DFID	Department for International Development
FFS	Farmers Field School
GDP	Gross Domestic Product
GLOF	Glacier Lake Outburst Flood
HI-AWARE	Himalayan Adaptation, Water and Resilience
HDI	Human Development Index
IDRC	International Development Research Centre
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Inter-Governmental Panel on Climate Change
LAPA	Local Adaptation Plan of Action
LFP	Livelihoods and Forestry Programme
LI-BIRD	Local Initiatives for Biodiversity, Research and Development
MCA	Multi-Criteria Assessment
MoSTE	Ministry of Science, Technology and Environment
NAPA	National Adaptation Programme of Action
VDC	Village Development Committee
VEC	Village Electrification Committee
WUG	Water User Group
WWF	World Wildlife Fund

Background

Promoting sustainable and effective adaptation measures in vulnerable areas of the world is a necessity. Adaptation measures contain a wide variety of interventions reflecting their multi-faceted nature. Adaptation measures are the gap between what might happen as the climate changes and what we would desire to happen (Adger et al. 2007). There are now examples of such measures being put in place that take into account scenarios of current and future risks of climate change and associated effects (Noble et al. 2014).

In the adaptation context, what is missing is an understanding about what works and what does not and how this links with existing policies and practices in disaster risk reduction, agriculture, health care, and so on. It is essential to identify locally suitable adaptation options that are acceptable to stakeholders and adequately address adaptation requirements at different scales. Especially so, because adaptation needs are highly diverse, dynamic, and context-specific. They vary between and among different stakeholder groups, communities and individuals (Noble et al. 2014).

The Hindu-Kush Himalaya mountain region is one of the most unexplored and untapped regions in terms of climate change effect, vulnerability, and adaptation. Attempts have been made in the past to document climate change adaptation, but they were inadequate and not systematic. This paper aims to present robust evidence and an improved understanding of adaptation approaches and practices and their potential as also their socio-economic cost-benefits in the region. It focuses on individual practices and builds on information from on-going coping adaptation in the Gandaki River-basin in Nepal. It gives additional evidence for further intervention as well as for monitoring.

The literature on climate change adaptation in this river-basin was reviewed to identify adaptation options, including actual and potential components of successful adaptation. A systematic assessment of the potential of current coping strategies, planned adaptation, and possible adaptation options through proper monitoring and evaluation was thought to expand significantly the understanding and evidence base of possible climate adaptation. We hope the methodology and process of documentation and analysis of climate change adaptation practices in this area will stimulate similar types of studies elsewhere. In addition, the paper gives an input to the development of a Climate Change and Adaptation (CCA) Matrix for Himalayan Adaptation, Water, and Resilience (HI-AWARE) river-basins.

HI-AWARE is one of the four consortia of the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA). The HI-AWARE Consortium is led by the International Centre for Integrated Mountain Development (ICIMOD) based in Kathmandu, Nepal. HI-AWARE is active in research and pilot interventions, capacity building, and policy engagement with respect to climate resilience and adaptation in the mountains and flood plains of the Indus, Ganges, Gandaki, and Teesta river-basins. Its overall goal is to contribute to enhancing the climate resilience and adaptive capacities of the poor, particularly the vulnerable women, men, and children living in these river-basins. In doing so, HI-AWARE uses the findings from research and pilot intervention outcomes to influence policy and practices that will improve the livelihoods of poor communitties in a sustainable way.

This paper supports the argument that adaptation practices constitute local knowledge and practices as well as planned interventions targeted at reducing risk and enhancing the resilience of vulnerable households and communities with respect to the livelihoods they depend on.

About the Gandaki River-basin

Physiography and socio-economic status

The Gandaki basin lies between latitude 25.6°-29.4° N and longitude 82.8°-85.82° E, with parts lying in Tibet, Nepal, and India. The basin contains three of the world's 14 mountains of over 8,000 metres (26,000 feet) - the Dhaulagiri, Manasulu, and Ananapurna. The elevation of the basin ranges from 60 m above sea level (masl) in the southern lowlands to more than 8000 masl in the north (Shrestha et al. 2011). The basin has a total catchment area of 46,300 km^2, most of it in Nepal.

The Gandaki is a trans-boundary basin shared by three countries: China, Nepal and India. The physiographic division of the Gandaki basin can be broadly classified into five zones: Terai, Siwalik (Sub-Himalaya), Lesser Himalaya (Middle mountains), Higher Himalaya, and Trans-Himalaya (Shrestha et al. 1999). The Gandaki Basin includes 19 districts in Nepal. Out of these, 12 districts fall entirely within the river-basin, while 7 partially cover the area.

The Gandaki has seven Himalayan tributaries: Daraudi, Seti Gandaki, Madi, Kali Gandaki, Marsyangdi, Budhi Gandaki, and Trisuli, also called Sapta Gandaki. After the seven upper tributaries have come together, the river becomes the Narayani. The Narayani flows through the Shiwalik foothills and plains of Nepal and enters India at Triveni from where it flows some 300 km through Bihar as the Gandaki River. The river eventually meets the Ganges near Patna City. This whole trans-boundary area is called the Gandaki basin, one of four HI-AWARE study basins (Figure 1).

The basin supports 19% of the total population of Nepal (according to Census 2011). About 40 million people of different ethnic groups live there, predominantly from the Tibeto-Burman group in upstream and Indo-Aryan group in downstream areas. Tibeto-Mongloid communities are also prevalent in the upstream of the basin, whereas Indo-Aryan migrants and communities of Tibeto-Burman origin such as the Tamang, Gurung, and Rai are dominant in the hills (ICIMOD 2016). The southern plains, which are prone to flash floods and riverine floods, are home to indigenous communities like the Tharus as well as migrants of different ethnic groups.

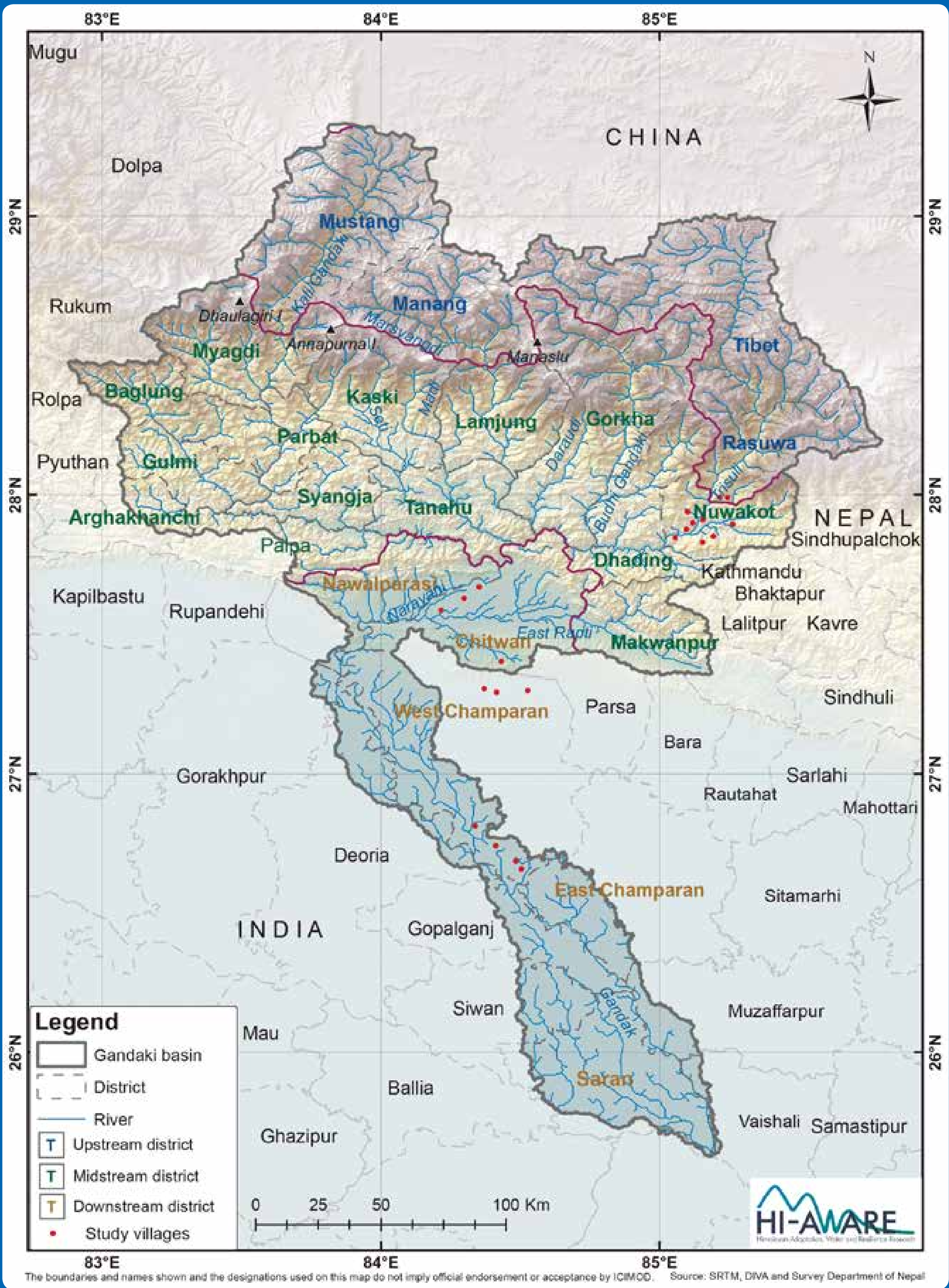
The Gandaki River-basin covers 31931.87 km^2 (CBS, 2011). The 36% of the area is covered by forest and 13% by shrub, while agriculture occupies almost 19% and about 7% is barren. The rest of the land is under snow or are rock outcrops, water bodies, and the like (CBS, 2011).

Agriculture and tourism are the main sources of livelihood throughout the Gandaki basin, with an estimated 66% of the total population engaged in agricultural activities (CBS, 2011). It is the most developed basin among the major basins of Nepal in terms of Human Development Index (HDI) and Gross Domestic Product (GDP). The basin is rich in terms of hydropower but also tourist attractions?. More than 50% of the total hydropower generated in Nepal comes from here. In the Budhi Gandaki basin in Nepal, for example, the glacier contribution to the total measured stream flow is about 30% (Jeuland et al. 2013).

Climatic condition of the river-basin

The climate has been changing in the Gandaki basin. While uncertainty remains regarding the precision of climate change predictions, forecasts suggest that changes in the climate will exacerbate the existing variability (Cruz et al. 2007). The average temperature of this area ranges from -90 °C in Mustang to 42.50 °C in Chitwan. The average annual rainfall is about 27 mm in mustang to 2500 mm in Chitwan. Warming is more pronounced in high altitude regions compared to the Terai (Shrestha et al. 1999; Chaulagain 2006; Bajracharya et al. 2007; Baidya et al. 2008). Projections show that the temperature rise will be accelerated in the mountains. For example, the

Figure 1: **Physiographic zones of the Gandaki basin**



Source: ICIMOD

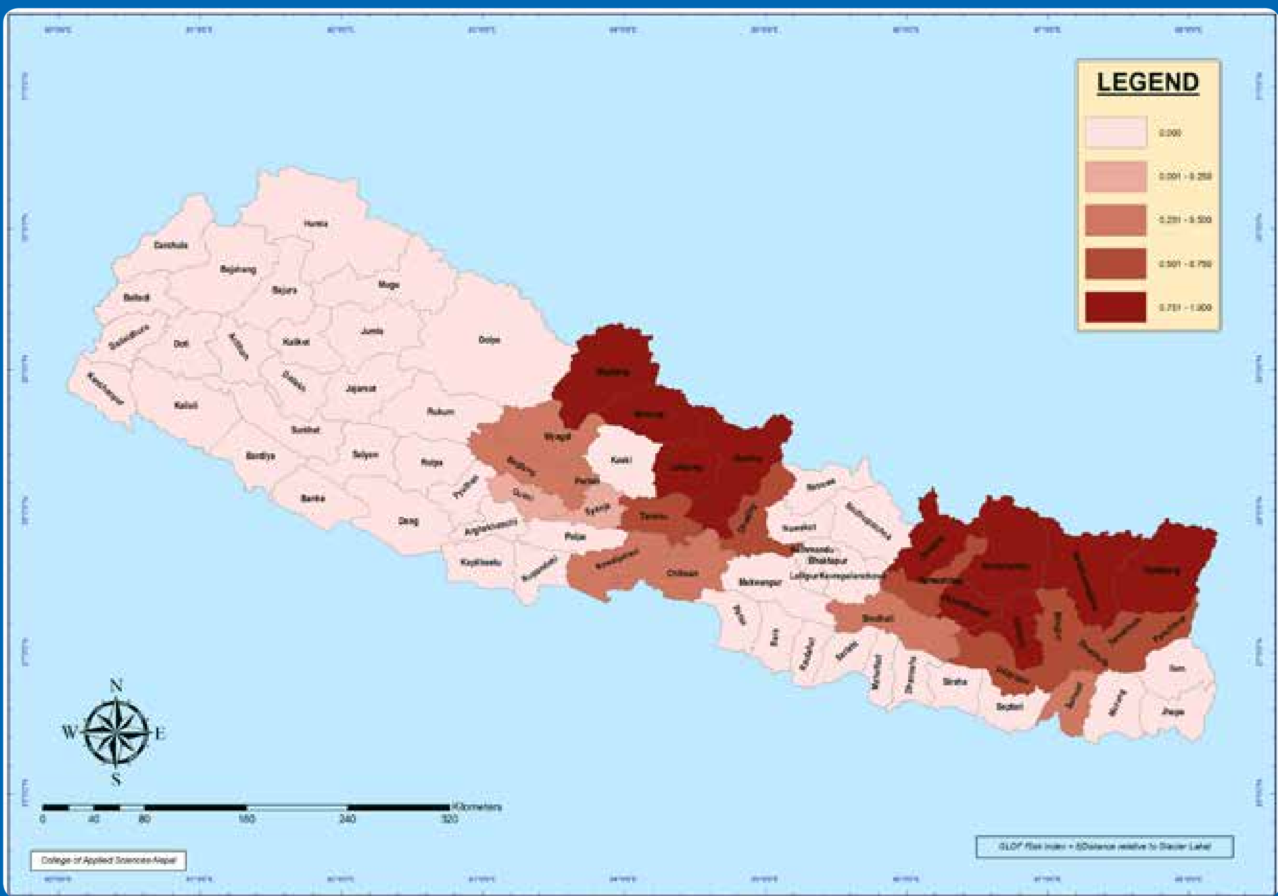
temperature in Mustang district was projected to rise in the range of 0.12 0 C in the northern most part (MoSTE 2010).

The number of rainy days (>2.5 mm/day) is found to be decreasing, while monsoonal withdrawal is delayed. Dry seasons and regions are also getting drier (Panthi et al. 2015). Daily rainfall data from 1980 to 2010 for five stations - Dhunche, Timure, Nuwakot, Dhading, and Rampur - show a variation in the trend of annual and monsoon rainfall. The stations in the middle hills show a decreasing trend in annual and monsoon rainfall, while in the Terai the trend is increasing. All this implies a greater variability in the rainfall pattern and uncertainty in terms of future risk.

The Gandaki basin is vulnerable to climate change as well as anthropogenic changes. Evidence shows that climate change has had a negative effect on Nepal in a number of ways including an increase in Glacier Lake Outburst Floods (GLOF) (Figure 2), the destruction of hydropower and irrigation infrastructure, biodiversity loss, and limited access to domestic water usage (Regmi 2015). In the water resources sector, erratic rainfall in the monsoon season poses the threat of increased flooding, landslides, and erosion as also reduced groundwater reserves due to excessive surface runoff (Bartlett et al. 2010).

The river-basin is prone to climate induced disasters. From 2000 to 2014, 939 people lost their lives due to flood and landslides in the area. The highest number of affected families was from Nawalparasi district (8187 persons out of 22,637). The total economic loss due to various natural hazards over that period in Nepal had been over 14 billion Nepali rupees. For the same period in the Gandaki River-basin, it had been NPR. 2,440,451,349 (over USD 31 million), about 17% of the total loss (ICIMOD, 2016).

Figure 2: **The GLOF risk for the Gandaki River-basin**



Source: MoSTE 2010

The losses of major crops and the decline in production have been important issues in the Gandaki River-basin (Regmi et al. 2009; Gentle and Maraseni 2011; Manandhar et al. 2011; Chaudhary et al. 2012; Bigs et al. 2013). A recent study carried out in the Western Himalayan eco-region by Joshi et al. (2012) showed that with increasing temperature, a shift to higher altitudes was observed for all forest types. Further, there was a strong perception among communities in the area of declining natural springs, ponds, and water sources (Regmi et al. 2009). Climate change apparently also affected water resources in our study areas. Vector-carried and waterborne diseases are increasing in the country, while a strong relationship between these diseases and temperature and rainfall has been identified (MoE 2010; Dhimal et al. 2015).

Objectives and Research Questions

The HI-AWARE project led an extensive review of on-going coping and adaptation measures, both autonomous and planned, with the aim to build on existing knowledge and evidence related to adaptation in the region.The main objective is to assess and document the adaptation approaches followed in policy and practice to address the risk and vulnerabilities of communities living in the Gandaki River-basin.

The following general questions were formulated to guide the case study documentation:

1. What are the major climate-related hazards and risks in the area? And how are they affecting various sectors such as agriculture, energy, water, and health?

2. What are the adaptation approaches being followed in policy and practice to address these vulnerabilities?

Specific questions were:

- What adaptation actions; both autonomous and planned; (including human, institutional, and organizational) are currently applied to reduce the effects of climate change on agriculture, water resources, health, and energy?
- How effective are the adaptation approaches being practices in the basin?
- What are major barriers to effective adaptation in agriculture, water resources, health, and energy, and how can those be overcome?

Framework on Classification and Criteria for Evaluating Adaptation Measures

Concepts: classification of adaptation measures

Climate change adaptation means a multi-sectoral approach to risk reduction. Adaptation is relevant in all climate-sensitive domains including agriculture, forestry, water management, coastal protection, public health, and disaster prevention. It may be prompted by a diverse set of current and future climate hazards, including observed and expected changes in average climate, climate variability, and climate extremes. Adaptation occurs against a background of environmental, economic, political, and cultural conditions that vary substantially across regions (Fussel 2007).

Adaptation to climate change may be classified according to climate stimuli, system and the processes or measures of climate change. A common classification of adaptation is made according to how it occurs. Adaptation may refer both to the process itself and to the outcome or condition of adapting. Most descriptions of adaptation imply a change 'to suit' new conditions 'better'. Changes that fail to reduce vulnerability are sometimes called 'mal-adaptations'.

Adaptation processes or measures may be reactive or anticipatory, spontaneous or planned, or distinguished in other ways (Smit et al. 2000).

Adaptation types (i.e., how adaptation occurs) have been differentiated according to numerous attributes (Carter et al. 1994). Scientists and researchers have identified some common typologies of adaptive action. A response may be to adverse effect or to cash opportunities and it may be a response to current, actual, or projected conditions (Smit et al. 2000, p. 203).

According to Smithers and Smit (2009), adaptive responses may be explained in terms of intent, scale, timing, duration, form, and effect, and even the role of government. Smitthers and Smit (2009, p.77) also explains adaptation types in terms of intent or purpose and the timing of action as also their temporal and spatial scope (see further Table 1).

Two forms of adaptation are based on intent and purposefulness. They include planned and autonomous or spontaneous adaptation. According to Walker et al. (2013), planned adaptation is the result of deliberate decisions, based on an awareness that conditions might change or have changed and that action is required to return to, maintain, or achieve a desired state. Planned adaptation often is interpreted as the result of a deliberate policy decision on the part of a public agency (Pittock and Jones 2000). Planned anticipatory adaptation is achievable through an array of mechanisms, such as knowledge and learning, risk and disaster management and response, infrastructure planning and development, institutional design and reform, increased flexibility of sensitive managed and unmanaged systems, avoidance of poor adaptation, and technological innovation (Grasso et al. 2010).

Autonomous adaptations on the other hand, are often those that are undertaken spontaneously as routine adjustments to conditions. Such adaptations are widely interpreted as initiatives by private actors rather than by government bodies, usually triggered by market or welfare changes induced by actual or anticipated climate changes (Leary 1999). Carter et al. (1994) define autonomous adaptation as 'natural or spontaneous adjustments

Table 1: **Bases for differentiating adaptation (adapted from Smit et al. 1999, p. 208)**

General differentiating concept or attribute	Examples
Purposefulness (intent) in relation to climatic stimuli	Autonomous (like by unmanaged natural system) vs. Planned (like from public agencies) Spontaneous vs. Purposeful Automatic vs. Intentional Natural vs. Policy Passive vs. Active and structured
Timing of actions	Anticipatory (prior modification) vs. Responsive Proactive vs. Reactive (from observed modification) Ex-ante vs. Ex-post
Temporal scope	Short-term (adjustments, instantaneous, autonomous) vs. Long-term (adaptation, cumulative, policy) Tactical vs. Strategic
Spatial scope	Localized vs. Widespread
Function/Effects	Retreat-Accommodate-Protect Prevent-Tolerate-Spread-Change-Restore
Performance	Cost-effectiveness - efficiency - implementability - equity

in the face of a changing climate'. According to Intergovernmental Panel on Climate Change (IPCC), autonomous adaptation is adaptation that does not constitute a conscious response to climatic stimuli, but is triggered by ecological changes in natural systems and by market or welfare changes in human systems (McCarthy 2001).

Most ecological, economic, or social systems undergo some spontaneous or "autonomous" adjustments in response to changing climate. To assess such responses it is helpful to distinguish three groups of adjustment on the basis of their 'degree of spontaneity': in-built, routine, and tactical. In-built adjustments are the unconscious or automatic reactions of an exposure unit to a climatic perturbation (Smit et al. 2000). In an unmanaged natural system adaptations are invariably reactive, while autonomous adaptations in social-economic systems are usually concurrent or reactive (McCarthy 2001).

Routine adjustments refer to everyday, conscious responses to variations in climate that are part of the routine functioning of a system. For example, farmers in semi-arid tropics frequently adjust the sowing time of their crops to the onset of the rainy season. At a higher level than routine adjustments are those that require a behavioural change, referred to as tactical adjustments. These may be required, for example, after a series of anomalous climatic events that indicate a shift in climate (Smit et al. 2000).

There are many overlaps and commonalities in autonomous and planned adaptation. It is also true that differentiating the two is sometimes not practical. Grasso et al. (2010) argue that the distinction between autonomous and planned adaptation may be blurred in practice. As far as reactive, autonomous adaptation is concerned, there are many possible adaptation actions based on experience, observation, and speculation, which cover a wide range of types, take various forms, and are essential components of climate change effect models. The discussion implies that classification of adaptation measures based on intent has to be looked at as a continuum.

Criteria for evaluating effectiveness of adaptation options

Assessing the effectiveness of climate change adaptation, autonomous and planned, should include looking at successes as well as limits.Successful adaptation is any adjustment that reduces the risks associated with climate change, or vulnerability to climate change impacts, to a predetermined level, without compromising economic, social, and environmental sustainability (Doria et al. 2009, p.810). According to Adger et al. (2005), successful adaptation is what balances effectiveness, efficiency, and equity through decision-making structures that promote learning and are perceived to be legitimate as an ideal from which much adaptation inevitably diverges.

There are various examples of successful climate change adaptation practices around the globe. The adaptation measures involve a mix of institutional and behavioural responses, the use of technologies, and the design of climate resilient infrastructure and climate smart practices. They are typically undertaken in response to multiple risks, and often as part of existing processes or programmes, such as livelihood enhancement, water resource management, and drought relief (Adger et al. 2007).

Within the adaptation debate over the past few years, increasing attention has been devoted to the limits of adaptation. The debate on limits relates to a growing awareness in academic and policy circles that not all climate change effects can be addressed by current and future mitigation and adaptation efforts. Also, people are also realizing that in many cases the effects will exceed the adaptation capabilities of individuals, communities, and countries. The discourse around limits to adaptation frequently focused on three dimensions: physical l, economic, and technical limits (Adger et al. 2009). More recently it has widened these 'exogenous' limits to adaptation to include more 'endogenous' ones referring to social, cultural, and individual limiting factors in society (ibid.). There are other concepts to understand adaptation limits such as the 'adaptation turning point'. Kwadijk et al. (2010) define this turning point as a point where the magnitude of change due to climate change or sea level rise is so much that the current management strategy will no longer be able to succeed.

Adaptation can be evaluated in different ways using context specific criteria. Brooks et al. (2011) suggested that the criteria by which success might be assessed include feasibility, efficacy, efficiency, acceptability and legitimacy, and equity. To this they added sustainability (Fankhauser and Burton 2011). Effective integration and coherence with wider national policies and development goals is another criterion, often sought after (World Bank 2010).

Smith and Lenhart (1996) identified evaluative criteria, including flexibility and potential for favourable benefit-cost analysis in their evaluation of adaptation options for climate-sensitive sectors in Africa. Raunhaar et al. (2015) proposed the evaluation of adaptation options based on how these promote the implementation of prevention, mitigation, and recovery-related adaptation measures in such a way that climate risks will be reduced up to acceptable levels. Grasso (2010, p. 19) argued that the success of adaption should be assessed through the promotion of equitable, effective, efficient, and legitimate action. Other criteria used for the evaluation of adaptation options are flexibility, robustness, coherence, and acceptability (Table 2).

To be sure, examining the social dynamics and outcomes of adaptation moves beyond simply accounting for the economic costs and benefits of adaptation. We need to consider the social acceptability of adaptation options, the institutional constraints on adaptation, and the place of adaptation in the wider context of economic development and of the evolution of societies in the future. (Adger 2003, p.29). A promising framework in which to evaluate successful planned adaptation has been proposed by Adger et al. (2005). It contains generic principles of policy appraisal seeking to promote equitable, effective, efficient, and legitimate action that is in harmony with wider sustainability.

Table 2: **Examples of criteria for evaluation of adaptation options**

- Effectiveness is the capacity of a system to adapt, to achieve its objectives. It is the reduction of impacts, exposure, or risks, the avoidance of danger, or the promotion of security (Adger et al. 2005).
- Efficiency is measured in terms of economic benefits - mostly the cost and benefit of any adaptation option (Noble et al. 2014).
- Adaptation action is appropriate if it is commensurate with the nature and magnitude of the impact it is intended to manage (Noble et al. 2014).
- Flexibility – flexible adaptation options will be more responsive and flexible to changing future conditions, can be modified or adapted, will allow for adjustments due to unforeseen changed conditions and can be implemented with flexibility (Fankhauser et al. 1999; Hallegatte 2009; UKCIP 2011).
- Robustness – robust adaptations can operate and perform under a wide range of uncertainties and future climatic scenarios. They are not dependent on any particular future scenario.
- Equity – this is a critical dimension, as it is generally recognized that the poorest and most vulnerable groups will disproportionately experience the negative impacts of climate change and that adaptation options can have negative spill-over effects (Adger et al. 2005; Adger et al. 2009).
- Coherence/synergy - alignment – it is important to consider the interaction and alignment between an adaptation option and other policies, measures, and sectors, to ensure its implementation does not negatively affect other policies or sectors and, so, lead to sub-optimal results (Hallegatte 2009).
- Coherence/synergy - enhancement – adaptation options should also seek to enhance and strengthen the outcome of existing policies and initiatives.
- Acceptability (political, bureaucratic, community and private sector) – the acceptability of an adaptation option by different stakeholders is a critical factor that will influence the successful uptake, implementation, and outcome of an adaptation option.

Adapted from Darryl et al. (2012), pp 19-20

Research Approach and Methods

Approach

Our research used case studies as the key approach in data collection (Yin 2003). A case-study matrix was used to classify and review systematically existing and on-going adaptation measures and approaches in the Gandaki River-basin. This matrix explores the various possibilities of adapting to climate variability and climate change from local to national level and contains several examples of adaptation measures. Adaptation measures were classified by sector (agriculture, water resources, health, and energy) in the plains, hills, and mountains for each case study areas (see Table 3).

Table 3: **Case study matrix**

Climate change risk across geographical areas	Adaptation options per sectors			
	Agriculture	Health	Energy	Water
Mountains (e.g., temperature increase)				
Mid hills (e.g., drought)				
Terai (e.g., flooding)				

What is a good adaptation decision will depend on the objectives of the decision-makers. In many cases it will be characterized as a decision that avoids exposure to potentially costly maladaptation, and is informed and robust (Reeder and Ranger 2011). As discussed in the earlier section on the framework, tvaluation of a decision – 'how good is an adaptation?'- may be based on various criteria. These may include effectiveness, flexibility, economic efficiency, social acceptability, timeliness, equity, institutional compatibility, farmer ability to implement, and net benefits independent of climate change. They have been used in literature to evaluate adaptation options (Adger et al. 2007).

A Multi-Criteria Analysis (MCA) was used in this study to identify context-specific criteria for looking at the effectiveness of adaptation interventions. These specific criteria were discussed with the communities where a specific case study was undertaken. Based on these mutually agreed criteria, a general effectiveness analysis was done.

Methods and tools

The collection of data was based on an extensive literature review as well as project websites, and on personal communication with all partner organizations for information on undocumented projects. The literature review was used to examine relevant documents on climate change adaptation in the study basin. It was particularly useful to analyse climate change adaptation at different scales and for adaptation across sectors.

In addition, the review provided a list of various coping and adaptation options in the river-basin, also across the 4 major sectors of agriculture, water, health, and energy. In-house team meetings (of the national team) shortlisted 15 potential case studies based on the field visit and literature review (Table 4).

Finally, the team agreed on 4 coping and adaptation options for detailed study. They used different criteria to shortlist key adaptation options for more in-depth case studies. In selecting the sites, the team took a comparative and cross-scalar approach, with study sites representing a range of climates (west – east), climate-sensitive sectors (agriculture, water, health, and energy), different hydrological conditions (upstream – downstream) and altitudes (high mountains, hills, plains), and varying cultural and socio-economic contexts in the three river-basins, with a focus on the most vulnerable people. A summary of the selected case studies is presented in Table 5.

Table 4: **List of potential adaptation case studies in the Gandaki River-basin**

S.No	Potential case studies	Locations	Focus areas
1	Solar-wind hydel	Bhorleni, Phaparbari, Makawanpur	Energy
2	Solar-wind hydel	Dhawadi, Nawalparasi	Energy
3	Integrated water resource management	Kirtipur, Nawalparasi	Water resources
4	Integrated vegetable farming	Deurali-9, Gaidakhola	Agriculture
5	LAPA implementation activities - water source protection	Ward number 8, Devchuli Municipality	Water resources
6	LAPA implementation activities - irrigation channel	Belanigirbari, Jhalbaas-6, Nawalparasi	Water resources
7	River bank plantation	Jhalbaas-6, Nawalparasi	Forestry
8	Public land management	Manari-1, Nawalparasi	Livelihood
9	Public pond management	Manari-4, Nawalparasi	Agriculture, Nutrition
10	Public land management	Ramgram Municipality, Nawalparasi	Forestry
11	LAPA implementation	Jamuhanawa, Manari-3, Nawalparasi	Food security, Nutrition
12	Rice - duck farming	Chitwan	Agriculture
13	Integrated watershed management	Rupa lake, Kaski	Agriculture and forestry
14	Community seed bank	Jogimara, Dhading	Food security
15	Micro-hydro plant	Charang, Mustang	Energy

Table 5: **Summary of the case studies**

Adaptation practices	Location	Focus	What problems were addressed?
Integrated water resource management	Kirtipur Village–Devchuli Municipality, Nawalparasi District–Inner Terai	Efficient use of soil and water management technologies	multiple hazards (drought, landslide)
Community seed bank	Jogimara VDC, Dhading District – Mid hills	Conservation and management of climate resilient seeds; Agriculture	drought
Micro-hydro plant	Charang VDC, Mustang District–Mountain	Renewable energy (mitigation and adaptation co-benefits)	Water scarcity and GLOF issue
Climate resilient adaptation practices	Manari VDC, Nawalparasi District–Flood plains	Climate resilient practices contributing to food security, health, and nutrition	Flash floods

Field visits were organized in selected districts of the Gandaki River-basin to document and understand prioritized and shortlisted adaptation measures currently being practised and promoted in the 4 sectors. Participatory tools of data collection included semi-structured interviews with farmers and adaptation practitioners working in the area. For each case study at least 10 farmers, women and men, were interviewed, including 4 government and NGO workers based at field level. In addition, 1 focus group discussion was organized in each case study location involving 10 households, to document people's perceptions on climate risk and the effectiveness of adaptation options.

Review of Adaptation Strategies in the Gandaki River-basin

Traditional coping and autonomous adaptation strategies

Autonomous adaptation is not a conscious response to climatic stimuli, but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. It is also referred to as spontaneous adaptation. Autonomous adaptation in the Gandaki River-basin includes actions that individuals, communities, businesses, and other organisations undertake on their own in response to opportunities and constraints they face as the climate changes.

Literature shows that most farmers in the Gandaki River-basin depend on monsoon rain for crop cultivation, so changing rainfall patterns could have devastating results. For generations smallholder farmers in this basin have used local knowledge and traditional methods and innovations to adapt to climate variability. These local-level adaptation strategies are now being used to help them cope with adverse climate change effects (Regmi et al. 2009).

To cope with scarcity of drinking water in the dry season, people in Bhorle Village Development Committee (VDC) of Rasuwa district installed a drinking water supply system in the village from natural water sources (a nearby spring). In the lower floodplains of the Gandaki in India, for example in West Champaran district, migration is the common practice to cope with unemployment and food insecurity of the people. They initially migrated to safer grounds to protect themselves and later to areas where they could get employment to support their families.

The significance of such local technologies has been documented in Nepal. These practices, currently followed by some hill farmers in the Gandaki River-basin, are helping to build the resilience of communities (Regmi et al. 2009; Bigs et al. 2013). Farmers in Nepal and their supporting institutions such as community based organizations are evolving and co-producing climate sensitive technologies on demand (Chhetri et al. 2011). Even in far-off Mustang District researchers found that farmers are capable of responding to climate change quickly (Manandhar et al. 2011, pp. 346-347). (See further Table 6.)

The options that farmers used to cope with (increasing) climate variability depend on communities actual conditions, which vary greatly in geographic terms. Traditional coping practices include intercropping, relay cropping, and crop mixtures in semi-arid regions, and water harvesting and conserving soil nutrients in arid conditions.

Coping strategies also differ according to the type of threat. For example, most of the adaptation strategies in the high mountains and hills focus on addressing drought and water scarcity. In the flood plains they are more concerned with flash floods and heat stresses. This means that a blanket approach is not appropriate for recommending or prescribing adaptation options. Moreover, the design of adaptation interventions has to be contextual and be based on local climate-change risk and vulnerability levels.

Autonomous adaptations have opportunities as well as constraints when addressing climate risk and effect. Bigs et al. (2013) argue that indigenous adaptation strategies in Nepal are vital to enable a bottom-up approach to encourage future sustainable solutions and to gather knowledge for an informed national policy. But there are limits to autonomous adaptation. Regmi and Bhandari (2013) argue that there are technological and financial limits to sustain local coping strategies and so, they have to be accompanied by external support. Macchi et al. (2011) claim that despite the vast repertoire of response strategies to climate change, these responses may not keep up with the fast pace of change communities are facing. In view of all this, it may be concluded that existing autonomous adaptation practices would need to be supported through new skills and knowledge to deal with additional risks and effects from climate change.

Table 6: **Autonomous adaptation strategies adopted by communities in the Gandaki River-basin**

Sectors	Geographical variations + adaptation activities		
	Mountains	Hills	Flood plains
Agriculture	Developing apple orchards and nursery farms in the higher areas and vegetable farming in the lower areas of Mustang District (Adhikari 2014) Changing cultivation patterns from high to low water-demand crops: mixing naked barley (Hordeum vulgare) with apples in Pangling-Mustang District (Kotru et al. 2014) Change in cropping calendar and cropping sequence from rice-wheat/mustard/lentil to rice-wheat to adjust to rainfall variability (Manandhar et al. 2011) Apple growing in northern belts like Kagbeni (Becken et al. 2013)	Potato cultivation on soil heaps to reduce soil moisture loss; Hanging nursery in traditional way for raising seedlings; Selecting right crops and varieties; Traditional seed exchange system in Nepal (Regmi et al. 2009, pp. 7-10; Chettri et al. 2013) Adjusting sowing times; introducing mixed cropping to salvage at least some of their production; introducing new crop varieties (CARE-LIBIRD 2009; Allan 2011) Soil conservation practices like terracing, constructing walls - adopted by the Chepang in Dhading (Piya et al. 2013) Integrated agro-forestry system (crop, livestock) in mid hills (Biggs et al. 2013; Panthi et al. 2015)	Mixed cropping of red gram and rapeseed in Chitwan (LI-BIRD 2010) Consumption loan for adaptation (Gentle and Maraseni 2012) Switching cropping sequences, adjusting timing of planting crops, conserving soil moisture through appropriate tillage methods, and improving irrigation efficiency (Paudel et al. 2014)
Water resources	Local water harvesting system. Use of small ponds locally called 'Ching' (Parajuli and Sharma 2001) Water management: installation of large roof water collection systems; Hiring assistant to fetch water in tourist areas (McDowell et al. 2013)	User groups led water-harvesting and distribution structures at Panchkhal (Adhikari 2014) Traditional method of conserving rainwater (Pradhan et al. 2015) Use Kholchas (rivulets) to compensate for the shortage of drinking water (Lohani and Banskota 2001) Reduce soil moisture (mulching, deep sowing, dry nursery of rice seeds)- (Machhi and Chaudary 2011) Grey water ponds in kitchen gardens; groundwater trenching; rainwater harvesting (ICIMOD 2009)	Rehabilitation of water channels (Gurung and Bhandari 2009) Small-scale water storage and conservation (Biggs et al. 2012; Vaidya 2015)
Health and sanitation	Building resilient traditional settlements and village tourism infrastructure in higher altitude of Lamjung (MoSTE 2015)	Disaster risk reduction through redesigning of traditional houses in Tanahun District (MoSTE, 2015)	Use of running fan (when no load shedding) and drinking water (Pradhan et al. 2013)
energy	Migration due to water shortages (Regmi and Adhikari 2007; Manadhar et al. 2011)	Labour migration (Machhi and Chaudary 2011) Tuins- traditional river crossing device (MoSTE 2013)	Taking loans to reduce effect of climate risk and threat to food security and loss of property (Bhatta et al. 2015) Temporary or permanent relocation to city or abroad (NCVST (2009)

Source: Author

Planned adaptation strategies

Climate change adaptation requires a multi-institutional and collective response. The role of communities, the government, private sector, civil society, and others becomes important to enhance the effectiveness of adaptation interventions. Recently, planned adaptation strategies are becoming more common in Nepal and other developing countries. Most of the planned adaptation responses in the Gandaki River-basin became prominent after the formulation of a Climate Change Policy (2011), a National Adaptation Programme of Action (NAPA), and the adoption of a framework for a Local Adaptation Plan of Action (LAPA). Various projects and programmes of the government, development agencies, and non-governmental organizations supported the design and implementation of planned adaptation strategies (Sterrett, C. 2011).

According to Walker et al. (2013), planned adaptation is the result of deliberate decisions. These are based on an awareness that conditions might change or have changed, and that action is required to return to, maintain, or achieve a desired state. Planned adaptation is often interpreted as the result of a deliberate policy decision on the part of a public agency (Pittock and Jones 2000). In short, planned adaptation measures follow a systematic assessment of climate change scenarios and a design of interventions that help in reducing risks and effects of climate change.

Most planned adaptation interventions, as documented for the Gandaki river-basin, were designed to address specific risks and threats at local level (Table 5). The literature review shows that a majority of the interventions were good development practices aimed to address issues of poverty and vulnerability. It is also few sectors specific such as adaptation strategies in sectors such as agriculture and water resources.

Planned adaptations in the basin have generally been made to respond to predicted effects on agriculture, water resources, energy and forestry to minimize people's vulnerability. This was done by focusing on sectoral interventions related to climate-smart agriculture, water management and flood control, clean energy promotion, and so on. For example in the West Champaran District, Eco-San toilets were built in some villages which took care of basic sanitation during floods. (See further Table 7.)

The most common planned adaptation has been to support communities in the preparation of local-level adaptation plans. For example, with support from Rupantaran Nepal people living in the Manari VDCs of Nawalparasi District developed a Community Adaptation Plan (CAP) and a Local Adaptation Plan of Action (LAPA). The LAPAs are a consolidation of adaption option priorities by them based on their climate risk and vulnerability situation. The World Wildlife Fund (WWF) has helped financially and technically with the installation of a bio-gas plant in villages to promote the use of renewable energy in Nuwakot. In West- Champaran, the government has played a role in early warning systems by giving information about the status of flood waters through radio.

Very few studies have looked at the effectiveness of planned adaptation measures to reduce risk to and vulnerability of communities. Literature has identified successes and failures of such measures. Studies like those by Chaudhary et al. (2011), Chettri et al. (2011), and Bigs et al. (2013) have highlighted key innovations and successes of agriculture-based adaptation strategies in Nepal. In turn, Jones (2011), Regmi et al. (2014), Bhattarai et al. (2015), Nagoda (2015), and Regmi et al. (2015) have identified socio-structural, institutional, technological, and financial constraints to planned adaptation responses in the country. A recent study by NAST and OPML (2016) showed that LAPA interventions were constrained by technology failures to address projected risks and effects of climate change.

The analysis brings out that adaptation interventions have been effective in areas where community institutions are playing an important role in identifying their adaptation needs and taking decisions on their implementation. Planned adaptation intervention in many cases was top-down, though, as also centrally controlled, short-term, and project oriented. That is why it often had little effect on reducing risk and vulnerability of households (Regmi et al. 2015). Literature implies that second-generation issues related to climate change are the technological and governance challenges that are shaping the effectiveness of adaptation interventions.

Table 7: **Planned adaptation strategies adopted by communities in the Gandaki River-basin**

Sectors	Altitudinal variations		
	Mountains	Hills	Flood plains
Agriculture	Crop diversification and value addition (Regmi and Adhikari 2007; Macchi and Chaudary 2011; Manandhar et al. 2011) Diversification of farming practices (Wu et al. 2014) Organic farming; Using bio-pesticides and bio-manure; Altering crop varieties (Machhi and Chaudary 2011) Community seed bank in Rasuwa promoted by World Wildlife Fund (WWF, 2014)	Agro-biodiversity management practices like home garden diversification; Value addition of neglected crops; Set up of community seed bank; Payment for ecosystem services (Regmi et al. 2009; Chaudary et al. 2012; Bhattarai et al. 2015) Local Adaptation Plan of Action (LAPA) and Community Adaptation Plan (CAP) piloting (Sterrett 2011; Regmi et al. 2014) Sustainable soil and water management (Lamichhanne 2013); Conservation tillage (Ghimire et al. 2010; Bigs et al. 2013); Climate-smart villages (ICIMOD 2015) and Climate-smart agricultural practices (LI-BIRD 2015) Climate-appropriate management practices like participatory plant breeding, varietal selection, and technology development (Chetteri and Easterling 2010)	Changing of crops farming to adapt to climate change by farmers of Kabilash-Chitwan (Gurung and Bhandari 2009) Bagar (river bank) farming (Baluwa kheti) in the Terai (Gurung et al. 2014) Development of stress- tolerant crop varieties (Chaudhary et al. 2012) Farmer field schools and early warning systems (Bhatta et al. 2015) Community seed bank in Chitwan and Nawalparasi (Shrestha et al. 2013) Promotion of flood-tolerant rice variety Swarna Sub1 in Western Champaran District, Bihar, India (Southasia Disaster Net 2012)
Energy	Renewable sources of energy, especially hydro, photovoltaic, and biogas (NCVST 2009) Installation of solar panels in Thulo Saybru of Rasuwa District (CARE and LIBIRD 2009)	Rural electrification - micro-hydro installation (Gippner et al. 2013) Renewable energy mini-grid including solar-wind hybrid (Yadoo et al. 2012)	Renewable sources of energy, especially hydro, photovoltaic, and biogas (NCVST 2009)
Water resources	Tsho Rolpa Risk Reduction Project (Adger et al. 2007)	Integrated Hedgerow and SALT technologies for soil and water management (Regmi et al. 2009) Sustainable soil and water management practices and technologies (IPM, nutrient management, mixed cropping) in mid-hills (HELVITAS 2012)	Micro-irrigation system such as Treadle Pump (Bartlett et al. 2011) Bio-engineering practices to control river bank erosion (Regmi and Bhandari 2013) Early warning system and flood disaster preparedness (Nischalke 2014) Replacement of shallow tube wells with deep tube wells for irrigation (Devkota et al. 2011)
Health and sanitation	Solar cooking stoves (Yadoo et al. 2013)	Improved sanitation practices (drinking water, toilet and household hygiene (CADP-N 2011) Improved health awareness and access to health services (MoSTE 2010)	Improved cooking stoves, bio-gas (Paudel et al. 2014; Sapkota et al. 2014) Flood-resistant ecological sanitation toilets (ECO-SAN) in West Champaran district (SEI 2014)
Others	Biodiversity conservation in Rasuwa (WWF)	Microfinance groups (Regmi et al. 2009) and cooperatives (ICIMOD 2009; Chaudhary et al. 2011) Ecosystem-based adaptation focused more on agro-forest based adaptation practices (Park and Alam 2015)	Public land management (Jamarkattel and Baral 2008)

Source: Author

Case Studies on Adaptation Measures in the Gandaki River-basin

Documentation of adaptation measures in the Gandaki River-basin included 4 case studies that covered agriculture, water, energy, and health within a specific geographic region. Each case study gives the socio-economic and climate change context of its area. It also introduces the technology/practice and its characteristics in terms of addressing climate risk. It then analyses how it enhances the adaptive capacities of the poorest and most vulnerable in the area. The case studies also look at key barriers and challenges to local adaptation strategies.

Adaptive integrated water resource management: Gateway to climate resilience: Case study of Kirtipur Village, Nawalparasi District

Context

Kirtipur Village lies in the Himalayan foothills, known as Shiwaliks, approximately 1,000 metres above sea level. The village is Ward Number 6 of Devachuli Municipality in the Nawalaprasi district of western Nepal. It is situated on ancient colluvial or landslide deposits in the upper reaches of the Deusat River. Further downstream in the Terai it is known as the 'Baulaha' or 'Mad' River. It has a sub-tropical to semi-temperate climate. Ethnic Magars have lived there for generations practising subsistence agriculture and shifting cultivation, often known as slash-and-burn. There are 153 households with a total population of 500 persons. Agriculture is the main source of income.

Important seasonal challenges and critical moments or stress periods for the villagers are the hotter summers and shorter rainy seasons. Irregular and unpredictable rain has made it difficult to cultivate up-hill lands. The Deusat is the main source of water for irrigation, but the accumulation of debris, under which the already reduced flow fully disappears in winter, prevents water from entering the irrigation channel any longer. There are also limited opportunities to grow vegetables and for other income-generation activities such as livestock rearing and growing cash crops.

The village has frequently experienced the effects of climate change and natural hazards. More erratic rainfall has disturbed the crop calendar and reduced the amount of water available for irrigation. Flash floods have triggered landslides. Communities adopted few coping and autonomous adaptation strategies such as labour migration and changing of crops, but it was not adequate for them to adapt in the longer run.

To get a better grip on the situation they started working closely with Practical Action, SAHAMATI and local government (Municipality) to identify options for sustainable development as well as climate change adaptation. They adopted the 'adaptive integrated water resource management' (AIWRM) approach to deal with climate-change hazards like droughts and landslides.

What is the AIWRM approach?

Adaptive integrated water resource management is a set of low-cost and efficient water management practices that strengthen the resilience of poor and marginalized farmers living in a fragile and climate-stressed environment. It is a planned adaptation strategy, designed with the help of public and private actors. It is an example of adaptive co-management and multi-governance approach in which various agencies come together to raise the adaptive capacity of vulnerable households and communities.

The AIWRM that villagers of Kirtipur had taken up, led to increasing the gravity flow of irrigation channels, making better use of available water for crop production, restoring vegetation to hill slopes, promoting agro-forestry, and protecting water sources through better forest management.

How did the AIWRM work in Kirtipur?

Community members participated in an initial vulnerability and capacity analysis and formulated community action plans. These plans were designed to increase household incomes, while reducing their vulnerability to disaster and climate risks. To have collective responses, people were organized under various community-based institutions such as Community Forestry User Group (CFUG), Water User Group (WUG), Farmers' Field School (FFS), and Farmers' Cooperative.

Villagers then identified a new, reliable, and sustainable water source upstream and built an irrigation channel. The project, supported by Practical Action, covered the partial cost of a 730-m long pipe to link the irrigation channel with this newly found (perennial) source of water. People, on their part contributed time and labour, and funded a small part of the irrigation system. They also initiated the construction of a small dam, water intake, irrigation canals, and water taps as a community activity.

With this new availability of water, Kirtipur decided to revive and diversify its farming system. Farmers were organized in a Farmers' Field School (FFS) programme designed to bring them together to carry out collective and collaborative inquiries to initiate community action to solve farming-related problems. The FFS helped farmers learn new skills and knowledge on off-seasonal vegetable farming, soil and nutrient management practices, and efficient water management. The School was linked to a local agriculture and climate based advisory service. District Advisory Officers gave training in land conservation, agriculture and horticulture, and livestock management.

People realized that protection of their natural ecosystem (like the forest) was important to reduce their risk from landslides and forest fires. The Community Forestry User Group decided to reduce their dependence on 'slash-and- burn' agriculture. They received technical support, and seed and materials from the government and NGOs. With their support, they introduced new crops and alternative farming techniques. Farmers planted trees, fruit, fodder and non-timber forest products to re-forest barren sloppy lands, and so, prevented landslides.

Closer to home, farmers improved terrace farming, also introducing fodder, forage and fruit species there, and diversified their kitchen garden.

Thanks to this diversification of home gardens and rain-fed lands (bari), people found alternative income generating and livelihood supporting activities. As a result, their dependency on the slash-and-burn method stopped completely. Those areas have now become community-managed agro-forestry land.

How did this adaptation technology reduce climate risk or vulnerability? What other benefits did it generate?

A small dam and modest piping enabled the village to produce food close to home. They had agreed to rehabilitate the hillsides and stop slash-and-burn agriculture. Through irrigation alone, over 90 families had benefited, by growing one more cereal crop and vegetables in winter. They were also able to plant and transplant summer crops in time without depending on rainfall, which has become more erratic. This not only helped the villagers to deal with more varied climate but also meant they can now grow vegetables in the dry season and produce three crops a year instead of two.

The AIWRM initiative has really created a 'multiplier effect' on people's lives. The taps ensure easy access of households to clean and safe drinking water. The irrigation system means that women and children no longer have to walk for two hours to collect drinking water. Children have more time to study, while women's work drudgery has become less.

Tula B. Magar, one of the treasurers of the irrigation user groups, mentioned that women have now started to

become small entrepreneurs, as they manage their time well and could now also engage in commercial vegetable production and sales. Tara Bahadur Ontaki and his wife were very happy with the adaptation options introduced in their village. They said that the benefits they were now receiving were not comparable to the past, because the improved irrigation channel had created huge opportunities for farmers to diversify their farming and grow a variety of crops. In 2015, their family had earned a net income of 12,000 Rupees. Tara B. Ontaki Magar said: 'We can now grow crops even in winter thanks to the availability of water, which otherwise was impossible due to extreme drought and low winter rainfall.'

Apparently, the interventions have helped reduce climate risk and the vulnerability of households. The landscape has changed from a degraded and drought-prone area to a more productive and richer one, in terms of agro-biodiversity. 'We have now managed to protect our village from extreme drought, landslides, and fire outbreak,' added Min Bahadur Soti Magar, a community leader. Communities have now abandoned the practice of slash and burn thanks to opportunities they could find in their home gardens. Nirmal, a community facilitator working in Kirtipur, said: 'The adaptive integrated water resource management practice has helped bring about a climate-smart village, where people themselves are managing natural resources and have generated benefits to increase their socio-economic capabilities.'

The effectiveness, efficiency, robustness, and sustainability of the approach

Effectiveness: The AIWRM practice is effective as it helps communities to cope and adapt better to climate change. People in Kirtipur village mentioned its multiple benefits. It allows farmers to sow timely seeds like rice in nurseries and helps timely transplanting of seedlings. It also allows them to do off-seasonal vegetable production, mostly in winter, which had not been possible before. With this increased diversification of sources of livelihood, income of the villagers had more than doubled compared to 2008.

Overall, AIWRM has reduced sensitivity to erratic rainfall and drought. 'The yield of each crop has increased', said Rima Kumari Baral, 'largely as a result of timely sowing of seeds.' A total of 22 households had initiated vegetable growing on a commercial scale since 2009. In 2016, 40 households are growing vegetables and selling the surplus in the market. Amar Sing Sunari Magar said: 'I do not have to think of going abroad for work as I can earn sufficiently here to support my family for their education, health, and other basic requirements.'

Efficiency: The AIWRM practice is efficient and cost-effective. The use of resources and technology was affordable to the communities. Amar Sing Sunari Magar, a resident of the village, said that they could continue with the management of the irrigation channel, since it was not so expensive and very simple. A cost and benefit analysis of this channel carried out by Practical Action shows that the net welfare gain attributable to the initiative is positive. These results support the view that this approach delivers value for money and deserves further funding.

Robustness and relevance: In terms of overall performance of adaptation measures, this practice shows a positive outlook. Villages were able to establish paddy seedbeds a month earlier compared to the past, because they no longer needed to wait for rain. In 2009, maize, a new crop sown in spring on these terraces, resulted in 20 farmers harvesting an additional 96+ quintal of cereal. In the first winter in which it was grown, 35 families earned an extra income of about NPR. 2,000,000 jointly and were also able to consume fresh vegetables grown in their own lands (Practical Action 2011).

Sustainability: The villagers of Kirtipur plan to keep up the good practices for climate resilience they had adopted. They would like to implement a forest management plan, extend the irrigation channel, and improve agricultural practices to keep up with the changing climate. Community-based institutions, such as a community forestry user group, water user group, and cooperative are already taking leadership in addressing disaster and climate change issues in Kirtipur.

Challenges and the way forward

This adaptation practice has scope for replication in the mid hills and drought-prone areas of Nepal. The Cost Benefit Analysis (CBA) carried out by Practical Action also suggests that scaling-up of such interventions to other geographic areas deserves serious consideration, provided baseline conditions in other districts of the country are comparable to those in the project site before the project came in (Willenbockel, 2011)..

There is only one barrier to the sustainability of AIWRM in Kirtipur village - paucity of funds. Some of these initiatives, such as the expansion of irrigation channels and their maintenance, will need additional financial investment and technical assistance. It is likely that if villages do not receive further support, their plans will not be fully implemented.

Saving climate resilient seeds for the future: Case study of a community seed-bank in Jogimara VDC, Dhading District

Context

The case study was made in Jogimara, a village in the south-west of Dhading District in the mid-hill region of Nepal. This region has a warm temperate climate, hilly terrains, and sloping lands. The altitude ranges from 292-1770 m above sea level. The number of households in the VDC was 1,157 and the total population 6,682 persons. Some 85 per cent depend on agriculture for livelihood. Chepangs (35%), Brahmins, Chhetris, and Newars are the chief inhabitants of Jogimara VDC. The main source of livelihood of more than 90% households in Jogimara VDC is agriculture.

Climate change is a pre-dominant issue in this district. The data show that in 30 years (1978-2008), temperatures increased to around 0.20 C with a maximum average temperature of

22.30 °C in 1999 and lowest average temperature of 20.30 °C in 1983. The mean winter temperature also indicates an increasing trend. On the other hand, there is a trend of declining post-monsoon rainfall.

Main climate-related risks and hazards in Jogimara Village are prolonged droughts, drying of water sources, landslides, and pest outbreaks. The months of April-July and December- March are critical stress periods for most farmers due to the effects of climate change. Extreme drought, in summer and winter, was found to be a primary cause of productivity loss for staple crops like maize and rice. Increasing incidences of diseases and pest were important causes of loss in productivity of leguminous crops such as cowpea, black gram, and mustard (Paudel et al. 2011).

Jogimara VDC is one of the areas of commercial vegetable production. Commercial and hybrid varieties are now replacing traditional and local varieties there. This recent focus of agriculture on commercialization has contributed to a heavy reliance of farmers on chemical fertilizers and pesticides in the area. People in Jogimara realized the importance of conserving their local varieties, though, as a buffer against environmental and socio-economic stresses. They are now closely working with governmental and non-governmental organizations to pilot and promote the concept of a 'community seed-bank' as a strategy to enhance their food security and climate resilience.

What is this community seed-bank?

A community seed-bank (CSB) is a community driven and community owned effort to conserve and use local and improved varieties for food security and to build resilience of farmers.

CSBs are usually inexpensive and employ relatively simple, low-cost storage and documentation technologies (Sthapit et al. 2013). The purpose of a CSB is, first, to save and exchange local seeds, keep them under the control of farmers for easy access, and use them for seed security at village level. It is also to consolidate community contribution for the promotion of conservation, sustainable use, and improvement of important and stress-tolerant, local, genetic resources and traditional knowledge (Shrestha et al. 2013).

Since climate change has a significant effect on agricultural production, growing local varieties, which have a high degree of genetic diversity, is highly important in the vulnerable areas of Nepal. For these varieties have the ability to withstand and adapt better to environmental stresses and changes.

The community seed-banks, in short, are community-based adaptation strategies to conserve stress-tolerant local varieties (tolerance to drought, flood, pest, etc.). They also conserve locally adapted varieties including rare varieties (for food, fodder, herbs, and medicines). Seed banks also serve as a disaster resilient strategy, because they help in the restoration of 'lost' varieties (due to disasters, and so on).

How does a CBS work?

Formation of groups: The first step is to assess existing farmers' groups and establish Ward and Village Development Committee (VDC)-level farmers' committees. A Biodiversity Conservation and Development Committee (BCDC) was established in 2009 with the support from the Local Initiatives for Biodiversity, Research, and Development (LI-BIRD) project. A total of 500 households of Jogimara affiliated with this group. An 11-member executive committee comprising men and women was formed with representation from different ethnic groups to manage these groups.

Awareness, training, and capacity building: Various awareness-raising activities, such as a diversity fair and 'Teej' song competition, were organized to sensitize the community. The aim was to raise awareness about the value of biodiversity, the need for conservation of stress-tolerant varieties, and the potential to bring lost genetic resources back to the area. To build the capacity of community members, the project team organized training and exposure visits on community-based biodiversity management practices including a community biodiversity register, community seed-bank management, and group management.

Documentation, collection, and storage: People developed their own rules and regulations for seed collection, regeneration, quality control, and distribution. For example, in Jogimara it was mandated that each ward had to conserve at least 1 local variety. Traditional seed storage structures like a 'ghaila' (made of mud), bamboo baskets, and plastics were used. The technical staff of LI-BIRD provided support and guidance on incorporating scientific basiss while documenting, collecting and storing the seed materials. A community building was constructed in Majhimtaar in Dhading district to host the seed-bank. Local seeds and materials were collected by organizing diversity fairs and by locating seed sources using a community biodiversity register. This register of Jogimara VDC has documented information, knowledge, and the source of 78 local varieties as well as the custodians of these genetic resources. The communities together with the support from technical staffs of LI-BIRD validated the material and information on the community biodiversity resiter in order to ensure that it contains valid information on local materials.

Regeneration, distribution, and multiplication: Village people established a diversity block for the regeneration, distribution, and multiplication of 'Ghaiya Dhaan-upland rice' (9 varieties), 'Barkhe-rainy season' rice (10 varieties), and millet (7 varieties). They also created a local fund to manage the seed bank and to support farmers in conservation and livelihood activities. Those who conserve local varieties receive a loan at 12% interest from the BCDC, which they use for other livelihood activities.

How does a CSB address climate risk and vulnerability?

The community seed bank in Jogimara is helping farmers to preserve local biodiversity and prepare for (more) erratic weather conditions. According to them, local seed varieties are more drought and disease resistant and require less pesticide than genetically modified crops. Villagers have conserved more than 30 varieties that have stress-tolerant characteristics. They have maintained 7 varieties of drought-resistant finger millet varieties in the diversity block and have been distributing to farmers to plant these varieties for multiplication.

According to Hari Ram Khatiwada, chairperson of the BCDC, 'Conservation and promotion of locally available seeds and crops is a good adaptation strategy.' Local crop varieties, like finger millet and horse gram, have a better nutritional value and are more drought-resistant. There are publications in Nepal which also highlight the nutritional and environmental importance of underutilized crops sucha s finger millet.'The local seeds we used could withstand drought as well as a pest outbreak,' says Chandra Kumari Magar, a female member of the Biodiversity Committee. According to local respondents, the seed bank is acting as a disaster response strategy, since it has given them seed materials during crop failure and disasters. We also found that the group had distributed 8-9 quintals of seed for earthquake disaster victims of 2015. Such conserving activities contribute to reduce climate risk and increase the resilience of local livelihoods to climatic stressors because of the increased ability to benefit from the unique characteristics of a range of plant varieties thriving in local climates in difficult conditions?

Effectiveness, efficiency, robustness, and sustainability of the strategy

Effectiveness: The community seed-bank in Jogimara VDC has been an effective means of conserving genetically rich, diverse, and climate-resilient varieties of seeds. The seed bank today stocks 78 varieties of seeds including grains (rice, maize, and millet), legumes (lentil, rice bean and horse gram) and vegetables (beans, sponge gourd and pumpkin).There are several neglected and underutilized local plant species, such as finger millet, buckwheat, horse gram, and taro that are conserved and managed by farmers. The seed bank has established a biodiversity fund to support conservation and use of local varieties. Anyone who borrows from the fund, must grow at least one traditional crop variety. To date, 155 farmers, mostly resource poor, have benefited from this seed bank.

Efficiency and cost effectiveness: The CSB is an efficient and cost effective practice of conserving local varieties to deal with climate-related extremes. Rama Dallakoti, a member of the BCDC, said that local varieties are stress tolerant plus the seed can be produced locally and would never need chemicals or pesticides. Besides, organic farming saves money, otherwise spent on buying seeds and fertilizer.

Relevance and sustainability: The seed bank is relevant to ensure food security as much as to deal with extreme disasters. According to Harimaya Sahi Thakuri, member of the BCDC: 'For us to develop a new variety, the traditional variety should be conserved.' From 2012, the CSB began to operate on its own without external financial support. The main source of income comes from the sale of seeds. Also, the Biodiversity Committee began processing finger millet and started to sell in the market. This value addition of an underutilized crop like this one has not only helped in its conservation, but also given some economic incentives and encouragement to the farmers.

Challenges and the way forward

The Biodiversity Conservation group of Jogimara is taking a leading role in conserving local, drought-tolerant and underutilized crops, maintaining a diversity of crops in their fields. The group has been supporting the poor and vulnerable households in their village to sustain their livelihoods, and implemented activities to enhance their capacity to deal with those climate risks and hazards.

The Committee faces a number of challenges related to the management and operation of the seed bank. According to the chairperson of the committee, due to lack of time and resources, it has been difficult for them to fund the staff of the seed bank and maintain a diversity block. Fortunately there is good potential to link the community seed-bank with the national gene bank and to get some support. Recently, the seed bank of Jogimara handed over 48 varieties of seeds from 19 different crop species to the latter. Linking a community seed-bank with the national gene bank, and other private and public sector agencies will help sustain such innovations.

Diversifying the role of community-managed micro-hydro to unlock low-carbon and climate-resilient pathways

Context

This case study was conducted in Charang VDC of Mustang District. The District is situated in the trans-Himalayan region of the country at an altitude of about 3000 m. It has a very low population density. According to the District Development Plan 2066-67 (2011/2012) period looks odd, the total population of Mustang was 13851, of which 7137 were men and 6714 women. The ethnic composition is dominated by Gurungs who make up about 59% of the total population. They are followed by Thakali (24%) and Dalits (8%), while Magars and Thakuri count for

3% and remaining ethnic groups 3%. A large proportion of its population is engaged in subsistence agriculture followed by trade (app. 7%), foreign (abroad) employment (4%), and civil service. Since Mustang has virtually no potential for agricultural development or opportunity for off-farm employment seasonal migration is prevalent.

Mustang is one of one of the highest affected and vulnerable districts in terms of climate change. The temperature is expected to rise by about 0.120 C in the northern-most part, and in the range of 0.06-0.120 C in most of the rest of the district (Practical Action, 2009).Precipitation records collected in 1980-1995 in the Kali Gandaki corridor show that rainfall in Mustang is declining, while some parts in the extreme south have no change in precipitation. Major climate hazards in the area include intense rains, drying of water sources, receding of glaciers, and outbreak of pest and diseases.

Climate change has an important effect on farmers who depend on agriculture for their livelihood. For example, warmer and drier winter as much as high temperatures have devastated apple farms in lower parts of Mustang, which resulted in a decline of quantity and quality of apple productivity. Worse, this district is one of the most popular trekking destinations in Nepal and the energy demand for cooking and heating is high. Speaking of energy use, more than 60 per cent of the families there have access to electricity from the national grid, but only 9 per cent of these make use of the five micro-hydro plants in the district.

Recently, 'micro-hydro' has been one of the adaptation and mitigation strategies for people to unlock opportunities for low-carbon and climate-resilient development. Mustang District has a hydropower potential of about 1500 MW, out of which only 451 kW has been tapped so far. Altogether 14 micro-hydro projects have been developed in the district till date. The promotion of hydropower can give good opportunities to local people and to the government to switch to clean energy and adopt a climate-resilient development path.

Climate-resilient practice: micro-hydro

Micro-hydro is a type of hydroelectric power that typically produces 5 kW-100 kW of electricity using the natural flow of water. It is a renewable, efficient, and reliable source of energy that does not directly emit greenhouse gases or other air pollutants, and that can be scheduled to produce power as needed, depending on water availability. It can generate other benefits along by helping mitigate greenhouse gas (GHG) emission and building resilience of village communities in Nepal.

A 16-kW run-off-river micro-hydro plant was installed in 1989 in Charang VDC of Mustang District. This plant has been a reliable energy source for 55 households to address their most important economic and environmental challenges. It was installed with a 25% subsidy from the government, a 75% loan arrangement from the Agriculture Development Bank, and active community participation.

The micro-hydro in Charang VDC provided for a climate-resilient practice, which made best use of water resources to generate electricity for local people. This energy source completely replaced kerosene use, thereby contributing to GHG mitigation. There are other socio-economic benefits of micro-hydro. It has helped promote children's education, boost rural tourism, and strengthen local livelihood.

How does micro-hydro work?

Formation of Management Committee: The Charang Khola Village Electrification Committee (VEC) was formed in Charang VDC to manage the micro-hydro. The committee consisted of 11 members (5 women and 6 men). It took up responsibility for the finances and management of the micro-hydro, devising all the rights regarding the tariff system and operator's payment. The committee would hire an operator on a monthly basis for the operation and maintenance of the plant. Initially, the VEC collected a minimal amount from the users to support operator payment. Now, after realizing the need for an emergency fund, they are collecting on the basis of consumption per unit, recorded in a meter box installed in each household.

Upgrading the system to meet the needs of people: The micro-hydro had been installed with the motive of electrifying an isolated, rural, mountain settlement of 55 households. To address their increasing electricity need,

the capacity of the system was strengthened locally (doing canal improvement, pole arresting line improvement, and wire capacity increment). After upgrading, the system is capable of supplying enough electricity for lighting at almost twice the rate of the initial estimation.

Uses of energy: Villagers used solar heating to supplement their power supply, especially in winter when the water freezes in the canal. This energy was, first, meant for lighting and household chores. But it has also supported the growth of local businesses like a small furniture factory, flourmills, grinding mills, and shops. In short, people have responded energetically to demographical changes and the weather variability by diversifying their source and use of energy. In view of the electricity crisis faced by villages in central and lower Mustang, the VEC is planning to increase the capacity of the micro-hydro plant in the near future and further diversify their energy sources.

How does micro-hydro address climate risk and vulnerability?

In the past, the water of Charang Khola was solely used for drinking and irrigation. Now, this (scarce) water is reused for electricity and other household purposes, hotels, and tourism as such. This diversification and efficient use of water has helped the villages to deal with water scarcity brought about by climate change. They are also preparing to cope with future climate risks by having a well-defined water and benefit sharing mechanism. > what 'benefit'?

People used to be dependent on imported kerosene for energy. Now with the micro-hydro installation and its successful operation for almost 25 years, they have noticed very positive changes in their situation. The availability of this affordable energy has helped them be more self-sufficient and resilient. They could save money otherwise spent on expensive kerosene. Women confirmed that such money could now be used for productive purposes such as children's education and buying warm clothes for winter. It was also evident in some households that the use of electric cooking appliances had lessened their dependency on traditional fuel sources like dung and firewood.

Most importantly, the micro-hydro energy supply and subsequent decline of kerosene use has helped reduce the negative effect of kerosene burning on the environment and the health of children, women, and the elderly. Shila Gurung, VEC member, reported: 'After the micro-hydro installation, we felt as if our whole life had been lifted up. Now no-one needs to buy kerosene anymore; instead the money can be used for our children's education. We can now utilize our evening hours to explore new opportunities for personal and community development.'

Effectiveness, efficiency and sustainability of the practice

Effectiveness: People said that in terms of social, economic, educational, and personal aspects proper utilization of available resources has made their lives easier. Access to electricity has allowed the children in the village to study comfortably at night, women to come out from the boundary of their kitchen, and men to be engaged in income generation activities. The present diversification of energy source (solar heating supplementing micro-hydroelectricity) has also become an important means to empower women and a support in livelihood upliftment.

Efficiency: The energy diversification has lessened the drudgery of work for the women, who previously were compelled to remain confined to their kitchens and do only household work. They have more time now to participate in social life and even have time for themselves. The grinding mill in the village has helped save time of the farmers otherwise spent on manual processing, which was labour intensive and time consuming. People are utilizing the time saved to diversify their livelihood opportunities and economic growth. Social groups, a village electrification committee, a mothers' group, and a men's group were formed to support them in social and livelihood activities. These groups encouraged collective and collaborative action to deal with local development and climate-related issues.

Relevance and sustainability: Micro-hydro is highly relevant to Charang VDC. Villagers felt that they were now independent and self-sufficient, because they could use the grinding mill and flourmills with micro-hydro energy. They considered the flourmill a good opportunity to deal with the declining labour force in their isolated localities due to a high rate of migration. Remarkably, in the present situation of electricity crisis in the country, where even people in the capital are experiencing darkness frequently, the inhabitants of Charang, one of the most remote, isolated villages in Mustang, are enjoying an uninterrupted supply of electricity throughout the year.

The villagers are committed to sustain the micro-hydro plant (MHP). Ms. Maya Bista, VEC Chief, recollected how they initiated the project: 'We all wanted to light up the village, so my father, along with other villagers, took loans'. In those days, we knew nothing about the system. I remember we once even lit a fire under the pipelines to facilitate water melting and continue electricity production. But we have grown up with micro-hydro. It's like part of our community, so we want to take it even further, now that the grid is there.' Like Maya, the entire village is committed to sustain the innovation. The management committee is also aiming to expand and improve the MHP.

Challenges and the way forward

Economic constraints, technical limitations, and weather adversity were reported as the most important limitations faced by these isolated communities. Frozen water has been a limiting factor in the production of electricity and drinking water in winter. Till date this limitation has been tackled with the aid of individual solar heating systems installed in almost all households. Increasing natural hazards like landslides and flash floods are the chief climate-related threats people have to deal with. These disasters are said to increase the overall repair and maintenance cost every year, so they require more financial resources for MHP management.

Despite these challenges, the micro-hydro technology has proved to be a successful climate-resilient practice in Nepal. The two-decade long experience of the Charang community in modifying and upgrading the system to suit their needs and to address climate change stresses, is a good lesson for other parts of Nepal.

Enhanced food security and nutrition through climate-smart farming practices: Case study of Manari VDC, Nawalparasi District

Context

Manari is a Village Development Committee in Nawalparasi District in the Lumbini Zone of southern Nepal. At the time of the 2011 Nepal census, it had a population of 5782 with 2771 men and 3011 women. Manari is located 5 kilometres east from the district headquarters. It is a flatland area and has an agriculture-based economy. Tharu are its main inhabitants along with some other ethnic groups like Madhesi, Brahmins, and Chhetri.

The village has a temperature ranging from 8-430C with an average rainfall of 1300 mm. The vulnerability assessment according to a report of the National Adaptation Programme of Action (NAPA) shows that the Nawalparasi district is moderately vulnerable with an index between 0.321 and 0.499. However, community in Manari VDC perceived there are changes in temperature, rainfall and winter fog. The change in weather and climate is affecting local agriculture system and livelihood. Communities have experienced increase in hot days, fogy days and insect and pest attack. Health hazards are also reported which include diarrhoea, cold wave, and malnutrition.

Flood, drought, cold wave, and heat stresses are the main climate-induced disasters observed in the VDC. It has experienced prolonged droughts and extreme weather events in the last 10 years, which contributed to the loss of agriculture production and increased economic burden on the families. A drought in 2009 caused more than 50% of production decline due to drying of rice seedlings. A cold wave in 2009 damaged major cash crops and vegetables such as mustard, potato, tomato, and pea. In addition, a health-related climate hazard was a diarrhoea outbreak in 2007.

A vulnerability mapping carried out in a local adaptation plan of action (LAPA) showed that Ward Numbers 3 and 4 of Manari VDC were the most vulnerable settlements, followed by Ward Number 1 (LAPA-Manahari 2013). The critical moments and stress periods in the VDC were April-July and November-February, when there would be a risk of flooding, winter drought, and chilling temperatures. The Livelihoods and Forestry Programme (LFP), Rupantaran Nepal- NGO, and the Resource Identification and Management Society (RIMS) Nepal along with government and other agencies helped the communities to prepare better and to improve their capacity to respond to climate-change effects on agriculture and human health. As part of the response, villagers prepared Community Adaptation Plans (CAP) in 2010 and the above LAPA in 2013[1].

What is their adaptation strategy?

Climate-smart farming practices are a set of community and ecosystem based adaptation practices and technologies that increase communities' capacity to plan and effectively respond to climate change risks and hazards. These practices would increase farm productivity and incomes, address issues of food security and nutrition (human health), make agriculture more resilient to climate change, and create other risk mitigation benefits. Climate-smart agriculture promotes coordinated actions by farmers, government, NGOs, civil society, and donors such as UK-AID, USAID as more climate-resilient pathways.

These special farming practices in Manari involve 4 important sets of adaptation practices, namely a) a multi-water use system, b) organic farming, c) rehabilitation of ponds for fish farming, and d) public-land management. These practices are locally suitable, low-cost, and sustainable. The technology consists of a composite of indigenous and improved climate resilience practices that local communities feel relevant and feasible to address their climate change problems. Poor and vulnerable households can easily adopt these technologies, even without external support.

How does it work?

Awareness and capacity building: Awareness raising activities were conducted in the VDC, with the support from external agencies, to sensitize people about climate change, its effect, and the need for action to deal with it. A Village Forest Coordination Committee (VFCC) was formed to lead climate change interventions in the VDC. The committee received training on climate change adaptation and helped prepare a local adaptation plan of action. Community members also participated in training and awareness raising activities to deal with climate change and to develop local measures in response.

Adaptation planning: The LAPA or Local Adaptation Plan of Action identified key climate risks, vulnerable households and settlements, and listed climate-smart adaptation strategies to deal with climate problems. It found that marginalized, poor, and landless farmers were the most vulnerable group. Then short-term and medium-term adaptation activities were developed on priority basis to support them.

Designing adaptation interventions: Villagers themselves took the lead in the design of adaptation interventions with technical support from government agencies and NGOs. Interventions consisted of organic and off-seasonal vegetable farming, micro-irrigation, piloting and promoting of the Treadle pump, and value addition and marketing of local products. Specific adaptation strategies adopted by farmers in Manari were:

Multi-water use system: They made efficient use of water by managing an irrigation channel and ground water. They used a Treadle pump (Dhiki) to lift groundwater for irrigation. This is regarded as an environment and climate friendly technology for household level irrigation. They also improved a traditional irrigation channel and used it to irrigate their uplands.

Organic farming: In Manari 3 Jamuhanawa, the Pragati Farmers Group was promoting organic farming to revive their farming system and address problems of food security and human nutrition. The group comprised

[1] LAPA and CAP are community-based adaptation plans. They are a process through which vulnerable and poor households within communities get involved in assessing their vulnerability, identifying adaptation deficits, and planning for responses and preparedness to deal with the adverse effects of climate change (Regmi and Subedi 2011)

32 households. They employed a traditional practice of making soil heaps and applying local pesticide control measures such as ash. The farmers used the Insect traps to monitor or directly reduce populations of insects. There is gradual shift towards organic farming in the study villages.

They were also using a so-called mini-plastic tunnel technology to protect seedlings from chilling winter temperatures. This local coping practice involves various steps. Farmers dig a 5-inch pit and prepare soil with local manure including ash. They then pour a small amount of water and plant the seedling. The seedlings are then covered with a mini-plastic tunnel.

Rehabilitation of ponds: The Suvakamana Women's group of Patani, Ward Number 4 of Manari, comprised 25 women-headed households. They restored and reused a public pond, which had become degraded and had been abandoned. Water came into the pond through an irrigation channel and rainwater harvesting. The women harvested 20 quintals of fish twice a year. With the money they repaired the pond, constructed a community building, and supported poor and vulnerable families in income- generation activities.

Public land management: The most important problem in a floodplain is the degradation of public and private land by river cuts and riverbank erosion. Public lands are common lands, which are mostly under the jurisdiction of local government according to the Local Self-Governance Act 1999 (Jamarkattel and Baral 2008). Community-based management initiatives of such public land include a climate change innovation in Nepal's Terai like the Nawalparsi District. In Ward Number 1 of Manari, villagers identified public land management as a strategy to control riverbank erosion and make productive use of degraded public land that was otherwise wasted, and left barren and degraded. They formed the Public Land Management group comprising 116 households. The group carried out plantation activities in 4.5 hectares of public land. They also adopted intercropping of turmeric as an income-generation activity. In another public-land development initiative, a degraded and barren riverine land was utilized for vegetable farming particularly for poor, landless, and vulnerable families.

How does the adaptation technologies address climate risk and vulnerability?

With climate change, flood risk and riverbank erosion have increased. There is more and more loss of productive land due to such erosion as also flash floods. Public land management is one of the effective adaptation measures, because it engaged communities in the management of degraded and barren land formed by flood and erosion. The plantation and intercropping, including livelihood activities, has brought about adaptation and other benefits - improving the environment as well as building resilience of poor, landless, and vulnerable households.

Efficient water management practices and technologies, such as the Treadle pump and irrigation channel, built the resilience of households by optimizing the use of depleting water resources and contributed to their livelihoods by creating income-generation opportunities such as fish farming and vegetable growing. Organic farming practices and associated adaptation options improved the nutrition and health of families and helped reduce pollution otherwise generated from the heavy use of pesticides and fertilizers.

Effectiveness, efficiency, reliability, and sustainability of the adaptation strategies

Effectiveness: The climate-smart farming practices, introduced in Manari VDC, have generated multiple benefits to the communities. Devendra Kumar Chaudhary of Manari 3 earned more than 150,000 NRS (1500 USD) through the sale of surplus vegetables (after domestic consumption). More than 30 farmers in his neighbourhood have now become local entrepreneurs. According to Sita Devi Chaudhary- a local resident, consumption of vegetables has helped improve the health of her children and family. She added that with this larger income they invested in improving the sanitary condition of the house by getting a toilet and drinking water source nearby. They were also using this money to control the problem of arsenic contamination.

It is evident that effective management of underutilized public land means an important benefit to communities not only to generate forest resources and supplement forest products but, more importantly, to reduce vulnerability and generate livelihood opportunities for the landless and poor households. The 7 public-land management groups in

Manari, which included more than 500 poor and vulnerable households, have conserved and managed more than 40 hectares of degraded and barren land and helped the landless and poor with income-generation activities. Ful Kumari Chaudhary of the Shreeram Public Land management group said they had earned more than 116000 NRS (1160 USD) from the sale of turmeric grown as an intercrop with forest species on their public land. The money is now given as a soft loan to poor, landless, and vulnerable households.

Relevance and efficiency: The low-cost and efficient adaptation technologies, like micro-irrigation and crop management, have economically benefitted farmers. Devendra Chaudhary of Jamuhanwan said that with the use of low-cost practices, he had saved money otherwise spent on buying costly fertilizer and pesticide. Sita Devi and Rameshwor used locally made pest control methods like the Foramen trap.

Farmers now utilize the upland and drought-prone areas of Manari properly. Devendra Chaudhary, a farmer from the area, said that 'with the irrigation channel, we are now utilizing this wasted agriculture land for off-seasonal vegetable farming.' He along with other farmers had made best use of the area for seasonal and off-seasonal vegetable production, and benefitted from it.

Sustainability: The adaptation practices introduced in Manari are sustainable, because it utilized local resources, skills, and knowledge. The local farmers group, cooperative, and public land management groups are managing the adaptation practices in the VDC. These local bodies collectively raised funds and voluntarily gave input and support in promoting adaptation options. The Subhakamana Women Fishery group of Patani is using the public pond and managing it for communities' benefit. They invested the income from the sale of fish in social welfare. This has helped them gain support and recognition from the local government and other local agencies. Sakuntala Chaudhary, executive member of the women's group, said: 'We are now united and, so, able to manage the pond without any external support.'

Challenges and the way forward

Due to a lack of policy clarity and legal recognition, this adaptation practice of public land management may face implementation hurdles in the future. A clear and consultative policy and guideline (based on practical experience) for public land management is yet to come (Jamarkattel and Baral 2008). Another challenge lies more in the expectation from local people towards external agencies for further support. For example, a majority of the farmers consulted asked for additional support to continue the innovations. This indicates some level of dependency of communities on external support and interventions. It may have implications in the sustainability of the adaptation strategy.

Discussion

People in the Gandaki river-basin are already experiencing climate change and its effects. Main climate-change risks and hazards in the basin include flash floods, landslides, drought, Glacier Lake Outburst Flood (GLOF), water shortage, and the outbreak of the pest and other diseases. Since most of the farmers in the basin depend on agriculture, the critical moments and stress periods were basically linked with crop cycles and the livelihood system people depended on. For example, April-August and November-March are crucial for dealing with climate risk and its main effects on their farming and livelihoods.

Effective adaptation strategies at local level are now necessary, as people's lives and livelihoods face an increasing burden of climate shocks and stresses. The findings in this paper show that communities have been using traditional knowledge, practices, and technologies to cope with adverse climatic stresses. Autonomous adaptation and coping mechanisms in the Gandaki river-basin include the conservation and sustainable use of important plant species, use of different soil and water conservation methods like drip irrigation, and technologies to retain soil moisture, changing cropping patterns, and crop composition.

The review of autonomous adaptation reveals that most users cope with these changes by short-term, reactive solutions. We found that autonomous adaptation deals with more climate variability and critical stresses over the year. In areas where external support is inadequate, autonomous adaptations were useful to communities to adapt to changing weather variability and short-term climate change effect. However, with the increased risk and uncertainty of climate change effects, autonomous adaptation is inadequate (Regmi and Bhandari 2013). In many areas, autonomous adaptation has failed to address the scale and intensity of climate change and has been inadequate to protect communities and their assets from loss and damages.

Although autonomous adaptation is useful as a coping strategy, there is a need to go beyond the individual level, and to plan and give support for appropriate technologies and strategies to adapt in the long run (Manandhar et al. 2011). Frankhauser et al. (1999) claim that for autonomous adaptation to be effective, individuals must have the right incentive, knowledge, resources, and skills to adapt efficiently. Due to constraints with respect to information, resources, and the like, autonomous adaptation alone may not turn out to be optimal, and governments have very important roles to play. As argued by Tompkins and Adger (2004), co-management between local and higher level institutions is particularly important for tackling climate change that extends beyond local scale.

With the challenges and limitations to autonomous adaptation, planned adaptation has become an important climate and development strategy in Nepal and the South Asian region as a whole. Common planned adaptation measures include local and community based adaptation planning, climate-smart farming, improved irrigation, soil and nutrient management technologies, improved access to climate resilient seed and technologies, and improved marketing. It would also mean strengthening community-based institutions including community-based insurance systems, improved climate information services, and diversification of agriculture with focus on localised climate and nutrition sensitive farming. It was evident from the case studies in the Gandaki river-basin that most of the adaptation options were integrated strategies, which addressed multiple critical stress periods within a year and beyond, and involved more than one climate risk and hazard.

The case studies indicate that planned adaptation practices were effective in addressing climate risk and the vulnerability of communities in the targeted villages. These practices had demonstrated multiple benefits in terms of addressing climate risk and enhancing livelihoods of vulnerable households. Yet, challenges and constraints to planned adaptation measures were also observed in the case studies. Most adaptation strategies were thought to be development-related actions to reduce vulnerability rather than specifically address climate change. In summary, the current planned adaptation was not incremental and transformative in terms of addressing additional and projected risks and effects posed by climate change.

This study reveals that the limits faced by households to adaptation have physical, economic, and technical dimensions (Adger et al. 2007). There is a problem of sustainability of the adaptation strategies due to financial constraint. Due to lack of financial resources many good adaptation strategies were abandoned or not practised by the communities. In some areas, the planned adaptation created more dependency of people on external agencies for support. Another challenge of planned adaptation is the problem of technical feasibility of certain technology and practices to suit the condition of poor and vulnerable households. There was also constraint due to a lack of top-down support and of linkages between locals and the district and central government including the private sector. Regmi et al. (2015) also identified issues related to financing constraints, technological barriers, and governance challenges limiting the sustainability of adaptation interventions in Rasuwa and Nawalparasi districts.

The findings show that autonomous and planned adaptation strategies are inadequate to deal with uncertainty and risk posed by climate change. They have to be designed considering not just the observed effects but future climate change risk and vulnerability including changing socio-economic, political, and demographic circumstances. In summary, an adaptation strategy has to be incremental and transformative to build the resilience of society and ecosystems.

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Himalayan Adaptation, Water and Resilience (HI-AWARE) Research
c/o ICIMOD
GPO Box 3226, Kathmandu, Nepal
Tel +977 1 5003222
Email: hi-aware@icimod.org
Web: www.hi-aware.org