

An Institutional Analysis of Glacial Floods and Disaster Risk Management in the Nepal Himalaya

Ian Thompson

Arizona State University, School of Sustainability

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1. Abstract

Institutional factors are rarely examined in disaster risks in the Himalayan region, as much of the focus so far has been on improving the scientific understanding of the natural hazards and risks. This is particularly true for glacial lake outburst floods (GLOFs), which are natural hazards endemic to high mountain ranges such as the Andes, Alps, and Himalayas. While these have put mountain communities at risk for centuries, vulnerability is viewed to be increasing due to climate change. While the science behind the causes and characteristics of these hazards is now better understood, there is an absence of research understanding the social, cultural and institutional drivers behind creating effective strategies to mitigate risks from GLOFs. This is more so for the Himalayan region, where institutions have recently started to address this risk, but contention between local communities and external organizations can hinder mitigation efforts. To better understand how people's perception towards disaster risk, a study conducted by Sherpa et al. (2019) examined the socio-economic and cultural perceptions surrounding GLOF hazards. This research highlighted gaps in how scientific knowledge is disseminated to local communities, and the resulting distrust in government mitigation projects such as lake lowering and Early Warning Systems. A clear need developed to conduct an institutional analysis of the governance systems responsible for disaster risk management and their interaction with local communities. This study examines the institutional conditions under which mountain communities create effective adaptation strategies to address climate induced hazards. We use a mixed-methods approach, combining: a) quantitative analysis of household surveys collected in 2016-2017 and b) qualitative analysis that maps out the various factors of institutions that influence the success of community-based adaptation efforts. Additionally, GLOF case studies from Nepal are compared to those in Peru, where institutions have a longer history of managing GLOF risks. The research finds that there are several considerations including: lack of cross-scalar communication networks, lack of local knowledge and participation in policy processes, and ineffective interorganizational coordination of knowledge sharing and funding streams for local projects. This disconnect between external versus local and informal institutions becomes an inherent issue in projects where agenda setting by external organizations plays prevalent roles in project implementation.

2. Background

2.1 Glacial hazards

Glacial lake outburst floods (GLOFs) are natural hazards endemic to glaciated mountain ranges such as the Andes, Alps, and Himalayas. While these have put communities at risk for centuries, vulnerability is viewed to be increasing due to climate change. Increasing water volume in these glacial lakes from glacial melt puts pressure on unstable moraines. This increases the susceptibility of flood events that can be triggered by weakening of the moraine, avalanches and landslides, or earthquakes that can cause moraine failure. Given the occurrence of such failure, the rapid onset of flooding can occur, posing serious risk to safety of downstream communities, livelihoods, and public infrastructure. As climate variability increases, the risk of these events becomes increasingly relevant in the lives of these communities. The increasing stress from heavy rain events, rapid melting of glaciers and potential landslides correlate with the increased occurrence of GLOF events.

While communities of these regions are aware of the existence of these risks, they are also faced with other substantial challenges of mountain life that contend with natural hazards. Verticality, a concept championed by Rhoades (2007) describes how the diverse ecosystems created by the topographic extremes have shaped the cultural development of the communities that occupy the land. The complex development of zone-specific agricultural and pastoral patterns to take advantage of the ecological diversity has also shaped trade systems between each zone to maximize the output of the land that has shaped these thriving communities for centuries. Because of this, the land itself plays an integral role in the identity of these communities, creating a strong sense of place for specific regions. Additionally, because of the regional isolation of mountain communities, strong local institutions have formed to manage mountain specific way of life and have developed hazard-specific adaptation strategies endemic to the region (Stevens, 1996). The social systems that define the communities of Solukhumbu are shaped by the cryospheric system in which they are located. Livelihoods such as agro-pastoralism and tourism are dependent on the lakes that are also the sources of risk in question. This reveals the complexity of disaster risk management as the problem is multi-scaler, from how individual vulnerabilities shape response, towards how rules and institutions are put in place to build resilience towards climate change and long-term hazard risk as a Social Ecological System (SES) (Rhoades, 2007).

A case study by Carey et al. (2012) analyzes adaptation efforts for Lake 513 in the Cordillera Blanca range in Peru by using a socio-environmental framework. This study provided an in-depth look at SES factors that either facilitated (technical capacity, visible hazards, institutional support, committed individuals, international role) or impeded (perceived risks, imposed policies, institutional instability, knowledge disparity, invisible hazards) attempted adaptation strategies for this specific glacial lake. This analysis provides a valuable holistic approach for disaster risk reduction in glaciated mountain ranges versus traditionally engineering-based analyses.

Watanabe et al. (2009) provides a useful look into the Imja Tsho lake in Nepal. The significance of this specific lake is in its conflicting scientific findings over the past few decades regarding risk of GLOF events. Previous studies of Imja Tsho have argued that this lake poses high risk to downstream communities due to increasing water volume, creating potential for future GLOF hazards. This has prioritized mitigation efforts around lake, including the integration of Early Warning Systems (EWS) into several downstream communities. The Watanabe et al. (2009) study sought to show that previous studies provided an incomplete scientific analysis of the risk for GLOF events, and new data collected proved that previous risk analyses overplayed the risk of GLOF events and taking attention away from potentially more dangerous hazards in other regions. However, other studies since Watanabe et al. (2009) have shown that Imja Tsho still pose a significant risk to communities in question (forthcoming), showing the ambiguous nature in accurately measuring GLOF risk.

2.2 Research questions

This research seeks to highlight the key institutional factors that influence adaptation strategies within the Solukhumbu region. Guiding this are the following questions:

What are the institutional conditions under which mountain communities interact to create effective adaptation strategies for climate induced hazards?

RQ 1.2 Who are the major actor groups influencing disaster risk reduction in the Khumbu region?

RQ 1.3 What are their development and objectives and priorities?

RQ 1.4 What are their funding streams, decision-making frameworks, and knowledge dissemination pathways?

2.3 Study site

This research focuses on the Sagarmatha National Park (SNP) and Sagarmatha National Park Buffer Zone (SNPBZ), also known as the Mt. Everest region. This covers approximately 1148 km² and is defined by its rugged landscape where elevation can increase dramatically over a short distance (DNPWC, 2006). This has shaped both the cryospheric ecosystem and the Sherpa people that are the predominant ethnic group within the park (Rhoades, 2007). Within SNPBZ there are 63 settlements and a population of approximately 8,000 people. Livelihoods are historically based in agro-pastoralism, taking advantage of the mountain environment (Stevens, 1996). Since since the creation of Sagarmatha National Park in the 1950's, livelihoods have been transitioning to tourism which has now become a dominant source of income. However, agro-pastoralism also remains an important source of livelihoods, especially for marginalized groups that may not have access to the tourism industry (DNPWC, 2006).

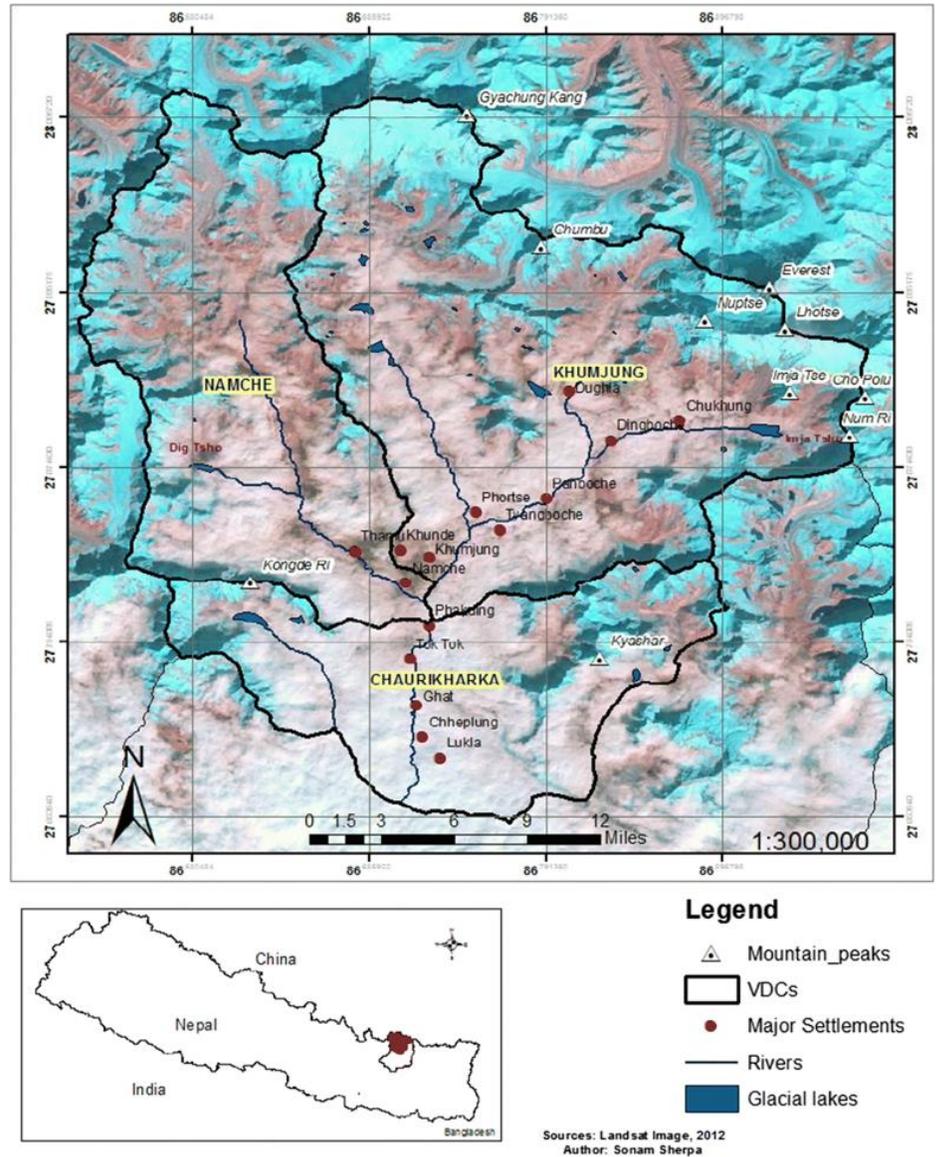


Figure 1. Study Region (Sherpa et al., 2019).

3. Theoretical foundations and gaps

To understand the current gaps in disaster risk institutions in Nepal, this work builds on concepts of community-based disaster risk reduction (Shaw, 2013) and community-based resilience (Berkes & Ross, 2013). Concepts such as agency, self-organization, and local participation in policy provide a lens to analyze institutional efforts and understand how social factors such as livelihoods influence risk perception in the Solukhumbu region by building on the work of Sherpa et al. (2019). Additionally, parallels are drawn to institutional development in Peru which has faced similar barriers to developing effective adaptation efforts that coincide with the social factors described above (Carey, 2010).

3.1 Social Perception

While the general risk of GLOFs is realized by Himalayan communities, the degree of risk is influenced by several socio-economic factors. Understanding these factors is vital in understanding the various ways the communities not only react to the risk emanating from GLOF events themselves, but also to proposed adaptation strategies. Study by Sherpa et al. (2019) reveals how different factors such as previous exposure to GLOF events, “cry wolf” effect from failed Early Warning Systems (EWS), and types of livelihoods shape the perception of risks held by community members regarding GLOF hazards. This concept is further supported in the literature by Dahal & Hagelman (2011), who provide the social analysis on risk perception. The authors provide a qualitative analysis that highlighted several social factors influencing how community members perceive the risk of GLOF events that are reported by government officials and research institutions. Factors such as cognitive biases and heuristics were shown to have substantial impacts on community perception of risk to GLOF events that often contradicted the scientific reporting on the risk of certain sites (in this case Tsho Rolpa Lake). After several evacuations, and absence of GLOF occurrence, the community began to distrust both the mitigation measures put in place and the institutions behind risk monitoring. This shows the criticality of social perception in adaptation strategies as communities lost their perceived risk of an event that is still considered a high-risk site (Dahal & Hagelman, 2014).

This paper seeks to build on this foundation by positing that current institutional efforts are doing little to incorporate these lessons into adaptation strategies. The case for this will be built in the following sections, comparing several institutional cases in which the neglect of various social elements led to failed efforts to minimize risk.

3.2 Historical cases

Regarding GLOF management, Peru has the longest history of institutional development that focused specifically on reducing risk of GLOF events (Carey 2010). This development was triggered by the 1941 GLOF of Laguna Palcacocha that led to 5,000 deaths and the destruction of nearly one-third of the provincial capitol, Huaraz. In response to this tragedy, the Government of Peru initiated the study of glacial hazards through scientific inquiry and monitoring to better understand the threat at hand. Over the next few decades, the approach to GLOF management continued to shift and transform. This variability in management led to several different adaptation strategies that were implemented with varying degrees of success.

These failed implementation strategies are often the result of Peru's hazard risk management failing to recognize the importance of various socio-economic factors (Carey, 2010). One of the largest barriers was the process of data collection and dissemination over time regarding glacial lake studies. For several decades, glacial studies were performed by international scientists who reported the results to the national government in the Capitol, Lima. This process excluded the local at-risk residents, which led to increasing fear and uncertainty regarding the lakes looming above them. This also added to historical regional disparity between the capitol and the mountain communities that were seen as "backwaters" (Carey 2010). Additionally, in partnership with many external interest groups in later decades, many scientific studies of potential hazards were centered around generating hydroelectricity in the region. A Andean communities perceived that this national agenda was for the development of infrastructure for coastal regions, rather than the safety of its mountain communities. This mirrors the natural exploitation of mountain regions seen in the Himalaya regions that will be discussed more in depth below (Rhoades, 2007).

This historical development of GLOF management in Peru reveals several key insights. First, the national government created programs that were designed to reduce the vulnerability of mountain communities to GLOF management. While they learned a lot through the science of glacial hazards, they simultaneously deepened historical divides between communities and the national government. This is largely due to a lack of recognition of various socio-economic drivers, such as economic class and regional power dynamics that shaped GLOF risk perception. Second, this lack of transparency, added with the lack of involvement of community leaders in the planning process led to social resistance to attempted projects in several at-risk areas. Local buy-in was not established and there was no attempt to incorporate indigenous knowledge into project designs. This could have streamlined prioritization of mitigation projects based on community input, while simultaneously building trust with communities by incorporating their concerns. Third, agenda setting played a public role in the prioritization of several glacial development projects. A concrete case of this was under President Fujimori who promoted a neo-liberalization of many public works projects in Peru. During this time, most glacial management projects were turned over to ElectroPerú, who was a partner with American-based Duke Energy (Carey, 2010). During this time, several contested projects were initiated that aimed to increase water volume for hydroelectric production of several lakes. Communities had petitioned to have several of these lakes drained, and public resistance to these projects caused them to be shut down. While community voices were heard in these instances, this added to the lasting distrust of government projects that have the potential to last well into the future. There is much to learn from cases in Peru, due to socio-economic similarities for both regions, however Nepal remains distinct in various elements. For instance, concepts of Buddhist Dualism are used to explain events as both natural and supernatural (Bjønness, 1986). This thought process will ultimately shape how mountain communities with strong Buddhist culture view risk from GLOF events. Additionally, the structure of local decision-making processes regarding natural resource management differ between Peru and Nepal. Nepalese mountain communities have a long history of collective resource management through traditional systems based on the ideals of collective action, and now more formal local institutions such as community user groups (Wakiyama, 2004).

3.3 External Institutions

External institutions consist of government and other non-governmental institutions that articulate the community's voice concerning power relationships, responsibility and accountability. They operate at multiple scales each operating based on organizational objectives and outputs that guide decisions in GLOF related projects. In the case of Nepal, these institutions include the Government of Nepal, UNDP, and several international cooperation, leading to the evolution of a complex institutional landscape to reduce risk of GLOF events. While out of scope of this paper, it is important to note that the diversity of institutions create multitude of agendas and priorities and drives a complex decision-making landscape. This creates complications in ensuring effective policy-to-action efforts, funding, and communication networks with local communities that are prioritized for reducing GLOF risk. While these challenges are clearly articulated in adaptation policy document such as Local Adaptation Plan of Action (LAPA), there is lack of transparency among the institutions (Byers et al. 2015). Within these cases, there are several challenges for effective participatory approaches. One such challenge is for external institutions to provide continuity in cross-scale communication and consistent funding mechanisms for proposed adaptation strategies. For instance, communities often report infrequent reporting by research organizations, and many projects remain unfunded or with no clear sources identified (Regmi & Star, 2014). Adding to this, many of the institutional partnerships happening at national and international levels to create policy lack any form of knowledge dissemination at local levels. While the knowledge generated from such efforts offers valuable information for creating policy, the absent of user input makes it difficult to translate into action. Rajib Shaw (2012) highlights the importance of including community input into policy efforts to foster local adaptation capacity and address disconnects between decision-making at each scale. This emphasizes the importance of continuous community-input for policy-making processes to ensure successful community-based disaster risk reduction.

In addition to policy-making and research institutions, there are several national and international Non-government Organizations and Civil Society Organizations involved in risk reduction in Nepal (Bishwokarma et al., 2012). From 1997 to 2014, over forty thousand of these organizations were registered in Nepal (Karkee & Comfort, 2016). They play a role in both sustainable development and disaster relief benefitting from a more decentralized project management approach, compared to the central government. Because of this, they are often lauded for being more representative of local interests. NGOs also have drawbacks as they are often from outside of the local social and cultural fabrics. They, often, operate independently of other organizations, creating wasteful overlap of certain functions, and gaps in information dissemination (Bishwokarma et al. 2012).

3.4 Local & Informal institutions

Because of the verticality associated with mountain communities, they have a long history developing effective local institutions and creating strategies fit for their circumstances (Rhoades 2007). For example, the Khumbu valley developed the "*shingo naua*" system that was used to historically manage common-pool resources such as forests in the region (Khatri-Chhetri, 1993). This self-organized system operated under the community perception that it was beneficial to collectively manage forest resources through communal efforts. This traditional management system operated based on localized knowledge of the region and considered the nuances of the cultural composition of each involved community (Agrawal 1996). Through this, communities were able to establish rules-in-use that dictated seasonal harvesting of resources, as well as social-enforcement mechanisms and leadership hierarchies (Khatri-

Chhetri, 1993). This reveals that social cohesiveness through trust was an essential driver of creating effective localized management practices. With the establishment of SNP, community rights to collect forest resources were stripped and communities were displaced, however. Two critical factors resulted in this regime shift. First, mountain communities were treated as peripheral to political power, as traditional management systems were displaced. Second, international influence over Nepal's resource management established an exploitative relationship between the national government and mountain communities as development policy was established (Wakiyama, 2004).

With the realization that centralized management approaches were not effectively conserving forest resources, the government transitioned back to a community-based management system by implementing a community forestry program. While this was done in realization of the importance that participation plays in effective management, it also ignored key social dynamics that have created contention with communities. For instance, rather than taking advantage of traditional local institutions (such as the "*shingo naua*"), the national government created community forest user groups in each region under the District Forest Offices (DFOs). While it is notable that this was done in consideration of equity in communities, these efforts were largely influenced by external agents. This created disconnected institutions by ignoring existing social cohesion and creating a new power relationship through the management of new institutional leadership (Wakiyama, 2004). Because of this, effective institutional management across scales become convoluted, as the national agenda pushes participatory planning considering competing interests at local levels (Wakiyama, 2004).

Another critical element of analyzing institutions within the case of Nepal is how community-based disaster risk reduction will take place. Shaw (2012) highlights the need for the consideration of local capacities and their roles in reducing localized risk in several cases throughout Asia. Some of the more critical points mentioned include that strong local institutions are vital to create effective resource governance regime at local level, and should be integrated into policies to ensure synergistic efforts. Similar institutions architecture evolving specifically for Sagarmatha National Park.

Figure 2 shows the institutional framework as within the Buffer Zone under the Department of National Park and Wildlife Conservation (DNPWC). Here, User Groups (UG) manage resources through community-based approaches with the Committee representing community leadership in three districts (Namche, Khumjung, Chaurikharka). Another local institution is represented in the Sagarmatha Pollution Control Commission (SPCC), which is a bottom-up management system for waste collection and disposal within the Sagarmatha National Park Buffer Zone (SNPBZ). With the addition

of both trekking and lodging associations, there is a diverse representation of local interests in which communities have self-organized to manage decisions. This links back to the concept of verticality, in

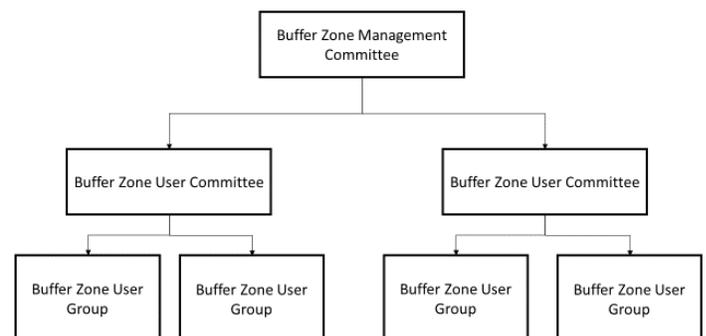


Figure 2. Sagarmatha National Park Buffer Zone Institutions (Adapted from (DNPWC, 2016))

which the heterogeneous SES conditions requires a diverse management strategy on a regional scale. This is problematic when considering that adaptation strategies for regionally and culturally specific challenges are originating from external institutions that are driven by disconnected political and economic interests. This is especially relevant with concern to livelihoods, in which it is vital that adaptation strategies recognize the importance of how they are shaped by the environment as well as their impact on risk perception (Sherpa et al., 2019). While the events such as national regime shifts, creation of Sagarmatha National Park, and growth of the tourism industry have changed the institutional landscape, local institutions have remained integral to decision-making processes within the region.

3.5 community-based adaptation

The discussion above highlights the need for context-specific solutions to addressing community risk. One such framework is the community-based disaster risk reduction (CBDRR) that outlines several conditions for effective CBDRR (Shaw, 2012). One such condition is that local institutions (formal and informal) play a critical role in maintaining community initiatives. Shaw also emphasizes the need for local initiatives to be integrated into government policy to ensure scalability. Additionally, local change agents play a critical role in implementation at local levels, backed by the compatibility with development policy. The CBDRR process also outlines several factors such as awareness by planning, vulnerability assessment, and risk management practices at local levels that lead to more sustainable outcomes. An example of this type of effort briefly described above is through the LAPA process. The LAPA is a participatory planning approach that seeks to develop community adaptation plans to reduce risk to GLOF events and climate change. Byers et al. (2015) shows how this approach is being integrated into both Peruvian and Nepalese institutions in partnership with the High Mountains Adaptation Partnership (HiMAP). Through providing a “science-based, community driven approach” to building adaptive capacity, LAPA seeks to address historical institutional asymmetries such as lack of transparency that have led to community distrust to government adaptation strategies. While these efforts vastly improve upon stakeholder engagement and integrating local knowledge, several factors impede institutional capacity for implementing these projects at a larger scale. Peniston (2013) shows that shortcomings such as regional scalability, effective coordination for infrastructure and funding streams and interorganizational cooperation are all factors that will need to be addressed for LAPA to have serious impacts on climate change adaptation and hazard risk management processes.

This paper also draws upon the works of Berkes and Ross (2013) who lay out several conditions for building community resilience through the integration of ecology and psychology concepts. Through this, community resilience is composed of agency and self-organization, with core concepts emerge such as people-place connections, values and beliefs, knowledge, skills and learning, social networks, engaged governance, community infrastructure, leadership and positive outlook. This complements the finds of Sherpa et al. (2019), blending governance and perception. These factors therefore offer tools for evaluating the efficacy of projects that are implemented by external institutions such as the Government of Nepal and aid agencies.

4. Methods

4.1 Quantitative

This research employs mixed methods (quantitative and qualitative) approach to analyze the current institutional landscape for disaster risk management in Nepal. In doing so, it add to the earlier research by Sherpa et al. (2019), that focused on social perception in GLOF risk. During May-June of 2016, Sherpa et al. (2019) collected 138 household surveys in the Khumbu and Pharak regions, within the SNPBZ. A subset of questions that reflect perceptions on coping mechanisms and institutional roles have chosen for this paper (see Appendix A). In order to explore the date, we first generated the descriptive statistics for each question. To expand upon this, a logit model was used with GLOF risk perception as the independent variable, and various sources of climate change information as the independent variable:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots$$

Additionally, Classification and Regression Tree (CART) analysis was conducted with GLOF risk perception as the dependent variable, and the various institutional factors (based on questions in Appendix A) as the independent variables. This provide predictor variables to show which factors influence risk perception the most.

4.2 Qualitative

Qualitative analysis consisted of document analysis of reports by various organizations involved in GLOF risk reduction. Key themes were identified as influencing adaptation strategy success and analyzed using frameworks such as community-based disaster risk reduction (Shaw, 2013) and community-based resilience (Berkes & Ross, 2013)

The following questions were used to guide the analysis:

- Who are the major actor groups influencing disaster risk reduction in the Khumbu region?
- What are their development and objectives and priorities?
- What are their funding streams, decision-making frameworks, and knowledge dissemination pathways?
- What are the interorganizational connections across scales?

The information collected was then used to create an institutional map for involved organizations that incorporates decision-making at different scales, information channels, and funding streams.

5. Results and Discussions

This analysis starts with seeking to answer the questions outlined for the household surveys conducted by Sherpa et al. (2019). This provides indicators of how various institutional factors can provide predictor variables in how community risk perception is influenced by sources of climate change information, warning systems, and coping mechanisms. These results are expanded upon by outlining gaps at different scales in the institutional landscape that shape adaptation strategies at the community level.

When inquired about coping responses, 54% of respondents reported that they did nothing in response to flooding events. This indicates a lack of individual capacity to effectively mitigate risk and loss given occurrences of floods. This lack of capacity correlates with the dissemination of climate change and flood warning systems in place. Approximately 31% of respondents who have heard of climate change received information from static sources such as radio, television, and newspaper outlets. This shows the predominance of one-way information flows comparative to the 11.6% who've learned through interaction with NGOs, government agencies, and training experiences, and the 13.8% who've received information through the education system. A similar trend can be seen from the distribution of flood information sources. The largest source of flood information is shown to be reactive, through sight and sound (30.4%) to know that a flooding event is occurring, compared to 16.7% of respondents being informed through Early Warning System sirens, and 19.6% through mobile device alerts. Figure 3 highlights the importance of warning systems, as those who identified no warning system had the lowest (0.139) perception of risk.

Regarding perception of responsibility for adaptation strategies, most respondents indicated that the government should be responsible for both leading and funding projects. For instance, 63% of respondents perceived that government officials should be leading projects concerning GLOF hazards, and similarly, 66.7% indicated that the government should be responsible for project funding, and 5.1% indicated that international agencies should play a role in this process. While the perceived responsibility relies on the government, there is also evidence of social restrictions for favored intervention strategies. While hazard zone planning is often considered a favorable approach from a governmental standpoint (Carey, 2010), livelihoods and geographic preference can highlight strong aversion towards potentially effective strategies. For instance, when asked whether respondents would be willing to move their business to a different location, 71.7% answered no. This shows both the importance that livelihoods play regarding risk perception and the expectations put on government agencies to provide effective strategies within the social structure of at-risk communities.

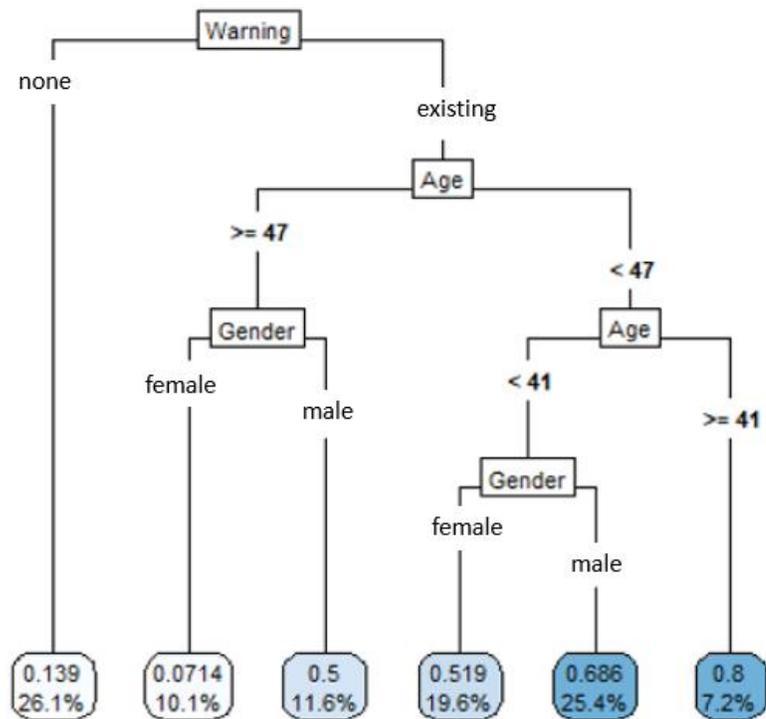


Figure 3. Classification and Regression Tree Analysis – Risk Perception

Further complicating the nexus of government onus and livelihood influence is in the parallel between increased risk perception and livelihood generation. The top three natural threats stated by respondents were water, scarcity, flooding, and blizzards. The major barriers to tourism are stated to be physical: infrastructure, transportation, and difficult terrain (38%), and other reasons such as bad weather, earthquakes, and lack of awareness. Many of these barriers also overlap with disaster risk response which is especially challenging in remote mountain regions as described above. This reiterates that there are multiple SES challenges presented to mountain communities. Additionally, external institutions are faced with the burden of providing effective management strategies to isolated communities in often harsh environments. This also shows that there is potential overlapping interests between local and external institutions through the recognition of development areas such as transportation and public infrastructure.

5.1 Institutional Mapping

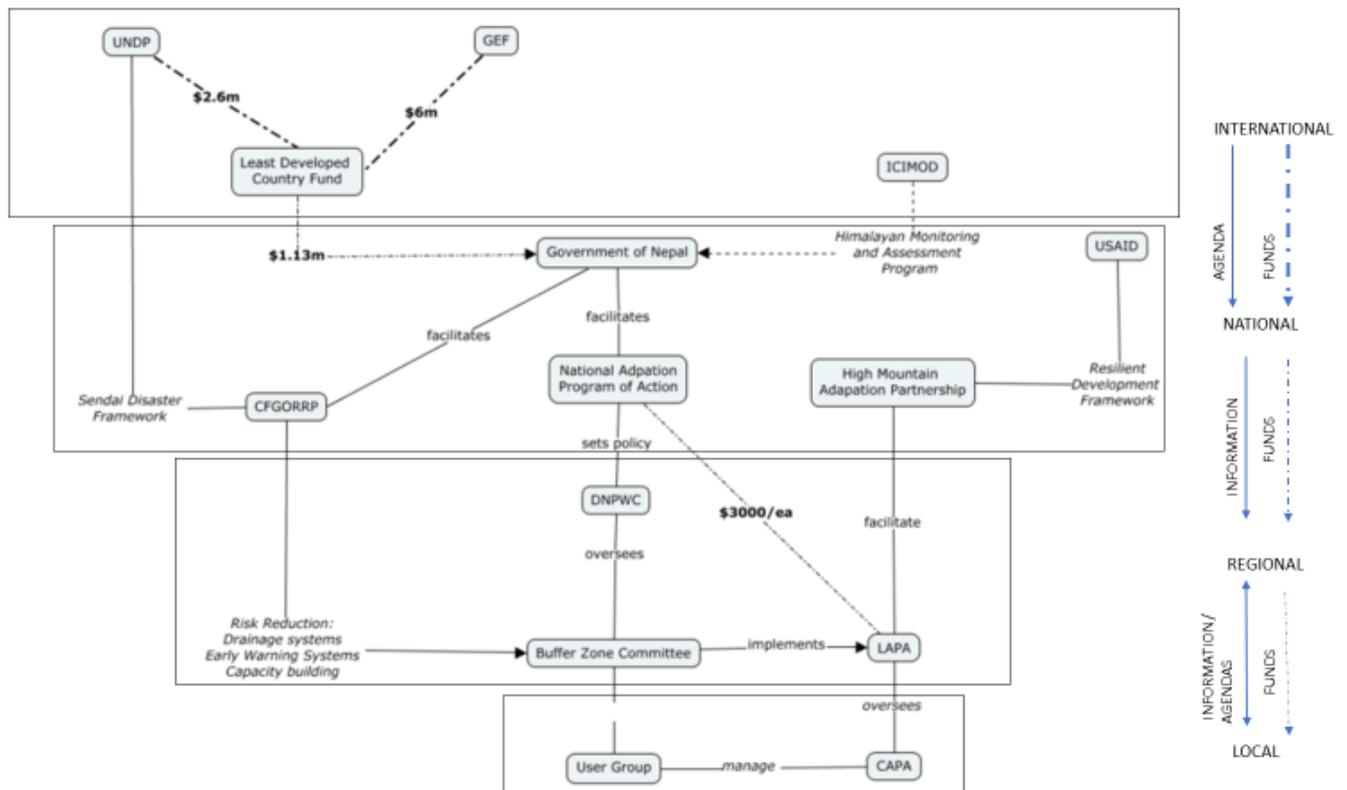


Figure 4. Institutional Map for Disaster Risk Management in Nepal.

Dotted lines represent current documented flows of information. Dotted lines represent financial flows, indicating a top-down funding pathway from international agencies to local levels for LAPA plans.

Evaluating the institutional landscape visualized in Figure 4, it is clear there is a complex interaction of stakeholders involved in disaster risk reduction in Sagarmatha National Park. The main points of evaluation for this study are:

- Information Flows:** This shows that most of information stays within the realm of the international and national scales, with some information being extracted from the regional level. Significant data collection goes towards generating reports and publication on issues such as governance, vulnerability, and disaster reduction mechanisms. This data is used to influence policy-makers at the national level in order to strengthen the science-policy collaborations such as those seen in ICIMOD's HIMAP knowledge platform that covers the Hindu Kush Himalaya region. This is backed by the respondents of the household surveys, where 31% answered that information regarding climate change was from static sources such as newspaper, television, and radio broadcasts. This is supported through the logit model, which showed information originating from NGOs and training have a higher correlation coefficient (.242, .286) of positively influencing risk perception than more static forms (.012, .076) such as newspaper, or tv/radio. Therefore, a more interactive flow of information between external and local institutions can play a significant role in influencing how communities are perceiving GLOF risk. Additionally, flood warning remains predominately reactive as 30.4% of participants rely on witnessing through sight and sound to know when flooding events are occurring. With only 16.7% relying on sirens, and 2.2% from radio, it shows that information dissemination between institutional scales remains largely disconnected. Supporting this, the CART analysis showed that when respondents identified no sources of warning, they also had almost no perception of risk involved (coefficient: 0.139) versus having some form of warning system. With 26.1% of respondents identifying no warning system, it is critical that a more established communication networks are maintained. It is also important to note that women were shown to have less access to different forms of information on climate change, which corresponds with lower risk perception compared to men. As Nepal continues to move towards more localized approaches, it is a promising sign knowledge dissemination will continue to increase. However as will be discussed in the LAPA case study below (Figure 6), there are clear disconnects between knowledge flow and adaptation actions.
- Funding Streams:** Most funding mechanisms originate from international organizations and are dispersed to the national government, and then disseminated through government agencies (UNDP, 2014). While NGOs can offer a more decentralized network for the distribution of program funds, inconsistencies in project funding remain a key barrier to implementing risk reduction projects (Regmi & Star, 2014). Peniston et al. (2013) for instance cites several occasions in which LAPA projects never extend past planning periods from a lack of established funding sources. Additionally, due to the reliance of NGOs that are external to communities at risk, funded initiatives are not guaranteed to represent locally-voiced concerns (Bishwokarma et al., 2012). Therefore, while there are local planning processes taking place that identify responsible funding parties (such as the DNPWC, among others) there is a delay in funding dispersal as they disseminate from international and national levels. Coordination of funds from independent sources will play a key role in creating more effective action and reducing project delays that are currently inherent. Figure 4 highlights this, as most adaptation funding comes from large-scale

international organizations such as the UNDP and GEF who disperse funding through the Least Developed Country fund(LDCF). Through this, Nepal's NAPA is funded and money flows down towards individual LAPA projects. However, Regmi & Star (2014) point out that dispersed LAPA funds often fall well short of the necessary amount for successful implementation.

- **Decision-making:** The majority of disaster response plan is guided by the vision of national and global institutions. For example, the UNDP's Sendai Disaster Framework 2015-2030, USAID's Resilient Development Framework, Nepal's National Adaptation Programme of Action continue to be a major driver of local actions. While each framework highlights stakeholder participation, the process is initiated with organizational objectives already outlined by the frameworks being used. Because of this, the planning process that shapes the overall risk reduction arena remains in the hands of external institutions. Therefore, while prioritization is often dictated by local institutions, the knowledge received and mechanisms for implementation are all dictated through external institutional guidelines. Additionally, NGOs above can create conflicts in creating long-term sustainable decision-making processes surrounding disaster risk reduction. For instance, several cases were reported by Rounce et al. (2016) in which government participation in program management decreased due to the presence of NGO projects. Combined with the misrepresentation of local voices in mountain communities, it is shown that NGO involvement is not guaranteed to increase local participation in decision-making processes.

5.2 Agenda Setting

To carry out international agendas for climate change adaptation, the United Nations Climate Change Commission and GEF group operate the Least Developed Countries Fund (LDCF). This fund prioritizes the development of NAPAs for developing countries by these international agencies who guide prioritization and provide financial funding for its implementation and is highlighted in Figure 4 (UNDP, 2014). Through this, prioritization often originates from international institutions whose priorities are on national scales, rather than localized initiatives that promote community-based adaptation measures. Shaw (2012) highlights the need for the consideration of local capacities and their roles in reducing localized risk in several cases throughout Asia. Some of the more critical points mentioned are that strong local institutions are vital to maintain localized efforts, and that these institutions should be integrated into policies to ensure synergistic efforts.

While Nepal's NAPA is a national policy, it sets the structure of its more localized LAPA process. Within this, influences of external priorities are witnessed such as the High Mountain Adaption Partnership initiative that was a partnership between USAID and the national government. During this initiative, USAID proposed changes to the LAPA process to better fit its own Resilient Development Framework (Byers et al., 2015). Therefore, although the project is framed as "community-driven, science-based" approach to adaptation, there are also clear indications of prioritization for project outcomes to fit within international development objectives. Additionally, although Nepal's government has initiated several LAPA projects throughout the country, the rate of objective implementation remains low due to disjointed organizational funding and regional organizational capacity (Regmi & Star, 2014).

Cases of agenda setting as highlighted above can have long term impacts on adaptation planning efforts. Community trust in institutions plays a significant role in creating effective GLOF mitigation measures

(Carey, et al., 2015). This can be seen in cases in Peru and Nepal in which institutional insensitivity towards community values and priorities caused social resistance towards well-intentioned mitigation strategies (Dahal & Hagelman, 2014). Because of this, traditional and informal institutions should be valued in creating community-based adaptation approaches that are more adept at dealing with regional nuances in geography and culture that shape people's perception towards GLOF risk.

5.3 Institutional Disconnect

As shown above, there are several key barriers for institutions at different scales to address and reduce risk for GLOF events in the Solukhumbu region. One of the most significant barriers is the misalignment of local and external institutional capacities and agendas. This is clear through the various transition's scene through Nepal's natural resource management history. Figure 5 shows how different factors govern within the risk reduction area. National policy promotes increasingly decentralized approaches to handling risk of GLOF events, yet they rarely interact with the indigenous institutions actively managing disaster response measures (Agrawal & Gibbson, 2001). The disconnect between indigenous and national institutions can lead to further conflict between stakeholders, where programs designed to address inequity merely shifted power dynamics between groups. A historical example the replacement of traditional forest management system with government-initiated community user groups that reset traditional leadership roles through the creation of new social elites within communities (Wakiyama,

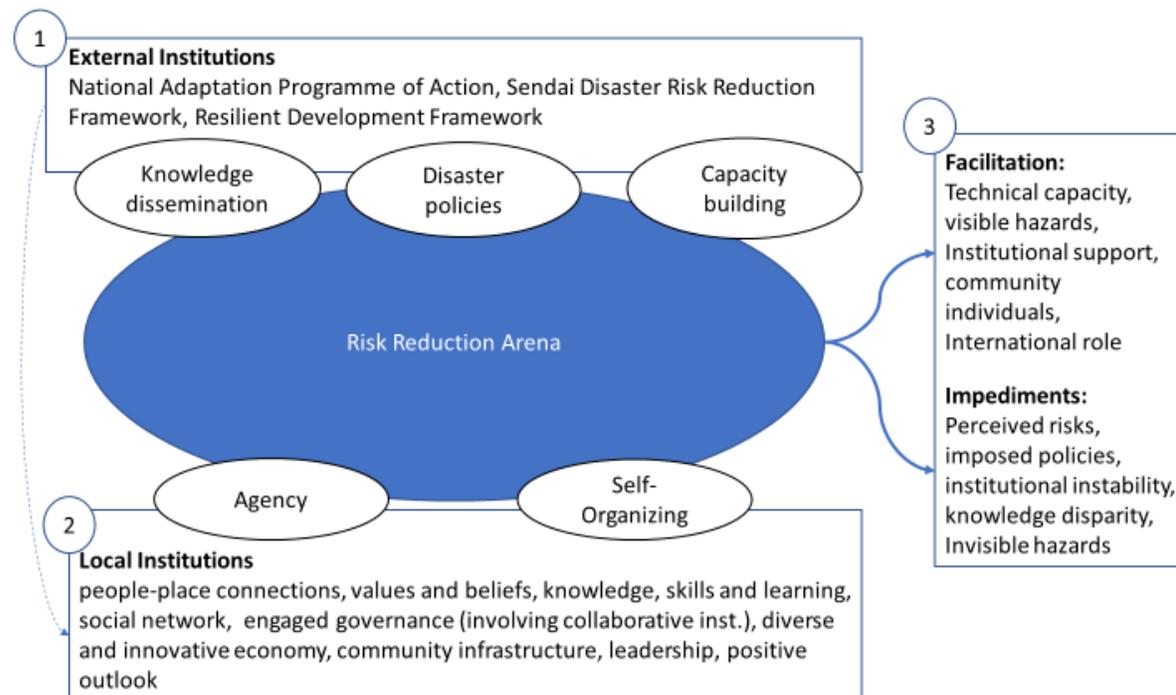


Figure 5. Institutional conditions shaping the risk reduction arena.

The underlying conditions influencing institutional actions at different scales. (1) External institutions are influenced by frameworks and policies that lead to knowledge dissemination, policy, and capacity building for risk reduction. (2) Local institutions operate under social factors that create agency and self-organization influencing their decisions within the risk reduction arena (Berkes & Ross, 2013). (3) SES factors surrounding GLOF management also influence the risk reduction arena (Carey et al., 2012).

2004). Additionally, it is reported in LAPA processes that leadership roles often exclude groups marginalized indigenous groups and women (Peniston, 2013). This complemented by discussed case studies from Peru highlights the importance of realizing the complex and often nuanced systems of knowledge social structure that influence institutional management of GLOF risk reduction.

Building on this, knowledge dissemination to local communities is lacking. Most external institutions focus on the generation of knowledge for science-policy interactions. Therefore, knowledge transfer remains within the external institutions, rather than to more isolated mountain communities (Dorji et al, 2019). Knowledge collected by organizations such as CFGORRP are largely disseminated through static means such as regional information centers or over radio. This shows that knowledge pathways remain disjointed and noniterative, which can increase confusion, fear, and discontent within communities. This is shown in the Imja Rolpa lake case study where lack of transparency of government efforts to minimize risk lead to increasing distrust towards external institutions (Dahal & Hagelman, 2014). This is further supported in an institutional capacity needs assessment conducted by CBFGORRP that analyzed each department involved in climate adaption and disaster risk management. One of the major recognized areas of need within each department is increased knowledge generation and its communication to remote mountain regions. This reveals two major insights: (1) knowledge dissemination from external to local institutions is inconsistent and largely lacking across institutions; (2) Interorganizational cooperation is knowledge sharing is lacking clear pathways across scales. This is evident as limited knowledge is listed as a weakness within each department of the government responsible for some aspect of GLOF management (Khumari, 2014). Additional support for this claim comes from ICIMOD's report on Disaster Risk Reduction in the Hindu Kush Himalaya. In its key findings, the report emphasizes the importance of increasing the resiliency of information systems that focuses on multi-stakeholder inclusivity (Vaidya et al., 2019).

The challenges described above highlight the legacy of institutional approaches to dealing with Nepal's mountain communities by the centralized government (Rhoades, 2007). Despite the rich tapestry of knowledge on successfully dealing with local environmental stressors in the Khumbu region, Sherpa communities still find themselves at odds with the central government contributing to the policy process. This is captured by Wakiyama's (2004) analysis on the development of community user groups that usurped traditional forest management systems over time. By failing to recognize the value of informal institutions and causing power imbalances and discord in mountain communities. Current external institutions often continue this trend in which development projects are framed within their standards and objectives. Community input is considered a part of each framework, yet it is not always practiced. For instance, the CFGORRP initiated risk reduction projects for Imja Rolpa through artificial drainage and Early Warning Systems. However, despite the emphasis placed on local participation in their project framework communities were subjected to fear and confusion from the lack of reporting by agencies responsible for the mitigation work (Dahal & Hagelman, 2014).

This institutional gap is increasingly important as agency and organization for tourism efforts manifest at local levels. For effective collaboration to take place within the Risk Reduction Arena (Figure 5), external institutions must be able to effectively navigate the values placed on tourism as an increasing source of livelihood (Sherpa et al., 2019). Tourism have brought Sherpa communities to the global stage. With this, access to information is increasing, while institutional decision-making and funding networks

largely resemble historical mechanistic approaches often seen in development projects (Regmi & Star, 2014). Examples can be found in past UNDP and World Bank projects, where external institutions were both the sources of information, funding, and project decision-making (Wakiyama, 2004). As this balance continues to shift, institutions must recognize the agency and priorities that are shaping Solukhumbu communities as they move forward.

5.4 LAPA case study

Through the creation and prioritization of the LAPA process, it is clear that traditional issues such as gender equity and indigenous knowledge and inclusivity are now being built into institutional policy for adaptation. However, there is still a disconnect between external and local institutions that is revealed through LAPA efforts that were initiated by the UNDP in partnership with the Government of Nepal from 2013-2017 shown in Figure 6 (UNDP, 2014). Despite increasing objectives for inclusion of social equity in the planning process, major adaptation actions (such as the prioritized drainage project of the Imja Lake) are often drastically delayed in their implementation. For instance, construction planning did not begin until 2016, leaving less than a year of the project duration for adaptation implementation due to the bureaucracy of the construction contract bidding process (CFGORRP, 2017). This disconnect between knowledge being disseminated to community members and concrete actions being taken can exacerbate existing distrust between communities and external institutions. Institutional gaps such as this highlight the need for effective policy that addresses.

This provides a concrete example of how the institutional gaps in Figure 4 regarding financial flows and knowledge dissemination can cause potential conflict in the Risk Reduction Arena in Figure 5. This disconnect between institutions regarding knowledge flow and adaptation actions can result in the impediments such as perceived risk, knowledge disparity, and institutional instability when project cycle transparency becomes an issue (Carey et al., 2015).

6. Conclusions

Overall, GLOF risk is an increasingly present hazard in the lives of mountain communities in Sagarmatha National Park Buffer Zone. People's perception of risk, and therefore response to adaptation measures is a complex mix of social factors such as livelihoods, exposure, and spirituality that all shape an individual's evaluation of his or her vulnerability to glacial hazards. While these communities have a strong history of creating local adaptation strategies that have shaped the geography and their way of life, a tumultuous history of the central government has changed the institutional landscape and communities' relationship to the resources they rely on (Wakiyama, 2004). Shifting power dynamics

2012 – Imja LAPA workshop held
2013 – Imja LAPA finalized
2014 – Imja GLOF hazard risk assessment
2015 – drainage system design completed
2015 – failed contract bidding causes delay
2016 – construction preparation for lake lowering begins
2017 – Project cycle ends

Figure 6. UNDP Imja Lake Project Timeline

towards a centralized approach to research management saw characterization of mountain communities as periphery to the overall interest of the national government. This changed the dichotomy of resource management from one of localized participation and use towards a more exploitive regional development strategy, such as the creation of Sagarmatha National Park and the promotion of the tourism industry (Rhoades, 2007). This time period saw the introduction of international agenda setting, as international aid agencies influenced national policies towards a more pro-development agenda and economic liberalization. More recent efforts to create decentralized management strategies have led to the disjointed creation of formal local institutions such as buffer zone user groups that often exist in direct competition to the institutions (Wakiyama, 2004). This shows that there is a clear disconnect between external institutions, and local informal institutions that have been shaped by unique geography, culture, and social structure.

As community-based disaster risk reduction becomes more of a national priority (such as in Nepal's NAPA), the value of local and informal institutions needs to be recognized by external institutions and play a more critical role in developing adaptation strategies to glacial hazards. This includes not only the incorporation of local knowledge into risk reduction strategies at the local level, but also the recognition of informal decision-making structures into national policy. There are several additional conditions that need to be addressed for effective institutional action to take place. Knowledge dissemination needs to be developed into clear pathways that address different organizations at each scale. Throughout this analysis, communication of knowledge and ideas is a clear barrier to effective interorganizational coordination. This includes clear and consistent knowledge sharing between the Government of Nepal, national and international organizations, and the incorporation of local knowledge into policy. In addition to the coordination of information, funding streams need to be effectively managed between institutions to ensure project continuity and scalability.

While the institution of GLOF management has changed from external agencies to a more localized process, it is important to recognize that these organizations have shaped this process and are still present. The implementation of LAPA processes marks an important milestone in external institutions recognition of localized adaptation strategies through building community agency and self-organization as described by Shaw (2012). However, the funding mechanisms remain disconnected and delayed from the LAPA process, barring the adaptation strategies prioritized from becoming a reality (Regmi & Star, 2014). Moving forward, policy mechanisms need to transform these funding mechanisms to ensure the money coming from international agencies able to be effectively utilized by local institutions that can more effectively manage these strategies in their perspective regions. This can help to overcome the traditional difficulties of centralized strategies attempting to implement projects under the difficulties of difficult terrains and disconnected knowledge of local concerns. Overall, this paper has painted an institutional landscape that visualizes information, policy, and funding networks and connects them to a more theoretical understanding of community-based adaptation efforts. Additionally, it forms a connection to the perceptions at the household level that offers key insight into how community members perceive adaptation efforts moving forward.

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Appendix A. 2016 – 2017 questionnaire subset

Question
What type of the problems you have encountered in water supply?
What was your response to cope with the events?
How would you know if the flooding is to occur?
What is the source from which you heard of climate change? Check all that apply.
If not, what is your main livelihood or income source?
In your opinion, what are the main challenges or problems for tourism in Khumbu?
What is the major natural disasters or uncertainties do you consider significant for tourism? Choose one
Would you relocate your business to different location, if the threat of flooding is imminent?
If you are concerned about the lake, who do you think should take the lead to do something?
What do you think should pay for draining?

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