Moving down or not?

A key question for Samzong, Yara and Dheye, three villages in Upper Mustang, Mustang District, Nepal

Part II: SAMZONG

November 2012

KAM FOR SUD

University of Applied Sciences and Arts of Southern Switzerland

SUPSI

The study at hand aims at finding a holistic response to climate change stress on high altitude Himalayan settlements. In particular, the three villages Samzong, Yara and Dheye have been studied. The outputs of the study include the following reports:

Moving down or not?

A key question for Samzong, Yara and Dheye, three villages in Upper Mustang, Mustang District, Nepal

Part I: Synthesis
Part II: Samzong
Part III: Yara
Part IV: Dheye

Each mentioned report is self-standing. Certain common parts are therefore repeated in each report.

The reports have been written by Daniel Bernet, Daniel Pittet, Christian Ambrosi, Giovanni Kappenberger and Michele Passardi. The reports are part of the overall study undertaken by

Kam For Sud (KFS)

Swiss NGO working for a sustainable development in Nepal since 1998, www.kamforsud.org

jointly with the

University of Applied Sciences of Southern Switzerland (SUPSI)

www.supsi.ch

and in collaboration with the

Lo Mustang Foundation (LMF)

Nepali NPO, formed and directed by Lama Ngawang Kunga Bista, dedicated to developing the Upper Mustang region in the fields of education, health, environment and tourism, www.lo-mustanglmf.org

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Title photo: The second water abstraction in Samzong capturing as much of the remaining river water as possible for irrigating the fields located south of the village (photo: 08/05/2012, Daniel Bernet)
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In the following the members of the expert team are briefly introduced:

Kam For Sud

Daniel Bernet: Environmental engineer with specialization in hydraulic engineering and water resources management from the Swiss Federal Institute of Technology in Zurich (ETHZ); Working experience in India and Nepal;

- Water expert, responsible for water supply related issues as well as editing the reports.

Daniel Pittet: Civil engineer with a postgraduate education in architecture and sustainable development from the Swiss Federal Institute of Technology in Lausanne (EPFL); Until May 2012 working as a researcher in post-disaster reconstruction, currently engaged by the cantonal administration of the Canton Ticino in vernacular architecture conservation; Experienced in applied research, project management, sustainability of built environment, post-disaster housing, eco-habitat and with extensive working experience abroad;

- Project coordinator, expert in housing, settlement and infrastructure related issues, as well as vulnerability towards natural disasters.

Giovanni Kappenberger: Geographer, glaciologist, meteorologist and climatologist from the Swiss Federal Institute of Technology in Zurich (ETHZ); Many years working as a meteorologist for the Federal Office of Meteorology and Climatology MeteoSwiss; Specialized in mountain meteorology and climatology with working experience in the Canadian Arctic, the Alps and the Himalayas;

- Expert in climate matters, snow and glacier evolution and the consequences thereof on water availability and associated risks such as flooding.

Michele Passardi: Economist from the University of St. Gallen; Worked for private companies in Zurich and as chief of the financial services of the Canton Ticino; Since 1996 working as a manager of a small consultancy company advising public and non-profit organizations in financial, institutional and project-management issues;

- Expert in economics and socio-economics, as well as analytical approaches.

Rajan Shrestha: MBA from the Tribuvan University in Kathmandu; Project coordinator of the Kam For Sud projects in Nepal with sound analysis and mediation capacities, as well as deep knowledge of the local cultural context;

- Expert in socio-economics, cultural facilitation and mediation.

University of Applied Sciences of Southern Switzerland

Christian Ambrosi: Geologist with a PhD from the University of Milan in applied geology; Lecturer and researcher in geology and rock mechanics at the DACD/SUPSI, head of the Geology and Natural Hazards Group of the SUPSI; Expert in natural hazards, slope instabilities, landslide numerical modeling, waterways transport of solid material, geo-mechanics and geo-resources;

- Expert in all issues related to hydro-geological risks.

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Executive summary

A collaborative study of the NGO Kam For Sud and the University of Applied Science of Southern Switzerland, locally supported by the NPO Lo Mustang Foundation and financed by the *Fondation Assistance Internationale* was undertaken in 2012 with the goal to assess the most appropriate response of three Himalayan settlements to face current and future stresses, which are at least partly driven by climate change and are related to water scarcity and natural hazards. The ultimate question for such highly stressed settlements is, whether it is appropriate and/or necessary to resettle the whole communities. The three villages Samzong, Yara and Dheye, situated in Upper Mustang, Mustang District of Nepal, were visited twice by a multidisciplinary team carrying out the field work necessary for the chosen holistic approach. The output of the study concluded in four self-standing reports including one for each village as well as a short synthesis.

Samzong, subject of the report at hand, located about 9 km northeast of Lo-Manthang in a very remote valley, consists of 17 nuclear families and totals 83 inhabitants including 22 permanent migrants. All families own a certain amount of fields and depend on subsistence agriculture complemented by stockbreeding. The latter, together with other accessory economic activities, generates monetary income which is crucial because the agricultural output can only partially cover self-sufficiency.

The climate in the region with yearly precipitation rates around 200 mm and less is extremely dry and cold, manifesting itself in an almost desert-like landscape. Agricultural activities in Samzong are low productive and almost solely dependent on the perennial flow of Samzong Khola. The river drains a non-glaciated catchment area of 38 km^2, which is expected to be linked strongly to snowmelt. Due to climate change, the temperatures in Upper Mustang are expected to rise 6 °C to 10 °C in winter and 4 °C to 10 °C during monsoon period at the end of the 21st century, relative to the reference period at the end of the 20th century. This drastic change in temperature, together with insignificant changes in precipitation volumes will lead to a considerable spatial and temporal decrease of snow cover. Furthermore the predominant diurnal winds in Mustang valley are expected to increase in magnitude, leading to enhanced dust and sand deposit on snow and glaciers, resulting in even higher melt rates. Consequently, the perennial flow of Samzong Khola is expected to decrease in the future.

The predominant problem in Samzong is the combination of insufficient water availability and inefficient irrigation supply systems. All surface water is currently allocated, so that a change in the river regime is directly affecting irrigation amounts and consequently agricultural yield. Possible water shortage mitigation strategies have been investigated.

Possible measures improving the water supply (supply management) are aiming at reducing water losses, providing additional storage volumes or changing irrigation patterns to increase the water use efficiency. Nevertheless, the study has shown that in general the sole application of supply management measures will only procrastinate, but not solve the cur-

rent problems in the long run. A significant reduction of the demand (demand management) does not seem to be an option for Samzong. The inherent characteristics of the village do not seem to allow a sufficient diversification of economic activities to become less dependent on agriculture, and thus reduce the related demand.

Another crucial issue in Samzong is the exposure of the village and its surroundings including the irrigation channels to natural hazards such as debris flow. The hazards could be mitigated by installing passive protections, or by moving highly exposed goods such as houses or stables to safer locations.

The implementation of possible measures generally improving the current situation of the village constitutes the possible future state “Stay.” To answer the key question of this study, this state was thoroughly compared to the state “Move,” by considering manifold aspects. In the following the possible state “Move” is characterized briefly.

The people of Samzong were given 9.75 ha of agricultural land by the former King of Upper Mustang, situated 4 km northeast of Lo-Manthang within the valley bottom on a plain on the left riverbank of Kali Gandaki, the main river of the valley. The plain is covered with vast amount of debris and boulders, which were mostly deposited during the past extreme flood event, likely a so-called Glacier Lake Outburst Flood (GLOF), dating roughly 25 years back. The removing of the debris from the plain to prepare it for future cultivation was initiated this year and is planned to conclude the following year.

The agricultural area is situated within a catchment area of 234 km^2 of which 10 % is glaciated, amounting to a glacier volume of about 0.87 km^3. The glaciers are essential in terms of water availability, since the precipitation is stored and released slowly during the melting season. Due to the glaciers and the size of the catchment, the water availability is certainly sufficient in mid-term, but might become less secure in long-term. Due to the beforementioned drastic temperature increase the glaciers might vanish within the running century. Though from a water availability point of view, the relocation site is highly preferable, it bears the risk of future GLOFs leading to similar debris deposits, as are currently present.

For the relocation of the settlement, Samzong’s inhabitants were given a slightly elevated plain measuring 0.83 ha, southeast of the agricultural area, which is particularly exposed to the typical diurnal winds. From a natural hazard point of view the settlement area is very safe, except the risk of shallow landslides along the scarp facing the Kali Gandaki, which can be easily mitigated by considering a safety distance of at least 15 m from the scarp to the constructible area. However, the granted settlement area (0.83 ha, -38 %) is sensitively smaller than the area in Samzong (1.34 ha). Based on characteristics of the old settlement and habitat, a conceptual layout for the relocated settlement is proposed. It integrates the lower space availability, equal land partition amongst the villagers (which is accepted by all families), modularity to account for the different means and desires of each family and measures to mitigating the adverse effects of wind exposure. Different technical solutions for supplying irrigation water to the fields and drinking water up to the elevated settlement are suggested, but they need further investigations. The prospects and difficulties of the relocation as discussed above constitute the state “Move.”

Finally, the two possible future states “Stay” or “Move” were compared. Considering all elaborations inherent to the holistic approach, the study concludes that it is appropriate and necessary for Samzong to relocate. The village is recommended to resettle at the acquired location taking the elaborated and presented consideration into account.

Glossary

Bhote Pipal	Poplar
Chörten	Stone made Buddhist monument
Ghalto	Local surface measure, equal to the area two men with two oxen can plough in a day; estimated experimentally to 3700 m^2 with an uncertainty of easily ±20 %
Ghenpa	Tibetan name for the traditional communal role assumed for yearly turns
Khola	River or stream
Latsey	Traditional Buddhist heap of rocks
Mani wall	Wall made out of stones carved with Tibetan prayer
Mukhye	Nepali name for Ghenpa
Tom	Plastic canisters with a volume of 5 or 35 liters

Note that many different spellings of places, water bodies and names were found in Upper Mustang. This is mainly due to the fact, that many names were translated from the local languages into Nepali and/or English. Consequently, the original meaning was partially or fully lost. To preserve the meaningful names, the local spelling was chosen for the reports of the study at hand. Where necessary, other common spellings are mentioned additionally.

Abbreviations and acronyms

ACA	Annapurna Conservation Area
ACAP	Annapurna Conservation Area Project
asl	above sea level
CBS	Central Bureau of Statistics
DDC	District Development Committee
DHM	Department of Hydrology and Meteorology
FAI	Fondation Assistance Internationale
GCM	Global Circulation Model
GLOF	Glacier Lake Outburst Flood
GPS	Global Positioning System
HH	Household
ICIMOD	International Center for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
JAXA	Japan Aerospace Exploration Agency
KFS	Kam For Sud
LMF	Lo Mustang Foundation
NASA	National aeronautics and Space Administration
NGO	Non-Governmental Organization
NPO	Non-Profit Organization
NPR	Nepalese Rupees
NSET	National Society for Earthquake Technology
NTNC	National Trust for Nature Conservation
SUPSI	University of Applied Sciences of Southern Switzerland
TMPA	TRMM Multisatellite Precipitation Analysis
TRMM	Tropical Rainfall Measuring Mission
VDC	Village Development Committee

Acknowledgements

The initial spark for this study goes back to few individuals: Lama Ngawang Kunga Bista, Giovanni Kappenberger, Silvia Lafranchi Pittet, project coordinator of Kam For Sud, and Daniel Pittet. Each of them had a very crucial role in making this study even thinkable in the early stage. Their open minds, dedication and drive provided the base for this study.

Especially, I would like to thank the funders of this project, the *Fondation Assistance Internationale* (FAI). Without their support, this study could not have been realized. Furthermore, through their positive and comprehensive attitude towards the necessity of quick reaction during the launching phase, the project could be realized within the desired short time span. This was crucial, since the issues at hand are and have been pressing. Consequently any delay would have been at the expense of the local people in Mustang.

On behalf of the expert team I would like to thank all the people who made both field visits with the vital field work possible. The villagers displayed great hospitality, helped in any possible way and were very cooperative. Also Lama Ngawang Kunga Bista and in particular his secretary Tsewang Gurung, accompanying and supporting both field trips with great passion, contributed a lot to the successful completion of the field work. Christoph Graf has to be mentioned explicitly as well, for his valuable contribution by documenting the first field visit with pictures and movies. Furthermore Tsering Gurung earned the team's gratitude through his uncomplicated, supportive and most welcome guidance and assistance all along the trips. Also the Trekking Team and Hari Dev Pathak in particular were appreciated. They settled all formalities and organized important basic points of the field trips to everybody's full satisfaction.

The external contribution concerning past, present and future climatic trends in Upper Mustang was done by Mario Rohrer. His analysis proved to be essential within the manifold facets of the study.

Aurora Guggisberg, secretary of Kam For Sud, looked after all administrative and accounting matters with her usual very supportive attitude, facilitating the work of all involved persons.

Finally, I would like to highlight the expert team's passion, devotion, curiosity and effort, without which the study at hand could not have been realized in this form. Last but not least, I would like to thank Daniel Bernet for editing the reports and putting together the contributions of all authors in a coherent form.

Antonio Galli
President of Kam For Sud

Preface

The ultimate goal of the study at hand is to answer the crucial question "moving down or not?" As can be imagined, finding an answer to this complex question required a highly adaptive strategy to use the available resources most efficiently and invest the efforts most effectively. Namely, during the field visits, a compromise had to be found to pay each option ("Move" or "Stay") due consideration, but to channelize as much time and attention to the preferable option at the same time in order to maximize the study's usefulness for the people.

Along these lines, the question was often raised, why the option "Stay" is considered even though it seems the people have already decided to "Move." Overall, it is considered to be crucial to elaborate all possible options and in the course to come up with a broad, sound and well-studied base, on which such difficult and far-reaching decisions can be taken objectively.

In order to lead the reader comprehensibly through the report, it is structured as follows. First some background information are presented (chapter 1), followed by embedment of the whole study in the local context (chapter 2). Samzong with its characteristics and related difficulties at the current location are outlined in chapter 3. With what means the current situation of Samzong could be improved in situ, is discussed in chapter 4. The elaborations represent the option "Stay" that has to be compared with the option "Move." The latter, including a general description, inherent issues and preliminary recommendations, is presented in chapter 5. Based on the previously elaborated options "Stay" or "Move" respectively, the study comes up with the answer to the central question of the study "moving down or not?" (chapter 6) followed by the final conclusions (chapter 7).

1 Introduction

Climate changes, deriving from global warming, have induced numerous and relevant consequences on the Himalayan region in terms of water regimes and availability. Such transformations directly impact the communities living in high altitude regions of the Himalaya through a severe weakening of their livelihoods and habitat. In case the communities do not find an adaptation strategy in situ, they are ultimately pushed to a permanent migration by the desperate need of water during the dry season.

However, the resettlement of a whole community is a complex undertaking as there are many interrelated sensitive issues. Besides practical and technical solutions, the socio-cultural and socio-economic aspects also have to be addressed deeply and carefully. In fact, they have a relevant weight for the sustainability, efficiency and success of the response and should not be underestimated. Thus, for elaborating the most appropriate response to the often-quoted climate stress, a holistic approach should be chosen.

1.1 Background of this study

The three communities of Samzong, Yara and Dheye, particularly affected by water stress, have expressed their suffering and their urgent need for solutions to the Lo Mustang Foundation (LMF), asking for support in identifying and implementing a proper strategy. In the course a group brain storming including LMF and Kam For Sud (KFS) has been held, arising several unsolved sensitive questions and matters. As a consequence, the need of a comprehensive analysis of the key question “moving down or not?” was highlighted.

Considering the complex, multidisciplinary tasks and the available expertise, respectively the missing knowhow, KFS has searched to complete the project’s team through collaboration with the University of Applied Sciences of Southern Switzerland (SUPSI), in particular searching for know-how in the field of natural hydro-geological risks.

With the project, KFS and SUPSI, with the collaboration of the LMF, joined their capacities and knowledge with the aim of comprehensively analyzing the particular situation of the three villages of Samzong, Yara and Dheye and defining the most appropriate, sustainable and effective strategy to respond to the water crisis in Upper Mustang.

1.2 Study objective

The main goal of this study is to identify the most appropriate and sustainable response to face the current challenges in terms of water availability as well as natural risks and associated socio-economic aspects for the villages Samzong, Yara and Dheye. On a very practical level the key question to be answered is the following:

"Is it appropriate and/or necessary to resettle the whole village? If yes, under which conditions could it successfully happen? If not, what are the alternatives to solve the water related problems?"

1.3 Methodology

The investigation of the study objective required a fair amount of field work. A multidisciplinary team was assembled and two trips to Upper Mustang were organized. The details thereof are described in Table 1.1. Additionally, a preliminary visit of Giovanni Kappenberger in fall 2011 provided valuable information about the situation of the snow and glacier mass in the region.

Generally, the team of experts (Table 1.1) was using the following methodological approaches during the field work:

- Investigations about hydrogeology, water availability and regimes, related challenges, opportunities and risks
- Elaboration of characteristics and layout of settlement, infrastructures and housing
- Investigations about vulnerability towards natural disasters
- Socio-cultural and economic surveys through semi-structured interviews and participatory techniques
- Interviews with key stakeholders and leaders at local level
- Group discussions among field trip participants, formulation of different strategies and multiple criteria comparative analysis
- Consultation and group discussion with the LMS about identified strategies and solutions

Pre- and post-processing of the field work included group discussions and meetings, mainly among the authors (Daniel Bernet, Daniel Pittet, Christian Ambrosi, Giovanni Kappenberger and Michele Passardi) complemented by Kam For Sud’s project coordinator, Silvia Lafranchi Pittet.

For the corresponding field of expertise of each author, common methodologies were applied. Due to the interdisciplinary and holistic approach of the study at hand, a further elaboration thereof is foregone. However, where appropriate, the methodologies are introduced in the corresponding sections.

Table 1.1: Characterization of the two field trips to Upper Mustang, during which all three villages (Samzong, Yara and Dheye) were visited.

Trip objectives	Trip period	Participants	Org	Function
➢ Investigation of all water related issues during the dry season (water demand, supply, associated problems and challenges by means of field investigations and surveys) ➢ Identification of possible water stress mitigation measures ➢ Preliminary socio-economic analysis ➢ Elaboration of the institutional and organizational context ➢ Establishment of local contacts ➢ Preparation of following trip	29/04/2012 – 19/05/2012	Daniel Bernet	KFS	Responsible for all water related issues
		Rajan Shrestha	KFS	Facilitator, translator, expert of the local context
		Christoph Graf	KFS	Cameraman, photographer, assistant
		Lama Ngawang Kunga Bista	LMF	Director of LMF, facilitator, local contact
		Tsewang Gurung	LMF	Secretary of LMF, translator, assistant
		Tsering Gurung		Guide, horseman, translator, assistant
➢ Assessment of all issues related to housing and living conditions ➢ Elaboration of all hydro-geological risks and possible associated mitigation strategies ➢ Deeper study of socio-economic issues and their inherent implications ➢ Capturing the community's perception of the problems, challenges and chances by means of surveys and community discussions ➢ Expanding understanding of the institutional and organizational context ➢ Further clarification of water related issues	18/06/2012 – 10/07/2012	Daniel Pittet	KFS	Project coordinator, housing and habitat expert
		Dr. Christian Ambrosi	SUPSI	Expert in hydro-geology and natural hazards
		Michele Passardi	KFS	Expert in economics and socio-economics
		Daniel Bernet	KFS	Responsible for all water supply related issues
		Rajan Shrestha	KFS	Facilitator, translator, expert of the local context
		Lama Ngawang Kunga Bista	LMF	Director of LMF, facilitator, local contact
		Tsewang Gurung	LMF	Secretary of LMF, translator, assistant
		Tsering Gurung	-	Guide, horseman, translator, assistant

1.4 Resources

The reports are based on the following resources:

➢ Field trip to Upper Mustang by Giovanni Kappenberger in the fall 2011
➢ Two field trips by a team of experts in late spring and early summer 2012 (Table 1.1)
➢ Report of the first field visit (Bernet 2012)
➢ Two reports about past, actual and future climatic trends (Rohrer 2012a; Rohrer 2012b)
➢ Maps of Mustang (Kostka 2001; D. Adhikari et al.)
➢ Satellite imagery provided by Google Earth Pro
➢ Additional literature (cited separately in the report, see bibliography)

1.5 Location

Upper Mustang (from Tibetan Mun Tan, "the fertile plain”) is the former Kingdom of Lo, now part of Nepal’s District Mustang, bordering the Tibetan plateau of the People's Republic of China in the north, the Nepalese Districts Dolpa west, Myagdi south and Manang in the east (Figure 1.1).

Figure 1.1: Map of Nepal, bordering China in the north and India in the east, south and west. The red ellipse highlights the location of Mustang District. North direction is ↑, the map was taken from Zurick et al. (2006).

The three studied villages are all located in the restricted area (section 2.1) of Mustang District (Figure 1.2). Samzong is located at the right[1] riverbank of the Samzong Khola at an altitude of about 4’000 m asl, roughly 9 km northeast of Lo-Manthang, the historical capital of Upper Mustang. As a matter of fact, Samzong is the closest Nepalese village to the Chinese border, which is permanently inhabited.

[1] Note that all right/left indications in this report are based on the flow direction of the corresponding river.

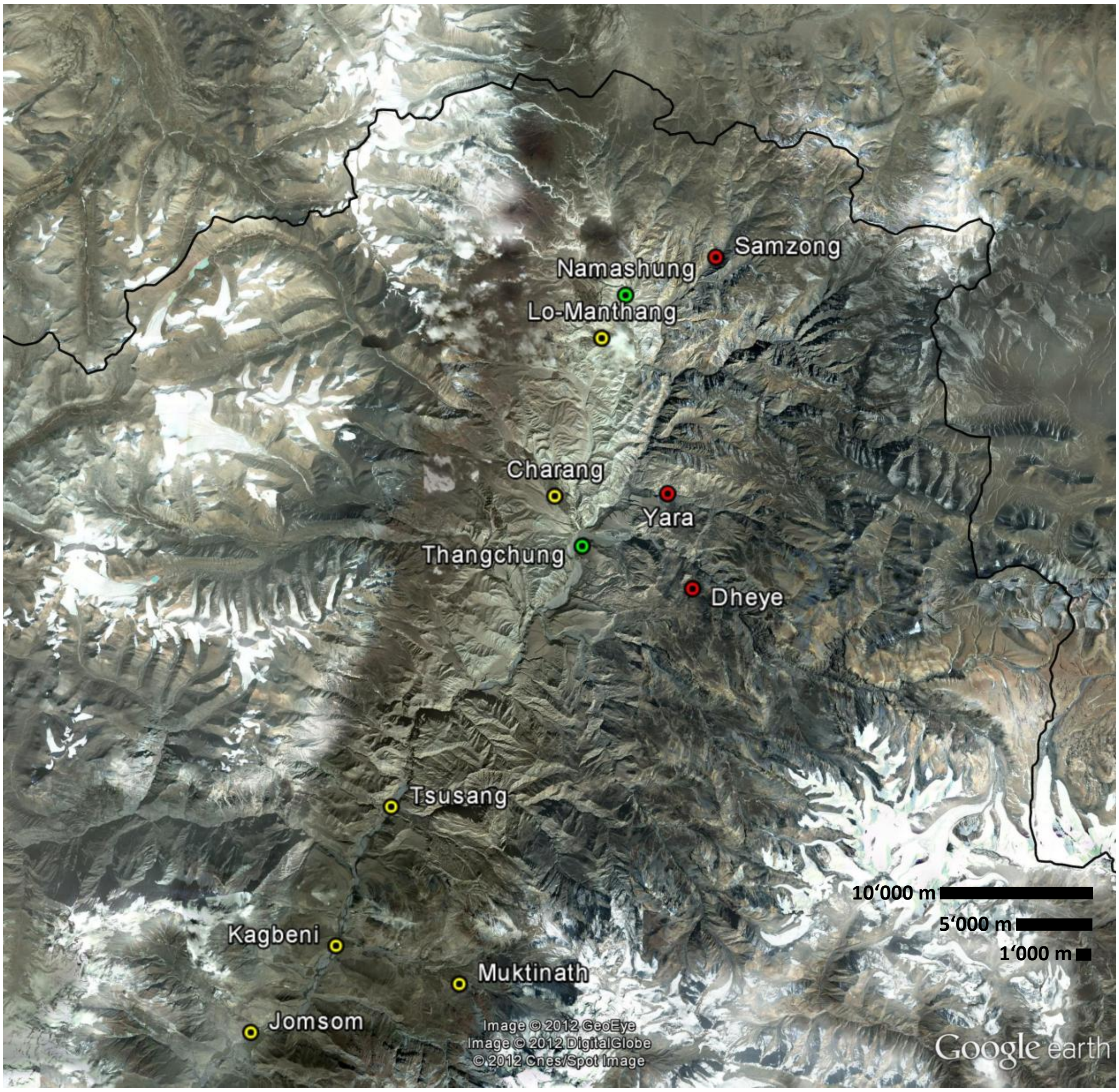

Figure 1.2: Overview of Upper Mustang. The main villages are indicated by yellow points, the studied villages are highlighted with red dots and the possible new locations of Samzong (Namashung) and Dheye (Thangchung) respectively are shown in green. The Chinese-Nepalese border is shown in pink, north direction is ↑ (source: Google Earth Pro, accessed 27/11/2012).

Samzong belongs to Tsoshar Village Development Committee (VDC) and is accessible on foot only. The rather rough path starts from Nenyor and leads over a pass into the valley formed by the Samzong Khola. Nenyor is situated just north of Lo-Manthang, on the left bank of the Kali Gandaki. On top of the right riverbank, a road leading from Lo-Manthang to the Chinese border is situated.

Apparently, the government is funding a road leading into the vicinity of Samzong. The main reason for the road seems to be the allotment of resources, but this could not be confirmed. However, the road should also reach Samzong. Recently, a first section has been constructed, which leads from Nenyor to the crest, over which the before mentioned foot path leads and which separates the main valley of Mustang, formed by the Kali Gandaki, from Samzong valley. The second half of the road should be completed next year. Currently there is no all-season carriage bridge connecting this road section with the existing main track linking Lo-Manthang with the Chinese border.

2 Contextualization

In this chapter general information is presented to embed the whole study in an appropriate context.

2.1 Administrative setting

Since 1991, the country is organized as a parliamentary democracy that has substituted the precedent constitutional monarchy.

Nepal is subdivided into 14 administrative Zones, which are grouped to 5 Regions. Each Zone is organized in Districts, which are all represented by District Development Committees (DDCs). Each District is further subdivided into Village Development Committees (VDCs). Finally, each VDC consists of several, but normally 9 Wards, depending on the population. Mustang is one of the 75 Districts of Nepal and lies in the Dhaulagiri Zone within the Central Development Region.

VDCs normally consist of 11 committee members, which are usually elected at the same time as the national legislature. Reportedly, the last official elections in Upper Mustang have taken place about 16 years ago. Since then the committees function in a "pro tempore" mode with a rather limited legitimacy consequently.

The three studied villages Samzong, Yara and Dheye are located in Upper Mustang which is a "restricted area." In Nepal there are several such areas, where the access for foreigners is limited by requiring costly tourist permits. The restricted Upper Mustang is part of the Annapurna Conservation Area (ACA), which is managed by the Annapurna Conservation Area Project (ACAP) since 1992 and refers to the National Trust for Nature Conservation (NTNC). The income of the permit is partly invested in projects within ACA. This has allowed the co-financing of projects in the field of water supply, mill construction, solar power plants, pedestrian bridges, health posts, environmental protection and initiatives of economic development (production activities, touristic services) to a more or less significant extent.

2.2 Institutional setting

The current institutional structure of Nepal is very weak. The precedent monarchical organization, which survived de facto until the massacre of the royal family in 2001, even though it had been transformed into a parliamentary democracy in 1990/91 already, has not allowed the development of proper and decentralized governance. A strong centralized and authoritarian approach on the country has been maintained. Consequently the most remote areas such as Mustang have only benefited marginally from services provided by governmental institutions. Generally such support has been confined to the supply of basic assistance in the fields of police and primary education. The only formal bodies present in such remote areas are the DDCs and the VDCs. As a consequence of the political instability of the last decades, their respective democratic legitimacy and working capacities are very limited.

2.2.1 Inherent characteristics

Collective decision making

Founded in the late 14th century, Lo had been an autonomous kingdom, strongly influenced by and tied to the ancient kingdoms of western Tibet in terms of culture, linguistics and even politics until the Chinese occupation of Tibet in 1959 (Craig 2004). Though being annexed to Nepal at the end of the 18th century, the kingdom of Lo, which corresponds to the territory of Upper Mustang today, could retain a degree of local autonomy. Certain traditional rights, allowances and honorary positions of the local rulers, sprung from the lineage of the royal family Bista, were respected by the central government (Craig 2004). Even though the last official King of Lo, Jigme Palbar Bista, has been deprived of any formal power by the Nepalese government since 2008, the royal family Bista still has a strong influence on the inhabitants of Upper Mustang nowadays.

Thus, Upper Mustang has a quite exceptional background, which is important to consider in order to understand the local customs and practices of taking decisions at local level for instance. As mentioned before, the institutions are very weak, which amplifies the importance of traditional decision making. An example is the practice of local assembly at village level, coordinated by a Ghenpa (called Mukhye in Nepali), a role assumed by a member of each household (HH) for one year in turn. During such gatherings decision about communal affairs are taken collectively.

These decisions are made outside of any formal framework and are seldom documented, as many of the villagers are illiterate. This practice seems necessary, since the institutional contributions are quasi absent. However, the fact that the villagers are practically not supported in finding and implementing solutions for their apparent and pressing problems, bears the risk that non-optimal solutions are found, mainly due to the lack of professional elaboration and assistance. For appropriate and sustainable solutions, access to trustable and complete information is crucial. Furthermore, the taken decisions often miss a time dimension, meaning to say the planning horizon is dangerously short.

Importance of social structure

It is important to recognize the central role of the social structure in the villages of Upper Mustang. For example, the discussions during the field visits in 2012 about possible relocations clearly underlined the fact that the unity of the communities (“staying together”) was considered to be of upmost importance. Even those not very much in favor of relocating would willingly move for the sake and overall fortune of the community. This example is particularly remarkable when compared with the level of family and community disaggregation observed in western societies. It is also surprising to notice that practical aspects (i.e. legal issues of land ownership of a complex and risky relocation project) are considered secondary after the wish to keeping the community united. The interviews have shown that a strong common responsibility and solidarity (which is lost in western societies to some degree) seems to have survived in the high Himalayas, likely through cultural and religious influences and maybe also due to the difficulties that the population must face daily.

2.2.2 Funding of local projects

Institutional funding

In Nepal, DDCs and VDCs are financed by the central government. The amount consists of an equal basic contribution for each DDC or VDC respectively and an additional amount depending on the size both in terms of population and area.

The share of funds at local level is decided by the respective committees on the basis of project proposals. Each year the way of distribution is reevaluated and reset. It is not allotted project-based, but rather on a year-to-year basis. Nevertheless it is possible that single projects receive funds over several years. However, the practice clearly does not facilitate planning at mid and long term and imposes, especially for larger projects, a high level of uncertainty. Consequently, rather “stage-wise” or “stop and go” approaches result.

Project funding

The fact that institutional funds are not allocated on project basis is one of the main reasons, why the communities have to tap other sources. Not surprisingly, during the field work and the associated numerous interactions and discussions, the communities often expressed the necessity of third party support for the realization of community projects, explicitly referring rather to foreign support than to Nepalese governmental institutions.

Additionally, local projects are often realized to a rather large extent by contribution of the community itself in terms of workmanship. The required input is often distributed equally among the community’s nuclear families, not considering each HH’s constitution and capacity, which would be typical for “western modern democracy.” The local practice roots in tradition and history and is therefore well accepted.

Such particularities have to be kept in mind while assessing the feasibility of supporting projects of local investments, especially for relevant and complex projects that involve the relocation of an entire village for instance.

2.2.3 Institutional setting as an opportunity

This situation of “institutional resignation” should not be appraised exclusively by western standards, since the judgment would be wholly negative. The fact that the central government is not highly present in these remote regions and that the impact of national policies (on territory as well as social and economic development) is limited, offers the opportunity of developing projects on local scale. Such undertakings could be well adapted to the actual needs of the concerned communities, while respecting cultural, religious and social peculiarities. If strong and rigid institutional structures would be in place, likely the projects would have to follow rather schematic approaches, which offer much less space for local adaptation of the projects.

Additionally, local customs and practices are influenced much less by politics due to the institutional weakness in the remote areas. For certain, this has helped preserving the unique natural territory and the particular Mustangi culture as it remained substantially unchanged during centuries.

2.3 Demographic setting

According to the 2001 census undertaken by the Central Bureau of Statistics (CBS), the population in Nepal counted about 23.15 million inhabitants and has reached 26.62 million based on the most recent census in 2011 (Central Bureau of Statistics 2012).

2.3.1 Mustang District

Among the 75 Nepalese Districts, Mustang is the 5th biggest District with an area of 3’573 km^2. However, in terms of population it ranks second last with a total of 13’799 inhabitants among which 6’482 or 47 % are female and 7’317 or 53 % are male. Only Manang District (3 p/km^2) has an even smaller population density than Mustang (4 p/km^2). In contrast, Kathmandu (4’408 p/km^2) has the country’s highest population density (Table 2.1).

The annual growth rate between 1991 and 2001 was 0.5 % in Mustang opposed to the national increase of 2.2 % during the same period. As shown in Table 2.1, the national growth rate decreased to 1.40 % in the following decade from 2001 to 2011, whereas in Mustang it became negative with a value of -0.82 %. In the same period, the average HH size decreased considerably in whole Nepal, as well as in Mustang and Kathmandu. Similarly, the sex ratio (number of males per 100 females) decreased during the last decade (Table 2.1).

Table 2.1: Population indices taken from the data published in the preliminary results of the national population census 2011 as well as the past censuses of 2001 and 1991. All data was taken from the census data portal of the Central Bureau of Statistics (Kitazawa and Kayastha 2012).

Period	Area	Population	Decadal change (%)	Annual growth rate (%)	Sex ratio (♂ per 100 ♀)	Average HH size (p)	Surface area (km^2)	Population density (p/km^2)
1991 - 2001	Mustang	14’981	+4.6	+0.5	120	4.62	3’573	4
	Kathmandu	1’081’845	+37.6	+4.7	113	4.60	395	2’739
	Nepal	23’151’423	+20.1	+2.2	100	5.44	147’181	157
2001 - 2011	Mustang	13’799	-7.9	-0.8	113	3.96	3’573	4
	Kathmandu	1’740’977	+60.9	+4.8	109	3.71	395	4’408
	Nepal	26’620’809	+15.0	+1.4	94	4.70	147’181	181

2.3.2 Upper Mustang

Headquarter of the DDC of Mustang District is Jomsom. Geographically and historically the District is subdivided into two sectors: Upper Mustang, with 5'395 inhabitants in 2001 and Lower Mustang, with 9'130 inhabitants in 2001 (CBS, Kitazawa and Kayastha 2012)[2]. Apparently, more current data disaggregated on VDC level are (not yet) available.

Upper Mustang is divided into seven VDCs that are themselves composed by one or more settlements each reachable within several hours by foot. According to the CBS (Kitazawa and Kayastha 2012) the seven VDC's total populations in 2001 were:

- Charang 661
- Tsonub 1'070
- Tsoshar 783
- Tsusang 668
- Ghami 850
- Lo-Manthang 848
- Zurkhang 515

According to CBS's data (Kitazawa and Kayastha 2012), the seven VDCs counted 1'171 HHs in 2001. As a comparison, during the field visits in 2012, 53 HHs were counted in the three studied villages (Samzong, Yara and Dheye) together and 17 in Samzong alone.

Of all 1'171 nuclear families in Upper Mustang 301 (26 %) declared to have other economic activities other than agriculture, in particular in sectors such as trade and business (76, 7 %) and services (179, 15 %) according to the CBS (Kitazawa and Kayastha 2012). In Upper Mustang, the large majority of nuclear families dedicated to agriculture own land and livestock. Consequently they practice cultivation and stockbreeding.

2.4 National performance of Mustang District

A study undertaken jointly by the CBS and the International Center for Integrated Mountain Development (ICIMOD) came up with a comparative analysis based on development indicators in the 75 Districts in Nepal (CBS / ICIMOD 2003). According to the "Overall Composite Index" based on data from the 2001 census, Mustang occupies the 19th rank[3]. The "Poverty and Deprivation" indicator places Mustang 33rd and 17th in the "Socioeconomic and Infrastructural Development Indicator." The position of Mustang District is particularly delicate with regards to the indicator "Per Capital Food Production" where it is placed 60th with only 2'196 kcal per day. However, in terms of number of living animals per family, Mustang with

[2] Note that the sum of the published, disaggregated data for Upper and Lower Mustang (Kitazawa and Kayastha 2012) add up to 14525, namely 456 less than the aggregated value for the whole district (14'981, Table 2.1). Apparently these 456 inhabitants are institutional and not attributed to a particular VDC.

[3] The study orders the ranks in three categories: Most developed (Rank 1-25), intermediate (Rank 26-50) and least developed (Rank 51-75).

about 20 animals per productive unit is ranked first among the 75 Districts. Also the ratio "Percentage of Irrigated Area" related to total operational agricultural land area is high in Mustang (82.62 %, 6th rank). This demonstrates the crucial importance of water supply with regards to agricultural activities in Mustang.

3 Current situation in situ

In this section, all relevant and elaborated aspects about Samzong's situation at the current location are presented. It is merely a description of the village in the present state with its characteristics, associated problem and challenges.

3.1 Socio-economic and institutional aspects

In this section, socio-economic, institutional and demographic issues similar to the general ones discussed in chapter 2 are presented, but with the simple difference, that the following information is specific for Samzong.

3.1.1 Demographic aspects

Based on the field survey, the village is composed of 17 nuclear families and a total population of 83, among which 39 are male and 44 female. Out of the total 83 people, 22 (27 %) are permanently living outside of Samzong. These permanent migrants rarely come back to the village, if at all. Opposed to that, most of the inhabitants move towards the lower regions of the valley or even further south often engaging mobile trade during the winter months. This is a form of seasonal migration, which is quite typical for the region. Only a few remain in the village during the winter.

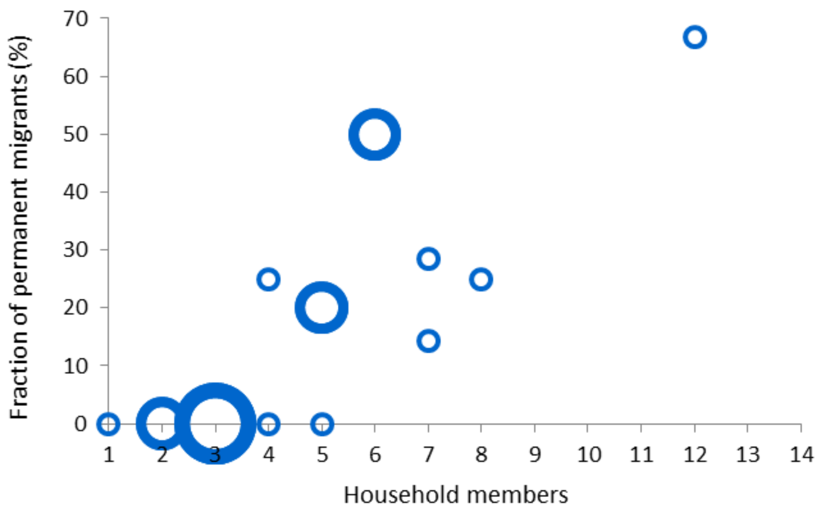

Figure 3.1: Scatter plot between the numbers of HH members against the fraction of permanent migrants of the corresponding family. The small sized circles correspond to a single HH, the medium to two families and the largest one to three HHs with the same characteristics (e.g. three HH members and no permanent migrants).

Most of the permanent migrants are studying at distant schools (Lo-Manthang, Pokhara, Kathmandu or India). As depicted in Figure 3.1, the size of the family seems to be slightly correlated with the percentage of permanent migrants. HHs with a total number of three or less members are all living in Samzong (at least during the bigger portion of the year). On the other hand, a fraction of the families with totally six or more members is living permanently elsewhere. The reasons for this may be manifold. For instance, large families might not be able to sustain their livelihood due to the limited resources and economic opportunities.

However, due to very small sample, it is difficult and it may be delusive to draw conclusions from the data and the corresponding tendencies only.

The average age of the permanent migrants (16 y) is considerably lower compared with the residents (34 y). The former group consists mostly of teenagers and school-aged children, whereas the latter is constituted by adults and young children (Table 3.1). This represents a considerable risk for the future demographic stability of the village, since the young migrants will return less likely after their studies because of the strong attraction of local, regional and even national centers (e.g. Lo-Manthang, Jomsom, Pokhara, and Kathmandu). Subjectively, such centers present major earning opportunities, better material living conditions and a large overall attraction as it seems.

Table 3.1: Samzong's age structure based on the socio-economic survey. The permanent migrants are almost exclusively teenagers and school-aged children, reflected by their average age and the corresponding low standard deviation. The residents however are generally older, but also include young children, represented with a lowered average age and an increased standard deviation.

	Permanent migrants	Residents	Total
Number of family members	22	61	83
Average age	16	34	30
Standard deviation	12	21	21

3.1.2 Institutions and local competences

The institutional structure of the village appears to be very weak. There is no governmental body, building, police quarter and neither a health post present. A small school has been constructed recently which has replaced the old one situated on the other side of the river. One teacher appointed by the central government is currently occupied with three children. However, the children often miss school due to different reasons, such as mutual misunderstanding between the teacher, not speaking the local language, and the parents, who do not regard school as a very important matter.

The management of the collective necessities is delegated to a traditional system based upon the roles of Ghenpa (named Mukhye in Nepali) and Vice-Ghenpa. Such roles are assumed through yearly turns involving a single representative of a nuclear family. The Ghenpa and Vice-Ghenpa have autonomous decisional power for simple matters also including settlement of disputes and punishment of violation of communal rules. For farther reaching issues, the Ghenpa gathers the assembly (involving all inhabitants) for taking collaborative decisions of collective interest.

In Samzong, there is apparently not a person with informal leadership characteristics present, who would be able to plan and implement strategies on mid to long term horizons. Consequently, the dependence from external supports is quite evident, in particular concerning the determinant role of Lama Ngawang Kunga Bista, leader of the relocation project of the village into the surroundings of Nenyor.

3.1.3 Economic activities and income

Economic activities are mostly limited to subsistence agriculture, strongly prejudiced by the scarce irrigation water, and to stockbreeding (goats, cows, horses and sheep). Based on the socio-economic survey, the average yearly income per nuclear family is about 50’000 to 60’000 Nepalese Rupees (NPR).

In Samzong, all the families own a certain amount of land area. There is no agricultural land, which belongs to somebody living elsewhere. Land ownership is distributed in a rather uniform manner, with areas expressed in the local surface measure that vary between one and three Ghalto per nuclear family. Out of 17 families, only three have land areas below one Ghalto.

In total, the population of Samzong owns 24 horses, 29 cows, 45 sheep and 840 goats. In fact, the main economic activity that allows generating additional income is to sell animals and/or their fur. Monetary income is essential to assuring the subsistence throughout the year, since the output from agricultural activities alone does not suffice. Safe one HH composed of only one woman, all nuclear families own goats. The average number of goats per family is of about 52 with a minimum number of 15 and a maximum of 140. Taking the total population of 83, this amounts to 10 goats per capita. The market value of a goat corresponds to about 6’000 to 7’000 NPR.

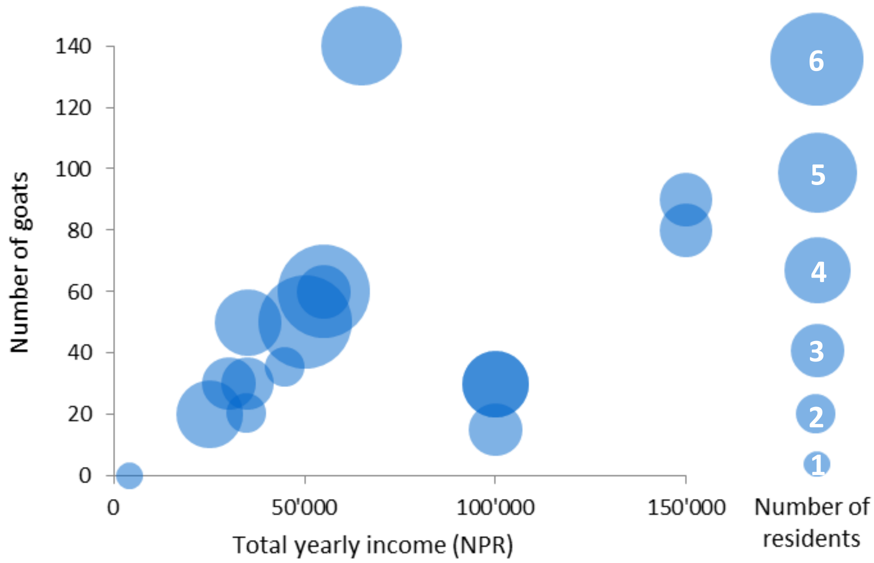

Figure 3.2: Scatter plot of the total yearly income and the number of goats per family. The size of the circle indicates how many family members are still living in the corresponding HH in Samzong, meaning that they are not permanent migrants, but residents.

The families’ incomes seem to correlate slightly with the number of family members and owned goats (Figure 3.2). However, it has to be noted, that the quality and reliability of the data could not be verified. It is not possible to exclude strategic answers or underestimations, influenced by the sensitiveness of the issue for instance. Besides, the fact that many men were out of the village during the interviews might also have biased the answers.

Few families are doing small accessory activities such as workmanship in construction, handicraft production, whereas the output from the latter is almost exclusively used for their own good. Mobile marketing during the winter months in places around Pokhara, Kathmandu or India is relatively diffused. 10 out of 17 families engage such activities but it only occupies 11 people in total.

There is no touristic infrastructure like a lodge or a restaurant. Partly this is due to the difficult access, as well as the fact that foreigners are not allowed to stay overnight in the village according to ACA policy. Also, Samzong has not accommodated any landmarks. Recently however, archeologists have become interested in the surroundings of the village. National Geographic printed an article about sky caves in Mustang last October (Finkel 2012). An archeologically promising cave had been found very close to Samzong and was cleared in an expedition in spring 2011. The excavated content of the caves including skulls, bones and wooden structures are apparently planned to be put in a modest museum in Samzong itself by personal support of a project member (Finkel 2012), which would be the first potential touristic attraction, along with the caves themselves. Though such findings (and the public reports thereof) may increase the popularity of Upper Mustang and Samzong in particular, the issue is quite delicate. Reportedly the way the expedition dealt with the deep cultural and spiritual heritage associated to such findings is highly questionable. The perspectives of westerners and the local people are certainly greatly differing in this matter, so that compromises cannot be circumvented if the touristic potential of such findings should be developed appropriately paying due respect to local customs and believes.

3.1.4 Perception of the main problems faced by the community

During the socio-economic survey each of the 17 HHs were asked to identify three main issues about which they are most concerned and to rank them according to severity (Figure 3.3). With this data, the three main issues mentioned in the Samzong community could be identified:

- Main concern: Lack of irrigation water
- Second concern: Risk of landslides and flooding
- Third concern: Lack of food

Unanimously, the lack of irrigation water was mentioned as the most concerning issue. The second most concerning issue is clearly the threat of flood and landslides. However, a few single HHs also mentioned other concerns (worries about food supply, transportation, wild animals in the fields, fodder quantity and problems with the irrigation channel and health). The third most concerns of the families are related to food supply, transportation and the threat of wild animals in the fields. Other worries (flood and landslides, lack of a hospital in the vicinity, accesses to the alps, size of fodder storage and the dysfunctional mill) were mentioned also, but each only by one out of the total of 17 HHs.

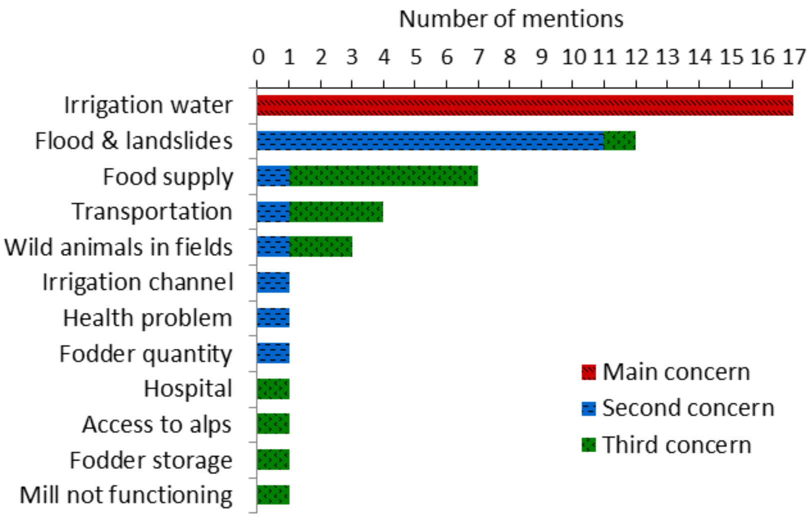

Figure 3.3: Visualization of the survey related to the identification and ranking of three main issues about which each of the 17 households are most concerned.

3.1.5 Willingness of the community to move

The relocation project is generally known to the population of Samzong, though there is no written material that documents it. On the basis of the discussions held together with LMF representatives, all families agree with the option of relocation, some by conviction, some because they do not see any alternative for resolving their problems and because they absolutely want to remain united with the community. In fact, the survey has clearly demonstrated that there is a very strong unity between the families of the village (section 2.2.1). Even those who seemed to be less convinced by the idea of relocating, clearly indicated to be willing to adapt themselves to the choice of the majority, maintaining the social structure of the community. No one mentioned to think about moving to another community in case of relocation.

All families state that they know and accept the foreseen land repartition system, which foresees equal land area for each family not depending on the number of family members (section 5.1.3). Similarly, the system of attributing the new plots at the relocation place through lottery is known and accepted by everybody.

The modality of financing the possible relocation does not seem to be considered as a main problem to the villagers. This issue was rarely mentioned in the interviews. Apparently the solution is "delegated" to third parties and in particular to the LMF which is leading the relocation project proposal, but also to other possible support sources, which have not yet been identified. Remarkably, the possibility of receiving financial support from governmental institutions has been mentioned only as an option with low priority.

When asked, the majority of the families was still favoring to relocate, even if all the issues, about which the families are concerned (Figure 3.3), would be solved. The selected site north of Nenyor named Namashung is unanimously recognized as valid and appreciated. Along the same lines, the road under construction leading into Samzong valley from Nenyor would not change their mind, even if it were completed already.

3.2 Housing

In the following sections all investigations and the corresponding results related to housing are exposed.

3.2.1 Settlement layout, spatial organization and density

The village of Samzong is located on a gentle slope in the valley bottom between a steep cliff north and the Samzong Khola south of the settlement. The houses are distributed into two main groups located at the center and arranged in a very organic layout. Together with several isolated single or small clusters of houses located towards the western, northern and eastern side of the main groups, the village forms a relatively dispersed settlement altogether (see Figure 3.4 and Figure 10.1 in Appendix A.1). There are several historical caves located within the cliffs in the north overhanging the village. According to the villagers, they were used as dwellings a long time ago. Nowadays many of them are totally abandoned because of geological instability and difficult access, though about 25 are still used as fodder storage. As mentioned in section 3.1.3, some of these caves have captured the attention of archeologists recently. They are interested in these human-built caves holding great mysteries in terms of who built them at what time and for what purpose (Finkel 2012).

The footprint of the settlement, including the buildings, nearby compounds, squares and public areas, while excluding agricultural area, covers 1.34 ha[4], corresponding to a density of 62 inhabitants per hectare. The total agricultural area covers 11.86 ha[5] among which 9.08 ha are presently cultivated and 2.79 ha are used for purposes such as grassland, trees, brick making etc. Considering only the currently cultivated fields, the productive field area pro capita is 0.11 ha. There are some trees (mostly Populus Ciliata, locally known as Bhote Pipal) mainly planted along the irrigation channel crossing the village longitudinally (Figure 3.4).

The public amenities are a preliminary school, a community hall and a solar energy powered mill. There is also a big prayer wheel at the entrance of the village and several small Chörten dispersed in the village and surroundings (see Figure 10.1 in appendix A.1).

[4] Measured with Google Earth Pro

[5] Measured on site during the second field visit using a handheld GPS device

Figure 3.4: Overview of Samzong seen from south. In the foreground abandoned fields (in grey), separated from the settlement by the Samzong Khola, can be seen. In the background the cliffs where ancient caves are located are visible. The currently cultivated fields can easily be distinguished due to their bright green color (photo: 28/06/2012, Daniel Pittet).

3.2.2 Characteristics of housing

The spatial organization of the dwellings in Upper Mustang is greatly varying depending upon size, available space, need and means of the HH and proximity to other houses. However, there are some typical elements that are found in most cases, as discussed in the following.

The dwellings are generally rather compact (Figure 3.5) with access to the rooms through a central courtyard and systematically accessible flat roofs (Figure 3.10 in section 3.2.3). Generally the houses are surrounded by compounds for animals fenced by stone walls, in case enough space is available. Roughly half of all houses in Samzong have two stories, including a ground and a first floor, whereas the other dwellings are composed by the ground floor only.

Three houses, each representing a typical small, medium (Figure 3.6) or a large house respectively, were measured in Samzong and are fully presented in Figure 10.2, Figure 10.3 and Figure 10.4 in appendix A.2.

Figure 3.5: View of the central part of Samzong seen from north. In the background Samzong Khola can be seen (photo: 29/06/2012, Daniel Pittet).

The comparison of the three typical house types (Figure 3.6) illustrates the variations of house compactness and land use (Table 3.2). The compact medium sized house with two stories is very efficient in terms of footprint, with a ratio (footprint/usable area) equal to 0.35 only. The small house with only one story uses proportionally more land and has almost the same value (0.5) as the bigger house with 1 to 2 stories (0.49).

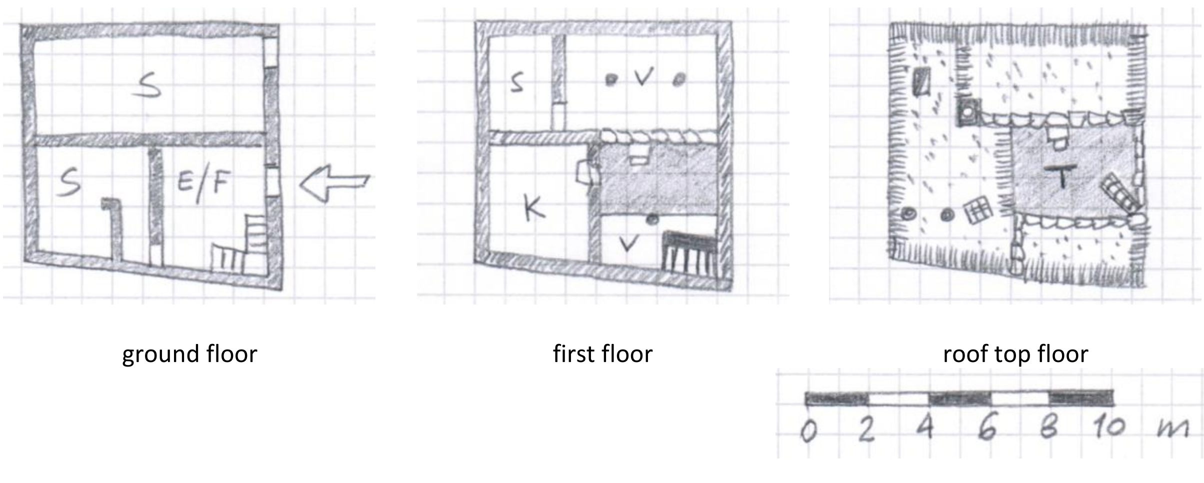

Figure 3.6: Representation of a dwelling from Samzong taken as a reference for a typical medium sized house (abstract of Figure 10.3 in appendix A.2, hand drawings: 30/06/2012, Daniel Pittet).

Table 3.2: Size and compactness of three house types of Samzong. The whole drawings of the corresponding houses are presented in Figure 10.2, Figure 10.3 and Figure 10.4 in appendix A.2.

House type	Indoor area (m^2)	Com-pounds (m^2)	Veranda area (m^2)	Roof top area (m^2)	Total footprint area (m^2) without compound	Total footprint area (m^2) including compound	Compactness ratio (footprint[a] / usable area[b])
Small (1 story)	62	62	0	62	62	124	0.50
Medium (2 stories)	99	0	27	68	68	68	0.35
Large (1-2 stories)	182	307	61	236	236	543	0.49

[a] Considers footprint without compound area

[b] Sum of indoor, veranda and roof top area

The indoor spaces are lit mainly through small openings in the flat roofs, through small windows and through the light coming from the open spaces and verandas if the doors are open. Consequently, natural lighting is rather limited and it is supplemented by small solar powered lighting systems in all but one house.

Indoor spaces are used for storage, sleeping, living and cooking, whereas verandas are generally used for handicraft production and living space. The roof top terrace is a very essential space used for drying firewood, cow dung and other goods. A shrine (red colored elements in Figure 3.5 and Figure 3.10 in section 3.2.3) is often built on the roof that may also host solar modules for the lighting systems. The vertical access is generally supplied by very simple ladders constructed by excavating a wooden trunk accordingly. In some cases more elaborate wooden stairs for accessing the first floor are provided.

The socio economic survey has also allowed collecting data on the houses' compositions, illustrated by Figure 3.7. The corresponding data can be found in Table 10.1 in appendix A.3.

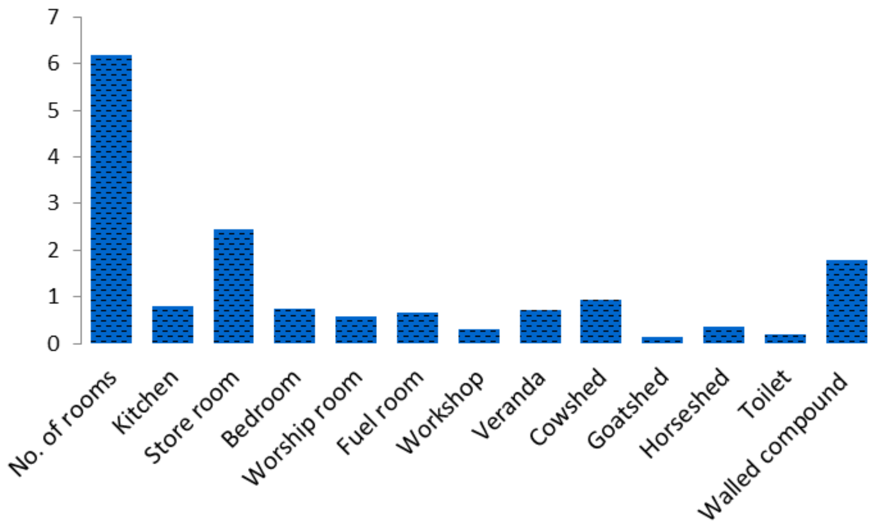

Figure 3.7: Average house composition of Samzong. The numbers indicate how many rooms are designated to the corresponding category on average per house, based on the field survey.

The number of rooms per house varies from 2 to 13 with an average value of about 6 (Table 10.1 in appendix A.3). Generally every house has one kitchen but in many cases (9 out of 17), the kitchen is also used as a sleeping place. Safe in one dwelling, all houses have store rooms varying from 0 to 6 in numbers with an average value of about 2.5. Also, the houses normally accommodate bedrooms, though in 3 cases they were not mentioned by the HH[6]. Worship rooms, fuel rooms and verandas are present in a majority of cases but not systematically, whereas workshops are rather marginal (5 out of 17) and toilets are exceptional (2 out of 17). The presence of cowshed is very common (only 4 HHs do not have one) while horse-sheds are less frequent (7 out of 17) and goatsheds are exceptional (3 out of 17).

3.2.3 Construction technology, systems and costs

Housing technology

The foundations are made of stones that are also used for the lower part of the walls in some cases. The walls are made of hand-made crude soil blocs of about 40 x 20 x 12 cm (Figure 3.8), laid out with soil mortar and covered with lime plaster. The walls are reinforced around the doors and windows with wooden beams. Isolated wooden poles complete the vertical structure that is linked to the wooden horizontal structure forming the slabs and flat roofs (Figure 3.9). The latter are covered with soil, in some cases mixed with ashes that assume the function of surfacing and water proofing of the slab and roof (Figure 3.10).

Figure 3.8: Hand-made crude soil blocs for wall construction in Samzong (photo: 29/06/2012, Daniel Pittet)

[6] This could be due to imprecision in providing the data and due to the fact that the sleeping place is often shared with other functions, generally the kitchen.

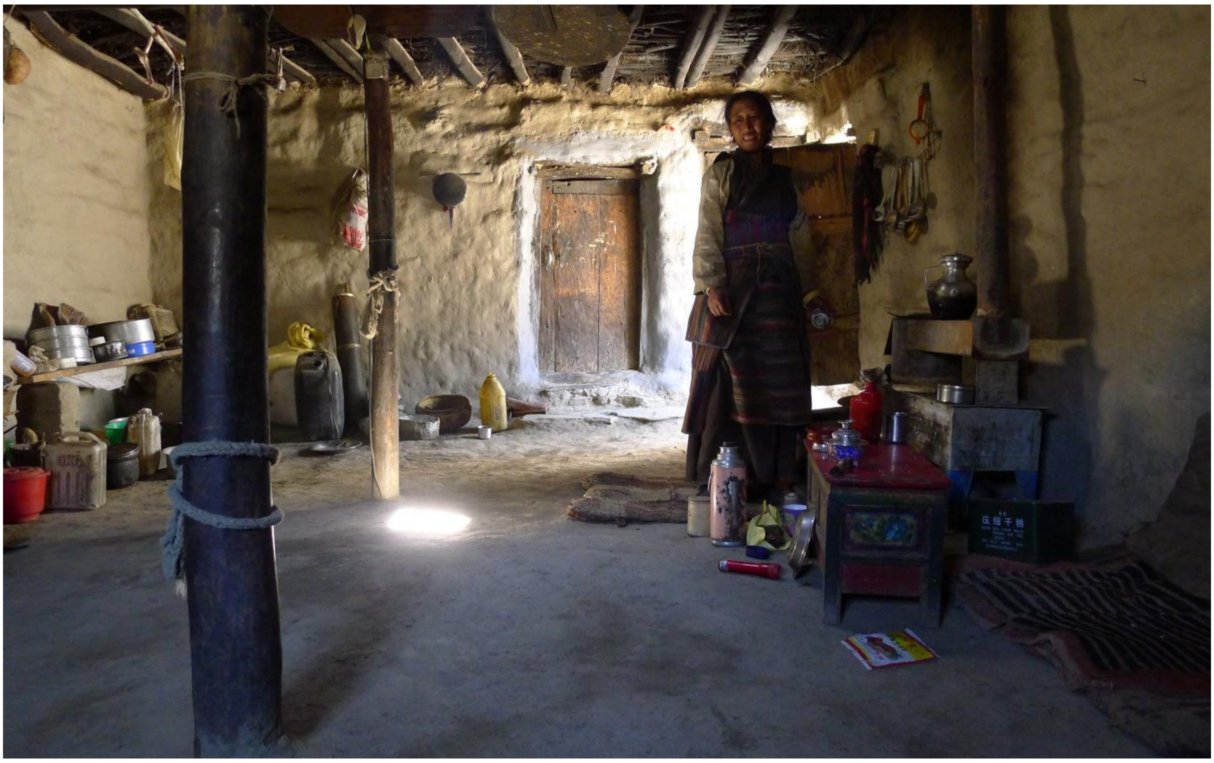

Figure 3.9: Inside view of a house in Samzong with earthen walls, wooden poles and wooden slab (photo 28/06/2012, Daniel Pittet).

Figure 3.10: Roof top with soil/ash surfacing, wood disposal for drying, solar modules for lighting system, shrine (in red) and pipe for fire smoke evacuation in Samzong. The places corresponding to inside partition walls are covered by flat stones for a better protection against rainwater penetration (photo 28/06/2012, Daniel Pittet).

Construction systems and maintenance of the houses
All wooden works (wooden part of the structure, doors and windows) are realized by professional carpenters hired from the region, whereas all the remaining works are done by the family members with the help of relatives and friends, in exchange of similar or other kind of workmanship.

The materials for constructing the walls (soil and lime) are available locally while materials such as nails, lockers and possibly glass are purchased in the regional market (in Lo-Manthang or in markets at the Chinese border). Construction wood is supplied mainly from other villages of the region and from China because the local production of such wood is insufficient for covering the needs.

The maintenance of the houses consists mainly in the regular surfacing of the rooftop in order to maintain a sufficient waterproofing. Such maintenance is done by applying and polishing a new layer of soil, sometimes mixed with ashes. Frequent surfacing of the indoor areas is also done for maintaining a smooth and clean pavement surface. Yearly plastering and lime painting of the walls is also realized, unless there is demise in the family during the year.

Construction costs
The construction costs of an average house with 4 to 5 rooms are estimated as shown in Table 3.3.

Table 3.3: Estimated average cost for a standard house with 4-5 rooms in Samzong. The values are based on a community meeting with representatives of 14 out of the total 17 HHs on 27/06/2012.

Description	Cost (NPR)
Workmanship of professional carpenter *1 month @ 500 NPR/day*	15’000
Workmanship for non-wood works *Free for exchange of workmanship with relatives and friends*	0
Required additional wood *Wood for beams, slab, roofing etc. additional to recycled wood*	500’000
Other materials *Nails, lockers, glass etc.*	40’000
Total direct costs	555’000

The supply of wood represents the highest share of the cost of a house by far. This is explained by the fact that construction wood is locally hardly available and needs to be transported from other villages, if not from China.

3.2.4 Issues and problems related to housing

The general housing conditions in Samzong are relatively good. In fact, the houses are in a very decent shape and generally well maintained.

However, some houses (5) and other buildings (such as barns, stables and compounds) are threatened by debris flows triggered by stormwater concentrating within the gorges north of the village, as discussed in more detail in the section 3.5. The assessed risk is in accordance with the reported main concerns of Samzong's inhabitants (section 3.1.4).

Another risk potentially threatening the buildings is related to the intensification of rainfalls in the region that has been observed and reported by Ardito (2012). According to this observation, some houses in Dheye village have undergone serious damages and even collapse of roofs during heavy rainfalls. Such an event could indeed be explained by an effective intensification of rainfall. In fact, an actual shift in precipitation patterns is neither supported nor contradicted by the climatic and meteorological analysis (section 3.3.4). However, according to Lama Ngawang Kunga Bista, a collapsing roof is most likely caused by irregular maintenance or to inappropriate construction and/or realization. It is true however, that the flat earthen roofs of the traditional houses of Mustang are designed for very dry climate with low intensity rainfalls and need regular maintenance therefore to preserving a sufficient level of waterproofing.

3.3 Climatic and meteorological setting

To understand the current circumstances and challenges with which the people of Samzong are confronted, it is crucial to put it into appropriate physical context. The past meteorological and climatic settings as well as future trends thereof have to be considered in order to qualify future prospects of the current settlement.

In particular the evolution of precipitation and temperature within the last decades in Upper Mustang is of interest. Furthermore future projections thereof are looked at. The corresponding investigations were done by Mario Rohrer, which concluded in two unpublished reports (Rohrer 2012a; 2012b). Here, only the relevant issues for the study at hand are reproduced.

3.3.1 Climatic setting

According to Rohrer (2012a) Mustang's climate "(…) is characterized by a cold, windy and dry climate." Very generally speaking, it seems that it is getting even drier. This circumstance is exemplified by the many abandoned agricultural fields that could be seen walking through Upper Mustang. Based on satellite information from 1990 and 1984, Kostka (2001) identified and visualized agricultural areas including abandoned portions in a thematic map (Figure 10.1 in appendix B.1). Looking at more recent satellite imagery with Google Earth for instance, it becomes apparent, that the abandoned field areas have been further increasing over the last decades. Though this tendency may have different reasons, it is very likely that there has been an ongoing reduction of water availability during the last century. This is also supported by the accounts of the interviewed locals. In addition, this tendency of "Upper

Mustang becoming drier since decades" has also been expressed by G. Miehe, a specialist of Tibet's climate (G. Miehe 2012, pers. com.).

In general, the climatic setting appears to be spatially highly variable. As a neat example thereof, clouds were producing very local precipitation in Upper Mustang in 1978, vertically distinctively delimited (Figure 3.11).

Figure 3.11: Local precipitation west of Samar produced by clouds which were formed by the uplifting air masses flowing upwards through the Kali Gandaki valley. Neither the valley bottom, nor the mountain tops, which were under the influence of an overlying high pressure system, received any snowfall. The picture was taken from Thorung Peak (6140 m asl) in northwestern direction (photo: 13/11/1978, Giovanni Kappenberger).

3.3.2 Air temperature

Actual trends of air temperature

Reliable meteorological data over longer periods are not easy to find in Nepal. Analysis of such data has to be done with care therefore. Nevertheless, according to Rohrer (2012a) a general warming trend over the last roughly three decades can be identified by comparing two different temperature interpolations (Figure 10.8 and Figure 10.9 in appendix B.3). The magnitude of the warming trend is questionable, as the two interpolations show inconsistencies, but roughly the warming seems to amount 1°C over the last 30 years in Mustang (Rohrer 2012a).

Future trends of air temperature

To identify future trends in air temperature Global Circulation Models (GCMs) can be used. For Nepal future trends are quite uncertain however according to Rohrer (2012a). Based on a single intermediate emission scenario (A1B of the Intergovernmental Panel on Climate Change (IPCC) report 2007, appendix B.2) the warming at the end of the 21st century ranges between +2 °C and +5 °C during the monsoon season represented by the month June, July and August (Rohrer 2012a). The range covered by different models predicting warming for the whole year is slightly smaller (Rohrer 2012a), which can likely be attributed to the fact that the monsoon season introduces greater overall uncertainties due to its complex inherent dynamics.

For Mustang, the positive difference at the end of the 21st century to the reference period (1961-1990) is considerably higher (Rohrer 2012b). In winter the temperature is expected to rise between 6 °C to 10 °C or 4 °C to 10 °C during monsoon season respectively (Rohrer 2012b). Analogically to the temperature trend of whole Nepal, the bandwidth of expected temperature increase formed by different models is bigger during the monsoon season (Rohrer 2012b).

3.3.3 Wind

The winds of the Mustang region are heavily influenced by the pressure fields forming over India and Tibet. The very strong diurnal winds (Figure 3.12) are well known and described in many articles, books and guides. As in most valleys, winds blow up or down, but not perpendicular to the valley axis.

The strong heating of the soil creates low pressure system over Tibet during the day, with an increasing pressure gradient between India and Tibet. This results in heavy diurnal upvalley winds in late morning and early afternoon.

Figure 3.12: Riverbed of the Kali Gandaki between Jomsom and Kagbeni. The heavy afternoon wind is visibly suspending and transporting a lot of sand and dust particles (photo: 19/10/2011, Giovanni Kappenberger).

Present wind patterns

As mentioned before, a particularity of the Kali Gandaki valley is that it is subject to quite unique diurnal wind both in terms of magnitude and asymmetry between night and day (Figure 3.13). In the late morning upvalley winds take up and reach its quite extreme maximum after midday to decay later on and display typically only gentle breezes during the night (Egger et al. 2000).

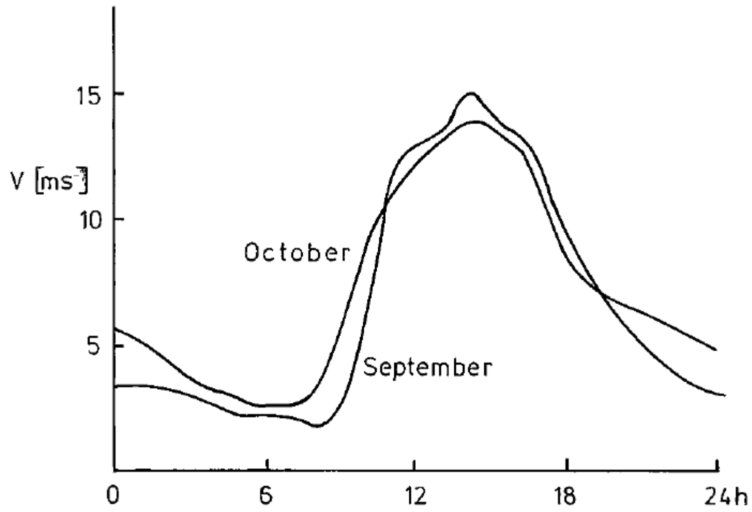

Figure 3.13: Graph illustrating monthly mean values of the hourly mean wind speed V (m/s) as observed in Kagbeni in September and October 1990 at a height of 30 ft, taken from (Egger et al. 2000).

The wind patterns could also be experienced during the field visits. It was observed that the strong winds during the day are not only rather inconvenient for any outdoor activity, but is clearly also leading to considerable soil losses.

Future wind patterns

As described in section 3.3.2, the temperatures are expected to rise considerably. However the general as well as the diurnal warming is not constant in space. Namely, it is expected that Tibet is subject to more pronounced warming than India. Furthermore, due to the immensely higher air pollution and therefore reduced irradiation in India, the diurnal warming is reduced (L. Zgraggen 2012, pers. com.). As the heat low over the Tibetan plateau is seen to enhance the strength of the valley wind (Zängl, Egger, and Wirth 2001), the increasing pressure gradients between India and Tibet are expected to lead to even more extreme upvalley winds in Kali Gandaki valley.

As a consequence of the increasing winds, more dust and particles are transported and ultimately deposited (confirmed by B. Neininger 2012, pers. com.). Deposition on snow and glacier surfaces lead to a decrease of albedo and therefore to enhanced melt rates. This has major implications for future water availability, since the latter seems heavily dependent on snow and ice melt (section 3.3.4 and 3.4.2).

3.3.4 Precipitation

Generally speaking, precipitation falls as snow at high level and at temperatures below zero degrees Celsius. The snowline (elevation above which it is snowing and below which it is raining) is varying permanently between seasons. In central Nepal the snowline can be as low as 2'000 m asl. In summer, during monsoon, the snowline can reach even 6'000 m asl.

Precipitation as snow is difficult to measure at the ground. In Mustang, there is no ground data available. The snow cover in Mustang shows a small trend towards a declining snow coverage (Gurung et al. 2011), but it is not significant, due to the short period of survey based on satellite imagery from 2002 to 2010 and the strong variability between one year to another.

However, it is likely that snow cover has become less during recent winters in the northeast of Upper Mustang, where the watersheds of Samzong, Yara and Dheye are located, generally producing less melt water.

Ground and satellite-based measurements and estimations are available for precipitation in general. This data allows indicating average precipitation rates as well as identifying past and future trends, as will be discussed in the following.

Average precipitation
Rohrer (2012a) states:

> *"The valley floor of the northern part of Mustang (Ghami, Lo-Manthang) is characterized by mean yearly precipitation sums of about 200 mm and less and has therefore a desert type of landscape. These yearly precipitation sums are the lowest in Nepal. (…) There have been precipitation measurements (and some air temperature measurements) since the early 1970ies, but there are some measurement gaps in the time series. Quality and especially homogeneity of the measurements is unknown - by the time being."*

The precipitation stations in Upper Mustang (Ghami, Lo-Manthang) are particularly unreliable (S. Miehe 2012, pers. com.). Additionally, this circumstance is underlined by the number of complete/incomplete years of the corresponding records. Therefore, the absolute precipitation sums as presented in Practical Action (2009) and listed in Table 3.4 have to be interpreted with care.

Albeit the uncertainty concerning the data's representativeness, a strong negative south-north precipitation gradient is exemplified (Table 3.4). This circumstance is further highlighted by Lumle, the station run by the Department of Hydrology and Meteorology (DHM) with the highest recorded average precipitation with a yearly value of 5403 mm (Practical Action, 2009). This station is situated only around 100 km south of Lo-Manthang with clearly one of the lowest recorded values. Furthermore, the data listed in Table 3.4 show that the yearly mean precipitation in Upper Mustang with a value ranging around 200 mm is extremely low.

For agricultural activities this exemplifies the predominant need for water sources other than direct precipitation.

Table 3.4: Average yearly precipitation rates for different stations in Mustang taken from Practical Action (2009).

Station	Station altitude[a] (m asl)	Direct distance[b] (km)	Yearly precipitation sums[a] (mm)	Available record periods[c]	Years of complete/ incomplete records[c]
Lete	2'384	0	1'308	1969-2005	33 / 4
Marpha	2'566	16	402	1967-2005	33 / 6
Jomsom	2'744	20	246	1972-2005	28 / 6
Ghami	3'465	54	174	1973-2005	25 / 8
Lo-Manthang	3'705	71	144	1974-2005	21 / 11

[a] Practical Action (2009).

[b] Direct distance to Lete measured with Google Earth. The different stations are in-line with the general north-south direction of Mustang valley.

[c] Taken from the data availability list published on http://www.dhm.gov.np/download, accessed 05/06/2012.

To have an idea about local precipitation sums at village level and have independent measurements, a few accumulative rain gauges (simply graduated cylinders) were installed during the first field visit dispersed in the three studied villages. During the second visit the gauges were examined. All instruments demonstrated that it had not rained in May and June 2012. Only a few water bubbles within the applied oil layer to prevent evaporation could be seen. These may have been caused by some very light showers. In each village, somebody was assigned to read and record the gauges at the end of the monsoon season, in beginning of October 2012 (Table 3.5).

Table 3.5: Measured local precipitation sums in Samzong, Yara and Dheye between the beginning of July and the beginning of October, representing the monsoon season 2012.

Station	Station altitudes[a] (m asl)	Direct distance[b] (km)	Gauge ID	Precipitation sum (mm)
Samzong	4'000	20	RS1	146
			RS3	60
Yara	3'600	6	RY1	86
			RY2	104
			RY3	86
Dheye	3'900	0	RD2	92
			RD3	95

[a] approximated with hand-held GPS device during the field visits.

[b] Direct distance to Dheye measured with Google Earth. The three villages are in-line with the general north-south direction of Mustang valley (Figure 1.2 in section 1.5).

In Samzong the reported values differ by more than twofold. The discrepancy might partially be due to the placement of the gauge RS3 on an insufficiently open roof. Furthermore, important differences can be explained by the irregularity of convective precipitation events. In Yara one reading is larger than the other two, while in Dheye, the readings are matching nicely.

In any case, the generally extremely low precipitation rates in Upper Mustang are illustrated. Related to agricultural activities this exemplifies the predominant need for water sources other than direct precipitation.

Actual trends of precipitation

The analysis of the data records[7] of the meteorological stations Jomsom and Marpha, both situated slightly south of Upper Mustang, by Rohrer (2012a) show “no precipitation trend (…) between 1970 and 2010.” Further, “at the entrance of Mustang valley and the southern side of Annapurna the precipitation amounts could be characterized by a positive trend, but also this has to be confirmed by a longer investigation” (Rohrer 2012b). The corresponding graphs are reprinted in Figure 10.10 and Figure 10.11 in appendix B.4.

Another way to investigate actual precipitation trends is to use satellite based estimations. Namely, with the help of a satellite called Tropical Rainfall Measuring Mission (TRMM), launched by the American space agency NASA and the Japanese JAXA, can be used for such tasks. For the analysis of precipitation trends in Upper Mustang a product named TRMM Multisatellite Precipitation Analysis (TMPA), version 6, available from 1998 to 2010 has been used by Rohrer (2012a), whose results are presented and discussed in the following:

In comparison to the ground data listed in Table 3.4, the TRMM product shows considerably higher values (Rohrer 2012a). This can be due to different reasons: Either, the values by the satellite produce truly overestimate the precipitation, the ground data could be underestimated due to the unreliable measurements or there could be a large gradient between the valley floor and the mountain slopes (Rohrer 2012a). The latter is rather plausible, as it is congruent with observations done during the field visits.

Most importantly however, the TRMM analysis indicates considerable year-to-year variations of precipitation volume (Rohrer 2012a). Further, the onset of the monsoon season is subject to very high variations as well (Rohrer 2012a). Both issues are making the climatic conditions less predictable, which has major implications for agricultural activities and the associated food security of villages like Samzong (section 3.4.4)

Future trends of precipitation

Precipitation trends are difficult to evaluate. For the whole Himalaya region climatological models do not show significant tendencies, but are suggesting slightly drier winters and slightly moister summers (IPCC 2007a). This seems to be a general worldwide trend, stating:

[7] Data recorded and provided by the DHM

"wet gets wetter, dry gets drier" (Stocker 2010). Generally, the precipitation, as well as the onset and end of the monsoon, are expected to be more variable.

However, the GCMs show a moderate increase of convective precipitation as well as a delay of the onset of monsoon by roughly 5 to 10 days in Mustang towards the end of the 21st century (Ashfaq et al. 2009 cited in Rohrer 2012a).

The moderate increase of convective precipitation is expected to be attended by a general increase of precipitation intensity. Besides, it has to be noted that the predicted shift of the monsoon's future start, is represented by an average value. The before mentioned highly varying onset of the monsoon season is expected to occur in the future as well.

In terms of future precipitation sums in Mustang based on different GCMs' predictions, Rohrer (2012b) states:

> *"Whereas in January the differences to the reference period (1961-1990) for the Mustang region is expected to be small in all models, the differences in July between models is very large."*

Furthermore, Rohrer (2012b) concludes:

> *"(…) a possible statement could be: no dramatic change in monsoon precipitation up to the end of the present century."*

However, even if the precipitation sums are not changing significantly in the future, the implications, particularly related to the snow cover, are severe. Assuming a constant future precipitation amount, the snow cover is going to become less and less substantial, because of the following reasons:

- Overall rising elevation of the snowline due to increased temperatures
- Faster disappearing snow cower due to warmer weather conditions
- Possibly more dust deposition, leading to decreased albedo and therefore a quicker melting process

3.4 Water resources

In the following sections the water demand, availability, management, related problems and challenges of the water resources in and around Samzong are summarized. Further details are reported in Bernet (2012).

3.4.1 Water demand

The assessment of the actual water demand is not a simple task. Thus, a detailed analysis of the demand was forgone in this study. Instead, some simple calculations are made to demonstrate the expected range of water demand particularly differentiating the demand for irrigation and for domestic uses.

The upper value of daily drinking water demand stated by Wacker and Fröhlich (1997) is rather high, as it includes the demand for washing clothes as well (Table 3.6). It is local practice however, to wash the clothes in the irrigation channels, so that no additional water is used for this purpose. The drinking water demand covers domestic activities such as cooking, drinking, personal hygiene etc.

Table 3.6: Estimate of the domestic water demand adapted from Wacker and Fröhlich (1997). Note that the calculation refer to the demand of the user not taking any losses into account.

Description	Value range
Total inhabitants (excl. permanent migrants)	$P_p = 61$
Daily drinking water demand per capita[a] (l/p/d)	$d_d = 15 – 40$
Daily drinking water demand (l/d)	$D_d = d_d \cdot P_p = 915 – 2'440$
Required water flow during 24 hours a day (l/s)	$Q_d = D_d/(24 \cdot 3'600) = 0.011 – 0.028$

[a] Taken from Wacker and Fröhlich (1997)

For the irrigation water demand (Table 3.7), the corresponding water flow during 12 and 24 hours respectively is differentiated, since it is quite common to have storage facilities to allow retaining the perennial flow of the rivers during the night as well.

Table 3.7: Estimate of the water demand for agricultural activities adapted from Wacker and Fröhlich (1997). Note that the calculation refer to the demand at the field level not taking any losses into account.

Description	Value
Total population (incl. permanent migrants)	$P_t = 83$
Cultivation area per person[a] (m^2/p)	$a = 1'000$
Required cultivation area (m^2)	$A = a \cdot P_t = 83'000$
Daily irrigation area based on a 17 days cycle (m^2)	$A_i = A/17 = 4'882$
Irrigation intensity[a] ($mm/m^2 = l/m^2$)	$d_i = 45$
Required water flow during 24 hours a day (l/s)	$Q_i = d_i \cdot A_i/(24 \cdot 3'600) = 2.5$
Required water flow during 12 hours a day (l/s)	$Q_i = d_i \cdot A_i/(12 \cdot 3'600) = 5.1$

[a] taken from Wacker and Fröhlich (1997)

The comparison between the domestic and the agricultural water demand (Table 3.6 and Table 3.7) shows that the required water demand differs by a factor of more than 100. This exemplifies that inappropriate water supply results much less in insufficient drinking water, but much more in insecure food production.

In general, the total water demand is subject to evolution during a whole year, whereas the irrigation water demand is mostly determining the total demand's dynamics, since the drinking water demand is staying almost constant throughout the year. The demand for irrigation water is directly linked to the growing season lasting roughly from April to September. During the largest part of the non-growing period, the demand is negligible. Only for field preparation prior to seeding as well as after the harvest, water is required on the fields.

It is important to note, that neither losses nor reserves are considered in the preceding estimations. The obtained values should therefore not be compared directly to the measured amount of released water (section 3.4.4). The estimates merely give an idea of how much water is needed at the user end for domestic and agricultural purposes respectively.

3.4.2 Water sources

The draining area of Samzong measures 38 km^2 (Figure 5.11 in section 5.3.1). The lowest point of this catchment is at an elevation of 3950 m asl and reaches to a height of 5190 m asl. The headwaters are not glaciated so that the perennial flow of the river is strongly linked to the precipitation during the monsoon season and especially to the snowfall during winter.

The headwaters of Samzong Khola splits in several branches each contributing to the surface water flow with differing degrees. The river is fed by several springs, whose yields decrease towards the end of the dry season or even fall completely dry. The surface flow within the branches disappears at numerous places within the riverbed to resurface later on again.

3.4.3 Water regime

The closest river gauging station to Samzong is located in Jomsom about 60 km southwest measuring Kali Gandaki's discharge. At this point the Kali Gandaki has been joined by numerous glacier-fed catchments. The correlation between the Kali Gandaki and the Samzong Khola is therefore expected to be very small. In addition, the available data are not very reliable according to the DHM, which is collecting and selling the data. Therefore the analysis concerning the water regime is mostly based on observations on site and their interpretations.

Monsoon precipitations lead to high discharges which can likely reach the 200-fold of the lowest flows. In general the soil has a rather low permeability. The heavy rainfalls during summer are therefore expected to being mostly discharged as surface water. However, the rainfall recharges the groundwater storage to a certain degree which is probably contributing to the perennial flow of the Samzong Khola especially during monsoon and post-monsoon. The effect of recharged groundwater during the monsoon on the surface flow in spring remains unclear.

The discharge in the Samzong Khola is most crucial during the pre-monsoon season during which the agricultural activities of the people demand an appropriate surface water supply. The surface flow of the river is believed to be heavily dependent on melting snow in the spring and therefore from the amount of snowfall during the winter. The stored water in form of snow is consecutively melted thereafter and slowly released. Once all the snow is melted in the catchment, the surface flow is fed solely by the present springs and thus by groundwater resources. In what way the groundwater is recharged by the meltwater and or monsoon precipitation is not clear however.

3.4.4 Water supply

Drinking water and irrigation water are supplied by distinctively different systems. In the following sections, the two systems are described and the associated problems and challenges are mentioned.

Drinking water supply

The drinking water is abstracted around 4 km northeast of and roughly 400 m above the village. The water of a small spring is captured by a concrete intake structure and collected within a chamber. From there the water is brought to the village in a PVC pipe with a small diameter. The pipe is routed above the left bank of the Samzong Khola. The pipe crosses the river next to the village and is connected to two fountains which provide a constant flow of drinking water.

The people fill their so-called toms (35 and 5 l canisters respectively) at the fountain and bring them to their houses to satisfy their domestic water demand. By means of a survey, the demand was estimated with 14 l/d per capita (Bernet 2012) or 870 l/d, which corresponds to the lower limit of the estimated water demand (section 3.4.1). The water is mostly used for cooking, drinking and personal hygiene. Additionally some cows are given drinking water as well. The vast amount of livestock is lead to the river to drink. For washing clothes not the drinking water is used, but they are cleaned directly in the open parts of the irrigation channels. In any case, only a small part of the provided constant flow of drinking water is actually used consumptively by the villagers. Therefore the drinking water supply is sufficient, which is also perceived in this way by the people of Samzong.

Irrigation supply systems

Due to the very low precipitation rates in terms of total amount, but also in terms of timing (section 3.3.4), agricultural activities are almost solely dependent on the surface flow of the Samzong Khola and particularly on how much can be captured. In Samzong there are presently two different irrigation systems bringing the water from the river to the fields.

The two different systems are shown in Figure 3.14 indicating different sections of the system, which are described in Table 3.8. A detailed description of the systems are also reported in (Bernet 2012).

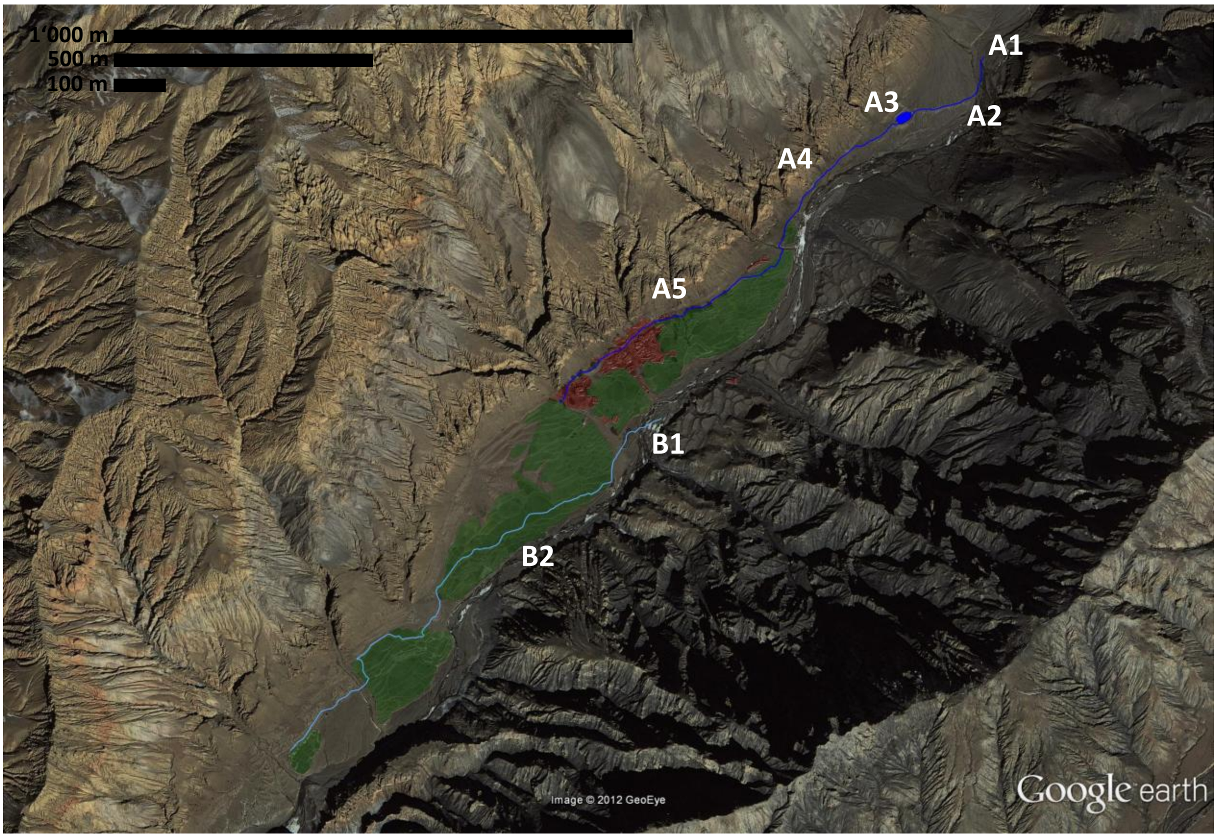

Figure 3.14: Google earth view of Samzong and its surroundings indicating the two irrigation systems (A and B). The red colored areas highlight Samzong village, the green colored area the agricultural area. The number codes correspond to different sections of the irrigation systems further described in Table 3.8. North direction is ↑ (source: Google Earth Pro, accessed 27/11/2012).

Irrigation scheme

Early each season the families draw a number by lot determining the order of the family's turn to use the irrigation systems for one day. Since all HHs own fields, one whole round is taking 17 days. On the 18th day the irrigation system is again at the first family's disposition.

Since the irrigation systems are usually damaged during the monsoon, the fields cannot be irrigated before winter. By mid-April, the irrigation supply is usually restored so that the irrigation process can be started. After irrigating the fields, they are plowed and sown related to the order drawn by lot. After sowing, the fields are left for 35 days. This means that there is a pause during which no fields are irrigated. During this time the water is brought to the trees planted in the village used for construction for instance. Afterwards the fields are irrigated without any pause. The frequency by which a certain field is irrigated depends on the available water and the farmers' choice which of their fields should get irrigated at which time during the family's turn.

Table 3.8: Summarized description of the two different irrigation systems (A and B) in Samzong. The corresponding sections of each system are indicated in Figure 3.14.

Section	Unit	Length / Volume	Description	Main issues
A1	Water abstraction		Handmade construction, made of locally available rocks, mud and earth to abstract the water	➢ Damaged and/or destroyed during high flows of Samzong Khola ➢ Reconstruction frequently necessary ➢ Bigger floods erode right riverbank making channel reactivation more difficult
A2	Reservoir supply channel	195 m	Hand-dug, open, earthen channel connecting water abstraction with the reservoir, major gully crossed by pipe-bridge	➢ Channel crosses gullies of different sizes which are subject to debris flow, leading to spillage and erosion ➢ Reconstruction frequently necessary ➢ Hand-dug channel subject to constant losses due to seepage
A3	Reservoir	450 m^3	Reservoir with sidewalls formed by piled up rock, mud and earth, cemented outlet which can be opened and closed by inserting an appropriate wooden stick	➢ Endangered by debris flow, deflected by earth dams ➢ Excavation of accumulated particles necessary each year ➢ Subject to constant losses due to seepage ➢ Supplies about half of the total agricultural area ➢ Under observed conditions, more than 200 m^3 released in a working day (approximately 9 hours)
A4	Transport channel	290 m	PVC-pipeline with 18 cm inner diameter routed on top of Samzong Khola's right riverbank	➢ Endangered by debris flow leading to erosion downhill of the pipe ➢ Riverbank erosion by Samzong Khola endanger bank stability ➢ Leaking pipes wash out and erode the soil downhill ➢ Leaks are difficult to seal without proper materials and tools
A5	Distribution channel	640 m	Hand-dug, open, earthen channel including minor piped sections (PVC, 18 cm ID) connected to field-level distribution via removable mud/earth closings	➢ Endangered by debris flow leading to erosion downhill of the pipe ➢ Spilled channels have to be maintained regularly ➢ Openings in the channel's sidewall to distribute water on field level cannot be closed properly leading to local losses ➢ Hand-dug channel subject to constant losses due to seepage
B1	Water abstraction		Handmade collection chamber made of locally available rocks, mud and earth connected to a roughly 40 m long PVC-pipeline supported by piled rock piers to abstract the water and lift it to the relatively elevated field area	➢ Damaged and/or destroyed during high flows of Samzong Khola ➢ Collection chamber subject to constant losses ➢ Leaking pipeline due to inappropriate pipe connections ➢ Inefficient pipeline due relatively high river bank and low overall slope ➢ Reconstruction frequently necessary ➢ Large boulders required for collection chamber and support piers difficult to find in the area ➢ Reconstruction of abstraction very laborious
B2	Distribution channel	1130 m	Hand-dug, open, earthen channel, in the middle section elevated against surrounding fields, connected to field-level distribution via removable mud/earth closings	➢ Openings in the channel's sidewall to distribute water on field level cannot be closed properly leading to local losses ➢ Hand-dug channel subject to constant losses due to seepage ➢ Elevated section difficult to maintain

Released water for irrigation

The quantification of the water used for irrigation is not simple. It is seasonally, diurnally as well as spatially variable. Nevertheless the abstracted water was measured with very basic methods during the field visits (Bernet 2012). As a reference, the measurements during the second field visit were chosen. In addition the cultivated area[8] was measured and put into relation (Table 3.9).

Table 3.9: Indicators describing the water availability for agricultural activities in Samzong. The values refer to the measured water abstraction rate during the second field visit in the end of June 2012. They do not take any losses of the distribution system into account and are therefore not effective but potential values. Note that the values are based on very rough estimates, are therefore associated with large uncertainties and have an indicative nature only.

Description	Value
Number of HHs owning fields	17
Total cultivated area (ha)	9.1
Average cultivated area per HH (ha/HH)	0.53
Total abstracted water (m^3/d)	1'322
Abstracted, useable water[a] (m^3/d)	787
Usable water per total cultivated area (l/m^2/d = mm/d)	8.7
Approximated irrigation depth[b] (mm/HH/d)	147

[a] Since the lower abstraction is unbuffered, only the water which is put to productive use, namely brought to the fields during working hours (i.e. 10 h), is considered as useable water.

[b] The total useable water is divided by the average cultivated area per household. The result is a hypothetical value, indicating how much water could be brought to the fields owned by each HH on average in one day, in case the abstracted water could be transported lossless.

Table 3.9 exemplifies that the abstracted water would be sufficient to supply the whole cultivated area with 9 mm of water each day, provided a lossless distribution system. During a HH's turn, the corresponding average field area could be supplied with roughly 150 mm. As a whole turn takes 17 days, each field could potentially be irrigated with 150 mm every 18 days. Compared to the postulated demand of 45 mm each 18 days (section 3.4.1), the supply is much higher. Likely, this can mostly be attributed to the fact that the irrigation systems are subject to very large losses. The losses differ spatially and temporally and could not be quantified in the scope of this project. Furthermore the regularity of irrigation may vary, since the systems are prone to failure due to spillage, erosion etc. and are time- as well as labor-intensive to maintain as described in the following section.

Main issues related to the irrigation systems

From a water availability and management point of view, the difficulty is that the resources are fully allocated during most times. The river flow of Samzong Khola therefore determines

[8] Cultivated area, defined as fields being visibly irrigated, opposed to areas under different use, such as using them in rotation or manufacturing bricks from their soil.

the amount of water which can potentially be used by the villagers not presenting any unallocated resources acting as a buffer or security during dry years.

As mentioned in section 3.3.4, the monsoon may vary increasingly in terms of year-to-year precipitation sums as well as the date it starts and ends in the future. This unpredictable climatic behavior is particularly severe for agricultural activities in Samzong, as the fully allocated water resources do not allow for any reserves in such cases. Thus, the vulnerability of insufficient water supply is large in relation with present and future changes in the river's surface flow.

As the water availability is limited and is smaller than the water demand for irrigation purposes at times, the efficiency of the irrigation systems is an issue. The distribution systems are subject to constant losses such as seepage and evaporation, and local losses such as leakages.

The drains of many gorges which collect and concentrate rainfall mainly during monsoon period cross the irrigation systems and frequently damage the installations, be it by eroding the soil downhill of the pipes and canal or by spilling the open channels. The necessary repair work, as well as overall maintenance of the irrigation system, is laborious and a tedious task.

In particular the section of the upper irrigation system between the reservoir and the village (A4, Table 3.8 and Figure 3.14) is prone to failure. Many spots are heavily damaged and the stability is severely endangered (Figure 3.15). It is expected, that the illustrated section will fail soon making repair very difficult.

The non-durability of the two water abstractions poses a challenge to the inhabitants of Samzong. The yearly high flows of Samzong Khola during monsoon period frequently damage or even destroy the abstractions. Damages to the lower abstraction are particularly severe, since the required boulders and rocks are hard to find to rebuild the piers for the PVC pipeline. Additionally, the corresponding fields cannot be irrigated as long as the abstractions or the damages of the following distribution systems are not reactivated independent of the available water resources.

Figure 3.15: View of the piped water distribution line between the reservoir and the village (green arrows, see also section A4 in Figure 3.14 and Table 3.8 respectively) on top of the Samzong Khola's (blue arrow) right riverbank. Particularly the illustrated section (A4) is endangered by different erosion processes. Water draining through gorges uphill is crossing the irrigation system which leads to erosion downhill. Also, numerous leaks in the pipes are washing out soil (yellow arrow) to an extent that the pipes are hanging loosely in the air at several places (red arrow). Finally, during high flow the right river bank is eroded further due to the river's bend decreasing the stability from below. The blue arrow indicates the flow direction of the Samzong Khola (photo: 06/05/2012, Daniel Bernet).

3.5 Geological conditions

In the following sections the geological setting, all related investigations and their results are summarized.

3.5.1 Geologic hazard setting

Layers of sedimentary rocks outcrop on the slopes above Samzong (Figure 3.16) belonging to The Tibetan-Tethys zone. The zone consists of a thick and nearly continuous lower Paleozoic to Paleocene marine succession and was deposited on the northern passive continental margin of the Indian Plate (B. R. Adhikari and Wagreich 2011; Godin 2003). These rocks consist of grey limestone, marls and shale with layers dipping toward northwest. Conglomerates belonging to the Pliocene-Pleistocene Thakkhola formation (B. R. Adhikari and Wagreich 2011; Colchen 1999) cover the sedimentary sequence and outcrop in the lower part of the slope forming a steep continuous cliff behind the village. These cliffs of about 50 m height are deeply incised by riverbeds forming small canyons. Conglomerates are eroded by mechanical and physical atmospheric processes such as hot-cool and dry-wet cycles. The resulting deposits consisting of sand and gravel form a 30° slope talus at the base of the cliffs that is subjected to gully erosion and small rockfalls. However, the houses are not affected by the latter.

Debris flow phenomena affect 9 canyons in and around Samzong. The debris deposits form small alluvial fans at the base of these gorges (Figure 3.17). The village itself is built on the debris flow deposits of past events. Alluvial deposits from the main river are present at the main valley bottom. Evidence of an actual erosive phase of the main river is the presence of many alluvial terraces along the river.

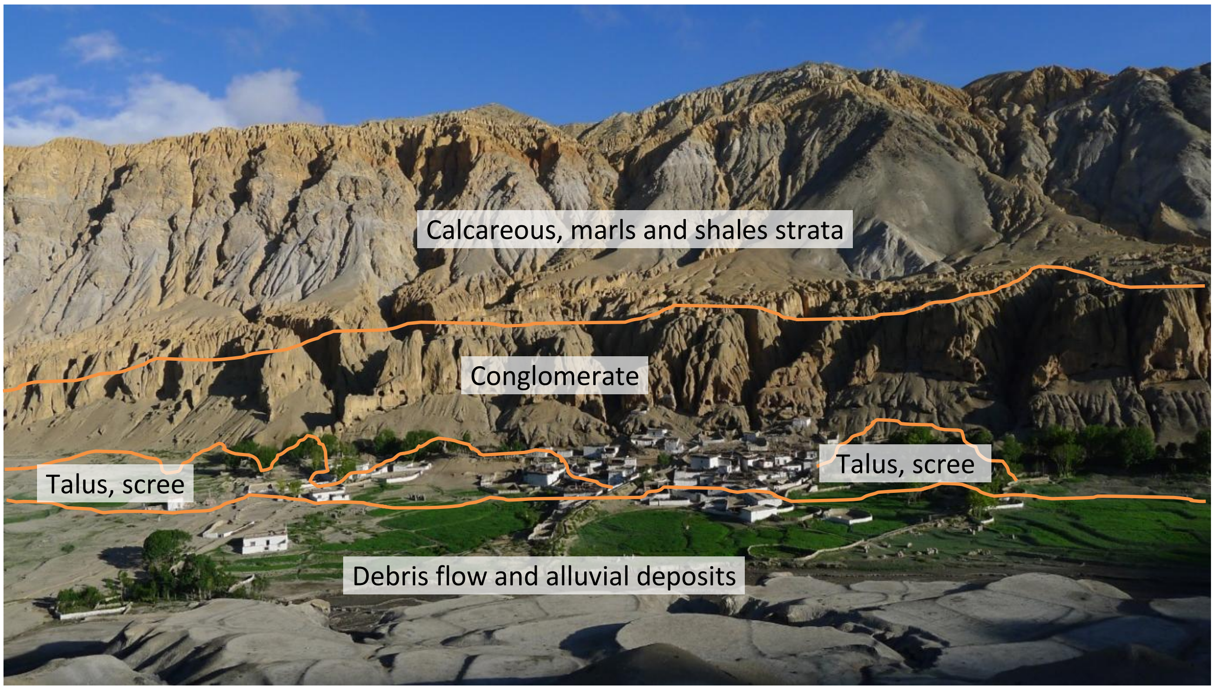

Figure 3.16: Samzong village and geological setting (photo: Daniel Pittet 28/06/2012).

Based on local sources, debris flow events periodically affect the village and adjacent areas representing a danger for the inhabitants, their property, goods and fields. Over the past 15 years at least three events have been counted. Traces of the last event (in 2011 according to local witnesses) are clearly visible in the southern part of the village where the debris flow deposits cover vast cultivated fields. Other deposits referring to past events are shown in Figure 3.17. For all of these events the magnitude, in terms of maximum deposit volume, was defined based on morphological evidences. These data are crucial to realizing a hazard map for Samzong.

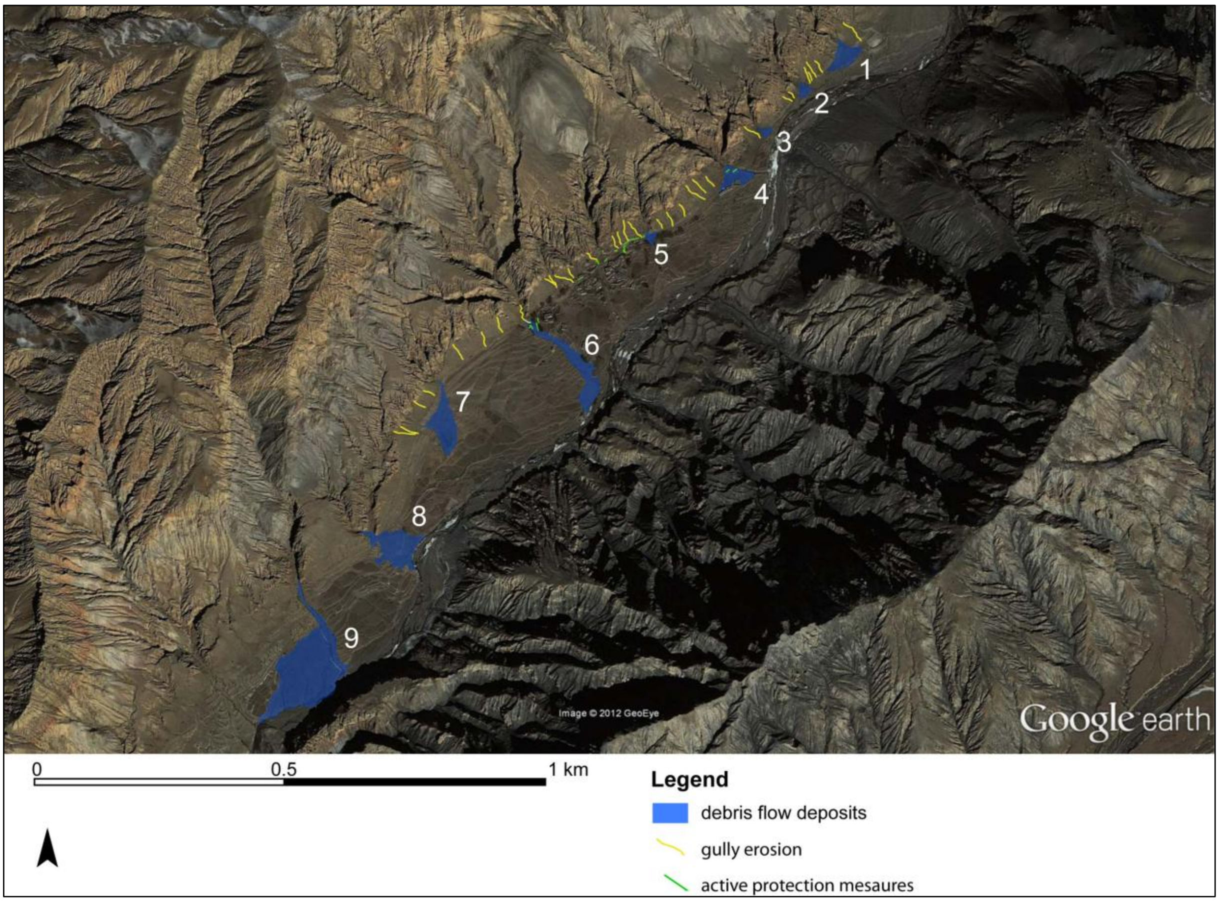

Figure 3.17: Geomorphologic map of Samzong. The numbers indicate the analyzed debris flow deposits (source: Google Earth Pro, accessed 08/08/2012).

The dynamics of such events are the following: Inside the canyons a continuous accumulation of loose material from the cliffs takes place. This material represents the source for the debris flow that is triggered in case of particularly intense rainfall events. The resulting debris material is then deposited at the base of the canyons. It is therefore a continuous process. The return period of these events is closely related to the charging time of the loose material within the canyons and to the return period of intense rainfall events. The former aspect is not easy to estimate because its dynamics depend strongly on weather processes and their seasonal variations. It is interesting to note that some protection measures against debris flow are present in and around the village. These protections are represented by several so called Mani walls each around 10 m long, consisting of dirt stones.

3.5.2 Hazard maps

The map of debris flow prone areas (debris flow hazard map) was elaborated for the village area based on the volume of past events and the morphology of the deposition area. The magnitude was defined as the estimated volume of all debris flow deposits at the base of each considered canyon. All nine debris flow deposits indicated in Figure 3.17 were analyzed.

For each deposition the granulometry, the slope of the fan, the length of the channel on the alluvial fan, the thickness referring to the last event and the deposition area (measured on-site with GPS) was defined (Table 3.10, left). Furthermore, the magnitudes (i.e. the volumes of the deposits) were related to three qualitative catchment sizes (small, medium and large).

Rearranging the collected field data (Table 3.10, right) visualizes, that future debris flow events are expected with extremely variable magnitudes. Hereby the magnitudes are depending on the size of the corresponding catchment size. From small uphill areas modest events with a maximum magnitude of about 100 m^3 are anticipated. From medium catchments debris flows with magnitudes in the order of one thousand, and from large catchments events with several thousand cubic meters are to be expected.

Table 3.10: Magnitude estimation of recognized past debris flow event (left) and relating the catchment size to the magnitude of past events (right). In the cells on the right side the deposition volumes in m^3 corresponding to magnitudes are indicated.

Deposit number (-)	Catchment size (-)	Area of deposition (m^2)	Deposit thickness (m)	Magni-tude (m^3)
1	medium	1907	0.20	381
2	small	475	0.20	95
3	small	297	0.25	74
4	large	1’538	0.80	1’230
5	small	312	0.30	93
6	large	4’196	0.50	2’098
7	medium	3’647	0.30	1’094
8	medium	4’983	0.30	1’495
9	large	1’6512	0.50	8’256

Deposit number \ Catchment size	Small	Medium	Large
1		381	
2	95		
3	74		
4			1’230
5	93		
6			2’098
7		1’094	
8		1’495	
9			8’256

The granulometry of the expected debris flow deposits correspond to gravel with few pebbles which rarely exceed 10 cm in diameter and display a maximum deposition depth of about 80 cm. Serious damages to structures are therefore not expected. Only houses directly adjacent to the channels can be completely destroyed in case of severe flows. In any case, people are at mortal danger especially outside their homes.

Based on the analysis of past debris flow events, the volume of expected occurrences, the morphology of the deposition area and the size of the related catchments, a hazard map of the Samzong village was drawn visualizing all debris flow prone areas. The hazard map is shown in Figure 3.18 and the corresponding data in Table 3.11.

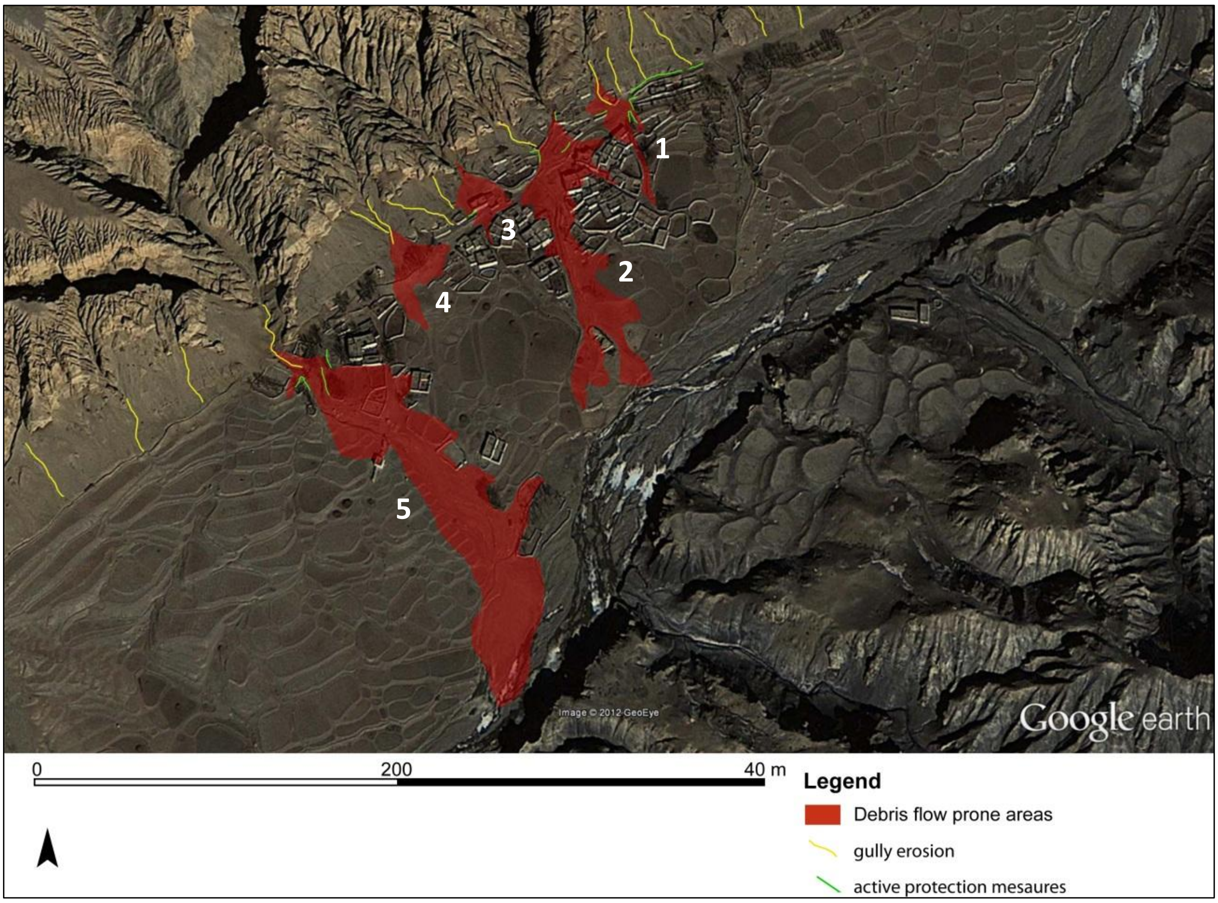

Figure 3.18: Hazard map of Samzong village (source: Google Earth Pro, accessed 08/08/2012).

Table 3.11: Data table of the debris flow prone areas shown in Figure 3.18.

Deposit number (-)	Catchment size (-)	Deposition thickness (m)	Deposition Area (m^2)
1	small	0.2	556
2	medium	0.3	3'407
3	small	0.2	545
4	small	0.2	825
5	large	0.5	7'557

Along with the settlement and the field area, also the irrigation channels are affected by debris flow from the uphill slopes. Furthermore, fluvial erosion and gully erosion endanger the downhill slopes.

3.5.3 Goods at risk

In accordance to the hazard map (Figure 3.18) the following elements could be identified and are at risk related to possible future debris flow events:

- 5 houses
- 4 barns
- 3 stables
- 4 walled courts
- 5'000 m^2 of agricultural area

4 Possible ways of resolving the problems in situ

Clearly, the present overall situation of Samzong is critical, as outlined in the preceding chapter 3. In this chapter strategies and measures are discussed, which aim at ameliorating the current situation of the village, presenting a hypothetical future state, which constitutes the alternative option "Stay" opposed to relocating the whole village.

4.1 Mitigating issues related to housing

As mentioned in section 3.2.4, a possible increase of rainfall intensity during monsoon period might weaken the resistance and waterproofing of the roofs. Serious damages as described by Ardito (2012) are most likely caused by inappropriate maintenance or initial construction details. Therefore, in case it is necessary, a simple and very efficient mitigation measure for improving the resistance of a roof against rainfall consists in increasing the frequency (e.g. after each significant rainfall event) and efficiency (e.g. using material containing more clay) of maintaining the roof surface.

In the unlikely case that the common well maintained roof system proves to be unsuitable under future changes in precipitation patterns, the following constructive measures could be thought of:

- Slight increase of the roof's slope, counteracting stagnant water, while preventing that the used materials are washed away
- Installation of proper gutters ensuring that the water is transported far enough from the walls in order to avoid local erosion of the latter
- Design of channels at ground level for directing the discharged water to the river
- Provision of mobile features installed during the rainy season increasing the water proofing and removed thereafter in order not to hamper with the common use of the roof for drying goods at the sun for the rest of the year

4.2 Water shortage mitigation strategies

As discussed in section 3.3, the expected significant rise of temperatures together with the rather irrelevant change in precipitation volume in the future, will lead to a heavy reduction in snow cover, both spatially and temporally. As the perennial river flow is believed to be fed mainly by snow melt during the dry season (section 3.4.2), it will adversely affect water availability in the future.

4.2.1 Water stress mitigation by supply management

In the following, possible supply management measures aiming at relieving the prevalent water stress in the existing village by augmenting or improving the irrigation supply are summarized.

Allotment of other water sources

As the current water source – the perennial river flow – is expected to be reduced largely in the future, the exploitation of other sources such as groundwater might be envisioned. However, little is known about the potential of tapping groundwater in the given context. In fact, the groundwater abstraction and use is reportedly not practiced in Upper Mustang. Furthermore, with a decline of snow cover, the groundwater resources are expected to decline similarly. To counteract this, methods to augment groundwater resources, such as water retention and infiltration could be thought of. Such methods do not seem suitable for Samzong however, due to the inherent hydro-geological characteristics, such as steep valley sides, frequent debris flow, large sediment transport and erosion during high flow of the Samzong Khola. Nevertheless, groundwater abstraction and use could be an option, but the potential thereof would need to be further investigated.

Loss reduction by constructive measures

As the allotment of other water sources seems difficult, ways to mitigating water shortages should aim at using and in particular also transporting the currently available water more efficiently. These range from reducing constant and local losses of the irrigation systems to installation of additional storage volume for better utilization of the available water. The latter is particularly difficult since the area is not favoring construction of large storage tanks due to the before mentioned hydro-geological characteristics of Samzong Valley. Overall, constructive measures to reducing water losses would have to be planned in detail.

Increasing water efficiency by non-constructional means

A non-constructive intervention to effectively reducing water losses would be to altering the traditional irrigation scheme. Instead of making the irrigation systems available for one family for one day, the total field area could be divided into different zones. Each day a particular zone would be irrigated. In this way the water would be brought to the fields more efficiently since local and constant losses occurring during the process of routing water to fields spread over the whole agricultural area would largely be circumvented. However this would require an adaption of the traditional irrigation scheme which would need to be socially accepted.

Furthermore, an optimization of the water use on a plot level could be envisioned. The plots should receive neither too much nor too little water and if possible in a most suitable interval. Rather than taking the amount of HHs as a base for the irrigation scheme, the way the water is distributed should root in the inherent characteristics of the agricultural area, namely the soil and crop type, as well as growing period and meteorological conditions. In this way, the crops itself would become much more important which would likely result in an increased productivity.

4.2.2 Water stress mitigation by demand management

Demand management aiming at reducing the agricultural water demand by changing the crops, applying other crop patterns etc. might be a possibility but the potential and feasibility thereof could not be evaluated within the scope of this study.

Generally, another possibility would be to switch to different activities, consequently becoming less dependent on agriculture and thus overall reducing the water demand. However this does not seem to be an option for Samzong. The inherent characteristics of the village do not appear to allow a sufficient diversification of economic activities. Namely, all families depend on agriculture for self-sufficiency to a large degree, there is currently no road and no exploitable touristic potential. Though the circumstances might change in the future, since a road is under construction (section 1.5) and potentially tourists might be interested to visit the reported sky caves (section 3.1.3), the induced changes are not expected to be sufficient.

4.3 Geological hazard mitigation strategy

Due to the low accessibility of the source area of the debris flow and due to the limited local availability of construction materials only small local protection measures for the passive[9] protection of the village are feasible. The construction of new walls and reinforcement of existing small stone walls are suggested to divert the flow away from endangered houses. The houses located within the red zones indicated in Figure 3.18 are advised to relocate to a new place outside the danger zones.

Before any protection works could be carried out, a careful geomorphological analysis is necessary in order to prevent, by the construction of protective measures, the transfer of the risk to other areas in the village.

With regard to the irrigation channel it is recommended to protect the river bank against erosion. The installation of gabions appropriately located is recommended. The measure is difficult to implement however since the required rocks of appropriate sizes and quantities are not available on site.

[9] Passive and active protection measures are commonly distinguished. The latter have the purpose of stabilizing the detachment zone itself (e.g. with reinforcements, nets, anchors, drainages etc.), whereas the former functions as interception or diversion of the masses which are already in motion.

5 Considerations for a possible relocation

Along with the assessment of the situation in the existing village Samzong, the circumstances at the new location were studied. For the different aspects and issues, considerations and recommendations are given.

5.1 Taken steps towards relocation

The community of Samzong, with the support of the LMF, has already initiated or completed the following steps towards relocation of the entire village, which are each discussed briefly in the following sections:

- Identification and acquisition of a site for relocating both the settlement and the fields
- Clearing the designated agricultural area from debris and boulders
- Establishment of a system of land property distribution for the relocated village

5.1.1 Identification and acquisition of a relocation site

The acquired site is located on the left bank of the Kali Gandaki, about 8 km southwest of the current village and 4 km northeast of Lo-Manthang in a place named Namashung (Figure 1.2 in section 1.5). On the opposite riverbank the main road going from Lo-Manthang to the Chinese border is situated. There is currently no carriage bridge allowing to cross with vehicles all year long. However, there is a pedestrian bridge, situated about 1 km south, and two others 1 and 2 km north respectively.

Figure 5.1: View of the agricultural area of the relocation site named Namashung. The large deposited boulders were very likely deposited by past Glacier Lake Outburst Flood (GLOF) events (photo: 25/06/2012, Daniel Pittet).

The land foreseen for cultivation has been given to the community by the former King of Lo (section 2.2.1). It has a size of 9.75 ha and consists in a plateau whose western border is confined by the Kali Gandaki. The site is characterized by vast deposits of boulders and debris, which can likely be attributed to past Glacier Lake Outburst Floods (GLOFs) originating from Kali Gandaki's headwaters (Figure 5.1 and section 5.3.2 and 5.5.1).

The land foreseen for the settlement has been provided to the community by the VDC free of charge. It lies about 10 m higher than the field area and is slightly southeast thereof. It has a size of about 0.83 ha and is characterized by a slight southwestern slope (Figure 5.2 and Figure 5.3). Another characteristic of the site is that it is exposed to regular and strong diurnal winds from southwest (Figure 5.2).

As outlined in the geological analysis of the site (section 5.5.2), the site is not subject to any geological risk, except local instabilities along the scarp which delimits the plateau frontally and laterally.

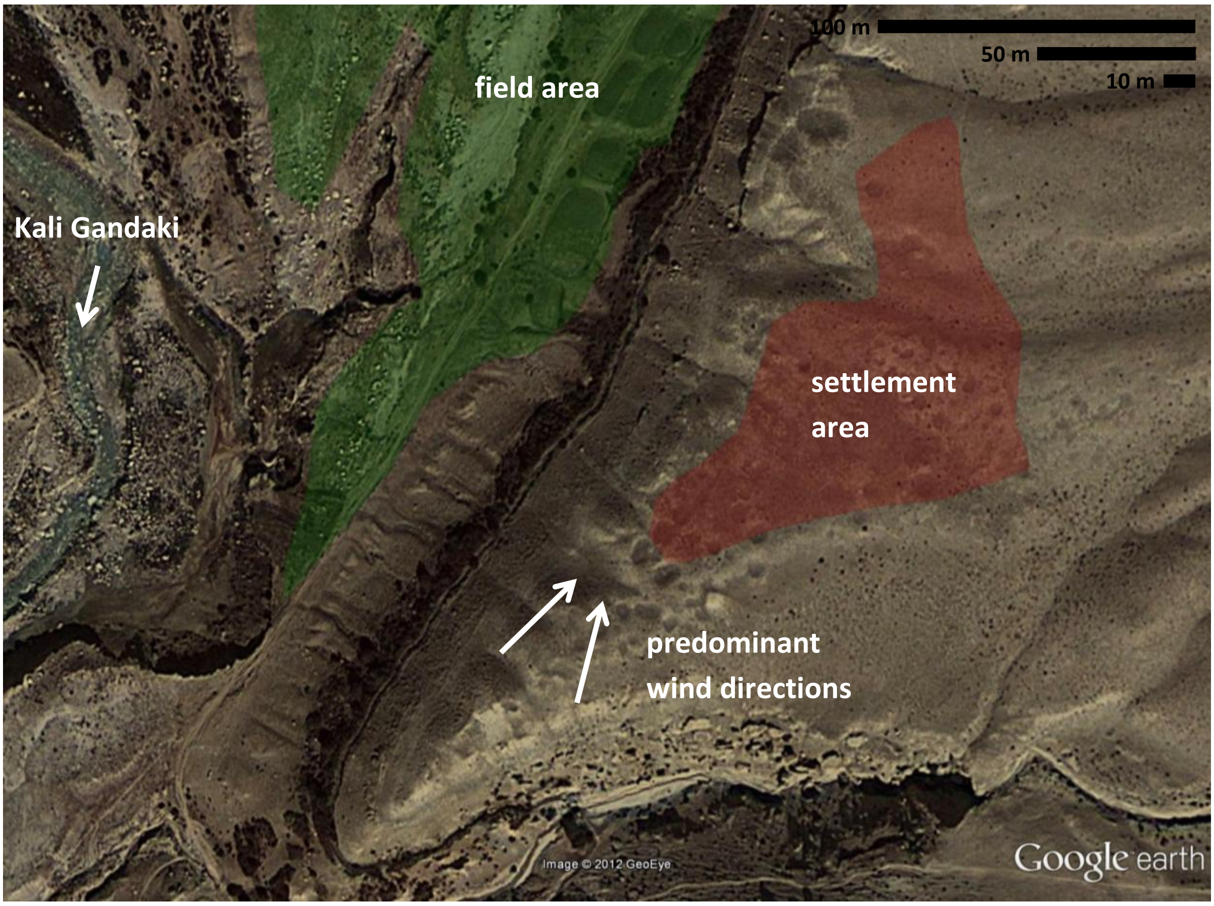

Figure 5.2: Satellite view of Namashung, the land foreseen for the relocation of the settlement of Samzong. North direction is ↑ (source: Google Earth Pro, accessed 27/11/2012).

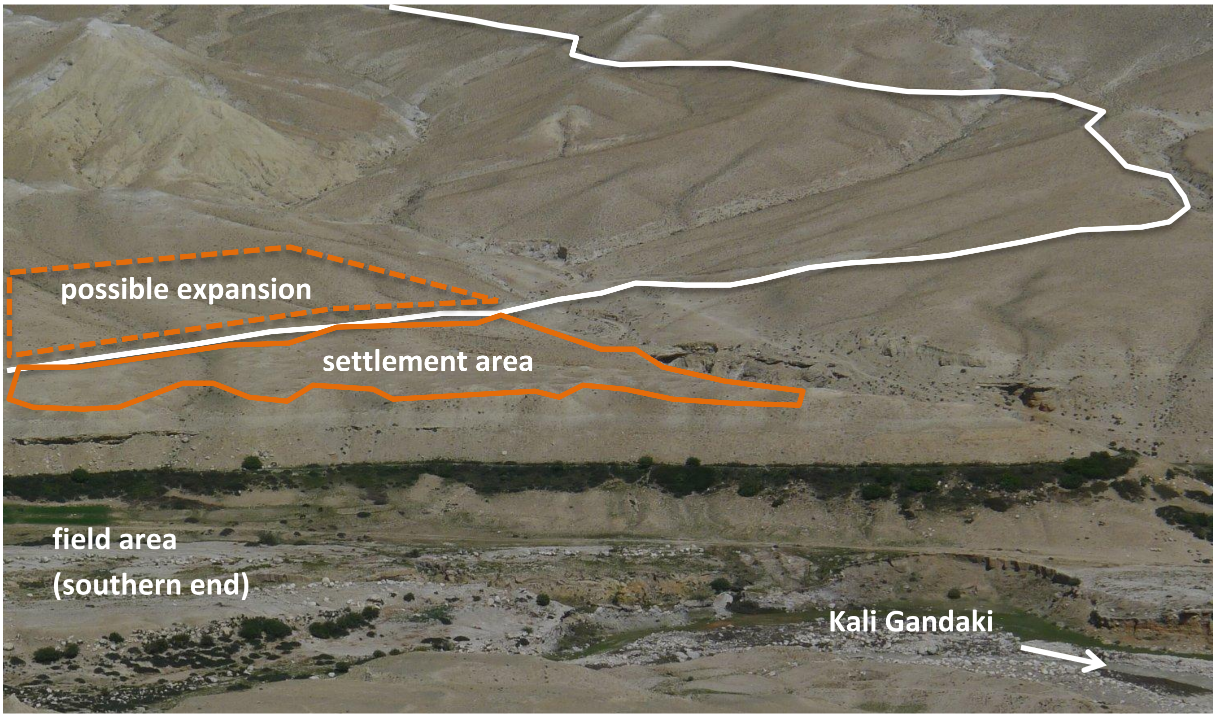

Figure 5.3: Namashung seen from west. In the foreground the Kali Gandaki river and the southern part of the land foreseen for the fields can be seen. The plain orange polygon shows the designated land for the relocation of the settlement of Samzong. The dashed orange form shows the area where possible further expansion of the settlement would be possible. The road under construction going to Samzong is highlighted in white (photo: 26/06/2012, Daniel Pittet).

5.1.2 Clearing the agricultural area from boulders and debris

Manuel Bauer, a Swiss photographer, acting on personal initiative and supported by the LMF, has been able to raise money for the clearing of the site from boulders and debris deposited by previous floods. With some delay the works commenced this summer 2012 and are expected to be finished in 2013.

As described in section 5.5.1, the total volume of deposits in Namashung amount to approximately 40'000 m^3. Given this huge volume it is therefore suggested[10] to remove the bigger blocks only and rehabilitate the gravelly and sandy material. Also the biggest blocks too heavy to be removed easily could be let in place and the fields could be arranged around them. All rocks which can be removed could either be pushed off the scarp to protect the river bank or even be used for building a dam as suggested in section 5.5.3. Apparently, part of the rocks are already planned to be piled up to a so-called Latsey, a traditional Buddhist heap of rocks found on almost every pass in Upper Mustang.

[10] This suggestion has been made during the second field visit to the responsible people of the site clearing.

Figure 5.4: Dozer removing large boulders from the agricultural area in Namashung (photo: fall 2012, Tsewang Gurung).

5.1.3 Organization of new land distribution

The community of Samzong, with the support of the LMF, has agreed on a system of land property distribution for both the agricultural and the settlement plots. The allocation will be made by dividing the available areas into equal surfaces that will be distributed to the HHs through a lottery system. Further private arrangements between the families for different land distribution will be possible. It is expected that the families will negotiate thereafter to take the families' varying workforce, economic strength and needs into account and trade their assigned land accordingly.

5.2 Housing

Based on the analysis of the existing village (section 3.2) and the field investigations concerning the relocation site, settlement and housing concepts, as well as associated costs and general considerations related to settlement and habitat were elaborated and are presented in the following sections.

5.2.1 Layout and spatial organization of the relocated settlement

Inherent characteristics of the settlement area

In terms of space needs and availability, it is interesting to compare the values of the existing village with the new location (Table 5.1). While the cultivation area is in the same range, the population density will significantly increase. This means that the new settlement will need to be developed with a sensitively higher density compared with the current village (100 versus 62 p/ha).

Table 5.1: Settlement and agricultural area related to the population of Samzong and Namashung respectively. The Settlement area was measured with Google Earth Pro, the cultivation area was estimated with GPS measurements on site and the population is based on the socio-economic survey undertaken during the field visits.

Description	Settlement area (ha)	Cultivated area (ha)	Total population 2012 (p)	Population density (p/ha)	Cultivation area per capita (ha/p)
Samzong *Current location*	1.34	9.08	83	62	0.11
Namashung *Relocation site*	0.83	9.75	83	100	0.12

Another issue to be considered for the new settlement is the exposure to strong winds from southwest (section 3.3.3) and the scarp facing the Kali Gandaki which is subject to shallow landslides (section 5.5.2).

Strategy to cope with the characteristics of the site

The necessity to develop a denser settlement can be addressed by constructing more compact houses of two levels (ground and first floor for medium and large houses) and by grouping the houses in order to be able to reach the density imposed by the available site. However, this must be done considering the necessity of further extensions of the single houses. Besides, in case of necessity of further extensions of the settlement area, the selected site offers the possibility of expansion towards northeast, beyond the road which is under construction (Figure 5.3).

A simple and efficient protection measure against local landslides from the scarp consists in maintaining a safety distance of about 12 m between the crest of the scarp and the closest constructions (buildings and infrastructures). The boundaries of the settlements area as shown in Figure 5.2 as well as the total available land area (0.82 ha) are already considering this issue. Therefore the line indicating the boundaries of the settlement corresponds to the constructible area.

The issue of exposure to strong wind has to be considered in the design of the settlement's layout and spatial organization in order to mitigate, as much as possible, the undesirable effects that wind can generate. A strategy is proposed which consists in using the settlement's boundaries (walls of the houses and compounds themselves) as a "wind barrier" in order to protect the open spaces. The concept is illustrated in Figure 5.5 and must respect the following rules (Gut and Ackerknecht 1993):

- Creation of a continuous wind barrier: Even small openings in the barrier placed in locations exposed to strong wind need to be protected in order to avoid local jet effects (very high speed winds created locally because of the creation of openings)

- Construction of a high wind barrier in order to increase the area of the protected zone beyond the barrier (this goes in accordance with the necessity of increasing the density using 2 story buildings for medium and large houses)
- Use of trees for mitigating the impact of wind

Proposed layout and spatial organization of the new settlement

The following proposition is an indication on how the characteristics of the site and the needs of the community in terms of housing could be respected. It is elaborated at the level of conceptual layout and has to be considered as such. That means a detailed implementation design would need to be elaborated by more detailed analysis and planning, also including the participation of the interested community, that goes beyond the scope of the present project. However, the present concept has been elaborated at real scale and the feasibility of the concept in terms of size is effective.

This concept aims at providing a basic structure of the settlement's spatial organization allowing some flexibility in the use of space in order to consider the variations of needs and means of the different HHs.

The principle consists in the supply of standard plots with modular possibilities of using the assigned constructible area. The standard plots of 270 m^2 are composed by 81 m^2 available for the core house, another 81 m^2 for possible house extensions and 108 m^2 of compound area that can be walled and could also be used for erecting livestock sheds. If a house desires an area of more than 81 m^2 then preferably, the surplus area should be provided by adding a second floor on top of the core house. The available ground area for HH expansions should be used only after the second floor on top of the core house has been exploited. In this way as much land as possible is kept for other uses around the houses.

The sizes of the various components (core house footprint, compound area and area available for future extensions) correspond to the maximum areas at ground level. It does not mean that all houses will be of the same size as schematically represented in Figure 5.6. Some families will use only part of the available space for constructing smaller houses whereas others will use the additional space available for building extensions. It should also be possible for a family to buy surplus land for building larger houses. The construction of sheds for livestock is not outlined but such elements can be integrated in the space of the compounds and also by using part of the remaining public space in accordance with the community.

The proposition includes the realization of 17 houses and plots of equal dimensions. Table 5.2 summarizes the corresponding area sizes.

Table 5.2: Areas of the plots, houses, compounds, public amenities, public spaces and the whole settlement.

Description	Area (m^2)
Core house area *Maximum ground level area for core house including walls*	81
Compound area *Compound area including surrounding walls*	108
Extension area *Available ground level area for (future) extension of the core house*	81
Total plot area *Area of each plot (core house, compound and extension area)*	270
Public amenities area *Required area for school and community hall*	168
Total maximum built up area *Area for 17 core houses and public amenities*	2’922
Total ground area *Area for 17 plots including compounds and public amenities*	4’758
Total available area in Namashung for the settlement *Available area not including expansion area beyond the road*	8’200
Remaining free (public) area *Not allocated, remaining free public area in Namashung*	3’442
Percentage of remaining public area *Remaining public area compared to total available area*	41 %

Besides, a school and a community hall are foreseen. They are proposed with slightly bigger dimensions compared to the existing structures of Samzong (16 x 6 m for the school and 12 x 6 m for the community hall) and are composed by only one floor. The solar mill is proposed just on the other side of the track where the space for further expansion of the village is available. Prayer wheels and Chörten are not included in the proposed layout yet, but there are sufficient public spaces inside and outside of the settlement for such amenities.

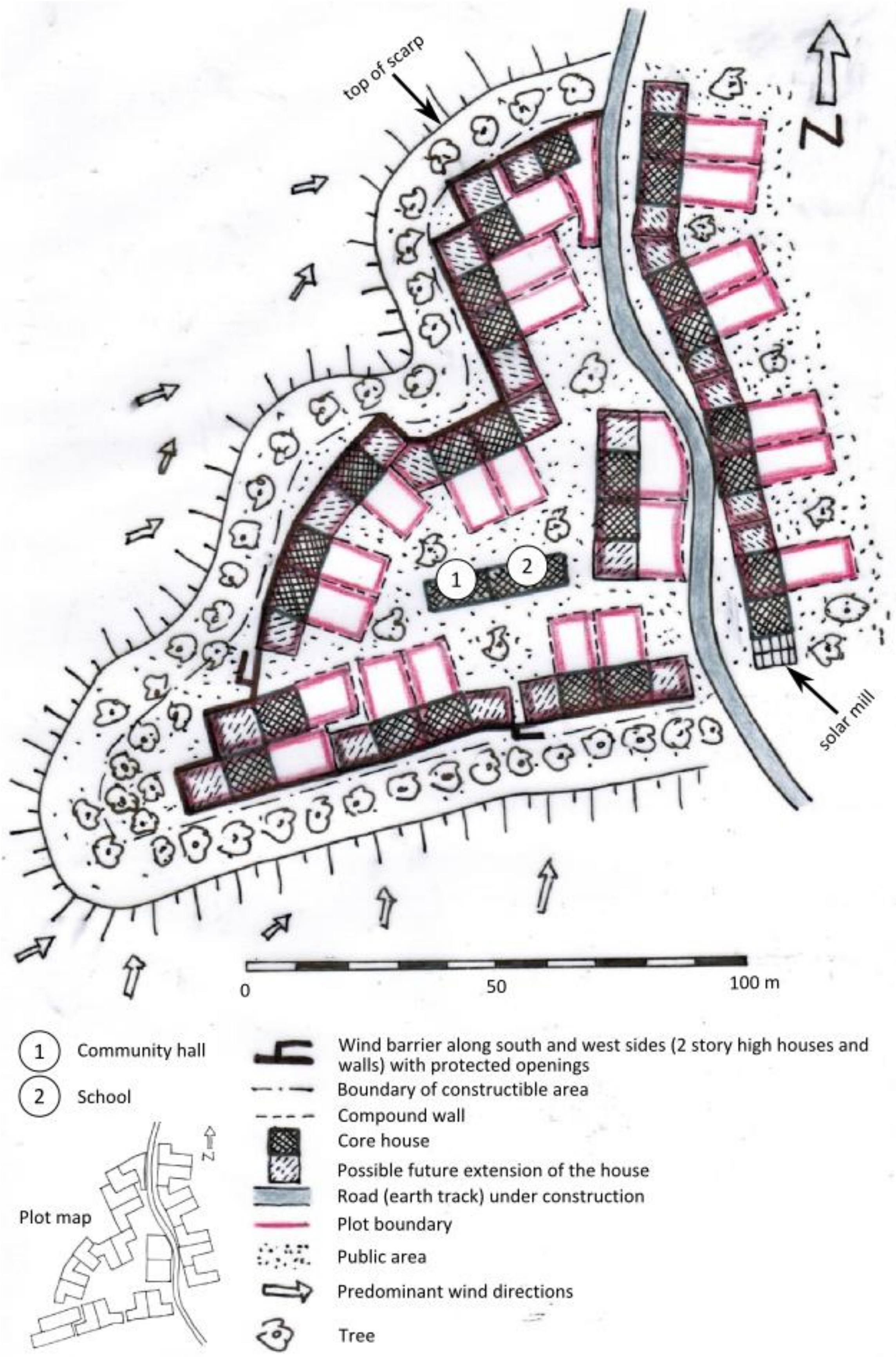

Figure 5.5: Conceptual layout of the relocation in Namashung (hand drawing: 03/09/2012, Daniel Pittet).

5.2.2 Considerations about house design

Local practices and characteristics

In section 3.2 information about the house characteristics and construction practices are presented. In addition, there are some aspects related to housing that the LMF has suggested to consider:

- The entry door should never face north. East or west facing doors are ideal and southward doors possible if necessary
- The houses should accommodate dry toilets (currently very marginally present), ideally placed in the outdoor compounds
- "Double family" house concepts would be appropriate in order to save space and costs
- Improving the house comfort would be appreciated, in particular increasing natural lighting and thermal comfort

Besides, the socio-economic survey conducted in Samzong revealed that, in case of relocation, the people would dismantle their existing houses in order to reuse the wooden elements for constructing new houses in Namashung. This is easily understandable considering the very high cost of construction wood (section 3.2.3). However, it is expected that the recycled wood will not be sufficient for the entire reconstruction, partly because some will not be in good shape anymore (degraded or rotten), partly because the size of the new houses might be larger than the existing ones and also because part of the existing houses will be kept as "Alp sheds" in case of relocation.

Housing strategy and concept

As introduced in the precedent sections, the housing concept should be flexible enough in order to respond to the large diversity of needs and means that the HHs have. Considering also the choice of the community to dividing the available area into plots of the same size for all families, the idea to develop a modular housing solution came up.

The concept has the advantage of being based on an equal plot division (the size of the plots are similar but the shape may vary as depicted in Figure 5.5) without impeaching the realization of houses of different dimensions and design and allowing various possibilities of further expansions, as presented in Figure 5.6.

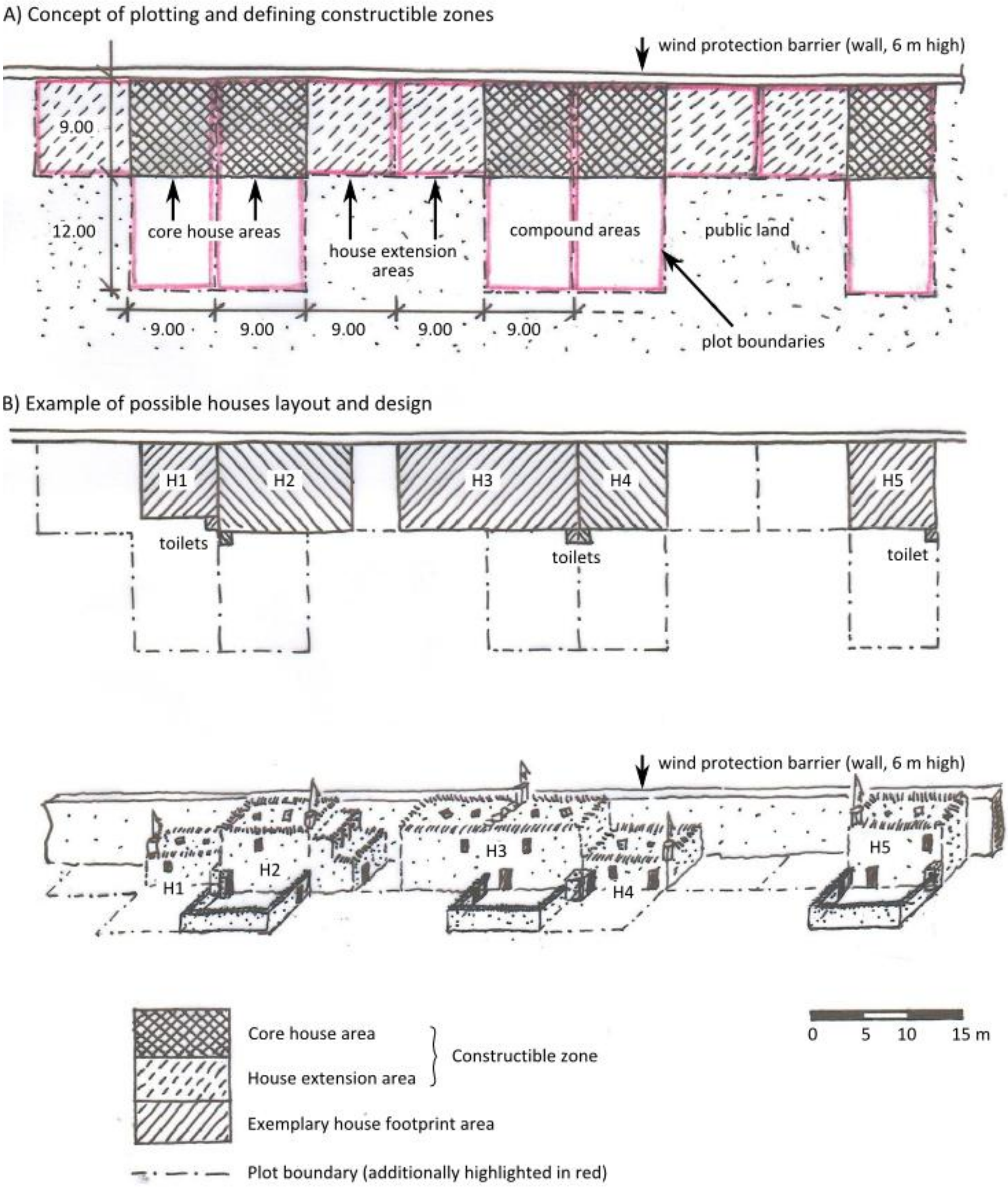

Figure 5.6: Housing concept for the resettlement of Samzong (hand drawing: 04/09/2012, Daniel Pittet).

House design

The detailed design of the houses should be very much inspired by the existing house design (Figure 10.2, Figure 10.3 and Figure 10.4 in appendix A.2) because it is very appropriate in the local context with regards to the following:

- Traditional way of life and culture
- Availability and affordability of building materials (except wood to some extend)
- Capacity of the communities to build and maintain the buildings themselves
- Thermal comfort considering the low technology employed (thick earthen walls are efficient in term of thermal insulation and air humidity regulation)

Besides, the fact that wood, the most costly building material, will be partly recycled from the existing houses implies the use of the same building technique and design which ultimately reduces the cost of construction.

However, the relocation and reconstruction could also be an opportunity to improve some of the characteristics of the traditional houses without modifying the construction systems and design heavily. In particular, as expressed above by the local actors (LMF) and as observed on site, the quantity of natural lighting inside the houses is currently very low. Though this is partly compensated by the availability of small solar lighting systems, a better natural lighting would be very much appreciated, mainly during the cold months in which the doors should remain closed. Enlarging some of the windows and the window of the kitchen, where most of the indoor daily activities take place in particular, could be an option. However, it would have to be done with limited extent: For instance one window of about 0.4 m^2 corresponding to a dimension of 65 x 65 cm (full light surface), instead of the current usual dimension of about 0.1-0.2 m^2 (full light surface) could be thought of. Moreover, the enlargement of this window should be realized using a double-glazing window glass in order to reduce the thermal losses and also to reduce the risk of breakage. Namely, a simple glass window of such dimension is very fragile whereas good quality double glazing windows are much more resistant. However, the availability and affordability of such good quality double glazing windows would need to be verified in the context of Mustang before implementation.

Sensitively improving the thermal comfort of the houses would be rather challenging and costly and would imply a deep transformation of the housing technique and concept such as using passive solar energy concepts for instance. Besides, passive solar energy could also be used to create additional income and improve agricultural self-sufficiency. An example of the application of such techniques in a similar context is the successful implementation of 55 greenhouses in the Lahaul-Spiti District, India, by the social eco-travel agency Ecosphere[11]. The yield of vegetables would complement the agricultural output and surplus production could be traded on local markets. Such initiatives would certainly be interesting to be investigated and experimented at small scale in the framework of a complementary study. In the presented context, it goes beyond the scope of the study at hand.

The detailed design of each house will have to be elaborated and discussed with the HHs separately in order to develop solutions that are as appropriate as possible to the specific

[11] http://www.spitiecosphere.com/conservation_climate_change_2.htm, accessed 12/11/2012

needs of the users and that take advantage of the local context. This task goes beyond the scope of the present project as well.

5.2.3 Costs of relocation related to housing

Costs related to the relocated housings are rather difficult to estimate because they imply many different actors and the related operations include a lot of uncertainties and unknown data. Also many related activities do not have direct costs but consist in workmanship of the community itself. However, a rough estimate of the direct costs linked with the housing relocation processes is presented here. It is based on the experience of the LMF, as well as on the indications given by the community of Samzong. The estimate, summarized in Table 5.3, is considers the (re)construction of 17 core houses of medium size as well as the construction of the wind protection barrier (wall, 6 m high and 340 m long).

Table 5.3: Rough estimate of the costs of relocation considering only the portion related to housing, based on LMF's expertise and indications given by the community of Samzong during the field visits.

Description	Cost estimate in NPR
Dismantling of existing house *Workmanship by the community*	0
Transportation of the recyclable material *Transport from Samzong to Namashung (NPR 15'000/house)*	255'000
Construction of the wind barrier protection wall *Length = 340 m, height = 6 m: NPR 400/m in height and length*	816'000
Supply of complementary quantity of construction wood *Average NPR 500'000/house*	8'500'000
Supply of accessory materials *Windows, nails, lockers etc., NPR 80'000/house*	1'360'000
Workmanship of professional carpenter *1 month @ NPR 700/day = NPR 21'000/house*	357'000
Workmanship for the construction of new houses *Labor by the community itself*	0
Total direct costs *The cost of villagers' workmanships is not included*	11'288'000

5.2.4 Exposure of the settlement to natural hazards

Hydrogeological risks

The selected site for the settlement is not subject to any hydro nor geological risk, as discussed in the section 5.5. Only local landslides along the scarp towards the Kali Gandaki are expected which can easily be avoided by respecting a safety distance of about 12 m from the scarp to the constructible area.

Seismic risks

According to the Nepal seismic hazard map of illustrated Atlas of the Himalaya (Zurick et al. 2006), Mustang District is located in a relatively high-risk seismic zone, though far less exposed compared with the Southern Siwalik foothills regions. It means however that the probability of a seismic event of a certain magnitude could happen in the future.

Consequently, the housing technology and house design including technical details such as connections between the wooden elements of the structure and the walls should be verified by experts before implementation in order to make sure that the structures are able to withstand foreseeable seismic solicitations. The National Society for Earthquake Technology-Nepal (NSET)[12] is certainly a contact to be activated for such expertise.

5.2.5 Energy concept

A possible relocation also offers the possibility to implement a locally adapted, sustainable concept for energy provision, such as using wind or micro-hydropower for instance. In the scope of this study, such a concept is not elaborated however, but the issue may be a point for further investigations.

5.3 Glaciers

Namashung, the designated area for a possible relocation of Samzong, is situated in a glaciated catchment. The glaciers play a major role, not only from a water resource point of view, but also related to present and future exposure to natural hazards. Therefore the present state and future trends in glaciation have to be addressed.

Generally the glaciers in Nepal are retreating, as in the most part of Himalaya (Fujita and Nuimura 2011; Bolch et al. 2012), but the situation is very heterogeneous. In some regions at great altitude, above 6’000 m asl, the mass balance of snow and ice is even slightly positive (Kappenberger 2011). However, the general warming leads to high melt rates at lower altitudes, resulting in negative total mass balance of nearly all glaciers in the Himalaya and over the whole globe.

5.3.1 Glaciation area and volume

Current state

The headwaters of the Kali Gandaki consist of several small glacier systems (Figure 5.7). One of these small tributaries, the Kyungchhama Khola, naturally flows towards Lo-Manthang. The yield of this river alone is not sufficient to cover the total demand of Lo-Manthang and several other villages upstream thereof. Thus part of the Kyimaling Khola, which is formed by

[12] www.nset.org.np

the Dhanggna and the Taththa Jyura Khola, is directed towards Lo-Manthang. This can quite easily be practiced due to the large, low sloping alluvial fan above Kyimaling (section 5.5.2).

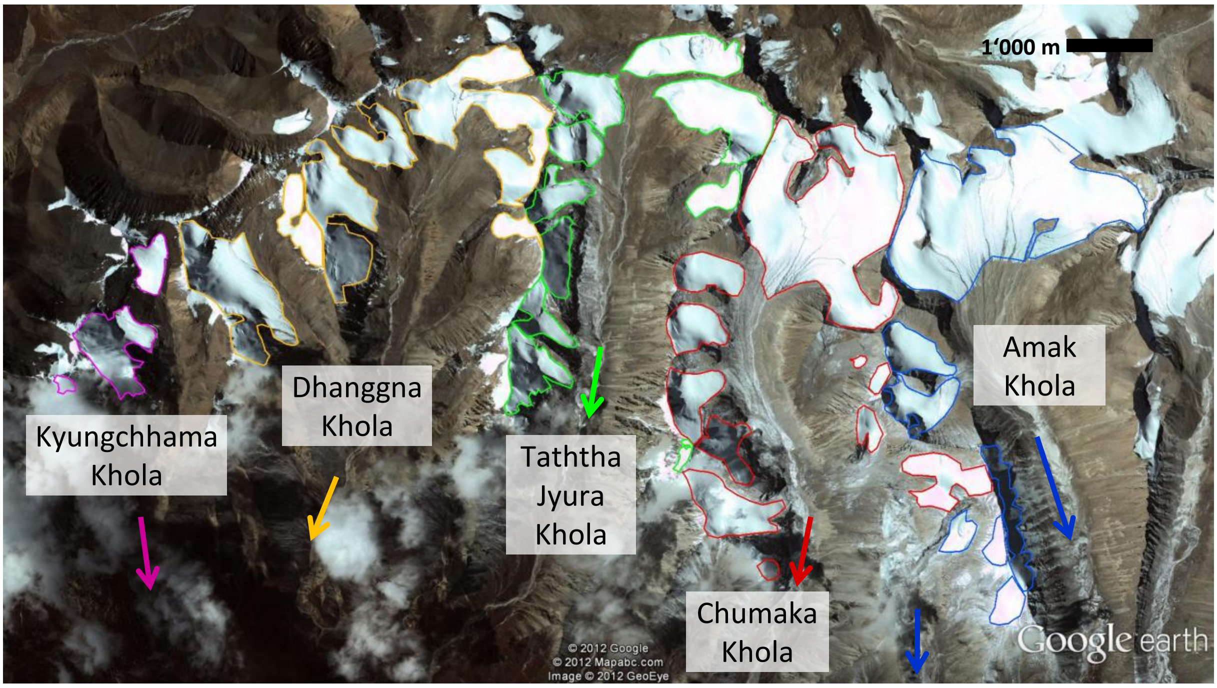

Figure 5.7: Glaciated area feeding the Kali Gandaki. The Amak Khola is formed by the blue highlighted glaciers, the Chumaka Khola by the red ones. These two rivers merge roughly 2 km upstream of Namashung, whereas the resulting river is called Kali Gandaki thereafter. The green polygons mark glaciers draining into the Taththa Jyura Khola and the orange ones into Dhanggna Khola. About 3 km west of the village Kyimaling they merge and form the Kyimaling Khola, which is merging into the Kali Gandaki just next to Namashung's field area. The violet polygons mark glaciers forming the Kyungchhama Khola, which naturally flows towards Lo-Manthang. North direction is → (source: Google Earth Pro, accessed 25/09/2012).

Using Google Earth Pro (Figure 5.7), the current glaciation area could be approximated. Linearly segmenting the non-linear relationship between glacier area and its corresponding volume given by Huss et al. (2008), the glacier volumes could be calculated. In fact, the surface area of each distinct glacier mass was measured, and with the corresponding linearized relationship, the ice volume of each glacier piece could be approximated. In the end, the total ice volume was obtained by summing up the separately estimated volumes. In this way, the glaciated area of Namashung was estimated to be roughly 24 km^2 with a corresponding total volume of about 0.87 km^3 (Table 5.4). Consequently, about 10 % of the total catchment area of Namashung (234 km^2) is currently glaciated.

Table 5.4: Rough estimate of the total glacier volume in the region which is relevant for the relocation site of Samzong. The glaciated area was approximated with Google Earth Pro and the glacier volume was evaluated using a linearized relationship based on Huss et al. (2008).

Glaciation system	Area (km^2)	Volume (km^3)
Amak Khola (1)	6.43	0.302
Chumaka Khola (2)	7.24	0.312
Taththa Jyura Khola (3)	4.57	0.185
Dhanggna Khola (4)	5.43	0.220
Kyungchhama Khola (5)	0.92	0.037
Kali Gandaki (1+2)	13.67	0.614
Kyimaling Khola (3+4)	10.00	0.257
Total (1-4)	23.67	0.872

Past and future trends

The comparison of the Corona satellite pictures from 1967 with the Landsat images of 2011 gives an idea about the changes in glaciation of three glacier systems in northwestern Mustang within the past 44 years (Figure 5.8).

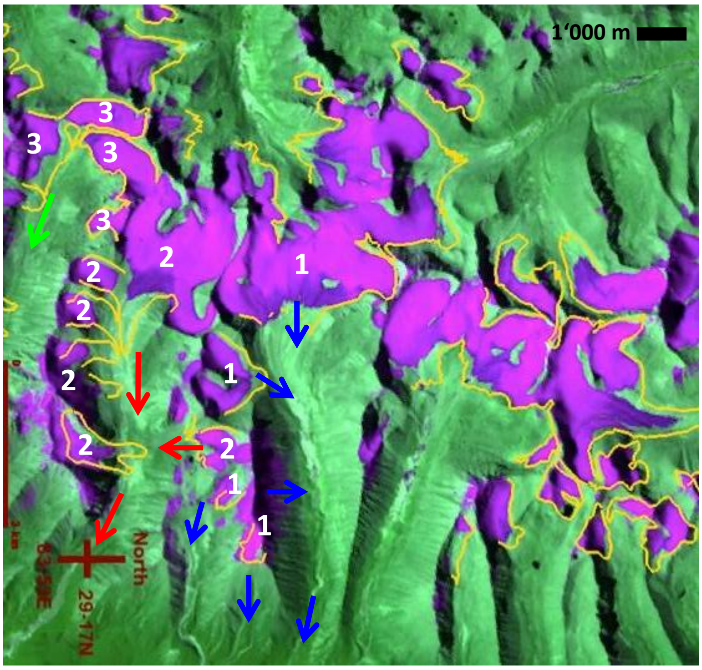

Figure 5.8: Comparison of the Corona images from 1967 (yellow delineations) and the outline of the glaciated area (violet surfaces) based on Landsat imagery from 2010 (Kappenberger and Lichtenegger 2012). North direction is →.

The numbered glaciers are all draining to Namashung and are forming the following rivers, whereas the estimated change in glacier volume within the past 44 years and the color of the arrow indicating the corresponding river are written in brackets:

1) Amak Khola (-9 %, blue)
2) Chumaka Khola (-21 %, red)
3) Taththa Jyura Khola (-17 %, green)

The change in glaciation was approximated by qualitatively estimating, how much the surface area of the corresponding glaciers shrunk within the past 44 years based on the presented imagery (Figure 5.8). From the resulting areas, the corresponding volumes (Table 5.5) were calculated using the methodology described before.

Table 5.5: Rough estimate of the current glaciation volume compared to 1967 of three catchments in north-western Mustang, based on satellite imagery (Figure 5.8).

Glaciation system	Volume 1967 (km^3)	Present volume (km^3)	Present volume (%)
Amak Khola (1)	0.334	0.302	91 (-09)
Chumaka Khola (2)	0.394	0.312	79 (-21)
Taththa Jyura Khola (3)	0.223	0.185	83 (-17)
Total	0.951	0.800	84 (-16)

The estimation shows (Table 5.5), that the masses of three glaciated areas, which all lie within the catchment of Namashung, decreased by roughly 16 %. Also, the analysis revealed, that the different glacier bodies are not retreating with the same velocity. Many factors such as exposition, debris cover, precipitation pattern, local temperature gradients etc. play a role.

Along with enhanced warming (section 3.3.2) and the increasing dust cover due to even more pronounced upvalley winds during the day (section 3.3.3), the glaciers are expected to shrink at a higher rate in the future. Therefore, the glaciers might face complete disappearance within the current century, given the small present area and volume respectively. This has major implications for water availability within the corresponding catchments of course. The glaciers, storing precipitation and releasing it slowly during melting season, are crucial for a suitable water regime for engaging in productive agricultural activities (section 5.4.3).

5.3.2 Glacier Lake Outburst Flood potential

Past sudden floods as well as possible future events related to glacier lakes are discussed in the following, whereas the focus lies on the source of such floods. In contrast, the hydrogeological risks thereof, endangering mainly the designated agricultural area in Namashung, is elaborated in section 5.5.2.

Past flood events

Reportedly, there have been two flood events, which can likely be classified as Glacier Lake Outburst Floods (GLOFs). The large debris deposits in Namashung (Figure 5.1 and section 5.5.1) give an idea about the flood intensity necessary for transportation of such vast amounts of boulders and debris. The first, smaller event took place 28 years ago according to a local eye witness. The larger flood arrived 3 years later, in May 1987, based on the same witness' account.

Looking on site at the flood traces close to Nichung, where the Chumaka Khola and the Amak Khola merge, it becomes clear, that the events, at least the larger one, originated from the former mentioned river. Unfortunately, the a trip into the valley of the Chumaka Khola by Giovanni Kappenberger on October 4th 2011 could not give further crucial indications about the course of events of the past flood events.

Despite the very scarce information, a possible sequence of events leading to the heavy flood roughly 25 years ago can be sketched: Heavy snowfall together with rather high temperatures led to a substantial, rather wet snow cover on the Chumaka Khola glacier (Figure 5.9, left). Further precipitation triggered the meltwater glacier lake L1 to spill (Figure 5.9, right). The overflowing surface water mobilized the already saturated wet snow along the way initiating a sort of slush avalanche, the like Giovanni Kappenberger could observe in the Canadian Arctic and even in the Swiss Alps. In the course a large water wave developed, transporting vast amount of bedload and depositing most of it along a river section from Namashung to at least 5 km upstream. This section is less steep and, particularly between Nichung and Namashung, much less confined, leading to massive deposits.

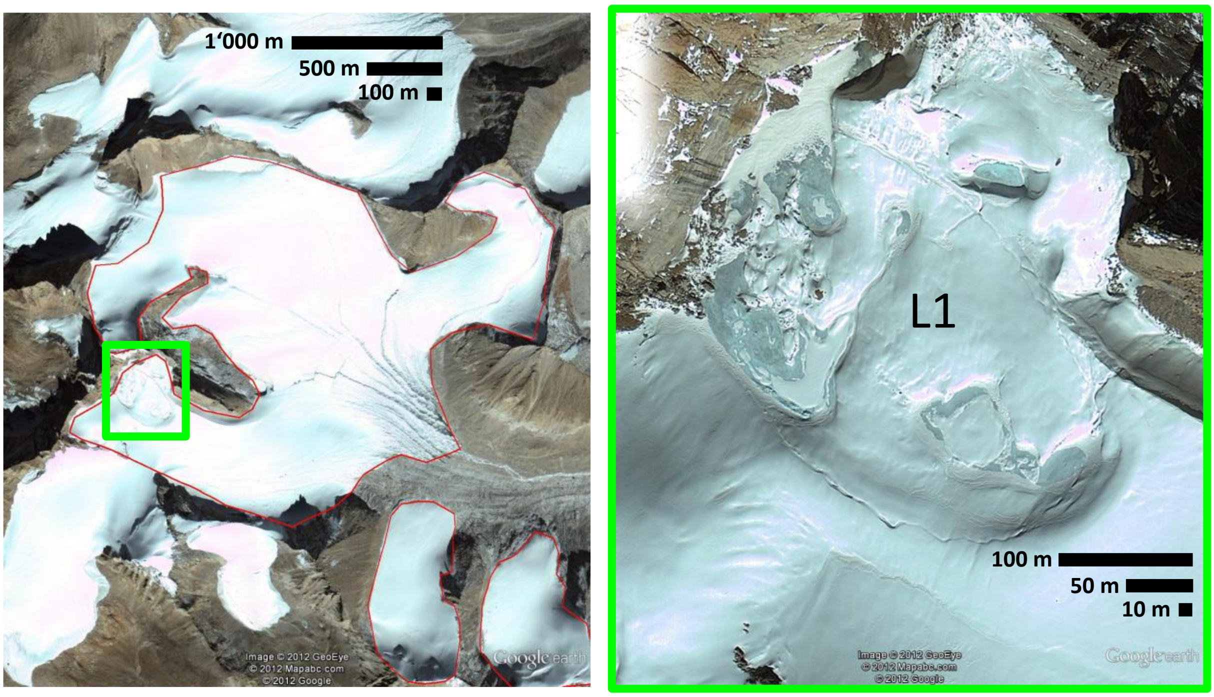

Figure 5.9: On the left, the Chumaka Khola glacier is indicated. The red polygons highlight all glaciers which drain into the Chumaka Khola. The green rectangle indicates the location of the meltwater glacier lake L1, depicted enlarged on the right. The flood could have been triggered by the possibly overflowing lake L1. North direction is ↑ (source: Google Earth Pro, accessed 26/09/2012).

In the Taththa Jyura Khola catchment there is also a glacier lake (L2, Figure 5.10) which might have caused or will trigger sudden flooding. It is thinkable, that an inglacial lake outburst occurred at some point of time, since a crater, a typical sign of such processes, is visible (Figure 5.10). However, the interviewed locals did not remember such an event.

Generally, polythermal (or cold) glaciers, typical for this region, can develop hidden lakes. Such lakes are neither commonly known nor well documented in literature, since they are often not visible, which makes it difficult to observe them and to study, understand and predict their behavior[13]. Apparently, meltwater enters the glacier and forms an internal lake, which can burst out and result in GLOFs. Since these lakes are not well understood their risks are very difficult to assess.

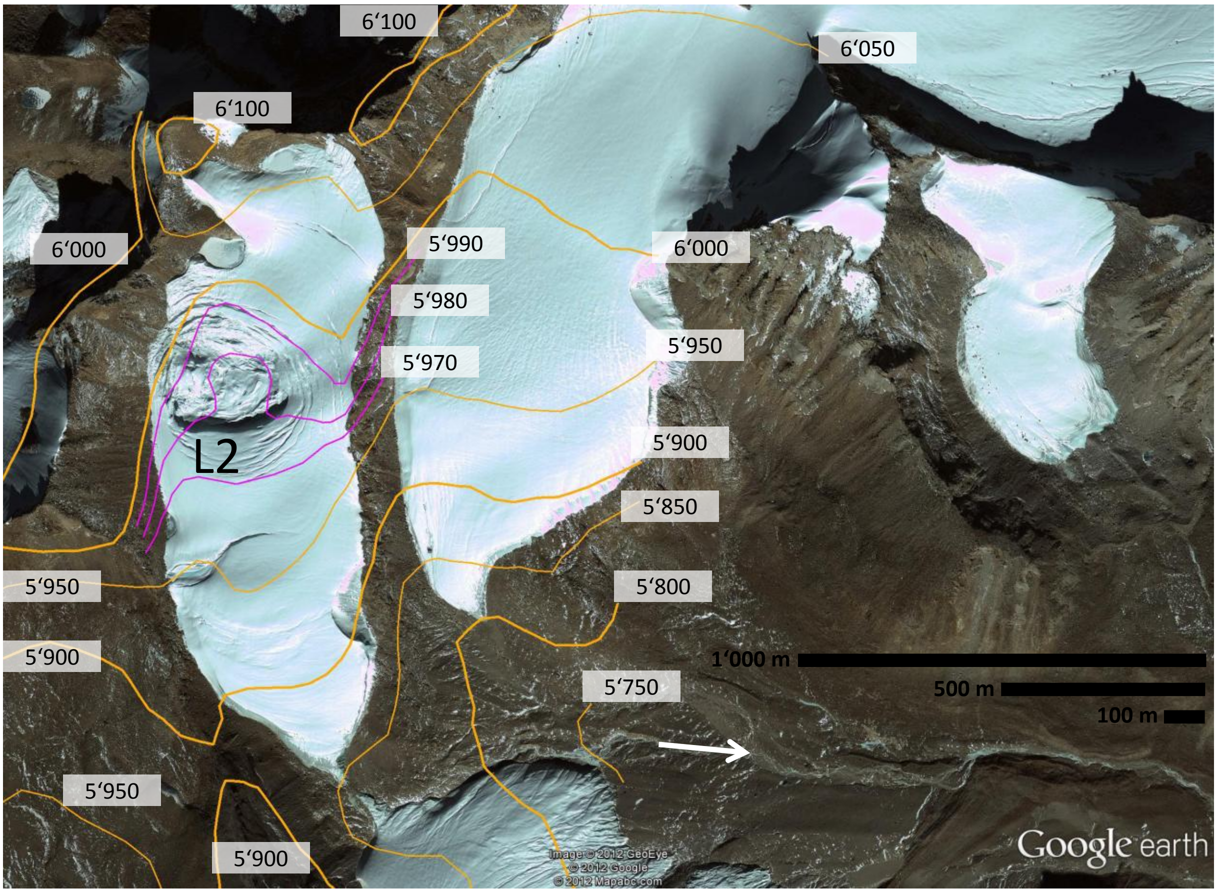

Figure 5.10: Crater ice lake L2 located within the Taththa Jyura Khola catchment with indicated contour lines based on Google Earth's underlying elevation model. The river's flow direction is indicated by the white arrow. North direction is ↑ (source: Google Earth Pro, accessed 29/09/2012).

Future events

How the risk of future events will evolve with time cannot be assessed easily, as mentioned above, especially in the light of the limited scope of this study. In general, the intensity of possible GLOF events will rather decrease with time, but as long as a catchment is glaciated, it basically also bears the risk of a GLOF, particularly in conjunction with warm and heavy precipitation events during monsoon season.

[13] An example of an event, triggered by an outburst of a hidden internal lake, is the dramatic outburst of the glacier de Tête Rousse in the Mt Blanc region in the Alps in 1892. Recently, it was detected, that the lake has been developing again (Vincent et al. 2012).

5.4 Water resources

The situation at the new location differs substantially from existing Samzong particularly related to water availability. In the following the water demand is assessed, the characteristics of the catchment are described and recommendations for the water supply are presented.

5.4.1 Water demand

The water demand for the new location is similar to the values assessed for the existing settlement (section 3.4.1). For the domestic water demand the upper limit of the range presented in Wacker and Fröhlich (1997) is taken, since washing is considered as well. It is certainly more convenient to wash clothes in the slightly elevated settlement area than in the irrigation channels down in the field area. Besides, it has advantages related to the water quality of the irrigation water. Furthermore it is desirable to have sufficient water for watering tress, bushes etc. which can be used as fodder and construction material. Also, livestock such as cows and horses may be given drinking water instead of being led to the river. To consider these demands, a daily drinking water demand of 50 l/p/d is taken, which equals to 4150 l/d considering a population of 83 people. It is recommended to install a tank able to store the daily demand, so that the abstracted water is buffered and can be used efficiently. The required water flow is therefore 0.05 l/s or 2.9 l/min which should be delivered to the village.

Analogous to the calculation of the irrigation demand in Samzong (Table 3.7) the required irrigation flow is elaborated for Namashung. The only difference is that instead of a generic value of field area per capita the actual measured potential field area is considered.

The potential agricultural area in Namashung (9.75 ha) is almost the same as the currently cultivated area in Samzong (9.08 ha, Table 5.1 in section 5.2.1). Thus no surplus area is available for a reservoir. Therefore the water demand has to be met unbuffered during working hours of about 10 hours. In this way, the required demand for agricultural activities at plot level in Namashung is 7 l/s. Note that this demand is limited to the growing season including pre- and post-season, as discussed in section 3.4.1.

It is important to note, that no losses are considered in the preceding estimations. This is due to the fact, that the expected losses are very much dependent on the chosen technical supply system. Furthermore the approximations do not include any reserves and are therefore rather representing the minimum water demand which has to be supplied to the user. Importantly, during the necessary and crucial detail planning, the capacities of the supply systems have to be dimensioned in order to accommodate appropriate losses and reserves.

5.4.2 Water sources

Right next to Namashung, the Kyimaling River merges into the Kali Gandaki. Generally both provide the possibility to extract water for the desired purpose in Namashung. However, only water from the Kali Gandaki is suitable to be provided by traditional water management systems such as earthen, hand-dug open channels. Water from Kyimaling Khola can only be made accessible, if the water is bridged over the Kali Gandaki using modern techniques.

The draining area at Namashung is roughly 234 km^2 of which roughly 24 km^2 (10 %) are glaciated (Figure 5.11). The catchment area of Namashung is more than six times larger than the one at the current location of Samzong, measuring only about 38 km^2.

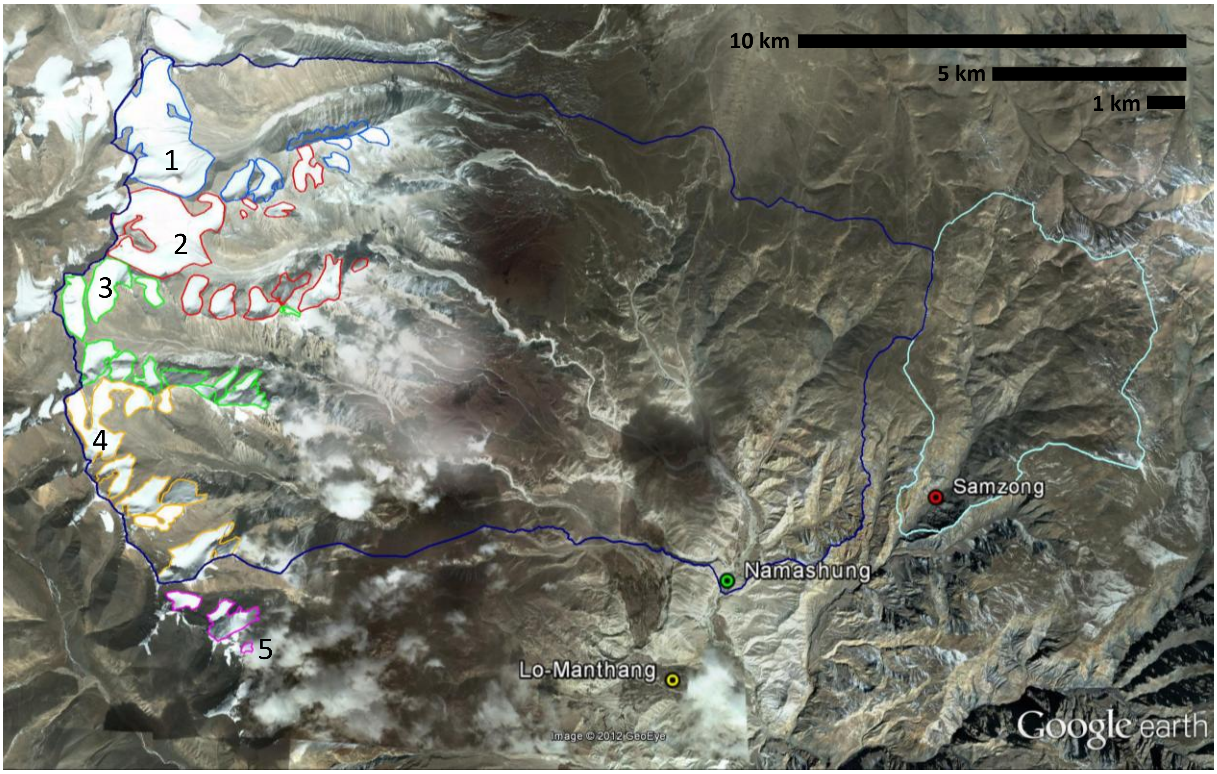

Figure 5.11: Catchments of Samzong (38 km^2) and Namashung (234 km^2) respectively. The current glacier masses are framed with different colored polygons, which form the following rivers:

1) Amak Khola (blue)
2) Chumaka Khola (red)
3) Taththa Jyura Khola (green)
4) Dhanggna Khola (orange)
5) Kyungchhama Khola (pink)

The rivers 1-4 drain naturally towards Namashung. However from Taththa Jyura (3) and Dhanggna (4), part of the water is directed towards Lo-Manthang, as the yield of (5) does not suffice to meet the demand. North direction is ↑ (source: Google Earth Pro, accessed 29/10/2012).

The lowest point of the catchment draining to the relocation site is at an elevation of 3775 m asl and reaches to a height of 6366 m asl.

5.4.3 Water regime

The perennial flow of both the Kyimaling and the Kali Gandaki is strongly linked to the melting dynamics of the glaciated area. Additionally, precipitation during the monsoon season influences the river dynamics.

As an example, the measured discharge of the Kali Gandaki, as well as the precipitation, both measured in Jomsom, are shown in Figure 5.12. The dynamics of the Kyimaling Khola as well as the glaciated headwaters of the Kali Gandaki are assumed to be similar[14] to the observed behavior of the Kali Gandaki in Jomsom. There is a low flow period during the winter months and heavily increasing flows during the melting season, even accentuated by the monsoon precipitations, which have a substantial fraction of rainfall due to the much higher associated temperatures during this season. On the other hand the precipitation events during winter are mostly in form of snowfall due to the low temperatures. This also explains that the discharge of the Kali Gandaki is not directly influenced by the corresponding precipitation events during the winter months (Figure 5.12).

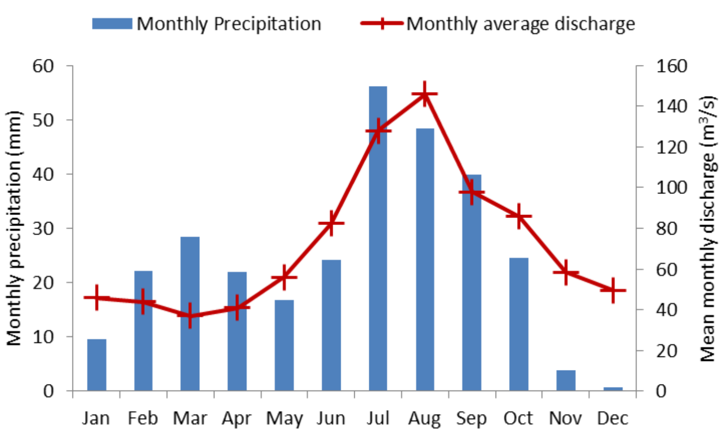

Figure 5.12: Measured average precipitation and discharge for the years 2002 to 2007 in Jomsom, Mustang (source: DHM, Kathmandu, Nepal. Discharge: station number 403; precipitation: station number 0601). Note that only the years 2002 to 2007 were considered, since the discharge records are very inconsistent in the preceding years. Also, the precipitation values are not representative for northern villages such as Samzong, since there is a large gradient from Jomsom northwards. Samzong appears to be substantially drier than Jomsom (section 3.3.4).

5.4.4 Water supply

Technically, the water can be taken from the Kyimaling Khola as well as from the Kali Gandaki to meet the total water demand. Likely, the domestic as well as irrigation water demand require two different supply systems. In the following different options for each system are discussed.

[14] The larger catchment of Jomsom formed by Kali Gandaki's drainage area is including tributaries which are not glaciated. The behavior of glaciated and non-glaciated tributaries is expected to be distinctively different. It is assumed however, that the Kali Gandaki in Jomsom behaves much alike a typical glacier-fed river.

Domestic water supply

Different drinking water supply options are summarized and qualitatively analyzed in Table 5.6. The options vary in cost range, degree of technical sophistication, maintenance and operation requirements, supply security, social acceptance and other inherent aspects. In general the different options would have to be elaborated in detail. It is important however, that the social acceptance of the system is given due consideration.

Irrigation supply system

Basically the water for irrigation could also be taken from Kyimaling Khola. If the drinking water is taken from the springs below Kyimaling, the Kali Gandaki has to be crossed (options A1-3, Table 5.6) and could be synergetic for transporting irrigation water to the fields in Namashung. Whether abstracting the required water from Kyimaling Khola instead of the Kali Gandaki had advantages and justified the more expensive and technical solution would have to be elaborated. The more obvious and straightforward option is to abstract the water from the Kali Gandaki and bring the water to the fields to Namashung by gravity flow in mainly open earthen channels which is discussed in more details in the following.

Conveniently the irrigation water abstraction is situated slightly more than one kilometer upstream of the northern boundary of Namashung's field area. At this spot, a water abstraction already exists. It supplies water to the village Nenyor which lies south of Namashung as well as some other fields along the way. Apparently, the abstraction could be used conjunctively with the concerned communities, ideally improving the installations for mutual benefit. From there the water could be routed in an open earthen or masonry channel along the left riverbank of the Kali Gandaki. Using the existing supply channel which is routed along the eastern boundary of Namashung to Nenyor by increasing its capacity for instance is reportedly hard to implement due to water right issues. A new parallel channel is suggested by Lama Ngawang Kunga Bista therefore. Mostly it follows an old destroyed and currently unused water course which forms the legal base for its reactivation.

Table 5.6: Qualitative assessment of different sources for the drinking water supply at Namashung.

ID	Source	Way of transport	Issues	Pros	Cons
A1	Spring below Kyimaling, on top of Kyimaling Khola's left riverbed	Pressure pipe including few pressure reduction basins, Kali Gandaki crossed by existing pedestrian bridge in Nenyor	➢ Kali Gandaki has to be bridged ➢ Height difference between abstraction and settlement ➢ Farming in Kyimaling might influence water quality ➢ Freezing, bursting of pipeline	✓ Expected good quality of spring water ✓ Yield expected to be sufficient even during winter months ✓ Tapping of spring water well accepted by the people ✓ Water abstraction not very susceptible to flood damages	× Pressure reduction basins required × Crossing of Kali Gandaki not simple, technical, rather expensive solutions needed
A2	Same as A1	Same as A1, but direct crossing of Kali Gandaki by construction of non-walkable bridge	➢ Same as A1 ➢ Inaccessibility of the bridge related to maintenance of the pipeline	✓ Same as A1 ✓ Rather short, direct pipeline	× Same as A1 × Likely more expensive than A1 × Difficult maintenance due to inaccessibility of pipeline at the crossing
A3	Same as A1	Same as A1, but direct crossing of Kali Gandaki by construction of new pedestrian bridge	➢ Same as A1	✓ Same as A1 ✓ Added value by better accessibility of Kali Gandaki's right riverbank ✓ Pipes at crossing also accessible	× Same as A1 × More expensive than A1 and A2
B1	Perennial flow of Kali Gandaki	Pressure pipe on the left riverside of Kali Gandaki	➢ Required treatment of abstracted river water ➢ Operation and maintenance of water treatment ➢ Water very rich in particles during melting season ➢ Water abstraction's flood security	✓ Kali Gandaki does not need to be bridged ✓ Low expected pressures	× Abstraction particularly prone to flood damages × Direct river water abstraction and use not well accepted by people × Water treatment requires alien, locally uncommon technology
C1	Same as B1	Pumping river water from the Kali Gandaki up to the settlement	➢ Same as B1 ➢ Operation, maintenance of technical installations	✓ Same as B1 ✓ Short transportation route	× Same as B1 × Pumping requires power source (solar, wind, grid power)
C2	Irrigation channel	Pumping water from the irrigation channel up to the settlement	➢ Same as C1	✓ Same as C1 ✓ Pump could be situated in the field area, much more secure from flood damages	× Same as C1 × Taking water directly from irrigation channel might not be well accepted by people

Around 400 m downstream of the abstraction there is an ephemeral stream which has to be crossed (Figure 5.13). As it seems difficult to use the existing infrastructure conjunctively, a separate unit is probably necessary. To bridge the ephemeral stream, the water could be put into pipes. To lift the water up to the scarp following the crossing of the mentioned stream, a sufficient height difference supplying the necessary potential energy is needed. Considering this, the pipeline would have to start around 300 m upstream.

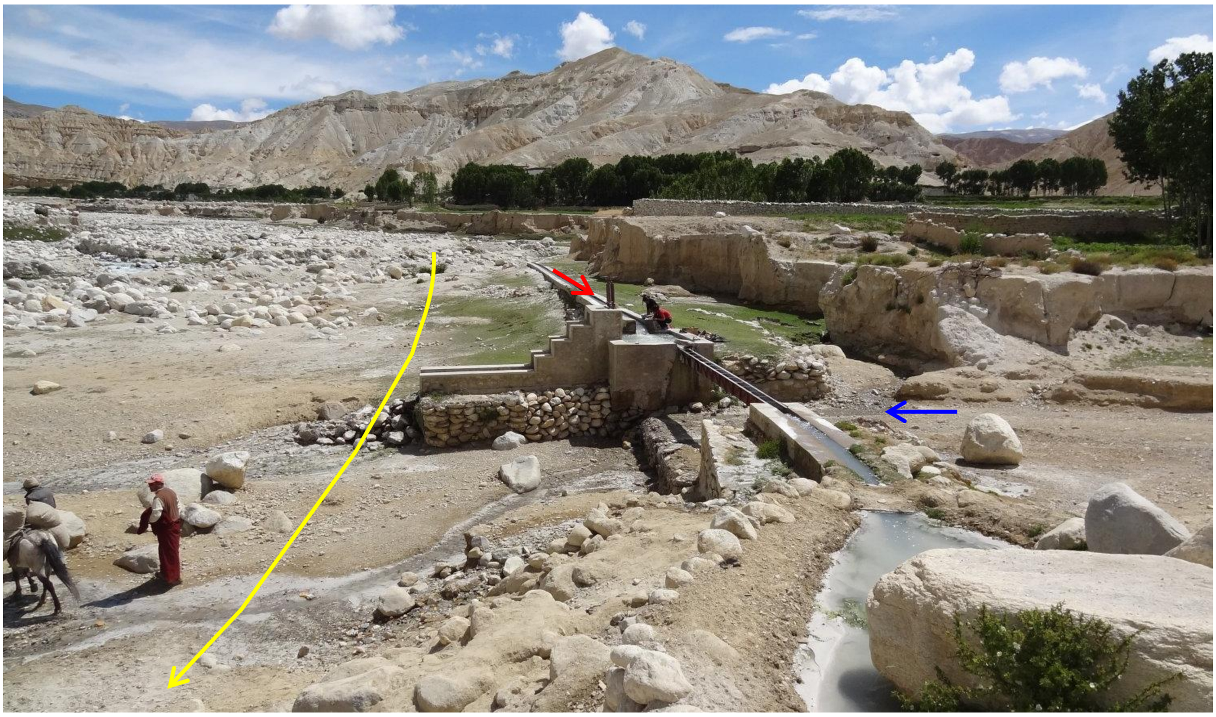

Figure 5.13: The existing masonry irrigation channel supplying Nenyor and surrounding households is indicated by the red arrow. The concrete spillway and the iron channel bridge crossing the ephemeral stream (blue arrow) are clearly visible. The irrigation water supply for Namashung is suggested to be routed as indicated by the yellow arrow. To cross the indicated stream and lift the water up to the elevated scarp, the abstracted water would have to be put into pressure pipes roughly 300 m upstream to come up with suitable height difference supplying the necessary potential energy (photo: 25/06/2012, Daniel Bernet).

After the riverbed crossing, the new channel would mostly lead along its old course. The course would have to be elaborated in detail, circumventing local depressions to come up with an evenly sloping profile. Also the area is full of large boulders which were deposited during the reported past heavy floods (section 5.3.2 and 5.5.1), so that concerned boulders have to be removed or a path around them has to be found. Last but not least the scarp is putting a constraint on the exact course of the channel. Seepage from channel could destabilize the scarp resulting in a collapse of the riverbank. Therefore the channel should be routed at least 5 m away of the scarp.

It is believed, that an open earthen channel is suitable. The abstracted water was observed to be rich in very fine particles which naturally sediment. These reduce naturally the seepage from the channels with increasing time of operation. Also, it is the cheapest technology, is locally well known and practiced and can be constructed with locally available materials.

5.5 Geological considerations

The relocation site constituted of the agricultural area within the valley bottom as well as the nearby, but slightly elevated location for the settlement, were studied in relation to geological risks and corresponding mitigation measures. By far, the inundation due to a possible future GLOF event is the major risk exclusively threatening the designated field area. Opposed to the discussion of the processes at the source of a GLOF (section 5.3.2), the actual threat of the agricultural area is elaborated in the following sections.

5.5.1 Exposure of designated fields to hydro-geological hazards

The designated field area, a plain in the valley floor, has been subject to devastating past flood events, as described in section 5.3.2. Considering the huge observed volumes of deposits along the river from Namashung to at least 5 km upstream, the flood is very likely due to a past GLOF originating from the Chumaka Khola. However, as exposed in section 5.3.2, also the glaciers within the catchment of the Kyimaling Khola could trigger future GLOF events. In the following, both hazards are discussed separately.

Floods from Chumaka Khola

The vast debris deposits in the designated agricultural area of Namashung were analyzed and are visualized in Figure 5.14. The deposit areas together with the corresponding thicknesses, as well as preferential flow directions are shown. Overall, the shown maps indicate, what might happen in a similar, future flood event. Additionally, it is demonstrated that the last devastating flood has only marginally affected areas with thin observed alluvial debris layers.

The alluvial deposit consists mainly of gravel and sand with pebbles and blocks that, especially in the northern sector of the fields area, are in the order of cubic meters. Overall, the alluvial sediments covering the devoted agricultural area in Namashung, measure approximately 75’000 m^2. Considering the observed deposit thicknesses, the total volume of alluvial debris is equal to about 40’000 m^3.

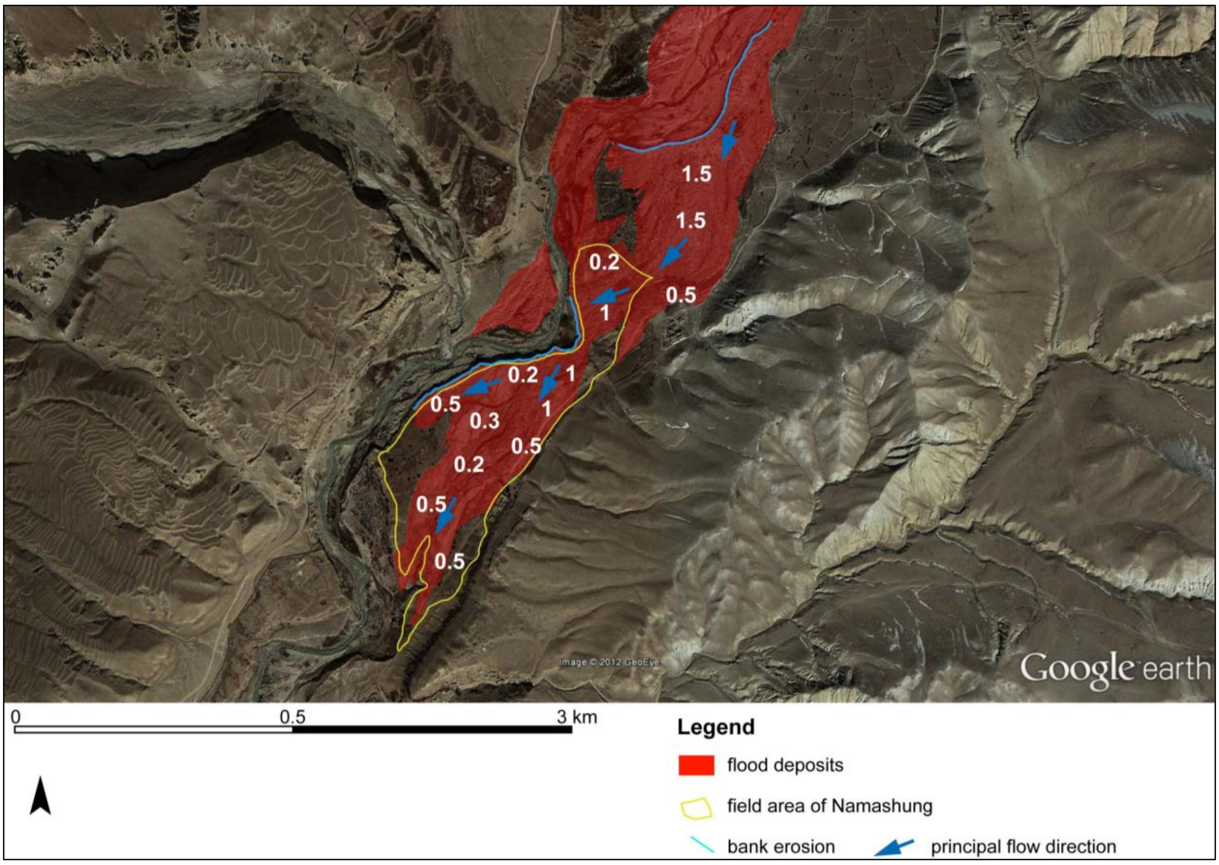

Figure 5.14: Flooded area in Namashung during the past GLOF event indicating preferential flow directions as well as corresponding deposit thicknesses in meters (source: Google Earth Pro, accessed 08/08/2012).

Floods from Kyimaling Khola

The Kyimaling Khola flows in a deep canyon before it joins the Kali Gandaki at the northern end of the alluvial terrace forming Namashung's agricultural area. Just opposite of the confluence large and clearly visible bank erosion is indicating past flood events from the Kyimaling Khola. As mentioned in section 5.3.2, such an event was neither reported by the locals nor could alluvial deposits originating from Kyimaling Khola be identified in Namashung.

Above Kyimaling a huge alluvial fan is present. Figure 5.15 shows the flood prone areas in case of ordinary events (blue) and extraordinary events such as a GLOF (red). In both cases the village of Kyimaling is strongly at risk related to flood events. Additionally, the Kyimaling Khola may spill and flow southwards following its old riverbed in direction of Lo-Manthang. Such an occurrence may constitute a serious hazard for any type of structures close to the riverbed such as bridges, houses, mills and power plants for instance. Nevertheless, during huge events the large fan above Kyimaling village, characterized by a low slope, offers a lot of space for deposition of alluvial debris. Therefore, at the field area of Namashung no hazard for alluvial debris deposition transported by the Kyimaling Khola is present. A further erosion of the Namashung terrace by the flood containing only remobilized debris from the canyon is possible however. Such an event could cause a minor loss of field area.

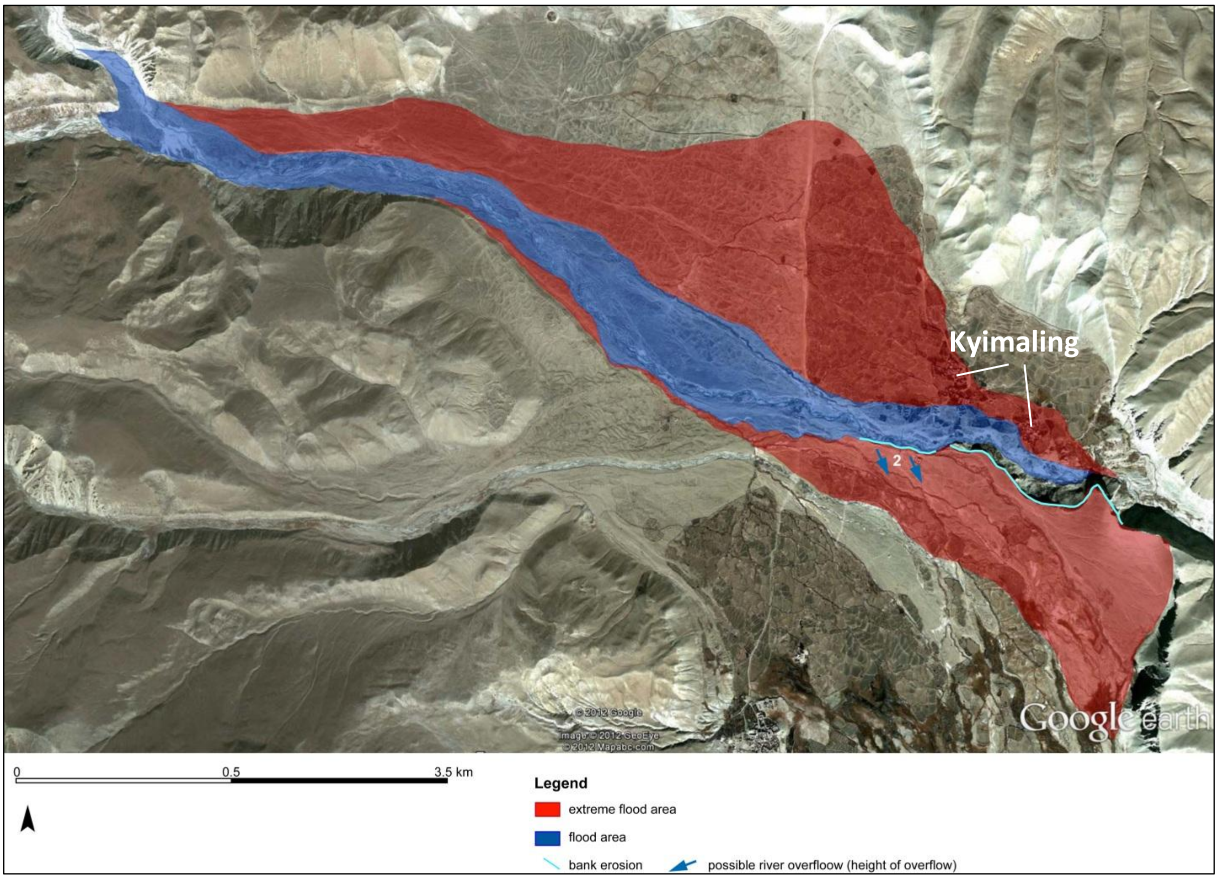

Figure 5.15: Flood prone areas around Kyimaling village. The main settlement areas are indicated in white (source: Google Earth Pro, accessed 08/08/2012).

Goods at risk

The planned fields in Namashung as well as all related structures such as irrigation channels, pipelines, access tracks etc. are at risk from flooding and erosion.

5.5.2 Exposure of the designated settlement area to geological hazards

As outlined in section 5.1.1, the designated settlement area for the relocation of Samzong village is situated on a plateau overlooking the main valley of the Kali Gandaki. Except local shallow landslides along the scarp which delimits the plateau frontally and laterally, there are no instable conditions present from a natural hazard point of view.

5.5.3 Mitigation of geological hazards in Namashung

Designated agricultural area

Regarding the agricultural area, it is recommended to realize riprap[15] or other bank protections along the riverbank as shown in Figure 5.16 using the removed blocks from the terrace.

[15] Rocks used to armor any kind of bank against water erosion.

At the base of the riverbank a further protection against erosion can be provided using appropriately designed gabions.

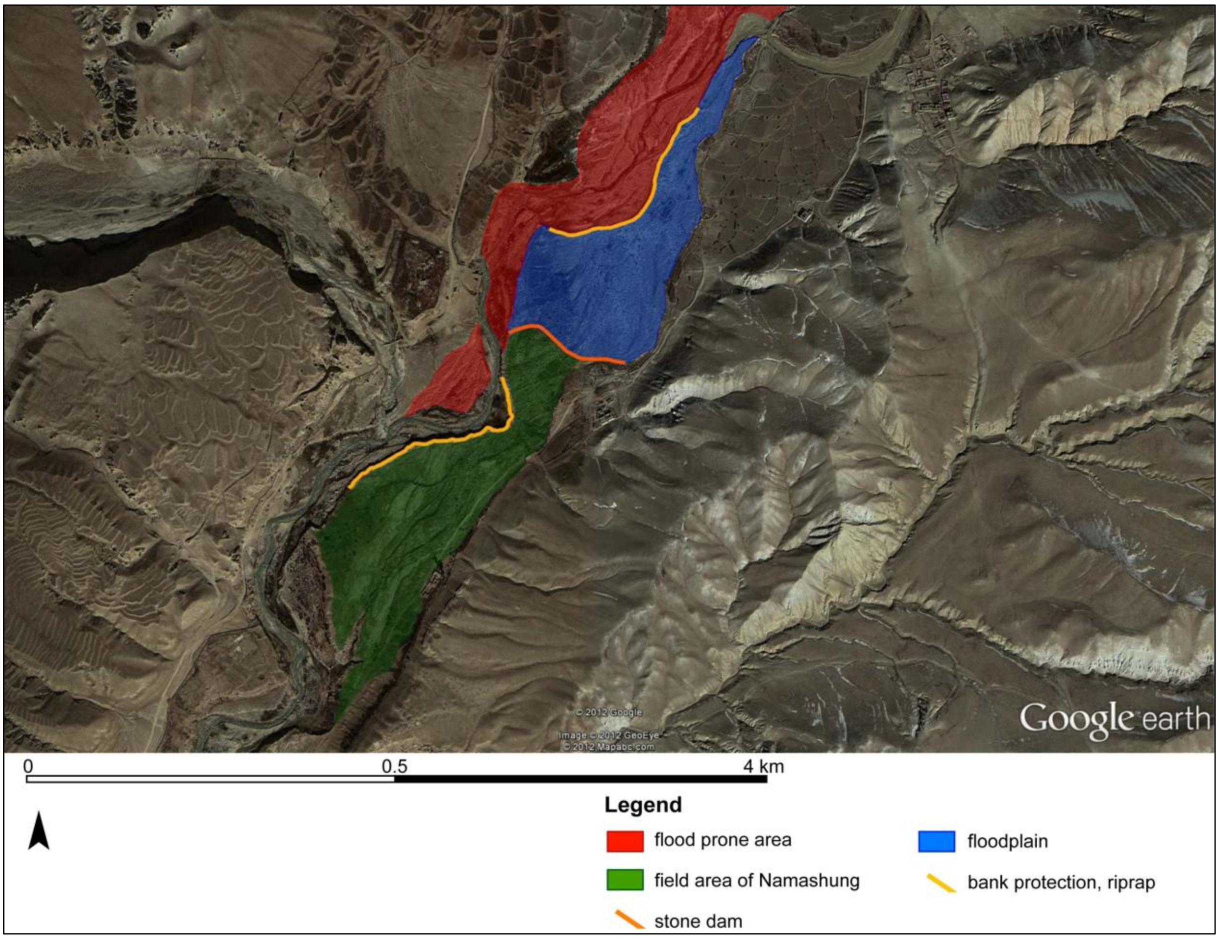

Figure 5.16: Field area in Namashung visualizing strategy for mitigating the flood hazard (source: Google Earth Pro, accessed 08/08/2012).

The field investigations revealed that most of the debris has been deposited north of Namashung. The effectiveness of this natural floodplain could be increased by building a block dam located as suggested in Figure 5.16. This dam should have a height of at least 3 m. Of course, such a measure would increase the exposure to adverse effects of GLOFs in the adjacent upstream plains. This might not be acceptable by the affected people and would have to be studied in more detail.

Designated settlement area

The hazard of possible shallow landslides can easily be avoided by respecting a minimum distance of 15 m from the edge of the escarpment to the constructible area.

6 Moving down or not?

The key question which needs to be answered in the scope of this study is: "Moving down or not?" In this chapter the outcome of the study is presented, whether, based on all the elaborations and findings, the communities are advised to relocate or stay at the present location and solve the main problems in situ (as well as possible).

6.1 Qualitative assessment

After all the issues have been studied and analyzed, the project team met and discussed twenty previously identified core issues. For each issue it was decided, whether the situation is better at the current or the displaced location or if it is indifferent. Qualitatively, this method provides an idea, whether it is favorable for the community to move or not, if the situation is obvious and broadly supported, which main aspects are affected and what the tradeoffs are.

The following two hypothetical future states were compared:

- "Stay:" Current location with implemented measures aimed at the mitigation of the main prevalent problems, as outlined in chapter 4.
- "Move:" Relocated community at the identified and acquired relocation site with implemented recommendations concerning the resettlement, as discussed in chapter 5.

Table 6.1 lists all issues together with the qualification which state is favorable. Each category of different aspects is discussed in the following sections.

6.1.1 Physical characteristics

Water availability
Water availability is considered the most important issue, in particular the availability for irrigation water, as it is the driver for agricultural activities, which is central for providing the (partial) subsistence in Samzong. As the demand for irrigation water surpasses the drinking water demand by manifold (section 3.4.1 and 5.4.1), the former is much more critical. In fact, rather simple technical solutions to enhance the quality of river water, in order to use it for domestic purposes, are available. If however the water quantity which can be abstracted and used is insufficient, there are no direct means to increment the water yield. Therefore, the weight of the criterion of irrigation water availability is highest.

The drinking water availability is similar in the two different states "Stay" and "Move." At the current location there is sufficient drinking water. At the relocation site, there are different sources (perennial river flow, springs; section 5.4.2) each with a sufficient yield one way or the other.

The irrigation water availability is clearly largely improved at the new location, so that from a water availability point of view the resettlement is favorable.

Table 6.1: Qualitative assessment of two possible future states "Stay" or "Move" with the indication which state is more favorable, if any. Note that the issues are not weighted, and the total count merely gives an unqualified count. However, the two most crucial issues are printed in bold.

No	Aspects	Issue	Qualification		
			Stay	Neutral	Move
1	Physical characteristics	**Irrigation water availability**			✓
2		Drinking water availability		✓	
3		Drinking water quality	✓		
4	Irrigation water supply systems	Technical complexity		✓	
5		Initial costs		✓	
6		Overall durability (Abrasion, exposure to natural hazards)		✓	
7		Maintenance and operation (labor, associated costs etc.)			✓
8	Drinking water supply systems	Technical complexity	✓		
9		Initial costs	✓		
10		Overall durability (Abrasion, exposure to natural hazards)			✓
11		Maintenance and operation (labor, associated costs etc.)[a]			✓
12	Geological risks	**Exposure of the settlement to geological risks**			✓
13		Exposure of the agricultural area to geological risks	✓		
14	Socio-economic issues and ambient conditions	Access to public services (i.e. health and education)			✓
15		Opportunities for economic activities		✓	
16		Opportunities related to tourism			✓
17		Demographic stability and evolution			✓
18		Communal cohesion	✓		
19		Access to natural and energetic resources			✓
20		Ambient environmental conditions (wind, sunshine duration, thunderstorms, etc.)		✓	
Total count			**5**	**6**	**9**

[a] The existing (and improved) water supply system in Samzong is compared to tapping spring water below Kyimaling (section 5.4.4) for providing drinking water at the new location.

Water quality

In the given context, the water quality is mainly an issue for drinking purposes, as for agricultural activities the water quality is considered harmless. The spring water at the current location seems of appropriate quality. At the source, as well as along its pipeline there do not seem to be any pollution. Only the pastureland close to the spring might degenerate the water quality due to livestock excrement.

At the new location, the drinking water may be taken from the perennial river flow or from a spring close to Kyimaling (section 5.4.4). The former is of lower quality compared with the spring water in Samzong Valley, because of the villages upstream of Namashung which may contaminate the river water additionally to the undesirable high amount of suspended particles. Also the spring water below Kyimaling is expected to be of lower quality, because the spring is believed to be fed mainly by infiltrating water used in and around Kyimaling. Therefore, the drinking water quality in Samzong is expected to be favorable.

6.1.2 Water supply systems

As mentioned before, a crucial issue is the amount of available water. Nonetheless how and if the available water can be transported to the village is another key issue. To address this, different characteristics of the drinking and irrigation water supply systems (technical complexity, initial costs, overall durability as well as maintenance and operation) of the two different states “Stay” and “Move” were compared (Table 6.1). Altogether they qualify at which location the water can be transported to the village more effectively and efficiently.

The technical complexity is a measure of the local appropriateness of a technical intervention. As could be observed in the given context, this issue is crucial in terms of capacity and means to operate and maintain the system by the local people themselves. The higher the technical sophistication and the farther a measure deviates from traditional methods, the more likely it is that the system fails. Reasons for such failures are manifold. For instance alien materials are locally not available, funds for special parts cannot be raised or the technical know-how may be lacking. Accordingly, the dependence from experts, outsiders or institutions increases with technically more sophisticated interventions. This is undesirable because the capacity and means to operate and maintain the systems, let alone the construction thereof in the first place, decrease. The weak institutional structures in Upper Mustang (section 2.2) further highlight the undesired dependence from outside support.

When neglecting maintenance, the durability of a technical system is considered to be a function of the capacity of the unit to withstand normal abrasion as well as impacts of natural hazards during its normal operation. Generally, a high exposure of a system to natural hazards, both in terms of frequency and/or intensity, is undesirable. In fact, the examples of past interventions seen during the field work revealed, that increased exposure to natural hazards had often led to a quick degeneration or even failure of the system. However, if the system were to be designed and implemented appropriately to withstand such impacts, the overall durability could presumably be acceptable.

Finally, the maintenance and operation addresses the required labor, both in terms of frequency and quantity, as well as the associated costs ensuring the desired operation period.

Irrigation water supply systems

The irrigation system is very similar for both states “Stay” and “Move,” so that the technical complexity and the construction costs are expected to be much alike. The exposure to natural hazards is deviating however. An exposure of the irrigation system to infrequent floods (i.e. GLOFs, section 5.3.2) at the new location is opposed to a frequent exposure of surface and debris flow of much smaller intensity at the existing location. The expected maintenance however is expected to be easier and less frequent at the new location.

Overall, the relocation seems therefore slightly favorable compared to an ameliorated situation in Samzong related to the irrigation water supply system.

Drinking water supply systems
The provision of drinking water to the elevated settlement area at the new location is not simple (section 5.4.4). Independent from the choice of water source (spring or river water; Table 5.6), the supply system needs to be technically more advanced, also increasing the expected costs. On the other hand, the durability of the drinking water supply system in Namashung is believed to be higher. In Samzong, the drinking water is transported along a steep mountain slope which is susceptible to erosion and landslides, thus requiring frequent and rather difficult maintenance.

Overall the drinking water supply systems in Namashung are expected to be technically more sophisticated and more expensive, to being more durable and less maintenance-intensive on the other hand. The state "Stay" and "Move" related to the drinking water supply systems are therefore rather indifferent overall, each state having certain advantages as well as trade-offs.

6.1.3 Geological risks

Due to the slight elevation of the designated settlement area in Namashung, the exposure to geological risks is very small and certainly favorable compared to the old location. However, the agricultural area at the new location is at risk of being inundated in case of a possible GLOF (section 5.3.2). The fields in Samzong on the other hand could easily be secured against debris flow by building appropriate dams (section 4.3). The exposure of the settlement to geological risk is considered to weight more however. Overall, the new location is slightly more favorable in terms of geological risk.

6.1.4 Socio-economic issues and ambient conditions

Overall, the new location is favorable in terms of the identified socio-economic issues and ambient conditions (Table 6.1). In the following, each issue is briefly discussed separately.

Access to public services
Due to the location of Namashung, in particular being close to Lo-Manthang, but also to neighboring villages such as Nenyor, Arka or Duk, are clearly improving the access to public services. Though the services are still very limited in Lo-Manthang itself compared to more developed villages or cities in the country, it is still a quite significant enhancement due to the exceptional remoteness of Samzong.

Opportunities for economic activities and chances related to tourism
Even though the location of Namashung is closer to other villages as mentioned before, it does not necessarily mean, that the opportunities for economic activities are broader. However, possible activities exploiting touristic potential are far greater at the new location.

As mentioned in section 3.1.3, the discovery of archeologically very interesting caves in the vicinity of Samzong certainly bear touristic potential, but as mentioned before, it is a sensitive issue and this circumstance should be paid due consideration and respect.

In general, the publication of the article in National Geographic (Finkel 2012), the planned support and documentary about the resettlement of a HH from Samzong to Namashung by the ZDF[16] as well as the personal engagement of Manuel Bauer, a renowned photographer, are generally increasing Upper Mustang's publicity and Samzong's profile in particular.

Demographic stability and evolution

As mentioned in section 3.1.1, children and teenagers are often sent to schools in regional or national centers or even to India. It is expected that a decreasing amount of these permanent migrants will return back to their home village after finishing their studies. This represents a considerable risk for the future demographic stability as the fraction of young people is expected to becoming even smaller in the future.

Since the relocated village in Namashung seems economically (touristic potential), as well as in terms of access to public services, more attractive, the future demographic stability is believed to be favorable in case of relocation.

Communal cohesion

As could be observed during the field work, the intra-communal cohesion of Samzong is very high. Meaning to say, all the interviewed people prioritized the wish of the community above personal preferences. For the inhabitants of Samzong it seems very important that the community stays together (section 3.1).

It is believed that the cohesion will be softened at the relocation site, mainly due to the much less isolated location together with the inherent implications. Whether a strong communal cohesion is favorable or not is difficult to answer and would require further studies.

Access to natural and energetic resources

The access to resources in general seems more favorable due to the proximity to other villages and mainly due to the much better physical accessibility. Only firewood might be more difficult to gather as the resource is scarce already and will become further stressed due to an increased competition after relocating. However, the former sources could still be exploited, even though the distances to the firewood sources as well as the transport routes will certainly increase. In any case, the scarcity of firewood could also be counteracted by purchasing gas, which would be available easier due to the improved accessibility of Namashung. Additionally it would be possible to increase the own wood production due to increased irrigation water availability.

[16] Second German national television station

Ambient environmental conditions
In general, the advantages of the new location in terms of increased sunshine duration and less threatening situation during thunderstorm event of the settlement are opposed to an increased exposure to the strong diurnal wind (section 3.3.3). Therefore, neither the current nor the relocation site is favorable related to ambient environmental conditions.

6.2 Summary

Based on the preceding (section 6.1 and Table 6.1), not only from a strictly quantitative point of view (9 against 5 issues in favor of "Moving" with 6 neutral qualifications), the prospect of "Moving" seems favorable. In particular, the most important issue, namely the irrigation water availability, but also another crucial circumstance, the exposure of the settlement to geological risks, are considerably better for the state of a relocated community in Namashung.

Furthermore, the water stress at the current location might be relieved but not resolved in the longer run by applying possible supply management measures (section 4.2.1). Only in conjunction with demand management measures, which are believed to be inapplicable for Samzong (section 4.2.2), a more sustainable solution might be found in situ.

Therefore, conclusively, the community of Samzong is recommended to resettle in the acquired site of Namashung, by taking the issues elaborated in chapter 5 into account.

7 Conclusion

Analyzing past, present and future trends of the water crisis in Samzong, this study concludes that the water stress will even increase in the future. Possible water shortage mitigation measures were investigated. Though, in light of the decreasing water availability in the future, the problems could not be solved in the long run. Therefore, holistically considering prospects, chances and opportunities, together with threats, weaknesses and problems of the two possible future states “Stay” or “Move,” this study concludes that the most appropriate response to the water crisis is to resettle the whole community of Samzong in Namashung, the land given to the people by the former King of Lo and the VDC respectively.

In general, a sound planning of the resettlement has to be envisioned in order to maximize opportunities and minimize the trade-offs. Along the same lines, further planning, as well as recommended further investigations is considered to be essential. Otherwise the resettlement may induce non-optimal or even adverse consequences. In particular, the following issues related to the relocation have been addressed on a preliminary basis and need further elaboration:

- Study of irrigation supply including different options, their feasibility, costs, pros and cons
- Different options and their feasibility, associated cost, pros and cons of drinking water supply, also studying a possible dual system (irrigation and drinking water)
- Possible passive protection measures of the agricultural area against extreme floods
- Settlement layout and corresponding constructive details for implementation
- Elaboration of an energy concept for the relocated settlement

It is clear, even at this preliminary stage, that the whole resettlement will require funds and aid from outside. The institutional structures as well as local competences do not allow a successful relocation of the community without support, be it in terms of funds or expertise, from outside.

Additionally, the study came across an unexpected critical issue. The village Kyimaling has shown to be exposed to a strong risk related to flood events. Though this issue is not lying within the scope of the study at hand, it is strongly recommended that further investigations are undertaken in order to prepare the community and to implement measures to protect the village against possible flooding.

Methodologically, the complex circumstances of the water stressed Himalayan settlements have proven to ask for a holistic approach including physical, social, environmental, economic and cultural aspects. Appropriate responses which are effective, sustainable and sensitive to the cultural and ethnical context are possible only if all relevant aspects are considered.

This study has shown, that such holistic approaches demand for a disaggregated, adaptive practice. A generic approach would not pay due consideration to the local particularities, which are manifold, despite the fact that the studied villages are seemingly very similar due to their proximity, their common political and cultural affiliation.

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9 List of figures

10 List of tables

A Housing

A.1 Settlement layout of Samzong

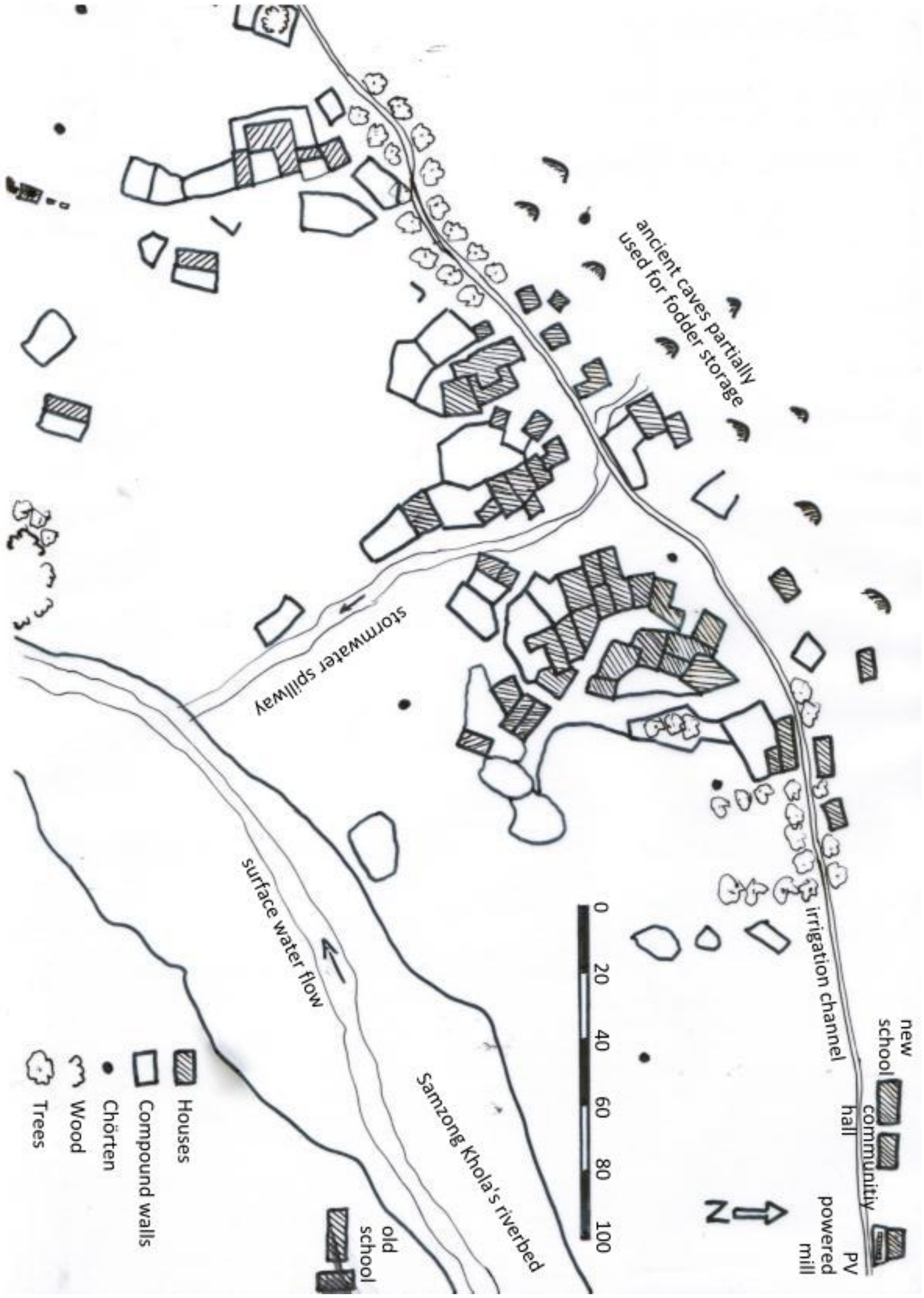

Figure 10.1: Schematic map of Samzong (hand drawing: 27/06/2012, Daniel Pittet)

A.2 Typical house layouts

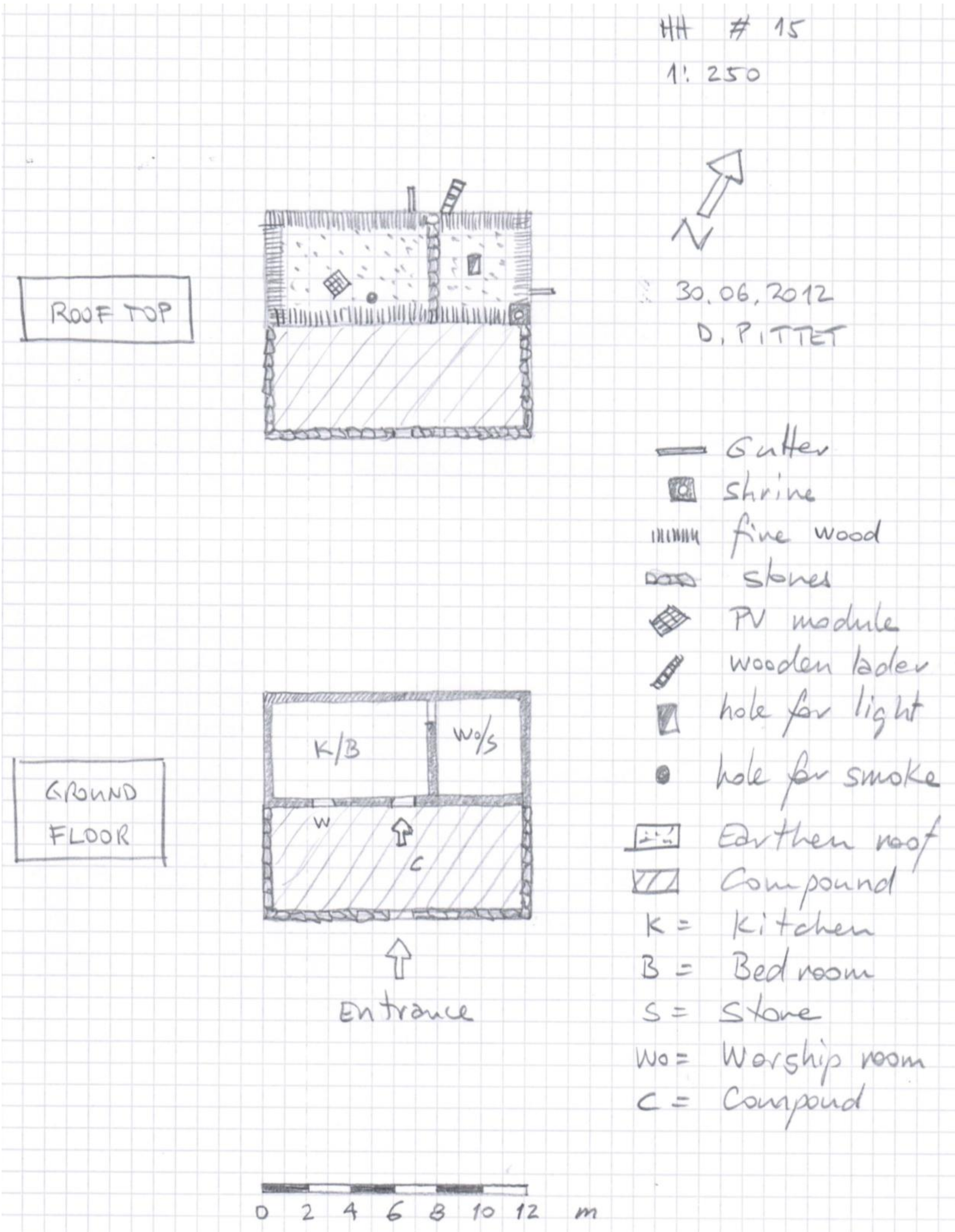

Figure 10.2: Representation of a dwelling from Samzong taken as a reference for a typical small house (hand drawing: 30/06/2012, Daniel Pittet).

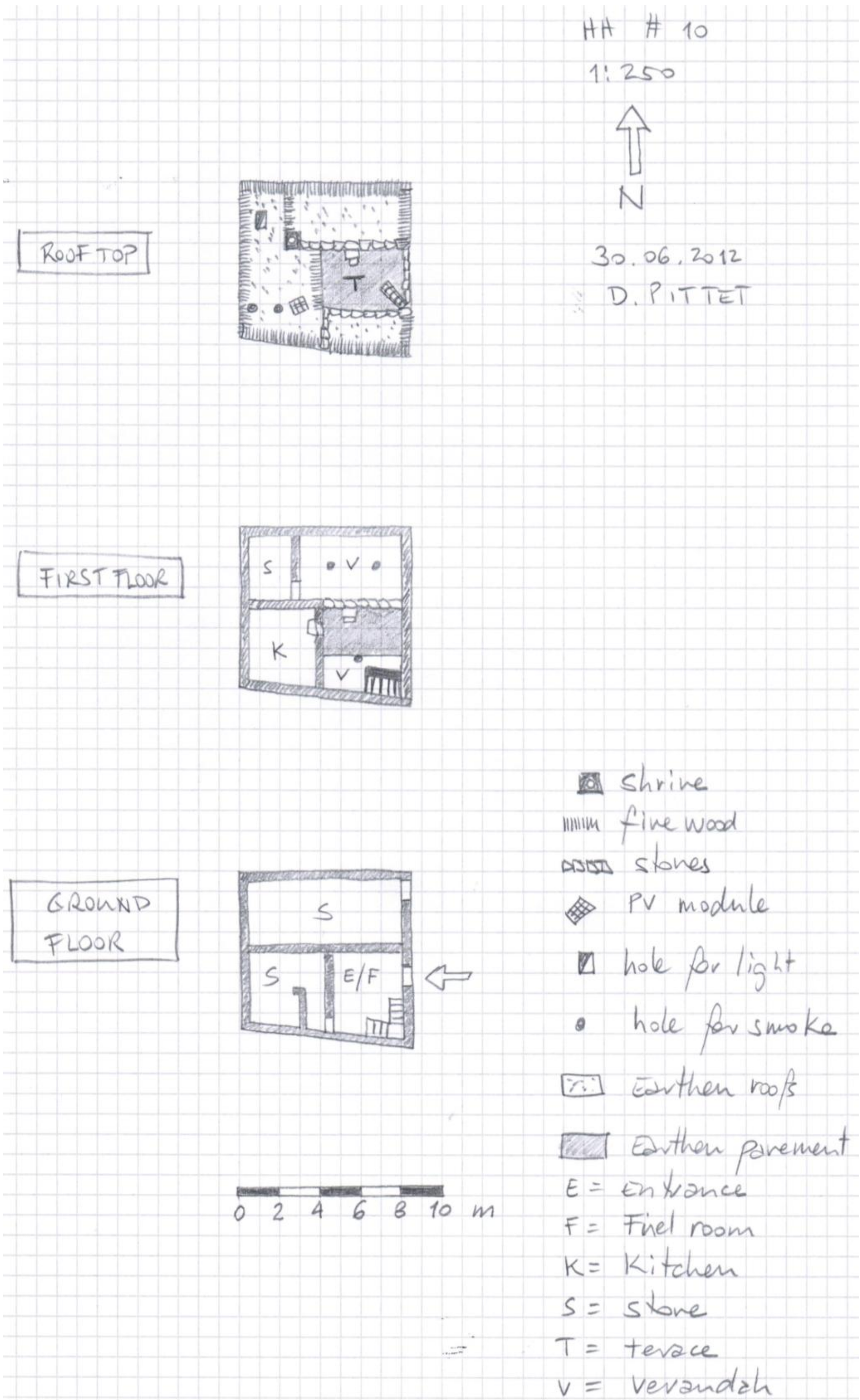

Figure 10.3: Representation of a dwelling from Samzong taken as a reference for a typical medium sized house (hand drawing: 30/06/2012, Daniel Pittet).

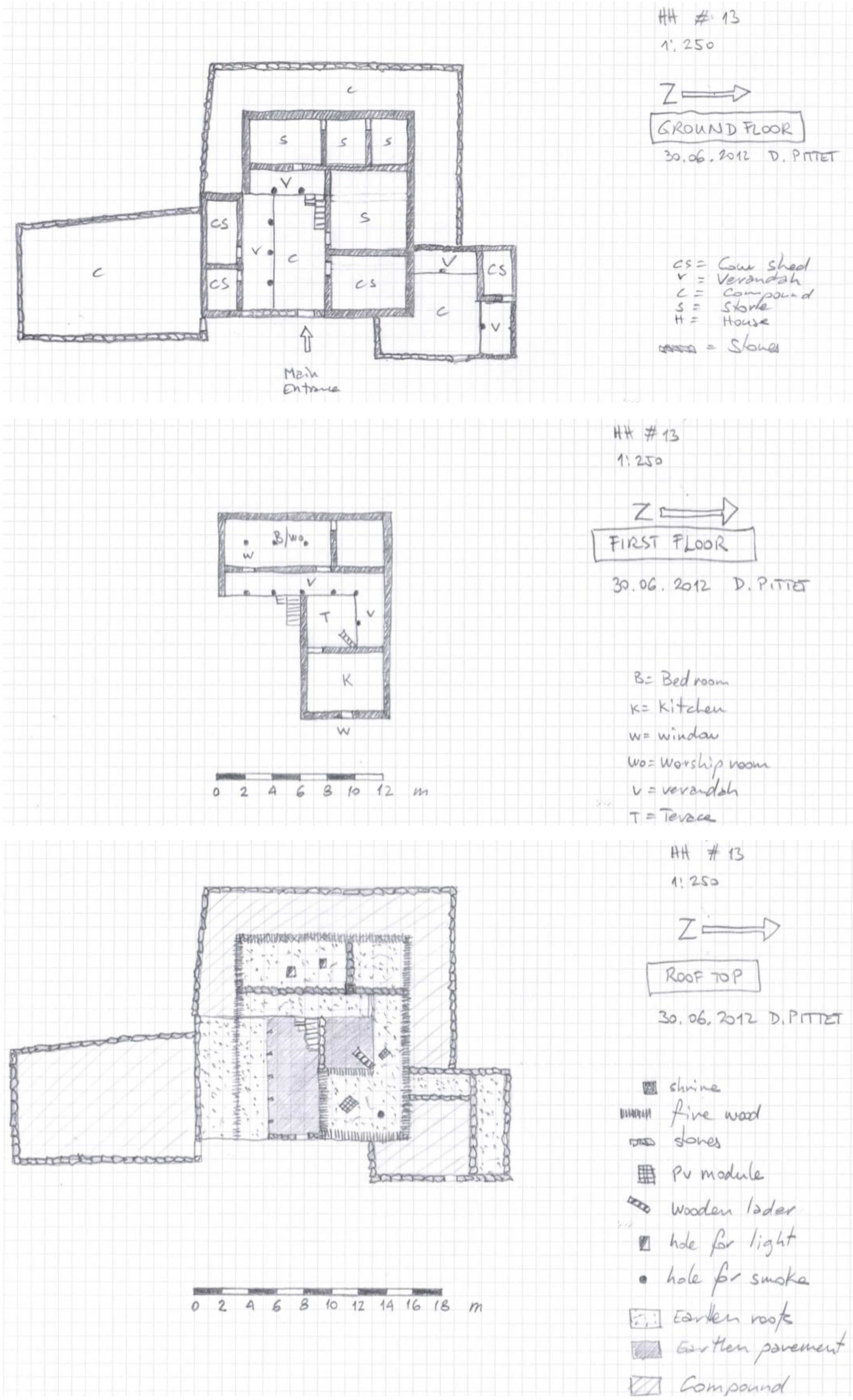

Figure 10.4: Representation of a dwelling from Samzong taken as a reference for a typical large house (hand drawing: 30/06/2012, Daniel Pittet).

A.3 House composition

Table 10.1: Composition of the houses in Samzong. The fractions (0.5 and 0.33) indicate that the functions are shared in a same room (e.g. in HH number 2, the kitchen and one bedroom are in the same room or in HH number 3, the goat-, horse- and cowshed are sharing the same space).

HH number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Mean**
No. of rooms	**2**	**6**	**13**	**8**	**6**	**6**	**3**	**5**	**5**	**8**	**7**	**2**	**12**	**3**	**2**	**7**	**10**	**6.18**
Kitchen	1	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	1	1	1	1	0.5	2	1	**0.79**
Store room		3	6	3	3	1	1	2	2	5	2	1	5	2	0.5	2	3	**2.44**
Bedroom	1	0.5	2.5	1	0.5	0.5	0.5	0.5	0.5	0.5	1		2		0.5		1	**0.74**
Worship room		1	1	1	1	1		1			1				0.5	1	1	**0.56**
Fuel room			1	1	1	1	1		1	1	1		1			1	1	**0.65**
Workshop			1	1		1					1						1	**0.29**
Veranda		1	1			1		1	1	1			3			1	2	**0.71**
Cowshed			0.33	1	1	0.5	1	1	1	2	1		4	1		1	1	**0.93**
Goatshed			0.33								1						1	**0.14**
Horseshed			0.33	1		0.5		1		1				1			1	**0.34**
Toilet				1		1											1	**0.18**
Compound	1	2	1	3	1	1	2	1	1	1	2	4	2	1	2	2	3	**1.76**

B Meteorology and climate

B.1 Visualized cultivated and abandoned fields

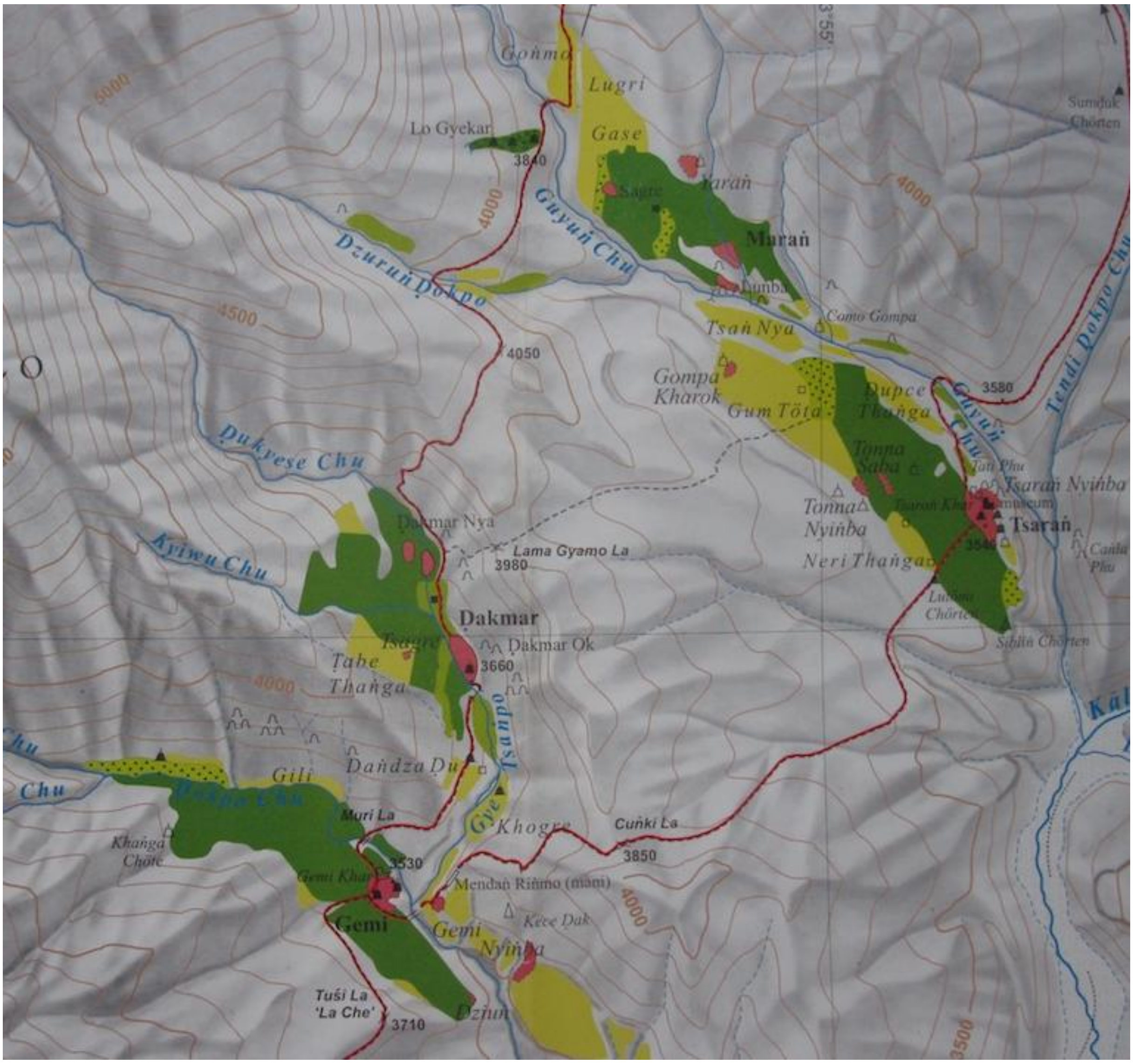

Figure 10.5: Abandoned fields (yellow-green) around Gemi (Ghami), Dakmar and Tsaran (Charang) on a themat-ic map of Upper Mustang by Kostka (2001), based on satellite information from 1990 and 1984. The dark green areas (including textured surfaces) indicate cultivated land. North direction is ↑.

B.2 IPCC scenarios

The Intergovernmental Panel on Climate Change (IPPC) present four different scenarios (Figure 10.6) in their fourth assessment report (IPCC 2007b), of which the intermediate scenario A1B is used in the analysis undertaken by Rohrer (2012a, 2012b).

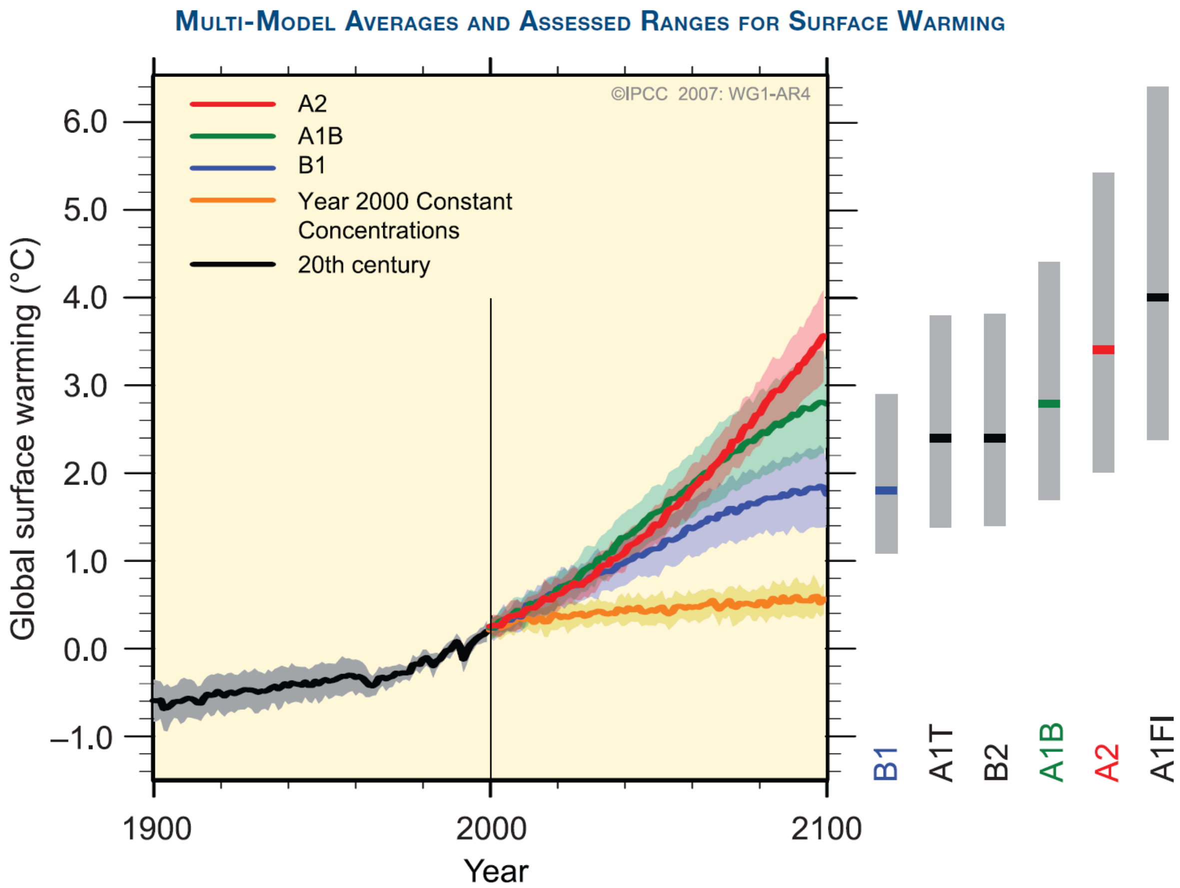

Figure 10.6: Multi-model averages and assessed ranges for surface warming, taken from IPCC (2007b): "Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios. The assessment of the best estimate and likely ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints."

For such scenarios (Figure 10.6), patterns for precipitation changes (Figure 10.7) are projected for instance (IPCC 2007b).

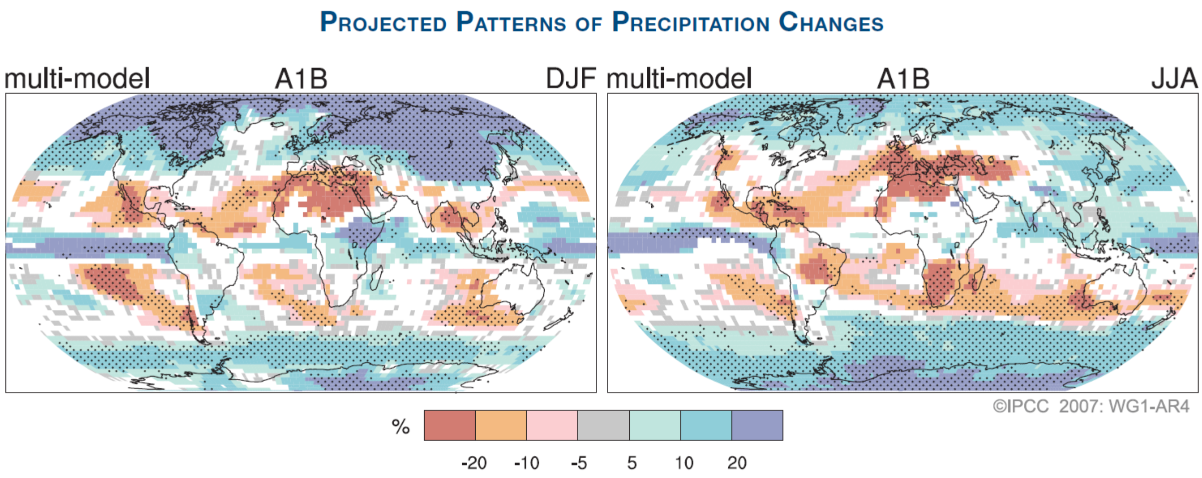

Figure 10.7: Projected patterns of precipitation changes, taken from IPCC (2007b): "Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change.

B.3 Temperature interpolations for Nepal

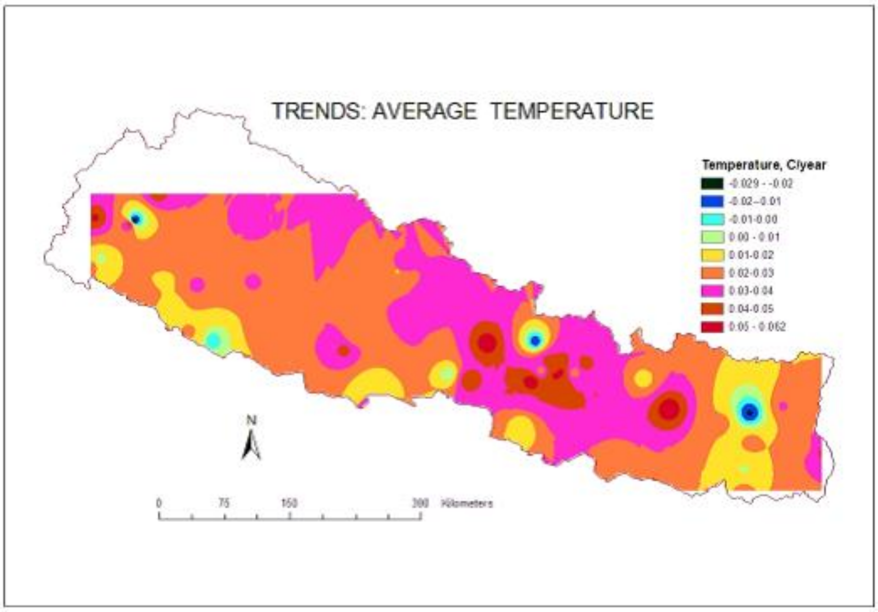

Figure 10.8: Trends of average temperature in Nepal in °C/year from 1975 to 2006 (Sharma 2009).

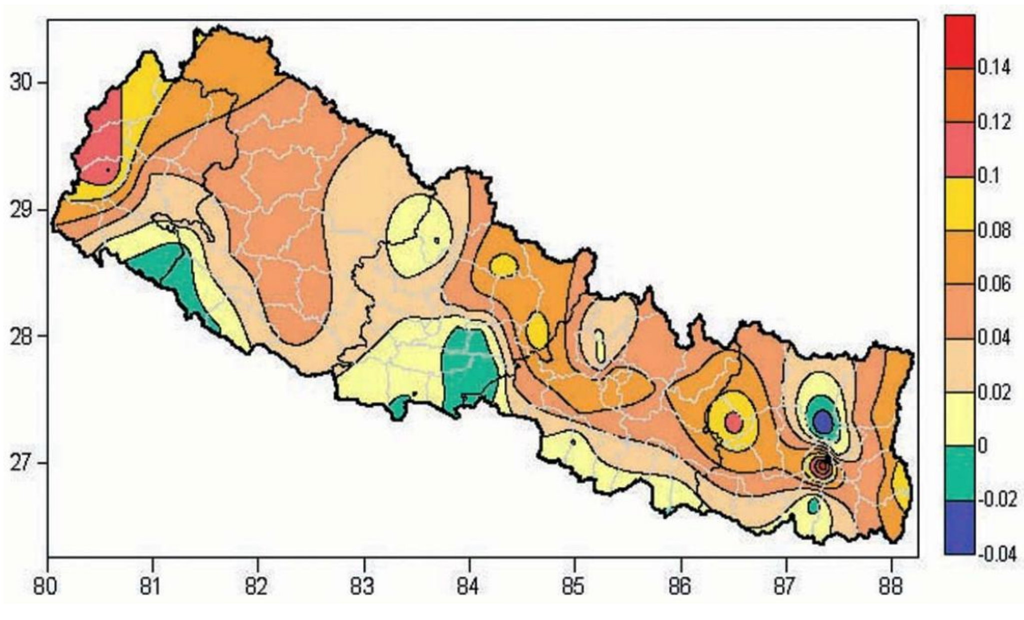

Figure 10.9: Trends of average temperature in Nepal in °C/year from 1976 to 2005 (Practical Action 2009).

B.4 Yearly precipitation sums in southern Mustang

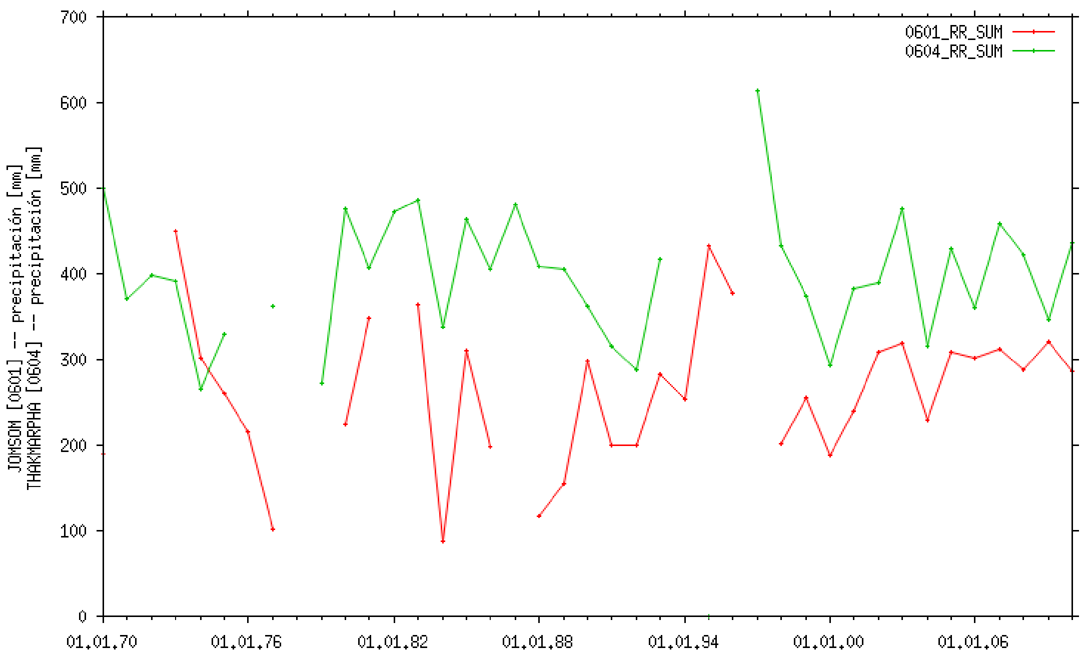

Figure 10.10: Yearly precipitation sums of the meteorological stations Jomsom (0601) and Marpha (0604), situated in lower Mustang showing no clear trend as shown and discussed in Rohrer (2012b).

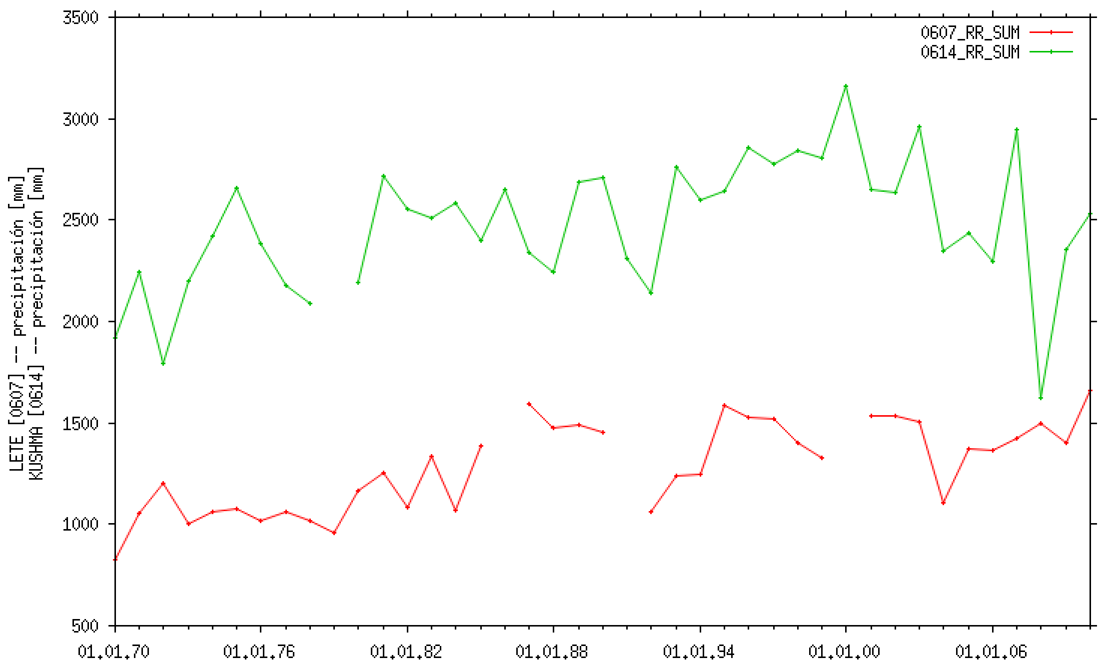

Figure 10.11: Yearly precipitation sums of the meteorological stations Lete (0607) and Kushma (0614) at the entrance of Mustang valley, situated in the south side of Annapurna showing an increasing precipitation trend which needs confirming however as discussed and shown in Rohrer (2012b).