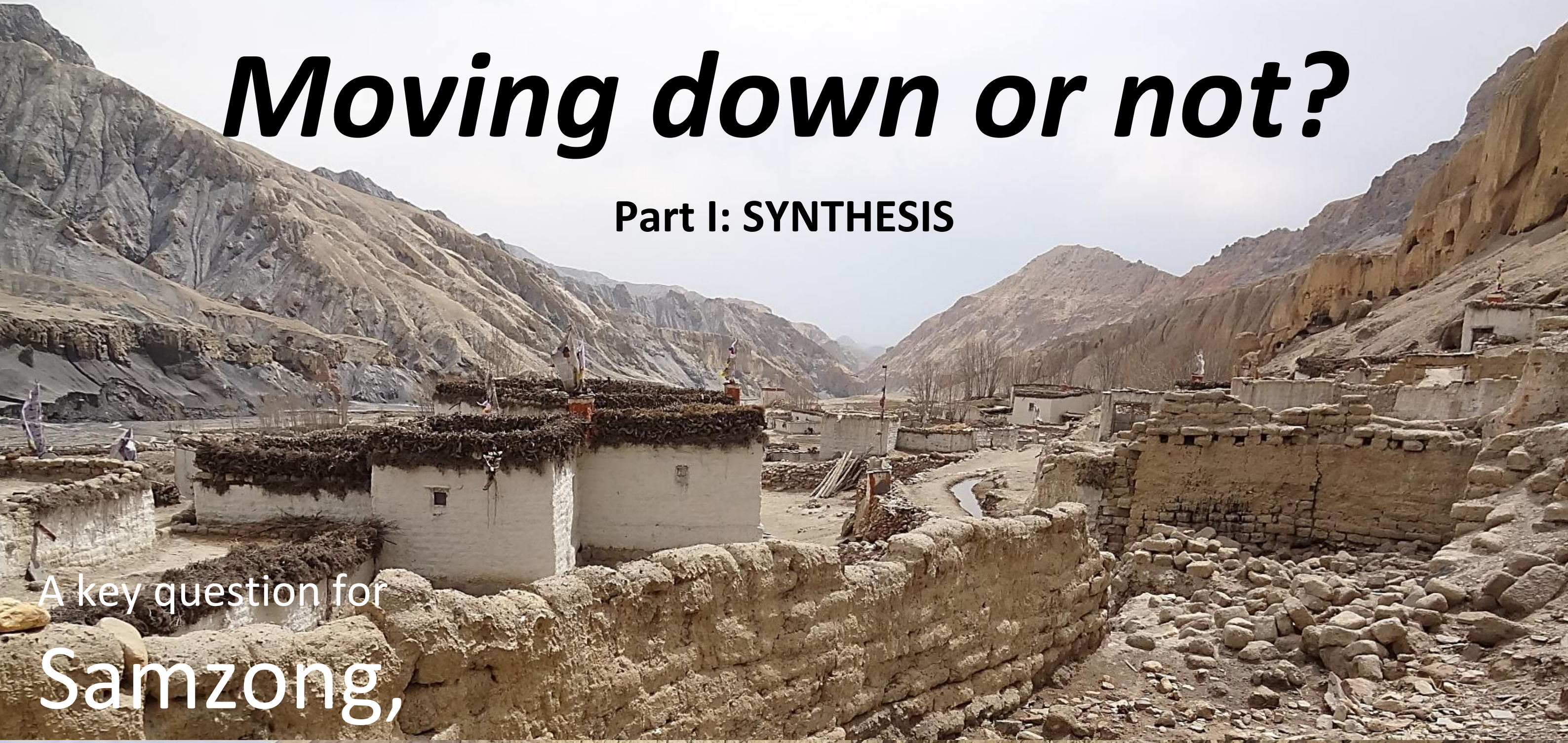
Moving down or not?

Part I: SYNTHESIS



A key question for

Samzong,

Yara,

KAM FOR SUD

University of Applied Sciences and Arts
of Southern Switzerland

SUPSI

November 2012

Dheye,

three villages in Upper Mustang, Mustang District, Nepal

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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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.

Table of Content

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 synthesis, representing the report at hand.

Based on the field surveys, the three villages together count 53 nuclear families and a total population of 296, of which 111 (38 %) are permanently living outside of the settlements. This group of permanent migrants is consisting mostly of children and teenagers who are sent to distant schools (Lo-Manthang, Pokhara, Kathmandu or India). In all villages, economic activities are mostly limited to subsistence agriculture, strongly prejudiced by the scarce irrigation water, and to stockbreeding (goats, cows, horses, sheep and yaks). The latter, together with other accessory economic activities, generates monetary income which is crucial because the agricultural output can only partially cover self-sufficiency. Of all the three studied villages, Yara exhibits the largest economic diversification, which can partially be explained by the fact that it lies within the range of two touristic attractions, as well as being accessible seasonally by a track.

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 the three villages are low productive and almost solely dependent on the perennial flow of the corresponding rivers. Compared to other villages in the region, the three studied settlements have small catchments and appear 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 the catchments within which the three villages are situated is expected to decrease in the future, generally increasing the water stress.

The predominant problem in all three existing villages is the combination of insufficient water availability and inefficient irrigation supply systems. All surface water is currently allocat-

ed, so that a change in the river regime is directly affecting irrigation amounts and consequently agricultural yield. Another crucial issue, which is only concerning Samzong however, is the exposure of the village and its surroundings including the irrigation channels to natural hazards such as debris flow.

In light of the heavy water stress all three villages are subjected to at their current location, an alternative is to "Move" the corresponding village to another place, as envisioned by the communities of Samzong and Dheye. Both communities are in possession of a relocation site, whose suitability for a possible resettlement was carefully examined within the scope of this study. Namely, the water supply security by applying appropriate technical measures, the vulnerability towards natural hazards and possible resettlement concepts were elaborated along with other aspects, which altogether constitute the possible future state "Move." In comparison, the current problems in the existing villages were analyzed and possible solutions elaborated, whose implementation constitute the state "Stay." Holistically comparing both states, this study concluded that the most appropriate response to the present and future challenges is to resettle the whole community of Samzong in Namashung and Dheye in Thangchung respectively. Above all, the key factor speaking in favor of a relocation of Samzong and Dheye, was that in both villages measures could be implemented relieving the water stress for a certain time, but surely not in the long run. In addition, the designated settlement area for the relocated community of Samzong, is much less exposed to natural hazards than the existing village.

In contrast, the community of Yara does not have a relocation site (so far). Consequently, the chosen analytical approach had to be different than the one applied in Samzong and Dheye. Nevertheless, the issue had to be addressed, whether the village should be advised to think about moving in the future or not.

The study has shown that in general, the sole application of supply management measures will procrastinate, but not solve the current problems in the long run. Unlike in the two other villages, in Yara the implementation of demand in conjunction with supply management measures might be feasible due to few inherent characteristics of the village. In fact, the community of Yara could be capable of developing adaption strategies in the longer term. Therefore, Yara is recommended to "Stay" at the current location and adapt to the current situation by implementing proposed supply management measures, while striving to become less dependent on agriculture by encouraging further diversification of economic activities (demand management).

However, considering the high level of uncertainty about future socio-economic and climatologic conditions, it is impossible to predict, whether the adaption strategies of Yara will be successful and sufficient. In case the water stress should prove to become unbearable and/or the community's adaptation strategies turn out to be insufficient, the possible necessity of "Moving" will have to be reevaluated.

Glossary

Dal	Soup made out of lentil, which is served with rice (Bhat) in the national Nepalese dish Dal Bhat
Ghenpa	Tibetan name for the traditional communal role assumed for yearly turns
Khola	River or stream
Mukhye	Nepali name for Ghenpa
Saligram	Fossil
Tom	Plastic canisters with a volume of 5 or 35 liters
Zipu	Herb used as a spice for Dal

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
DDC	District Development Committee
DGSD	Deep-seated Gravitational Slope Deformation
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
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
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

In addition of a synthesis report, the project's outputs include a detailed, self-standing report for each of the three studied villages Samzong (Part II) Yara (Part III) and Dheye (Part IV). In these reports the answer to the crucial question "moving down or not?" is elaborated in detail.

The synthesis report at hand however focuses on commonalities and differences between the three villages while details are left aside in order to provide an overview about the topics. Particularly, the specific characteristics of each village concerning housing and related concepts, water supply systems and their possible improvements as well as the geological conditions and their inherent implications are not discussed in this report. Merely, the most important aspects are mentioned and put into relation. Only the chapter about Upper Mustang's climatic and meteorological setting, common for all three village reports, is reproduced here at full length due to the central role related to the evolution of the problems and challenges the villagers have to face today and in the future respectively.

In order to lead the reader comprehensibly through the report, it is structured as follows. First some background information are presented (chapter 1), in which the purpose of the study is explained, followed by a short description of the study's main goal together with general methodologies. An embedment of the whole study in the local context along with a brief introduction of each studied village wraps up the first chapter. Differences and commonalities of the three villages related to socio-economics are discussed in chapter 2. Issues associated with the settlements' footprints and housing characteristics are summarized in chapter 3. Chapter 4 is concerned about climatic, meteorological as well as glaciological matters. Water related issues are summarized thereafter, in chapter 5. Chapter 6 summarizes the key issues related to the geological investigations. The discussion of the final answer to the key question "moving down or not?" can be found in chapter 7 and finally, the conclusion is drawn in chapter 8.

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. In addition to 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[1] were organized. 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.

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.

1.4 Contextualization

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). Mustang is one of the 75 Districts of Nepal and lies in the Dhaulagiri Zone within the Central Development Region.

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).

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). In 2008 the last official King of Lo was deprived of any formal power by the Nepalese government. Nevertheless, the royal family Bista, from which lineage the former Kings have sprung, exhibit a strong influence on the inhabitants of Upper Mustang even today.

Though the country is organized as a parliamentary democracy since 1990/91, the precedent monarchical organization survived de facto until the beginning of the 21st century and did not allow the development of a decentralized government. Consequently the most remote areas such as Mustang have only benefited marginally from services provided by govern-

[1] The details thereof are described in appendix A, along with a brief description of applied general methodological approaches and used resources.

mental institutions. Generally such support has been limited 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. In terms of financial support, the governmental DDC and VDC allot a limited amount of money based on proposals from the corresponding villages on a year-to-year basis. Thus, from a project perspective, rather “stage-wise” or “stop and go” approaches result.

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).

Due to the weak institutional structure and the particular historical background of Upper Mustang, local leaders and traditional community-based decision making play a central role. 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.

Furthermore, it is important to recognize the central role of the social structure within 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. 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.

1.5 Village portraits

The three studied villages Samzong, Yara and Dheye are all located in Upper Mustang which is a “restricted area.” The restricted Upper Mustang is part of the Annapurna Conservation Area (ACA), which is managed by the Annapurna Conservation Area Project (ACAP). 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. In the following each village, as well as the corresponding relocation sites for the cases of Samzong and Dheye, are introduced briefly.

1.5.1 Samzong and Namashung

Samzong is located at the right[2] 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 (Figure 1.2). Samzong belongs to Tsoshar VDC and is accessible on foot only. This year the first half of a track intended to connect Samzong with the existing road between Lo-Manthang and the Chinese border has been completed.

In desperate need for a solution of the pressing problems at the current location, the people of Samzong sought the help of the LMF. As an ultimate solution, the relocation of the whole village has been envisioned. In the course, a site 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 has been acquired. The land foreseen for cultivation, a plateau whose western border is confined by the Kali Gandaki, has been given to the community by the former King of Lo. 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 in summer 2012 and is planned to conclude in 2013. The land foreseen for the settlement has been provided to the community by the VDC for free. It lies about 10 m higher than the field area and is slightly southeast thereof.

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

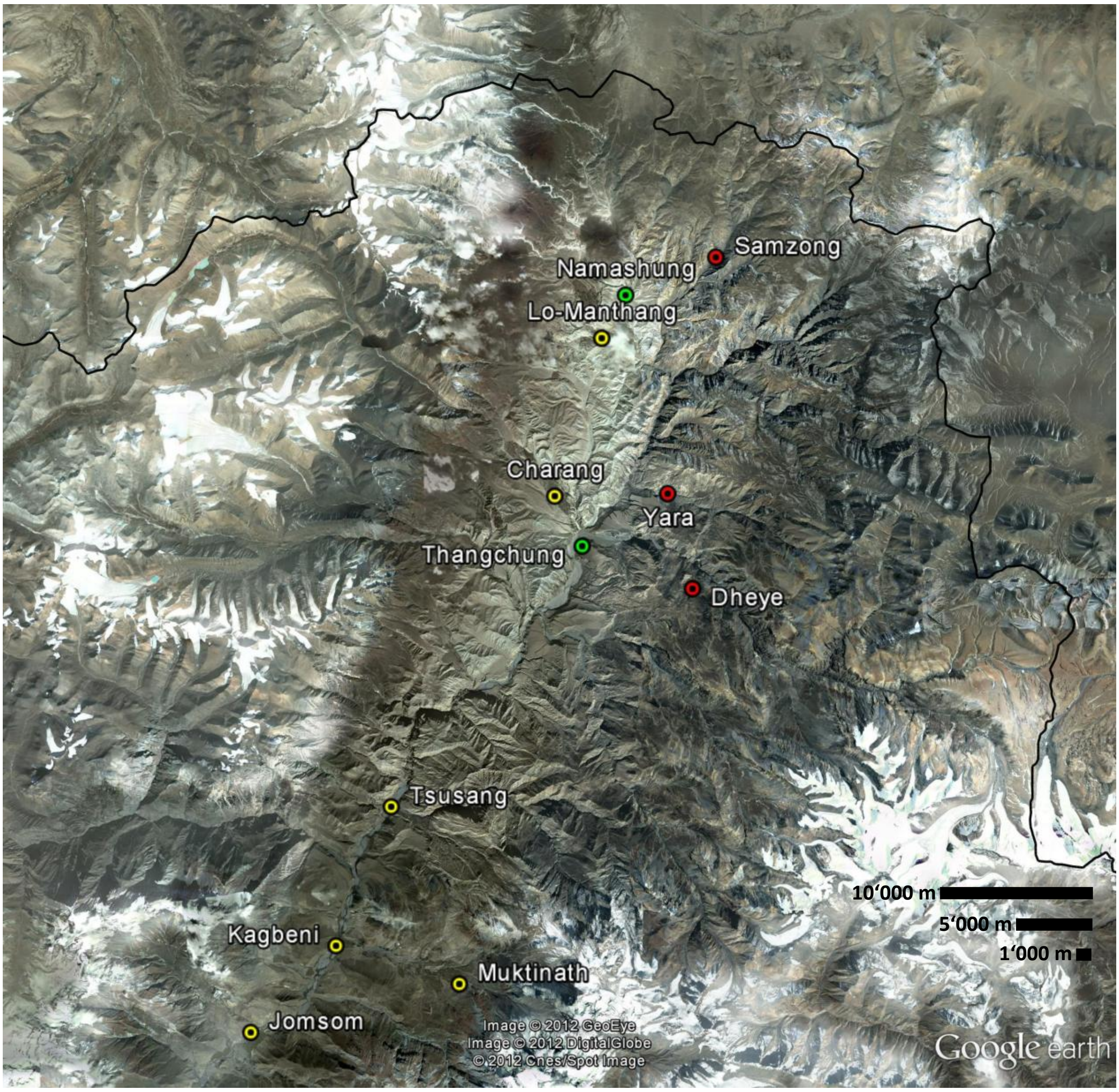

Figure 1.2: Overview of Upper Mustang. The main villages are indicated by yellow points, the studied villages are highlighted with red dots and the possible new locations of Samzong (Namashung) and Dheye (Thangchung) respectively are shown in green. The Chinese-Nepalese border is shown in pink, north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

1.5.2 Dheye and Thangchung

Dheye lies on a ridge at almost 4'000 m asl and is accessible on foot only. The village is located more than 10 km southeast of Charang and belongs to Zurkhang VDC (Figure 1.2).

The community of Dheye is put heavily under stress by the increasing lack of water, by the difficulties of accessing the village due to frequent damage of the path leading to the village and by other factors such as the remoteness of the village. In the course, the village has taken the initiatives toward relocating the whole village. The selected site called Thangchung, is located about 4 km southeast of Charang, on the opposite, left bank of the Khali Gandaki. It is a plateau, elevated roughly 30-40 m relative to the confluence of the Dhey Chang Khola and Charang Khola with the Kali Gandaki. The land of Thangchung falls already within the jurisdiction of Dheye village and is currently utilized by the community for herding their livestock during winter (T. G. Gurung 2011). Recently a track leading up to the plain has been built.

To generate additional income, the community of Dheye initiated the construction of an orchard on the western end of a slightly elevated, vast plateau named Chawale to the left of the active riverbed of Dhey Chang Khola a few years ago which was partly completed in early 2012. The project proposal (T. G. Gurung 2011) envisions the cultivation of the whole plain of Chawale.

1.5.3 Yara

Yara lies about 7 km east of Charang on an elevation of around 3650 m asl and belongs to Zurkhang VDC. The village is situated on the right riverside of Puyung Khola (Figure 1.2). Like the two other villages, Yara is confronted with severe water stress related to agricultural practices.

Unlike the two other studied villages, the community of Yara has neither identified, nor acquired a relocation site.

2 Socio-economic and institutional aspects

In this chapter socio-economic, institutional and demographic issues, specific for the three villages, are presented.

2.1 Demographic aspects

Based on the field survey, the three villages together count 53 nuclear families and a total population of 296, among which 150 (51 %) are female and 146 (49 %) are male. Out of the total population, 111 (38 %) are permanently living outside of the settlements (Table 2.2).

Table 2.1: Demographic constitution of the three studied villages Samzong, Yara and Dheye, based on the socio-economic survey carried out during the field visits.

Description	Samzong	Yara	Dheye[a]	Total
Number of households	17	22	14	53
Total population	83 (100 %)	114 (100 %)	99 (100 %)	296 (100 %)
Number of female	44 (53 %)	61 (54 %)	45 (45 %)	150 (51 %)
Number of males	39 (47 %)	53 (46 %)	54 (55 %)	146 (49 %)
Number of residents	61 (73 %)	74 (65 %)	50 (51 %)	185 (63 %)
Permanent migrants	22 (27 %)	40 (35 %)	49 (49 %)	111 (38 %)

[a] Within the past decades 10 households left Dheye and settled elsewhere. Including the relocated families, the total population amounts 157 including 55 (47 %) females and 83 (53 %) males.

Overall, the demographic constitutions of the three villages are comparable, but some differences are highlighted in the following. In the whole Mustang District, there are less females (47 %) compared to males (53 %). A similar ratio is found in Dheye, whereas in Samzong and Yara it is the opposite. The fraction of permanent migrants is lowest in Samzong and highest in Dheye, whereas in the latter village half of the whole population does not reside in the village anymore. This circumstance leads to the fact, that in absolute numbers, Dheye has the fewest residents, although the total population is second biggest. Samzong on the other hand has the smallest total population but second most residents.

The permanent migrants rarely come back to the villages, if at all. Opposed to that, most of the inhabitants move towards 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 villages during the winter.

The age structures of the three studied communities are very much alike (Table 2.2). This exemplifies that for all villages, permanent migration concerns a very distinct demographic group. In fact, permanent migrants are almost exclusively teenagers and school-aged children, reflected by the average age of 17 years together with a rather low standard deviation. The residents on the other hand consist mostly of adults and young children, underlined by the relatively low average age associated with a large standard deviation (Table 2.2). This circumstance can be explained by the fact, that most young children are kept at home and looked after, while school-aged children and teenagers are sent to distant schools (Lo-Manthang, Pokhara, Kathmandu or India). 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 such local, regional and even national centers. Subjectively, such centers present major earning opportunities, better material living conditions and a large overall attraction as it seems.

Table 2.2: Age structure of the communities Samzong (S), Yara (Y), Dheye (D) and the total population (T) based on the socio-economic surveys. 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 Population			
	S	Y	D	**T**	S	Y	D	**T**	S	Y	D	**T**
Number of family members	22	40	49	**111**	61	74	50	**185**	83	114	99	**296**
Average age	16	17	16	**17**	34	37	36	**36**	30	30	27	**29**
Standard deviation	12	8	7	**9**	21	21	20	**21**	21	20	18	**20**

Excluding a few outliers, the size of the households (HHs) seems to be slightly correlated with the percentage of permanent migrants, as depicted in Figure 2.1. With the exception of 4 families from Yara and 1 family from Dheye, all HHs with a total number of 3 or less members are living in the village (at least during the bigger portion of the year). On the other hand, without exception, a varying fraction (greater than zero) of all families with 6 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 or exactly opposite, large families might have the means to send some members to outside schools due to higher overall income. It has to be noted however that it is generally difficult and may be delusive to draw conclusions from the data itself.

Figure 2.1 highlights further, that Samzong consists of rather small families with a low fraction of permanent migrants, whereas Yara's constitution is wide-spread and Dheye consists mostly of large families including many migrated family members. This visually underlines the demographic characteristics of the villages presented in Table 2.1.

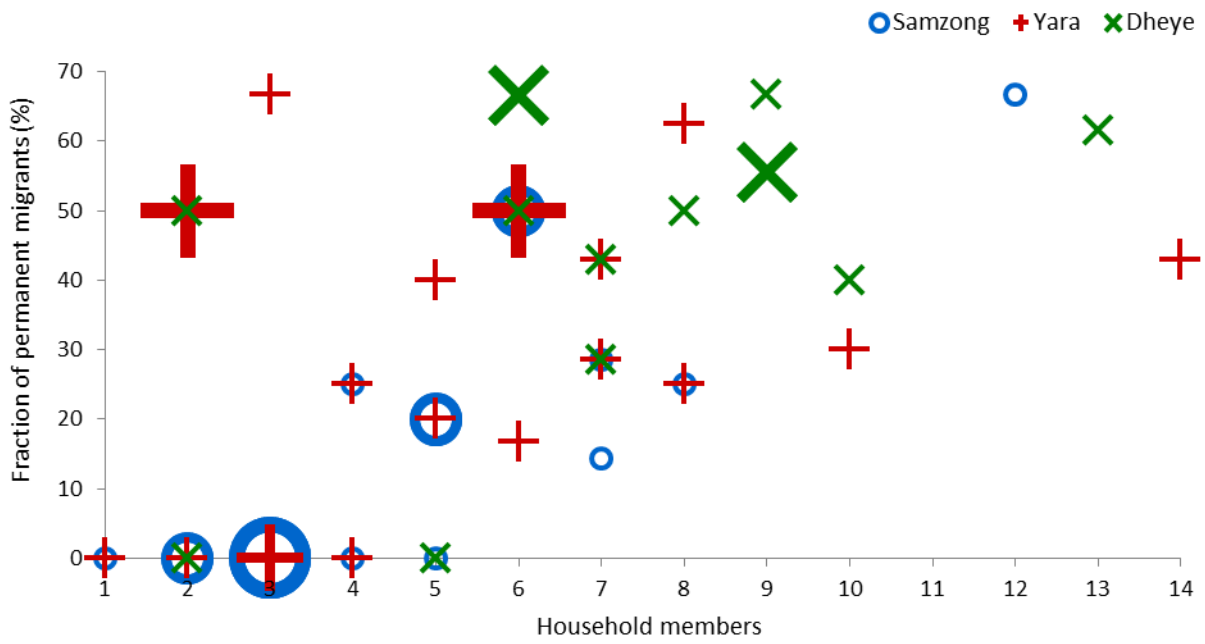

Figure 2.1: Scatter plot between the numbers of HH members against the fraction of permanent migrants of the corresponding family. The smallest sized markers correspond to a single HH (e.g. 1 family in Samzong with total 7 HH members including 1 (14 %) permanent migrant), medium markers to two families (e.g. 2 families in Dheye with 6 HH members of which 4 (67 %) are permanently migrated) and the largest ones to three HHs with the same characteristics (e.g. 3 families in Yara each consisting of 2 HH members of which 1 member has permanently migrated).

2.2 Institutions and local competences

As mentioned in section 1.4, the institutional structure in Nepal is very weak, particularly in such a remote place as Upper Mustang. In the studied villages, there are no governmental bodies, buildings, police quarters nor health posts present. Each village has a small school with very few children and one or two teachers, who are appointed by the central government. Apparently, 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.

Only in Dheye there seem to be persons with informal leadership characteristics. The community is organized, very proactive and is taking actions on their own accord, mainly due to the lack of institutional and other support from outside. The initiatives are clearly originating from within the community and are not driven by outsiders.

In the cases of Yara and Samzong, the support comes from outside to a large degree. The LMF, together with other actors, has taken over the lead in the endeavor to solve the pressing problems, particularly in Samzong. It might seem that the people of Samzong are more passive in comparison to Dheye, but the cases have to be differentiated. Samzong, under heavy stress related to irrigation water availability and natural hazards, could not move as an ultimate solution to the problems, since the community was not in possession of an appropriate relocation site. Therefore they were constricted and had to seek help. Only due to the engagement and support of Lama Ngawang Kunga Bista, along with others, land suitable for a possible relocation of Samzong could be organized and granted to the community. Dheye on the other hand has had vast land, including the two plains Chawale and Thangchung (section 1.5.2), which had belonged to the community as long as could be remembered. These areas could be used for any activity subjectively able to ameliorate the overall situation of the community, without being dependent on help from outside.

Certainly, engaging in action based on own initiative is admirable and is proof of a good adaptive strategy of the community, but it also bears the risk, that non-optimal solutions might be found due to the limited expertise and know-how of the community itself. On the other hand, being dependent on outside help restrains the capacity of the community to find best solutions for themselves and even worse, the people might be instrumentalized. However, in the given context of such complex problems involving the relocation of whole villages, expertise, farsightedness and sound planning is eminent to come up with most appropriate responses.

2.3 Economic activities and income

In all villages, economic activities are mostly limited to subsistence agriculture, strongly prejudiced by the scarce irrigation water, and to stockbreeding (goats, cows, horses and sheep).

In Samzong, all families own a certain amount of land area. Though in Dheye there is one family (7 %) and in Yara even eight families (36 %) which do not own land by themselves, almost all families practice agriculture.

According to the field surveys, the three villages together own 87 horses, 117 cows, 3879 goats, 148 sheep and 80 yaks. In fact, the main economic activity that allows generating additional income is to sell animals and/or their fur. As an example, the market value of a goat corresponds to about 6’000 to 7’000 Nepalese Rupees (NPR).

All the families were asked about their yearly income. In Figure 2.2 the stated incomes were related to the amount of goats and the total number of residents of the corresponding families. The incomes vary greatly among all HHs but they seem to be grouped. While the incomes of Samzong are the lowest, the incomes of Yara include some low values but also reach up to higher amounts, also including an outlier with the clearly highest stated value of all three villages. Dheye on the other hand has indicated to earn most overall. The same holds for the amount of goats. Except one HH, all families in Samzong own some goats, but among all villages the least. In Yara there are a considerable amount of families who own few or even no goats at all. Overall, the inhabitants of Dheye own the most goats per family. Furthermore, Figure 2.2 illustrates, that the HHs with the most residents are located in Yara.

In any case, 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. In fact, the seemingly grouped values might be an indication of systematically varying answers per village, but the issue would have to be studied closer to make such statements.

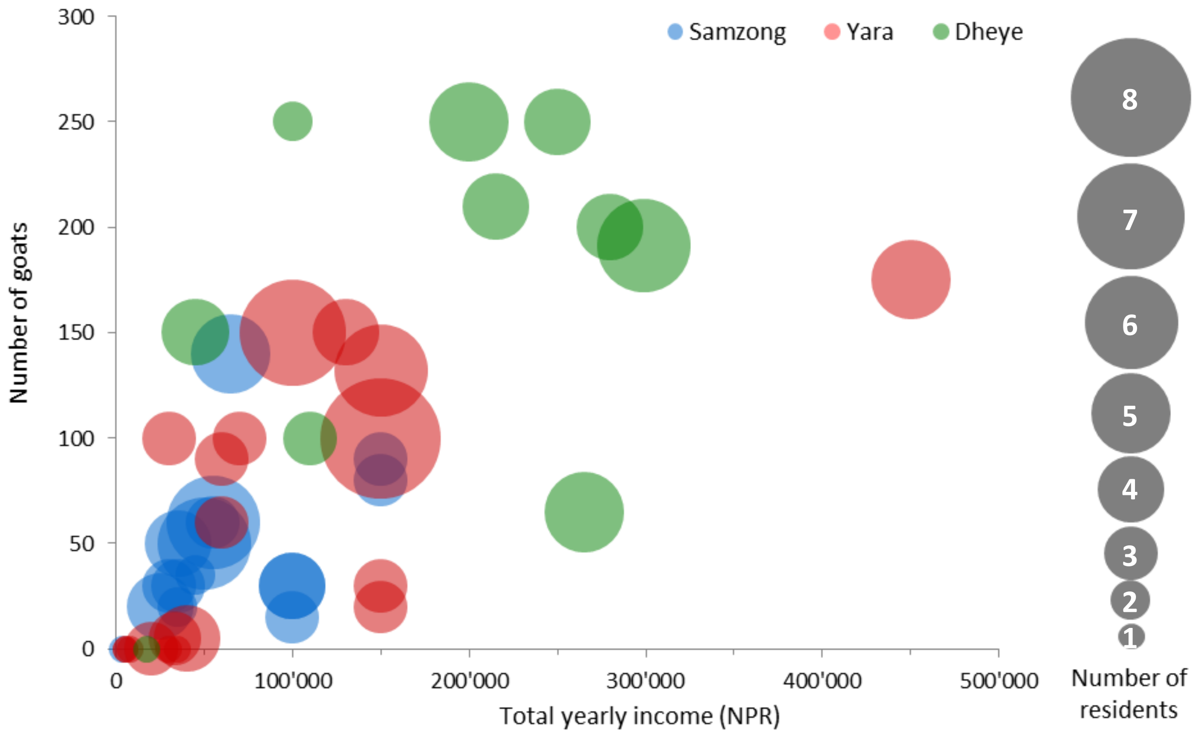

Figure 2.2: Scatter plot of the total yearly income and the number of goats per family. The size of the circle indicates how many family members are still living in the corresponding HH in Samzong, meaning that they are not permanent migrants, but residents.

Monetary income is essential to assuring the subsistence throughout the year, since the output from agricultural activities alone does not suffice. In addition to stockbreeding, another common income generating activity is engaging in winter marketing in suburban areas of Pokhara, Kathmandu or India for instance. Other activities executed by numerous families include collecting Zipu, an herb which is sold as a spice for Dal, workmanship in construction or other paid labor. A particularity in Dheye is that the villagers collect fossils, so-called Saligrams, which can be found in the region in comparatively high numbers and which are sold to tourists later.

Of all three studied villages, Yara displays clearly the largest diversity of economic activities. It seems that not only the range is larger, but likely also the degree to which some of the families depend on activities which are different from agriculture and stockbreeding. For instance, this is underlined by the fact, that about half of all the households in Yara do not own goats at all or only in insignificant numbers (Figure 2.2). Moreover, there are eight families which do not own fields, which might be a reason, why other sources of income have to be tapped. Above all however, Yara is the only one of the three studied villages, which is, at least seasonally, accessible by a track and is providing touristic accommodations. Namely a guesthouse with attached campground and another separate camping site are available. Both provide accommodation for tourists or pilgrims who are mainly visiting Dharmadha Kunda or Luri Gonpa, two local attractions. These circumstances are certainly also a reason for the more diversified economic engagements in Yara. As a matter of fact, at least two HHs, namely the owners of the accommodations, directly earn part of their living from tourism. Few other families take the opportunity presented by the tourists coming to Yara by working as local guides or execute paid labor in case of need. Besides, a few individuals carry out additional jobs such as health assistant, manufacturing and selling horse equipment, producing handicraft and running a small shop and operating a tractor transport service, which are found only in Yara and not in the other two villages.

2.4 Perception of the main problems faced by the communities

During the socio-economic surveys each of the 53 HHs was asked to identify three main issues about which they are most concerned and to rank them according to severity (Figure 2.3). With a striking majority, the insufficient irrigation water was identified by the villagers. This clearly exemplifies, that the problem is not constricted to a few individuals of a community, but to the vast majority. Interestingly, four HHs mentioned the fact that they are landless as the main issue. However, this problem is limited to Yara, where out of the 22, 8 HHs are not in possession of own agricultural fields (section 2.3).

The second concerns are already more dispersed. Many people are concerned about floods and landslides, but this is mainly due to Samzong's villagers who contribute the vast majority of the votes for this particular issue. A concern which was mentioned by all three villages to a similar degree is food supply.

The analysis of the main concerns exemplifies nicely, that the striking commonality between the villages is the lack of irrigation water. It also illustrates, that the vast amount of families are dependent on agriculture and the productivity thereof. Water scarcity certainly lowers the output, which directly affects the livelihoods of most HHs. On the other hand, the large range of issues, which are of lower concern to the villagers, demonstrate that other common problems are not so clearly identifiable. Of course all villages are embedded in a similar context, but nevertheless, the commonalities related to the main concerns do not really go beyond the general lack of irrigation water.

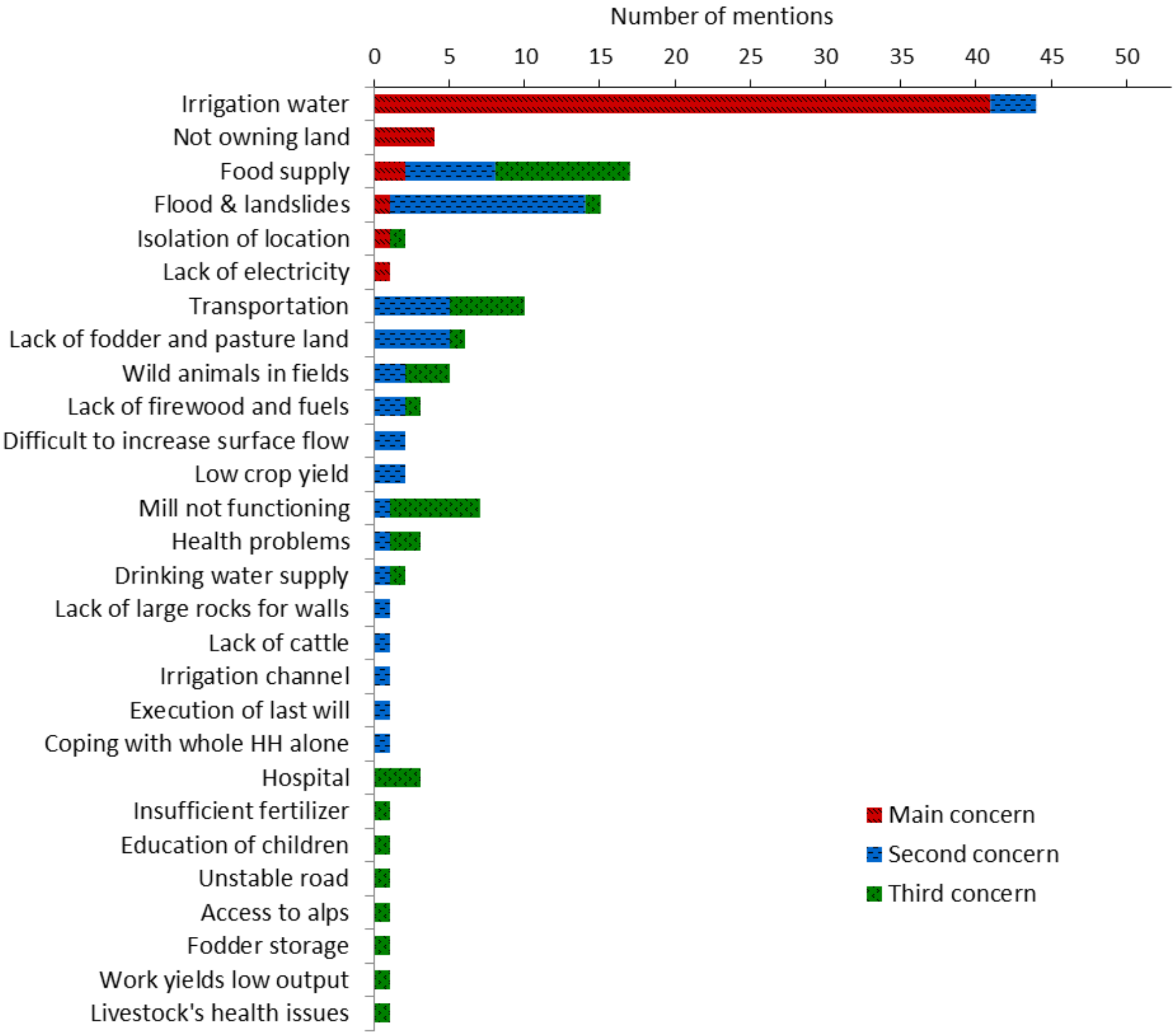

Figure 2.3: Visualization of the survey related to the identification and ranking of three main issues about which each of the 53 HHs (corresponds to the presented axis) are most concerned. Note that few families abstained from choosing altogether and numerous families identified less than three main issues.

3 Settlement and housing

In the following sections the commonalities and differences between the three settlements related to space availability and housing are discussed. Schematic maps of the three studied villages can be found in appendix B.

3.1 Space availability and density

The population density of Samzong and Yara are very similar, whereas Dheye has the highest value underlining the particularly dense layout of the settlement. The cultivated areas of Dheye and Yara are very similar, while Samzong's field area is slightly smaller (Table 3.1).

Table 3.1: Settlement and agricultural area related to the populations of the three studied villages together with the respective relocation sites. 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 surveys undertaken during the field visits.

Description	Settlement area (ha)	Cultivated area (ha)	Total useable area (p)	Total population 2012 (p)	Population density (p/ha)	Cultivation area per capita (ha/p)
Samzong *Current location*	1.34	9.08	10.42	83	62	0.11
Namashung *Relocation site*	0.83	9.75	10.58	83	100	0.12
Dheye *Current location*	1.18	10.39	11.57	99	84	0.11
Thangchung *Relocation site*	6.13	13.71	24.93	99 (157)	16 (26)	0.14 (0.09)
Yara *Current location*	1.69	10.56	12.25	114	67	0.09

For a possible resettlement, the comparison of the corresponding areas is interesting. In case of Samzong, the total as well as the agricultural area remains almost the same, but the available settlement area would become sensitively smaller resulting in a much larger population density (Table 3.1). To account for this circumstance, an appropriate settlement layout was elaborated on a preliminary basis in the scope of this study and is presented in corresponding village report (Part II: Samzong).

The available space of Dheye's relocation site is more than twice as big as the existing footprint. The layout of the settlement as proposed by T. G. Gurung (2011) reserves a vast area for the settlement itself, which leads to a heavy reduction of the population density, even if the recently dislocated families would return as envisioned by the community (bracketed values in Table 3.1). It is suggested to build the settlement in a rather dense manner to have additional area available for agricultural purposes for instance. A further discussion of this matter together with a possible settlement layout is presented in the corresponding village report (Part IV: Dheye).

3.2 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.

3.2.1 House layout

The dwellings are generally rather compact with access to the rooms through a central courtyard and systematically accessible flat roofs (Figure 3.4 in section 3.2.3). Generally the houses are surrounded by compounds for animals fenced by stone walls, in case enough space is available. In the three villages at least half of the houses 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 or a large house respectively, were measured in Samzong and are presented in appendix C.

3.2.2 Partitioning

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 is often built on the roof that may also host solar modules for the lighting systems (Figure 3.4 in section 3.2.3). 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 surveys have also allowed collecting data on the houses' compositions, illustrated by Figure 3.1. Generally the absolute number of rooms varies greatly. On average, the inhabitants of Dheye have the most and Yara the least amount of rooms per house. All houses accommodate bedrooms and a kitchen, though in numerous cases the rooms are used for different purposes. Generally, store rooms and compounds are very common, but in Yara the corresponding numbers are much lower.

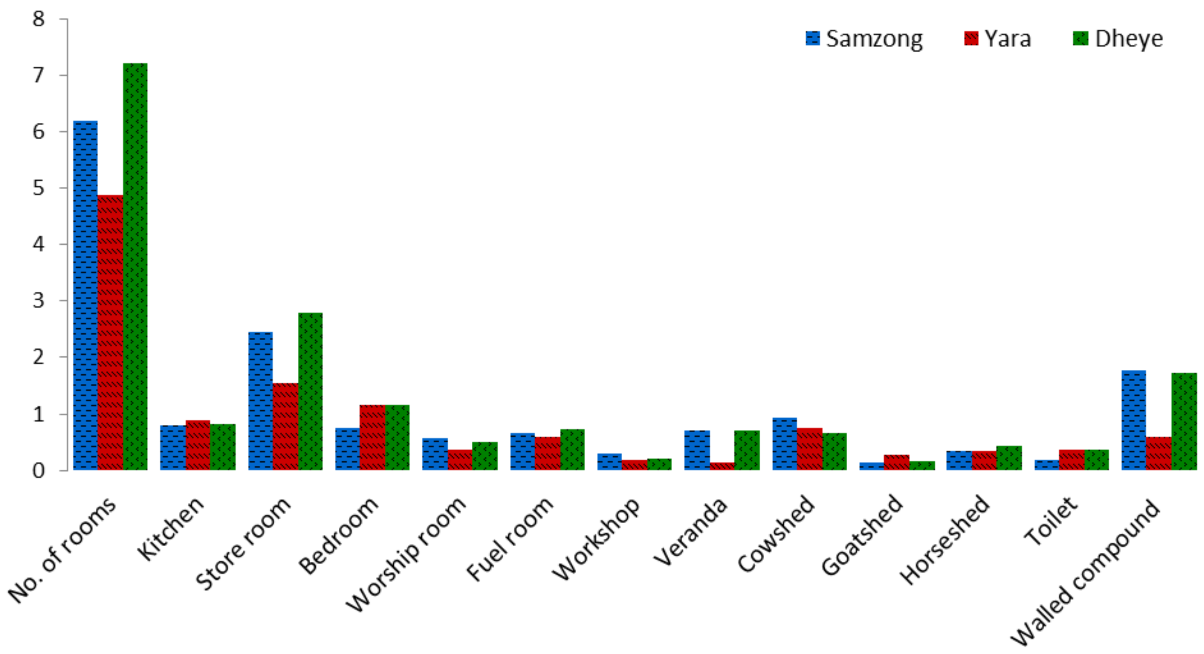

Figure 3.1: Average house composition of the three studied villages. The numbers indicate how many rooms are designated to the corresponding category on average per house, based on the field surveys.

3.2.3 Construction 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 3.2), 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 3.3). 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 3.4).

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 for instance). 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.

Figure 3.2: Hand-made crude soil blocs for wall construction in Samzong (photo: 29/06/2012, Daniel Pittet)

Figure 3.3: Inside view of a house under construction in Yara with earthen walls, wooden poles and part of the wooden slab structure (photo: 03/07/2012, Daniel Pittet).

Figure 3.4: 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).

3.2.4 Maintenance

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.

3.2.5 Construction costs

The construction costs of an average house with 4 to 5 rooms were estimated (Table 3.2). 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.

Table 3.2: 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

4 Climatic and meteorological setting

To understand the current circumstances and challenges with which the people in Upper Mustang are confronted, it is crucial to put it into appropriate physical context. The past meteorological, climatic and glaciological 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.

4.1 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 11.1 in appendix D.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 4.1).

Figure 4.1: 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).

4.2 Air temperature

Actual and future trends of air temperature were analyzed and are reported in the following sections.

4.2.1 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 11.10 and Figure 11.11 in appendix D.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).

4.2.2 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 D.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).

4.3 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 4.2) 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 4.2: 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).

4.3.1 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 4.3). 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).

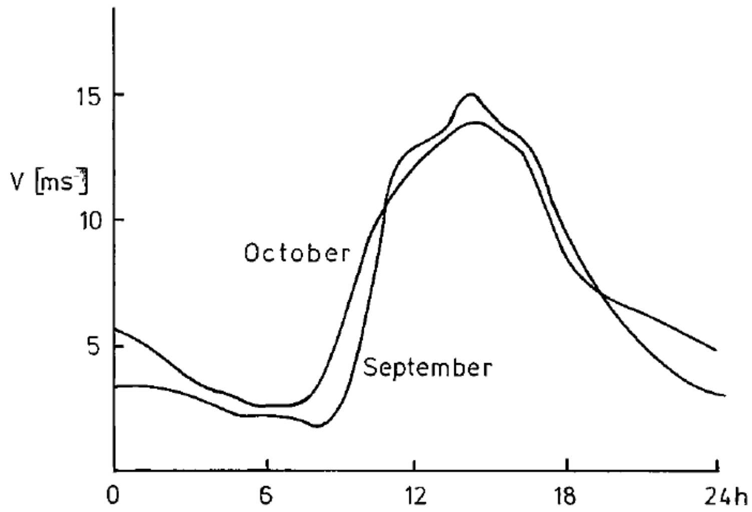

Figure 4.3: Graph illustrating monthly mean values of the hourly mean wind speed V (m/s) as observed in Kagbeni in September and October 1990 at a height of 30 ft, taken from (Egger et al. 2000).

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.

4.3.2 Future wind patterns

As described in section 4.2, 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 4.4 and 5.2).

4.4 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 (D. R. 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.

4.4.1 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 4.1 have to be interpreted with care.

Albeit the uncertainty concerning the data's representativeness, a strong negative south-north precipitation gradient is exemplified (Table 4.1). 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 4.1 shows 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 4.1: 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] Measured with Google Earth

[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 4.2).

Table 4.2: 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.

4.4.2 Actual trends of precipitation

The analysis of the data records[3] 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 11.12 and Figure 11.13 in appendix D.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 4.1, 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 5.3)

4.4.3 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: "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.

[3] Data recorded and provided by the DHM

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

4.5 Glaciers

As exposed in section 5.1, the relocation sites Namashung and Thangchung are situated within glaciated catchments in contrast to the current locations of all three studied villages. 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.

4.5.1 Glaciation area and volume

Current state

Using Google Earth Pro, 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.

The glaciated portion of Namashung's catchment was estimated to be roughly 24 km^2 (10 %) with a corresponding total volume of about 0.87 km^3. Thangchung's glaciated fraction was estimated to be almost twice as big with an area of 45 km^2 (12%) associated with a much larger total volume of about 3.42 km^3 (Table 5.1 in section 5.1).

Past and future trends

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 satellite imagery[4]. From the resulting areas, the corresponding volumes were calculated using the methodology described before.

The exemplary estimation revealed, that the masses of three glaciated areas, which all lie within the catchment of Namashung, decreased by roughly 16 %. Also, the analysis has shown 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.

Direct comparison of the present with past glacier extent could not be done for the glaciation within Thangchung's catchment in the scope of this study. However, compared to the glaciated area in Namashung for instance, the catchment reaches to considerable higher elevations and the glaciers are more massive, underlined by the estimated volume of about 3.42 km^3 (Table 5.1 in section 5.1). Furthermore, based on "before-after" observations by Giovanni Kappenberger in the region, it is not unlikely that the glaciers in Thangchung's catchment have retreated much less than the ones in the headwaters of Namashung.

For the future, the glaciers are expected to shrink at a higher rate, due to enhanced warming (section 4.2) and the likely increase of dust cover due to even more pronounced upvalley winds during the day (section 4.3) and insignificant change in precipitation (section 4.4).

Due to large still present glacier volume in the catchment of Thangchung, the higher elevation together with a reduced retreating behavior in the past, it is believed that the area will certainly stay (partly) glaciated within the current century. It is possible however that the

[4] Corona imagery from 1967 were compared with Landsat images from 2011 by Kappenberger and Lichtenegger (2012).

glaciers in Namashung's catchment will face complete disappearance within the current century, given the small present area and volume respectively. This has important implications for water availability within the corresponding catchments, since 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 5.2).

4.5.2 Glacier Lake Outburst Flood potential

Past flood events

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[5]. 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.

In Namashung, there have been reportedly two flood events originating from the headwaters of the Kali Gandaki, which can likely be classified as GLOFs within the last 28 years according to a local eye witness. Apparently, the most recent one, dating back 25 years, has been responsible for the vast debris deposits in Namashung, which are being removed or pushed aside to make the area cultivable (section 1.5.1).

There were no past flood events reported in Thangchung, which could be attributed clearly to GLOFs, which does not necessarily mean that there have not been any before. However, clear signs of a GLOF could not be observed during the field work.

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 in case of a future GLOF event from the headwaters of the Kali Gandaki.

The river passing Kyimaling merges the Kali Gandaki next to the designated field area of Samzong's relocation site. Though the fields are not expected to be inundated in case of a future GLOF event from the Kyimaling Khola, the escarpment might be subject to local erosion.

Though not directly subject of the study at hand, in the course of the elaborations concerning GLOFs it became apparent that the village Kyimaling is strongly at risk in case of future flood events. Additionally, the corresponding river may spill and flow southwards following its old riverbed in direction of Lo-Manthang in case of huge events. In addition to Kyimaling

[5] 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).

itself, 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.

Due to the relative elevation of Thangchung, the site is not at risk associated with possible GLOF events. However, extreme flood events, particularly sudden floods with associated flood waves, could endanger whole Chawale, the plain on the left of the Dhey Chang Khola close to the confluence with the Kali Gandaki, which is only slightly elevated relative to the active riverbed. Consequently, all constructions including the partially realized orchard (section 1.5.2), buildings as well as a potential water supply pipeline to Thangchung are at risk in case of exceptional flood events.

It has to be noted that sudden flood events of the Dhey Chang Khola could also be triggered by landslides. Such an event has been reported in the more recent past. A sudden flood could only be averted due to the swift intervention of Nepal’s military forces. Due to the activity of the landslides in the region, a similar occurrence cannot be excluded in the future.

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.

5 Water resources

In each village report the water resources including water demand, regime, sources, supply systems, associated problems and challenges as well as mitigation measures are discussed in detail. In the report at hand, the main issues are compared with each other and the main water related problems as well as possible mitigation strategies are discussed.

5.1 Catchments

Each of the three studied villages as well as the two respective relocation sites lie within different catchments. Though water availability is not directly proportional to the corresponding characteristics due to the complex and interlinked processes of runoff formation, they still give an indication about water regimes and general water availability. Table 5.1 summarizes all five relevant catchments.

Table 5.1: Catchment characteristics of the three studied villages and the respective relocation sites. The lowest and highest points in each catchment, as well as catchment size and area of glaciation were elaborated using Google Earth Pro. The glacier volumes were evaluated using a linearized relationship between glaciated areas and their corresponding volumes based on Huss et al. (2008).

Description	Samzong *Current village location*	Namashung *Samzong's relocation site*	Dheye *Current village location*	Thangchung *Dheye's relocation site*	Yara *Current village location*
Lowest point (m asl)	3'950	3'775	3'872	3'276	3'550
Highest point (m asl)	5'190	6'366	5'185	6'759	5'921
Catchment area (km^2)	38	233	10	366	51
Area of glaciation (km^2)	-	24	-	45	-
Glaciation percentage (%)	-	10	-	12	-
Glacier volume (km^3)	-	0.87	-	3.42	-

The striking commonality of the three existing village, all under heavy water stress, is that their catchment is not glaciated. It seems that other villages in Upper Mustang, which are situated along a river draining a glaciated area, do not face similar problems due to a much more favorable water regime.

Dheye's catchment is by far the smallest. Considering the observed and measured surface water flows during the field visits, Dheye's river did not have proportionally less yield than the other two non-glaciated catchments. As revealed by the geological field investigation, Dheye is situated on a huge Deep-seated Gravitational Slope Deformation (DGSD), which suggests that water from outside of the catchment which has been delineated according to topography is accumulating in Dheye's river.

Comparing the three existing villages, Yara lies within the largest catchment. Additionally, the catchment reaches up to higher altitudes than Samzong and Dheye, which have very similar characteristics related to elevation. Yara is located sensibly lower than Samzong and Dheye, which is favorable related to agricultural activities due to noticeably elongated growing seasons.

The two relocation sites have striking advantages compared to their corresponding villages. They are both glaciated, they include a much higher catchment area and they span over a larger altitude range (Figure 5.1).

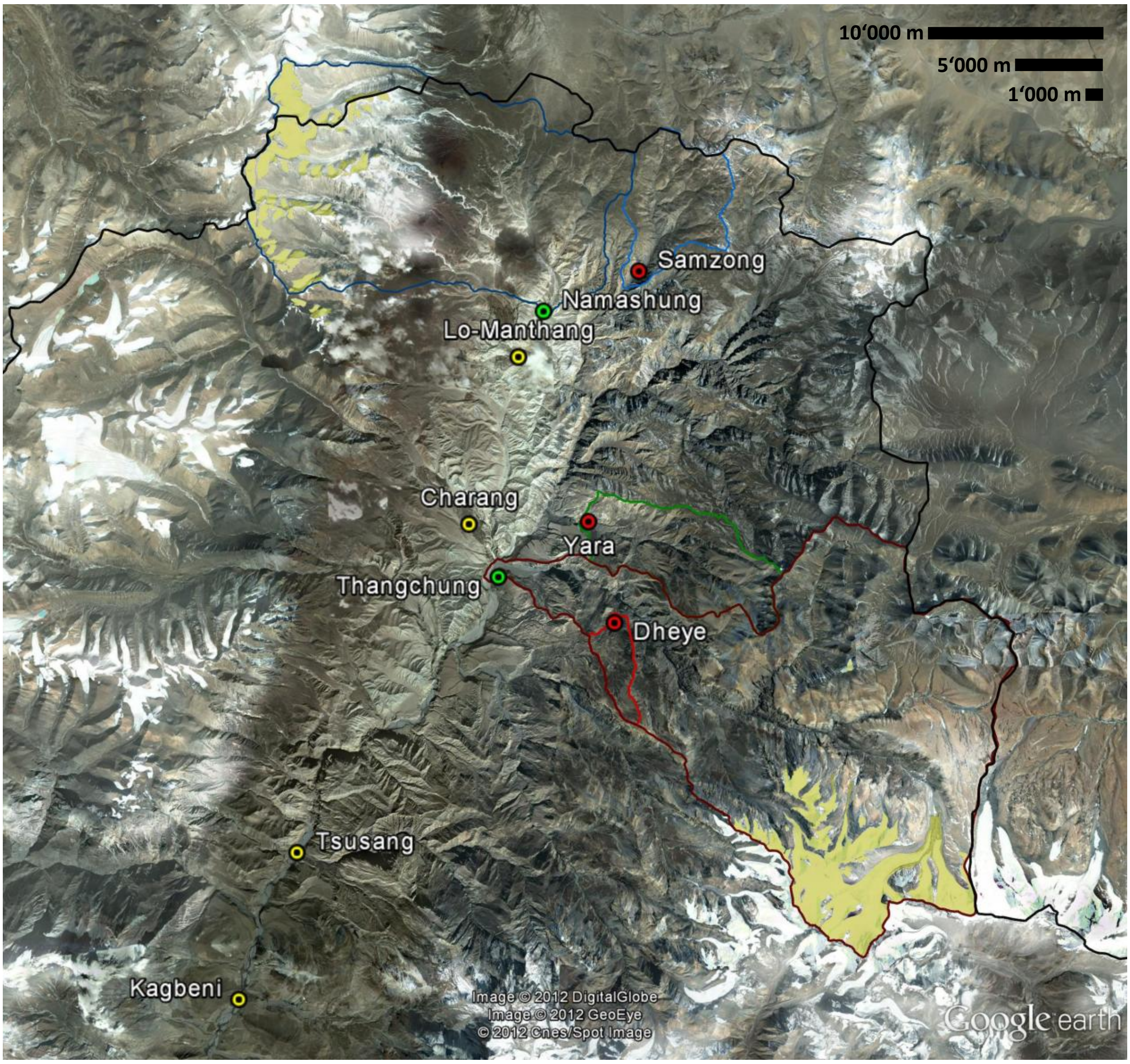

Figure 5.1: Catchment area of Samzong (blue) and the corresponding relocation site Namashung (dark blue), of Yara (green) and Dheye (red) with the corresponding catchment of Thangchung (dark red). Glaciated areas are dyed in yellow. The existing villages are highlighted in red, the corresponding relocation sites in green and main towns in Upper Mustang in yellow. The border of Nepal is shown in black. North direction is ↑ (source: Google Earth Pro, accessed 27/11/2012).

Comparing the two relocation sites, Thangchung clearly tops the characteristics of Namashung. It is larger, includes a more extensive glaciated area associated with a much higher glacier volume and covers a larger range of altitudes (Table 5.1). Based on this interpretation, future water availability is more secure in the catchment of Thangchung compared to Namashung. The glaciers within the latter catchment might vanish completely within the current century (section 4.5). In this case, it is hard to guess, if the catchment will be suitable to providing an appropriate amount of irrigation water at the right time for agricultural activities of the people depending on the corresponding river.

5.2 Water regimes

Qualitatively assessed, the five before mentioned catchments can be categorized into glaciated and non-glaciated catchments which are expected to behave distinctively different.

The perennial flow of glaciated catchments is strongly linked to the melting dynamics of the glaciers. Additionally precipitation during monsoon season influences the river dynamics. During the winter month, the rivers exhibit low flow periods. During the melting season, the discharge is heavily increased, accentuated by monsoon precipitations, which have a substantial fraction of rainfall due to the much higher associated temperatures during the season. On the other hand the precipitation events during winter are mostly in form of snowfall due to the low temperatures, explaining the unaffected discharge by precipitation events during winter (Figure 5.2). Furthermore a very distinct diurnal flow pattern evolves during the melting season, characterized by low flow during the night and the first half of the day, opposed to heavily increased discharges during the second half of the day.

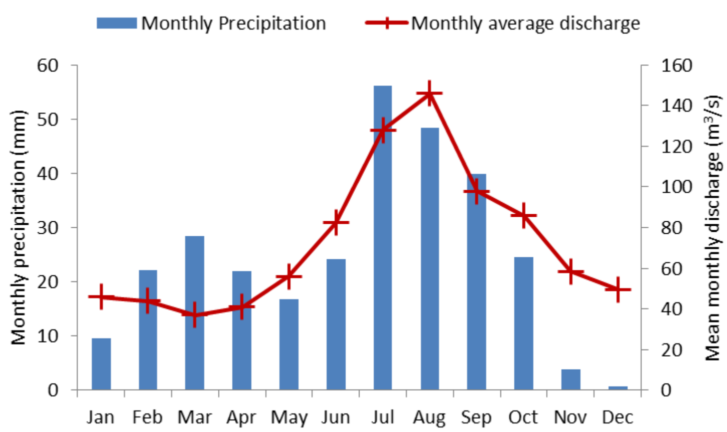

Figure 5.2: Measured average precipitation and discharge for the years 2002 to 2007 in Jomsom, Mustang (source: DHM, Kathmandu, Nepal. Discharge: station number 403; precipitation: station number 0601). Note that only the years 2002 to 2007 were considered, since the discharge records are very inconsistent in the preceding years. Also, the precipitation values are not representative for northern villages such as Samzong, Yara and Dheye, since there is a large negative gradient in north direction (section 4.4).

The perennial flow of rivers in non-glaciated catchments in Upper Mustang is believed to depend mainly on snow melt 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.

During the monsoon season precipitations can lead to comparatively high discharges which can likely reach even the 200-fold of the lowest flows. Heavy precipitation events during summer with an associated large fraction of rainfall are 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 non-glaciated rivers, especially during monsoon and post-monsoon. The effect of recharged groundwater during the monsoon on the surface flow in spring remains unclear.

5.3 Water supply

In all three studied villages, drinking water and irrigation water are supplied by distinctively different systems as described in the following sections.

5.3.1 Drinking water supply

The comparison between the domestic and the agricultural water demand is discussed in each village report in detail. The estimations show that the required water demands differs by a factor of more than 100, which exemplifies that inappropriate water availability results much less in insufficient drinking water, but much more in insecure food production. This is underlined by the fact, that in all three villages, the drinking water supply was found to be sufficient, opposed to the scarcity of irrigation water.

In all three villages, spring water is captured and transported to the village in plastic pipes. The pipeline is connected to tabs dispersed within the village, where the people fill their so-called toms (35 and 5 l canisters) to cover their drinking water demand.

To transport the necessary, comparatively small amount of drinking water from the springs to the village, the communities of the three villages go through quite a lot of trouble (i.e. frequent, labor-intensive maintenance). First, this roots in the believe that the quality of spring water is better compared to the perennial water flow, which is probably true, but could neither be supported nor refuted within the scope of this study. Second, taking the water from the same source as the irrigation water is generally not accepted, above all since it is considered to diminish the water yield for irrigation, although objectively the quantity is negligible. Particularly the latter is an important social aspect which has to be considered for the planning of the drinking water supply in case of resettlement of the villages, since it might be necessary to abstract drinking water directly from the irrigation water supply. This is discussed in more detail in the corresponding village reports (Part II: Samzong and Part IV: Dheye).

5.3.2 Irrigation systems

The present irrigation systems are quite similar in all three villages. A combination between traditional techniques (i.e. open, hand-dug channels) and more modern units (i.e. plastic pipelines, masonry channel sections, concrete reservoir outlets etc.) can be found. As much of the perennial river flow is abstracted and directed to a reservoir. The reservoir's outlet is closed during nighttime, so that the abstracted water can accumulate during non-operating hours of the irrigation system. Each day it is another family's turn to direct the abstracted and captured water to their fields according to their wish. The order by which the families take turn is determined by a lottery held early each year. The water from the reservoir is routed to the fields by creating opening by hand or adding rocks, soil and mud in order to close corresponding channel sections. Overall, the irrigation systems are associated with a lot of losses and are quite laborious to maintain.

For the two relocation sites, ways of transporting a suitable amount of water to the fields are discussed in the corresponding village reports (Part II: Samzong and Part IV: Dheye).

5.3.3 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[6] was measured and put into relation (Table 5.2).

Table 5.2: Indicators describing the water availability for agricultural activities in the three studied villages. The values refer to the measured water abstraction rate during the second field visit in the end of June or beginning of July respectively. 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	Samzong	Yara	Dheye
Number of HHs owning fields	17	14	13
Total cultivated area (ha)	9.1	10.6	10.4
Average cultivated area per HH (ha/HH)	0.53	0.75	0.80
Total abstracted, potentially useable water[a] (m^3/d)	787	603	448
Potential water per total cultivated area ($l/m^2/d$ = mm/d)	8.7	5.7	4.3
Approximated potential irrigation depth[b] (mm/HH/d)	147	80	56

[a] In Samzong there are two irrigation systems, of which one is unbuffered. From this abstraction, 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.

[6] 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.

As expected based on the catchment characteristics (section 5.1), the abstracted water in Dheye is smallest, despite the fact that the abstraction is most efficient compared with the other two villages. Likely, the fact that more water is captured in Samzong than Yara is due to the usage of two different abstractions in Samzong opposed to a single one in Yara.

According to Wacker and Fröhlich (1997) an irrigation depth of roughly 30 mm each 13th day, which corresponds to 2.5 mm per day, would be sufficient for agricultural activities. The coarse calculations presented in Table 5.2 exemplify that the abstracted water in all three villages (potential water per total cultivated area, Table 5.2) seem to be considerably higher than the postulated demand of roughly 2.5 mm per day. The fact that the communities are still under heavy water stress displays the heavy water losses associated with the present water supply systems. The losses itself differ spatially and temporally and could not be quantified directly in the scope of this study.

Note that the approximated potential irrigation depth (Table 5.2) should be interpreted with care, as it depends on the number of landowners, the total cultivated area, as well as total abstracted water. A direct comparison between the three villages has therefore to account for this circumstance.

5.3.4 Main water related problems

The predominant problem in all three villages is the combination of insufficient water availability and inefficient irrigation supply systems. Due to the very low precipitation rates in terms of total amount, but also in terms of timing (section 4.4), agricultural activities are almost solely dependent on the perennial river flow and particularly on how much can be captured and transported to the fields. This issue will become even more accentuated, since 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 since all surface water is currently allocated not presenting any reserves in case of need. Thus, the vulnerability of insufficient water supply is large in relation with present and future changes in the river's surface flow.

5.3.5 Water stress mitigation by supply management

In the following, possible supply management measures aiming at relieving the prevalent water stress in the existing villages 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 in the future (section 4.4), 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. In any case, 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 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 considerable constant water losses associated with the open, earthen transport channels should be decreased by installing additional plastic pipes. The pipes, besides being manufactured in Nepal, being low-cost, easy to install, operate and install, have the striking advantage of being adaptable to local settlings and deformations, which are very common in the given context. In contrast, the implementation of rigid measures, explicitly mentioning masonry and cement works, is strongly discouraged. Though the waterproofing of such structures is generally good, these interventions are very prone to failure and collapse under the given circumstances.

Where the area is spacious enough, the accommodation of increased water storages could be thought of. It has to be noted, that the capacity would have to be increased immensely to effectively be less dependent on the perennial flow. In the current configuration the reservoirs are merely storing the water which would be lost during the night, when the irrigation system is not in operation. In such a setting, the irrigation is directly dependent on the perennial river flow at that time. Since the water is already completely allocated during the growing season, more water can only be made available, if the river is tapped during off-season and stored for later use. For instance, the river water could be accumulated in the spring, before the growing season starts, or even in the fall after the harvest. However, such strategies raise crucial issues which would have to be addressed further, as discussed in the corresponding village report (Part III: Yara).

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.

5.3.6 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.

Another possibility would be to switch to different activities, consequently becoming less dependent on agriculture and overall reducing the water demand. However, only for Yara this seems to be a feasible option. At present, the community exhibits clearly the largest range of economic activities between the three studied villages (section 2.3). It seems possible to further diversifying the economic activities due to a few inherent characteristics, such as the location of Yara within the rather close vicinity of other settlements, the benefits from being accessible seasonally by tractor and being well situated on the way to attractive touristic sites.

6 Geological conditions

The geological conditions of each of the five studied locations vary greatly and are very site-specific. While all details are discussed in each village report, here a brief summary of crucial implications is given.

6.1 Samzong and Namashung

Samzong is prone to debris flow phenomena which were studied and for which a hazard map was elaborated. In case the community would remain at the current location, possible natural hazard mitigation measures are proposed. Concerning the debris flow phenomena, measures for the passive protection of the village are recommended, while houses located within red zones of the hazard map are recommended to move to a safer location within the village.

Namashung’s field area is and keeps being at risk from being inundated in case of extreme floods from the headwater of the Kali Gandaki. In case of relocation, local protection measures, namely bank protection and a possible stone dam to divert the flow, are suggested in order to mitigate adverse effects of a possible future extreme flood event.

Furthermore, a flood event originating from the Kyimaling Khola, which merges the Kali Gandaki next to Namashung’s designated field area, is possible. In this case, only local erosion of the escarpment is expected. However, the village Kyimaling would be endangered heavily in such an event. Though not directly within the scope of this study, it is strongly recommended that further investigations are undertaken in order to prepare the community of Kyimaling and to implement measures to protect the village against possible flooding.

The settlement area of the relocation site is not subject to any natural hazards except shallow landslides, which can easily be avoided by respecting a minimum distance of 15 m from the edge of the escarpment to the constructible area.

6.2 Dheye and Thangchung

The village, the fields, as well as a vast area surrounding Dheye are located on a huge DGSD. Except a few cracks in some of the lower situated houses, it seems that the DGSD did not have any adverse effects on the village itself up to present. In case the community stays at the current location, the DGSD might cause more serious damages to the lower part of the settlement in the future due to the retrogressive behavior of the landslide.

The normal access path leading to Dheye crosses a very active section at the toe of the DGSD, which has even caused damming of the Dhey Chang Khola numerous times in the recent past. In addition to the path which is directly at risk, the landslide may dam the river again and trigger a sudden flood, which can cause devastating destructions along the flow course of the flood. Consequently, the plain Chawale on which an orchard has been partially realized recently and which is planned to be cultivated wholly, is at risk to extreme floods.

Thangchung, overlooking the confluence of two tributaries (Charang Khola and Dhey Chang Khola) of the Kali Gandaki is situated next to the toe of Chawale. The elevated plain of Thangchung, which has been identified by Dheye's inhabitants for a possible relocation site possibly accommodating the moved settlement along with all fields, is not endangered by flooding. However, the escarpment may be subject to shallow landslides, so that the constructible area should not come closer than 15 m to the escarpment. Furthermore, the threat of rockfall and debris flow at the foot of the steep slope delimiting Thangchung in southern and southeastern direction, can be mitigated by respecting a distance of at least 20 m from the foot of the slope to the constructible area.

6.3 Yara

The village along with all fields, as well as a large area surrounding Yara is located on an extensive DGSD, which has caused the abandonment of many houses within the village. It is recommended that the Gonpa and particularly the school are relocated, since they are at eminent risk due to their location close to open trenches. Furthermore, it is desirable that the infiltrations related to the agricultural activities are reduced as much as possible, since this is accelerating movements associated with the DGSD.

A map indicating areas which are associated with rather small deformations was elaborated. In case houses have to be rebuilt, the indicated areas are recommended to be used.

7 Moving down or not?

The key question which needed to be answered in the scope of this study has been: "Moving down or not?" In this chapter the outcome of the study is summarized, 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). Note that this chapter is elaborated in much more detail in the separate village reports, whereas in the report at hand merely the final answer as well as the comparison of the three villages is discussed.

7.1 Yara

In contrast to the other studied villages, the community of Yara is not in possession of a relocation site (so far). Consequently, it is not possible to compare and evaluate two concrete options and thus, the chosen approach has to be different than the one applied in Samzong and Dheye. Nevertheless, the issue has to be addressed, whether the village is advised to think about moving in the future.

Since water availability is expected to decrease in the future, the sole implementation of water shortage mitigation measures (supply management) will procrastinate, but not solve the current problems. In what time frame the community could be confronted with the same problems again may range from few years to several decades.

However, Yara presents few characteristics speaking in favor of potential capacities to develop adaption strategies for mitigating adverse effects of the expected further decrease of water availability. The village is located within the rather close vicinity of other settlements, it benefits from being accessible seasonally by tractor and is well situated on the way to attractive touristic sites. These examples indicate, that the already more diversified range of economic activities practiced in Yara in comparison to the two other villages, could be further developed to become less dependent on agriculture as an effective demand management measure.

Therefore the recommended strategy for Yara is to "Stay" at the current location. The adaptation of the community to the difficult current and future conditions should be supported by implementing water shortage mitigation measures (supply management), while encouraging further diversification of economic activities at the same time (demand management).

Considering the high level of uncertainty about future socio-economic and climatologic conditions, it is impossible to predict, whether the adaption strategies will be successful and sufficient. Only if the climatic and meteorological evolution proves to become unbearable and/or the community's adaptation strategies turn out to be insufficient, the possible necessity of "moving" will have to be reevaluated.

7.2 Samzong and Dheye

For Samzong and Dheye twenty previously identified core issues were qualified, whether the current location with implemented measures aimed at the mitigation of the prevalent problems (“Stay”) or the resettlement of the communities at the respective relocation site with implemented recommendations (“Move”) is favorable (appendix E, Table 11.3 and Table 11.4).

The qualitative assessment for Samzong resulted, broadly supported by many issues, in favor of “Moving” (appendix E, Table 11.3). Above all however, 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. Therefore, conclusively, the community of Samzong is recommended to resettle in the acquired site of Namashung.

In Dheye, the result of the qualitative assessment is quantitatively supported by fewer issues supporting the resettlement of the whole community. However, similarly to Samzong, the most important issue, namely the irrigation water availability, is considerably better if the community relocates to Thangchung. Above all, given the gloomy future water availability driven by climatic and meteorological evolution (chapter 4 and 5) even highlighted by the particularly unfavorable catchment characteristics of the current location (section 5.1), the community of Dheye is recommended to resettle in Thangchung. Under these circumstances, “Moving” seems the only sustainable response to the present and future challenges with which the people of Dheye are confronted.

Related to the recommended resettlement of Samzong and Dheye, the corresponding village reports give recommendations in the fields of water resources management, natural hazard mitigation strategies as well as settlement layout and housing. In particular, what would be the best solution to supply a sufficient amount of irrigation water to the elevated location of Thangchung remains unanswered within the scope of this study. Until this issue is resolved, the relocation of Dheye should not be initiated.

8 Conclusion

Even though each situation in the three studied villages is different, the striking commonality between them is the prevalent scarcity of irrigation water. It seems that the root of the water scarcity lies in an ongoing decrease in water availability over the past decades, rather recently accelerated by climate change. Analyzing past, present and future trends of the water crisis in the three studied villages this study concludes that the water stress at the current locations will even increase in the future. In fact, for small non-glaciated catchments, the like within which the three studied villages are situated, the evolution of future water availability is gloomy. On the other hand, larger, glaciated catchments, such as the ones of the corresponding relocation sites of Samzong and Dheye, are expected to supply a sufficient amount of river water surely during the larger part of the current century, if not for longer.

Mainly for these reasons along with inherent characteristics of the current locations, this study concludes after having analyzed the two possible future states “Stay” or “Move” holistically that the most appropriate response to the water crisis is to resettle the whole communities of Samzong and Dheye.

For Yara however, due to its potential capacity to implement demand management measures, the study came to the conclusion, that it is best to “Stay,” although the sustainability of this option cannot be fully assessed at present. In fact, in addition to depending on the actual evolution of the water availability as well as other external drivers, the possibility of staying at the current location will also be determined by the community’s active role in developing suitable adaptation strategies. In particular, it has to be seen how well the potential of diversifying the economic activities will be effectuated by the people of Yara.

In any case, as long as the relocation of Yara can be prevented with proportionate means the investments in the existing settlement should be considered worthwhile. In fact, the inherent adverse effects of the relocation process including the high demand of time, effort, additional financial means, and socio-economic issues are all very likely to be exceptionally heavy burdens for the population.

For the recommended relocations a sound planning based on appropriate know-how and expertise has to be envisioned in order to maximize opportunities and minimize the trade-offs. Otherwise the resettlement may induce non-optimal or adverse consequences, if it does not make a relocation even impossible altogether. In particular, the following issues related to the relocation have been addressed, but require 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)
- Settlement layout and corresponding constructive details for implementation
- Elaboration of an energy concept for the relocated settlement

- Overall concept for resettlement including financial, organizational, economic, feasibility and organizational aspects, while particularly considering the time dimension as well

Additionally, the flood security of Chawale including the already realized as well as the additional planned orchards should be investigated in more detail. Until now, the community of Dheye has invested a lot of workmanship, money and outside support into the realization of this project. If possible floods are not taken seriously, necessary measures not foreseen and implemented, the investments could be wasted easily.

Overall, the study revealed sensitive issues, summarized in the following:

- Information: Institutional absence together with critical conditions may press people to take decision based on biased or limited information. In order to come up with suitable responses to complex problems, all stakeholders need to be consulted and informed and the decisions need to be based on necessary and appropriate expertise and know-how. This supports the demand for a holistic but nevertheless disaggregated and adaptive approach.
- Leadership: Both local leaderships, as well as external initiators have associated advantages as well as disadvantages. In the optimal case, internal and external actors are collaborating synergistically.
- Finances: Before taking action, the appropriate finances should be cleared. This principle seems to be lacking especially associated with local (internal) leadership. Furthermore, it is clear, support – be it in terms of funds or expertise – from outside is required. The institutional structures as well as local competences do not allow the implementation of appropriate stress relieve measures, even only at short-term, without support from outside.
- Planning: Though the institutional structure and the associated financing of local projects discourages rather than demands planning in longer term, the necessity of farsightedness and structured project implementations is eminent.
- External actors: It is important that all external actors understand the subtle but very significant local context and pay due considerations to it in case of any kind of involvement.
- Suitable partners: For a complex project such as the resettlement of a whole village, partners have to be sought who possess the required resources, know-how as well as experience, which they are willing to allocate fully to the project’s successful realization.
- Commitment: Partners who are involved in and committed to the realization from the very beginning to the end should be prioritized over actors who are only willing to support a certain aspect of the whole project. It may be necessary to turn offers down in order to ensure the successful implementation and prevent the disastrous situation of a community only partly relocated due to insufficient involvement or withdrawal of some of the partners.
- Role allocation: All stakeholders should be assigned to specific roles with associated competences, which should be respected and followed at all times. In fact, only through re-

specting the professionalism of all stakeholders, it is possible to achieve a qualitatively good output.

- Changing circumstances: It is important to be aware, that changing circumstances, which cannot be influenced by the stakeholders directly, might change the whole situation drastically. For instance, the opening of the Chinese border, the completion of the partly realized all-season road to Lo-Manthang or the abolition of the expensive tourist permits necessary for entering Upper Mustang might induce such transformations effecting largely changed circumstances.

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10 List of figures

11 List of tables

A Methodology and resources

For the corresponding field of expertise of each author (Table 11.1), common methodologies were applied. Due to the interdisciplinary and holistic approach of the study at hand, a further elaboration of the applied methodologies is foregone. In the detailed village reports, the specific methodologies are mentioned in the corresponding sections, where appropriate.

During the field work, the team of experts (Table 11.1) was using the following general methodological approaches:

- 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

All the reports, including the synthesis report at hand, 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 11.1)
- 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; Adhikari et al.)
- Satellite imagery provided by Google Earth Pro
- Additional literature (cited separately in the report, see bibliography)

Table 11.1: Characterization of the two field trips to Upper Mustang, during which all three villages (Samzong, Yara and Dheye) were visited.

<table>
<tr><th>Trip objectives</th><th>Trip period</th><th>Participants</th><th>Org</th><th>Function</th></tr>
<tr><td rowspan="6">➢ 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</td><td rowspan="6">29/04/2012 – 19/05/2012</td><td>Daniel Bernet</td><td>KFS</td><td>Responsible for all water related issues</td></tr>
<tr><td>Rajan Shrestha</td><td>KFS</td><td>Facilitator, translator, expert of the local context</td></tr>
<tr><td>Christoph Graf</td><td>KFS</td><td>Cameraman, photographer, assistant</td></tr>
<tr><td>Lama Ngawang Kunga Bista</td><td>LMF</td><td>Director of LMF, facilitator, local contact</td></tr>
<tr><td>Tsewang Gurung</td><td>LMF</td><td>Secretary of LMF, translator, assistant</td></tr>
<tr><td>Tsering Gurung</td><td></td><td>Guide, horseman, translator, assistant</td></tr>
<tr><td rowspan="8">➢ 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</td><td rowspan="8">18/06/2012 – 10/07/2012</td><td>Daniel Pittet</td><td>KFS</td><td>Project coordinator, housing and habitat expert</td></tr>
<tr><td>Dr. Christian Ambrosi</td><td>SUPSI</td><td>Expert in hydro-geology and natural hazards</td></tr>
<tr><td>Michele Passardi</td><td>KFS</td><td>Expert in economics and socio-economics</td></tr>
<tr><td>Daniel Bernet</td><td>KFS</td><td>Responsible for all water supply related issues</td></tr>
<tr><td>Rajan Shrestha</td><td>KFS</td><td>Facilitator, translator, expert of the local context</td></tr>
<tr><td>Lama Ngawang Kunga Bista</td><td>LMF</td><td>Director of LMF, facilitator, local contact</td></tr>
<tr><td>Tsewang Gurung</td><td>LMF</td><td>Secretary of LMF, translator, assistant</td></tr>
<tr><td>Tsering Gurung</td><td>-</td><td>Guide, horseman, translator, assistant</td></tr>
</table>

B Schematic maps

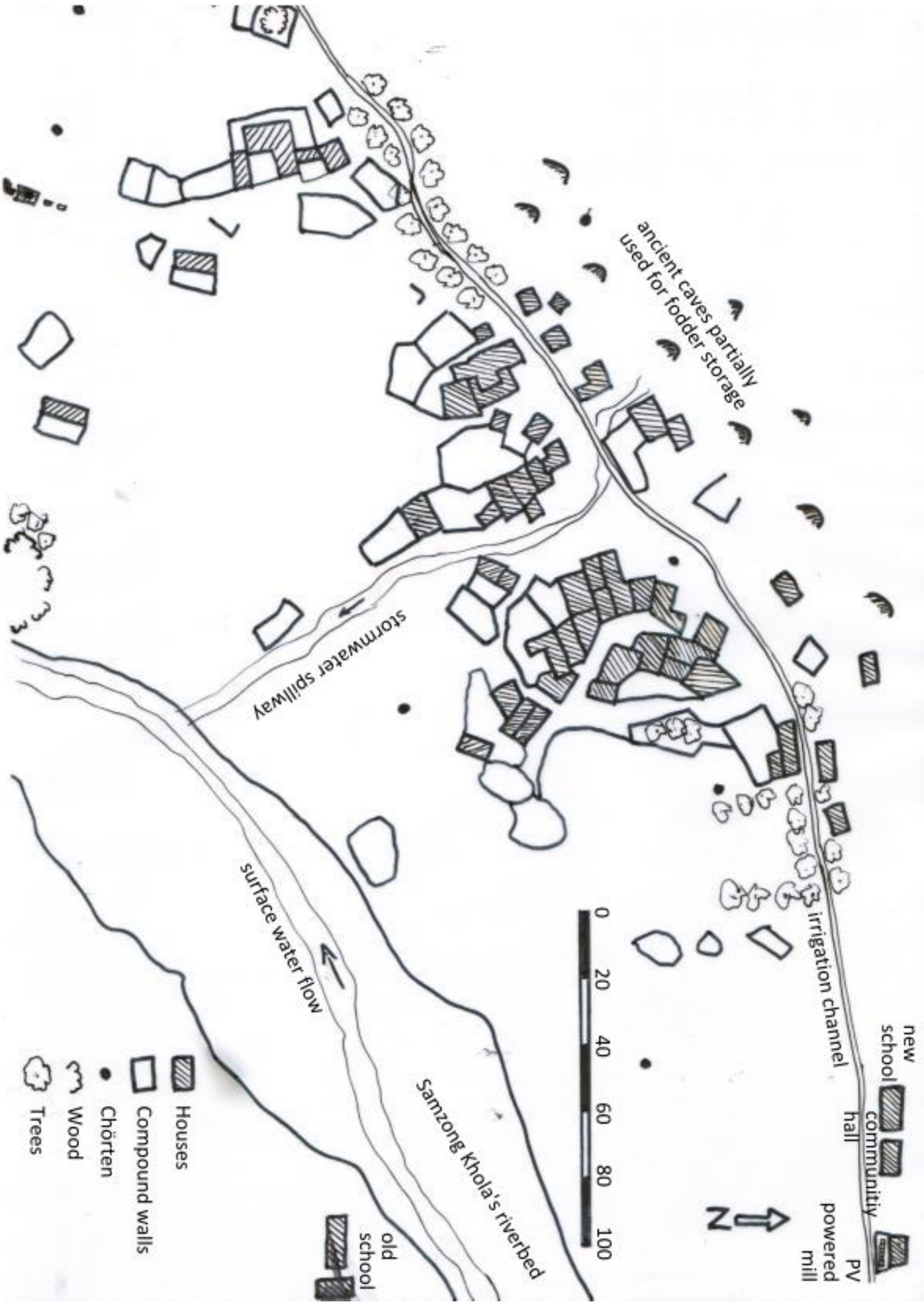

Figure 11.1: Schematic map of Samzong (hand drawing: 27/06/2012, Daniel Pittet)

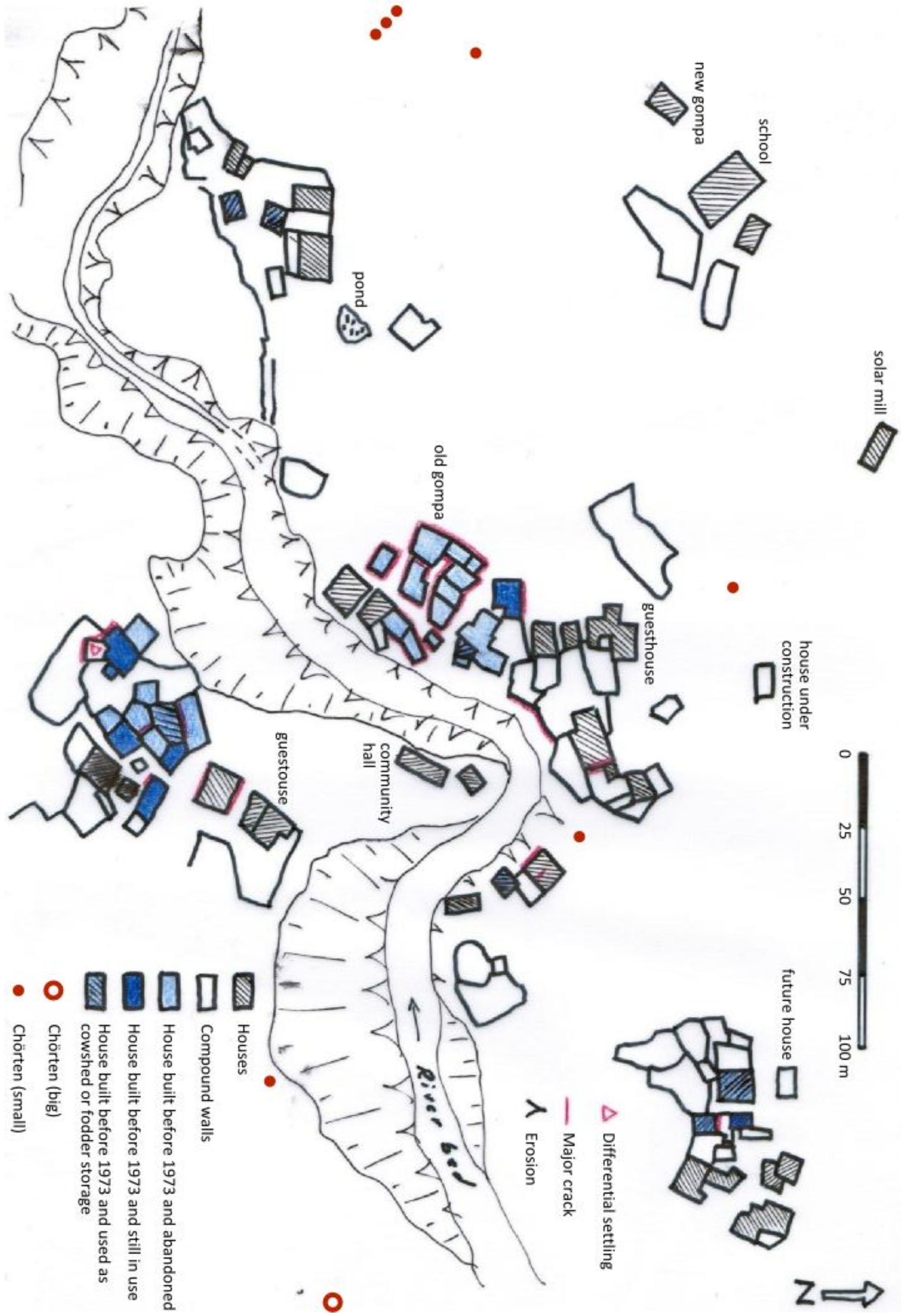

Figure 11.2: Schematic map of Yara (hand drawing: 02/07/2012, Daniel Pittet)

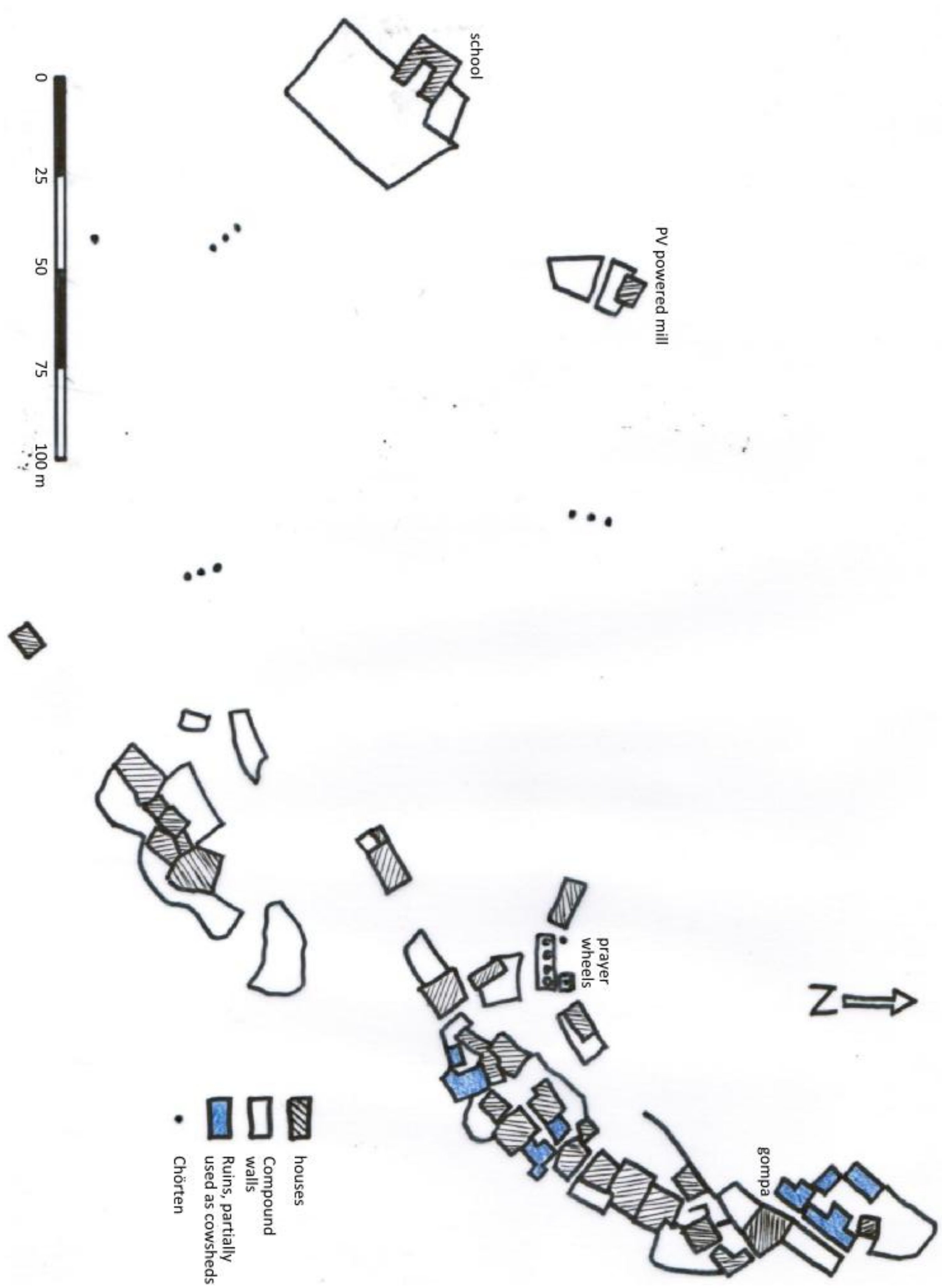

Figure 11.3: Schematic map of Dheye (drawing: 06/07/2012, Daniel Pittet)

C Typical house layouts

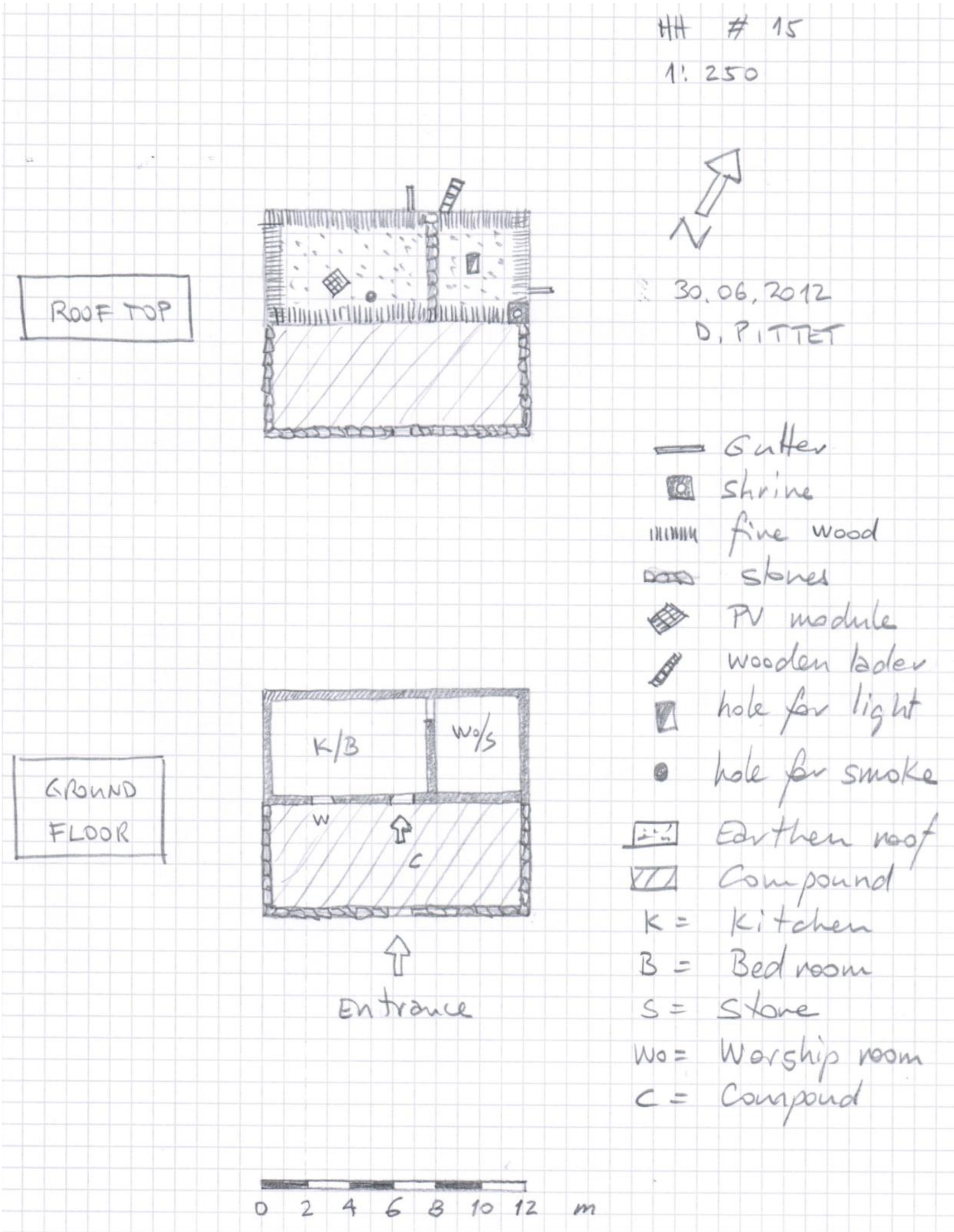

Figure 11.4: Representation of a dwelling from Samzong taken as a reference for a typical small house (hand drawing: 30/06/2012, Daniel Pittet).

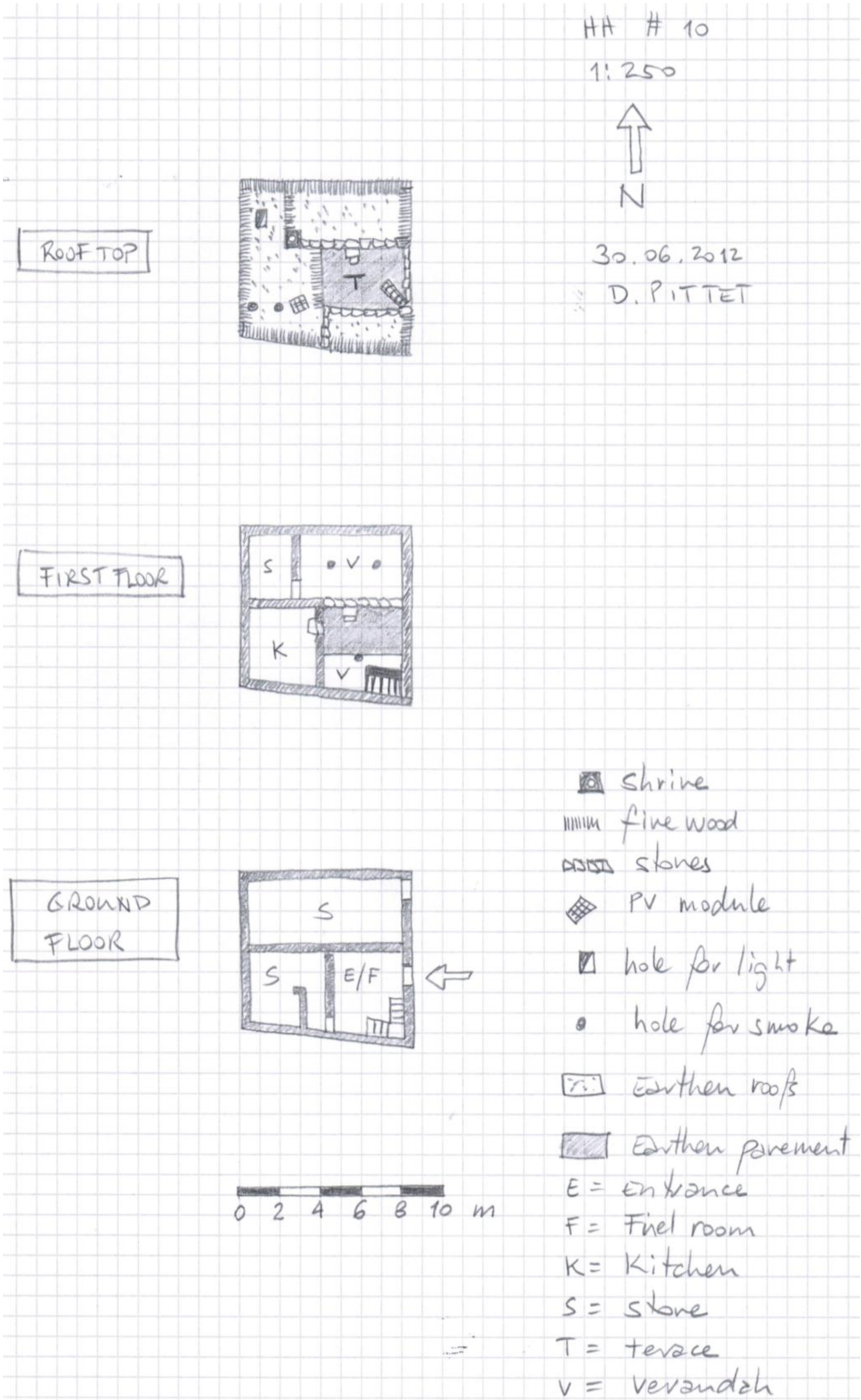

Figure 11.5: Representation of a dwelling from Samzong taken as a reference for a typical medium sized house (hand drawing: 30/06/2012, Daniel Pittet).

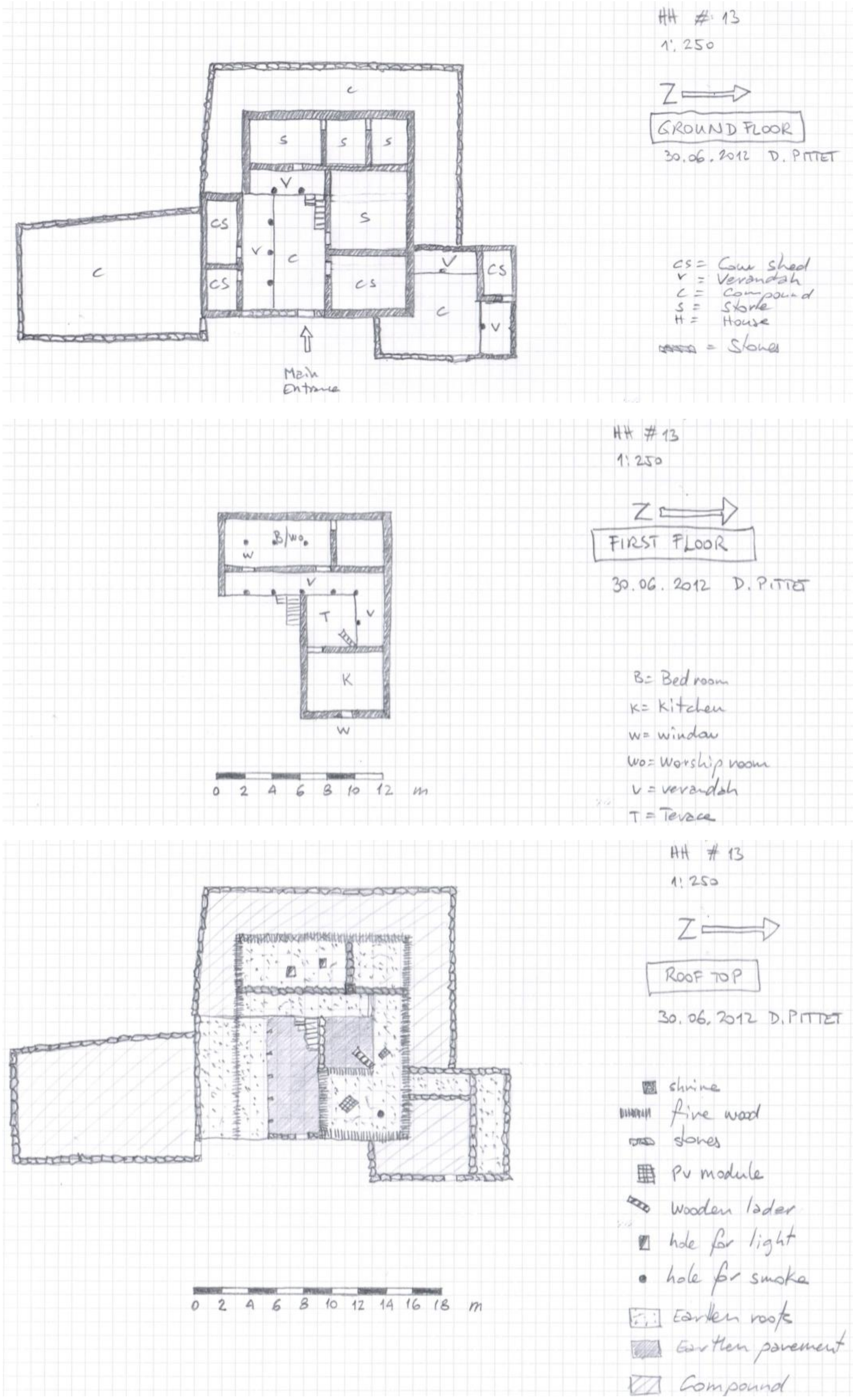

Figure 11.6: Representation of a dwelling from Samzong taken as a reference for a typical large house (hand drawing: 30/06/2012, Daniel Pittet).

The comparison of the three typical house types (small, medium and large) presented in Figure 11.4, Figure 11.5 and Figure 11.6 respectively, illustrates the variations of house compactness and land use (Table 11.2). 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).

Table 11.2: Size and compactness of three typical house types of Samzong. The drawings of the corresponding houses are presented in Figure 11.4, Figure 11.5 and Figure 11.6.

House type	Indoor area (m^2)	Com-pounds (m^2)	Veranda area (m^2)	Roof top area (m^2)	Total footprint area (m^2)		Compactness ratio (footprint[a] / usable area[b])
					without compound	including compound	
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

D Meteorology and climate

D.1 Visualized cultivated and abandoned fields

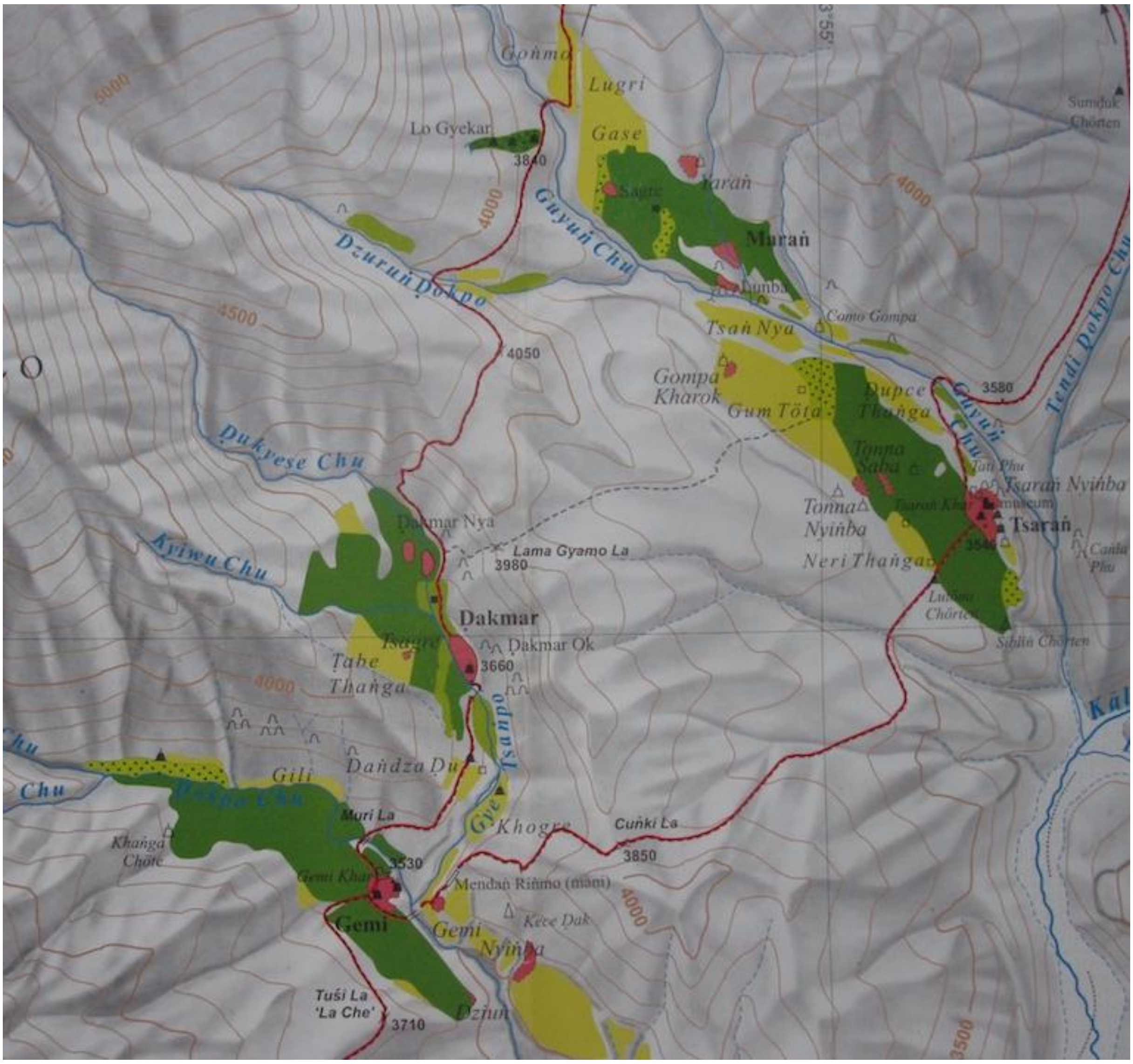

Figure 11.7: Abandoned fields (yellow-green) around Gemi (Ghami), Dakmar and Tsaran (Charang) on a thematic map of Upper Mustang by Kostka (2001), based on satellite information from 1990 and 1984. The dark green areas (including textured surfaces) indicate cultivated land. North direction is ↑.

D.2 IPCC scenarios

The Intergovernmental Panel on Climate Change (IPPC) present four different scenarios (Figure 11.8) in their fourth assessment report (IPCC 2007b), of which the intermediate scenario A1B is used in the analysis undertaken by Rohrer (2012a, 2012b).

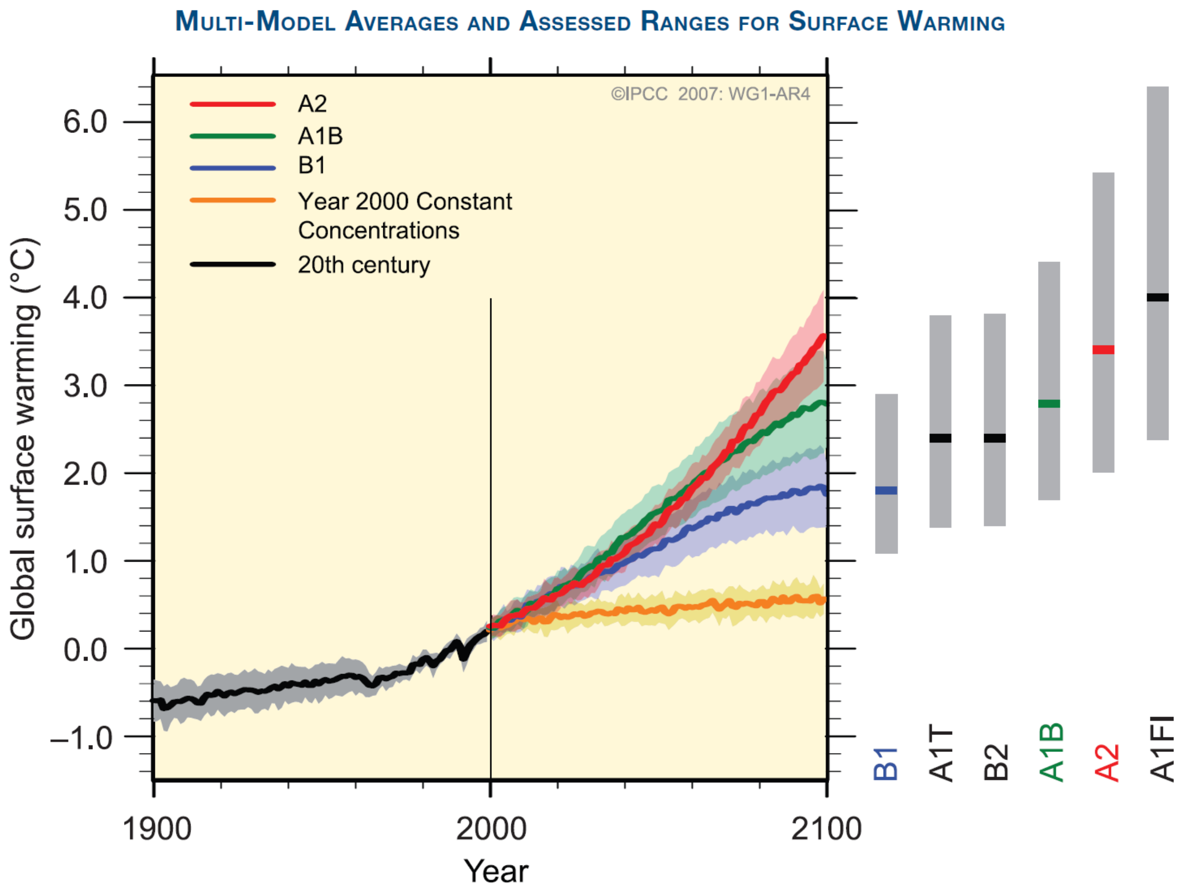

Figure 11.8: Multi-model averages and assessed ranges for surface warming, taken from IPCC (2007b): "Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 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 11.8), patterns for precipitation changes (Figure 11.9) are projected for instance (IPCC 2007b).

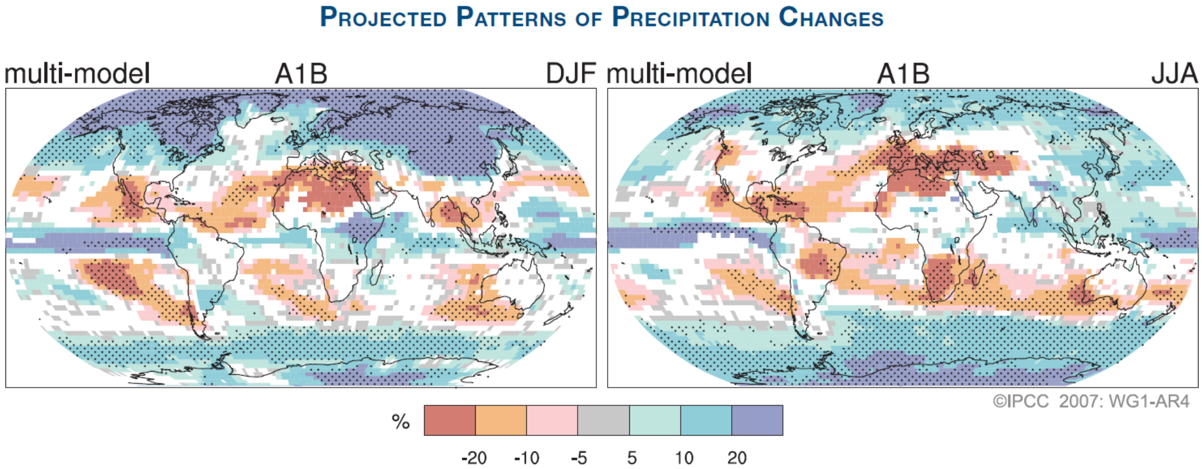

Figure 11.9: Projected patterns of precipitation changes, taken from IPCC (2007b): "Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). 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.

D.3 Temperature interpolations for Nepal

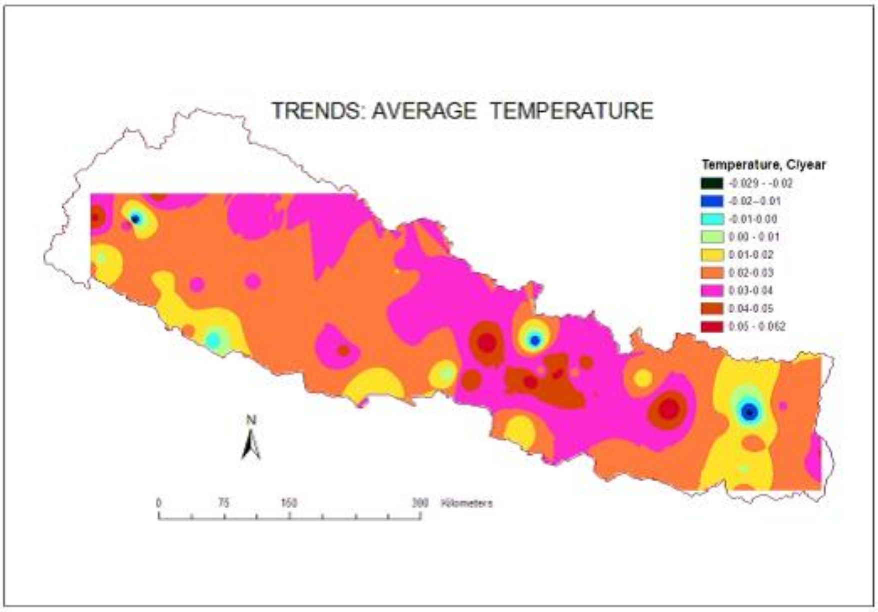

Figure 11.10: Trends of average temperature in Nepal in °C/year from 1975 to 2006 (Sharma 2009).

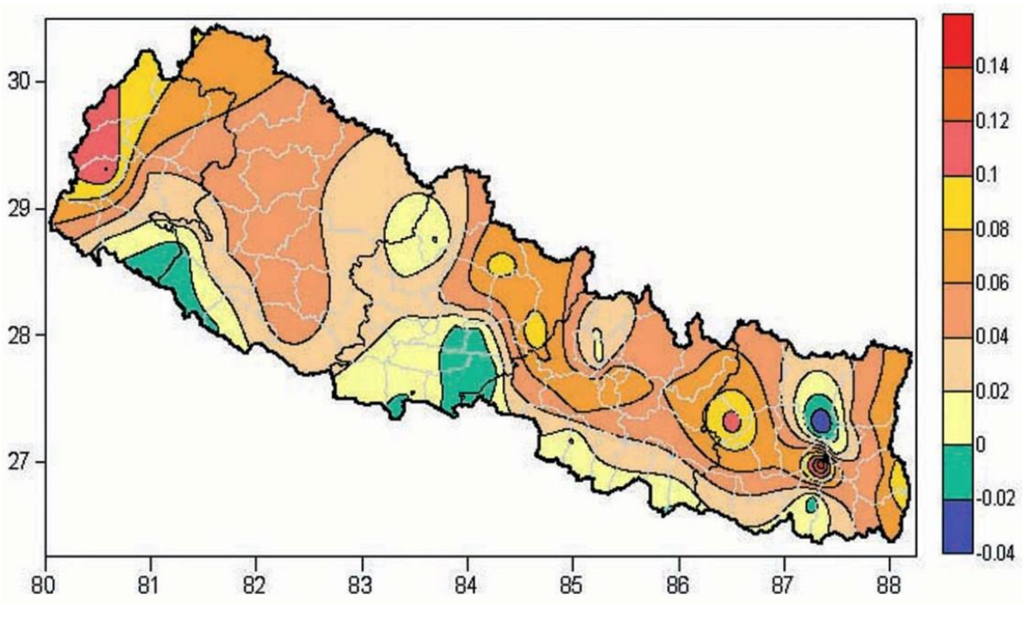

Figure 11.11: Trends of average temperature in Nepal in °C/year from 1976 to 2005 (Practical Action 2009).

D.4 Yearly precipitation sums in southern Mustang

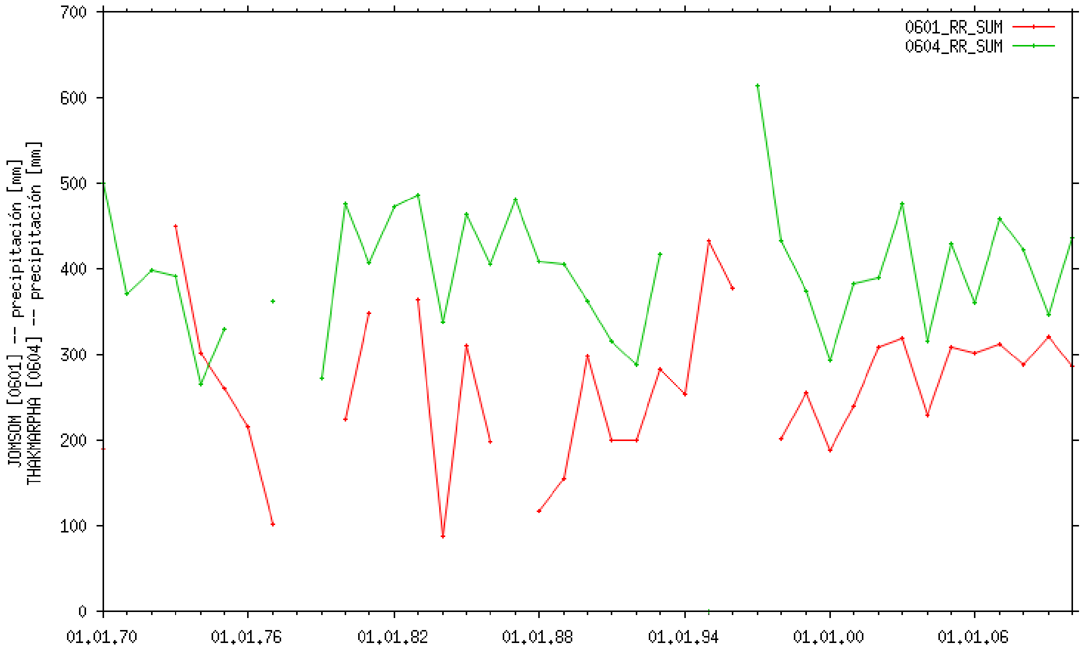

Figure 11.12: Yearly precipitation sums of the meteorological stations Jomsom (0601) and Marpha (0604), situated in lower Mustang showing no clear trend as shown and discussed in Rohrer (2012b).

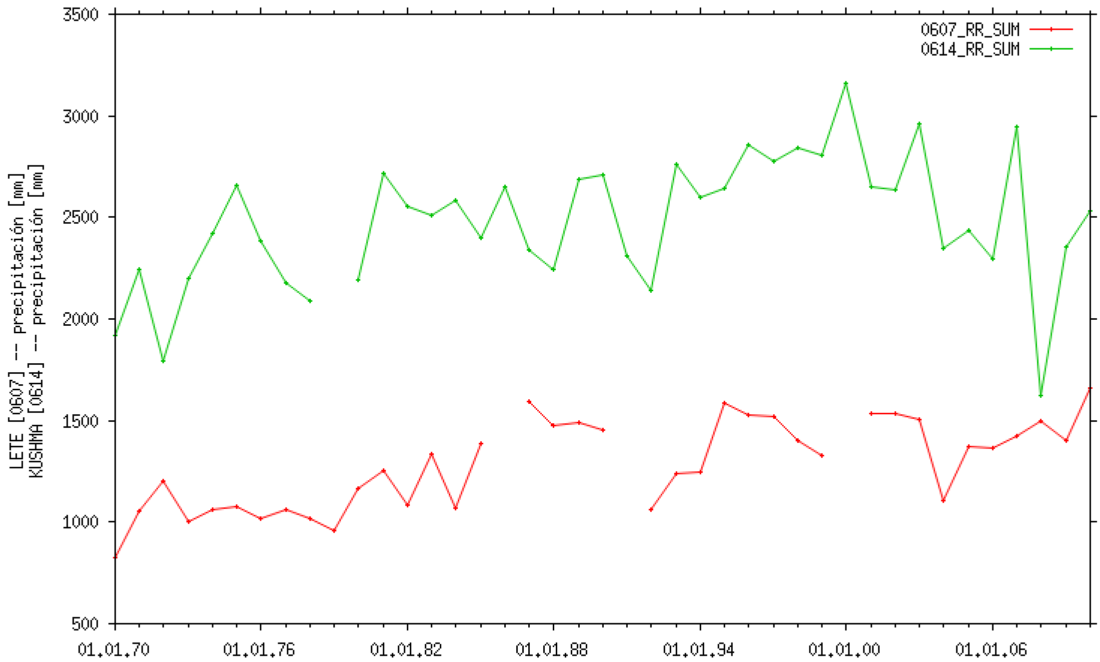

Figure 11.13: Yearly precipitation sums of the meteorological stations Lete (0607) and Kushma (0614) at the entrance of Mustang valley, situated in the south side of Annapurna showing an increasing precipitation trend which needs confirming however as discussed and shown in Rohrer (2012b).

E Moving down or not?

After all the issues had 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 provided 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
- "Move:" Relocated community at the identified and acquired relocation site with implemented recommendations concerning the resettlement

The result of this qualitative assessment concerning Samzong and Dheye are summarized in Table 11.3 and Table 11.4 respectively. Note that in the corresponding village reports, the issues are discussed in detail.

Table 11.3: Qualitative assessment of two possible future states "Stay" or "Move" of Samzong 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 for providing drinking water at the new location, as described in the corresponding village report.

Table 11.4: Qualitative assessment of two possible future states "Stay" or "Move" of Dheye 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 character-istics	**Irrigation water availability**[a]			✓
2		Drinking water availability[a]		✓	
3		Drinking water quality	✓		
4	Irrigation water supply systems	Technical complexity	✓		
5		Initial costs	✓		
6		Overall durability (Abrasion, exposure to natural hazards)[a]	✓		
7		Maintenance and operation (labor, associated costs etc.)[a]		✓	
8	Drinking water supply systems	Technical complexity	✓		
9		Initial costs	✓		
10		Overall durability (Abrasion, exposure to natural hazards)[a]	✓		
11		Maintenance and operation (labor, associated costs etc.)[a]	✓		
12	Geological risks	Exposure of settlement to geological risks			✓
13		Exposure of 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			**9**	**3**	**8**

[a] Assuming that the water is transported to Thangchung by gravity flow in a pressure pipe, as described in the corresponding village report.