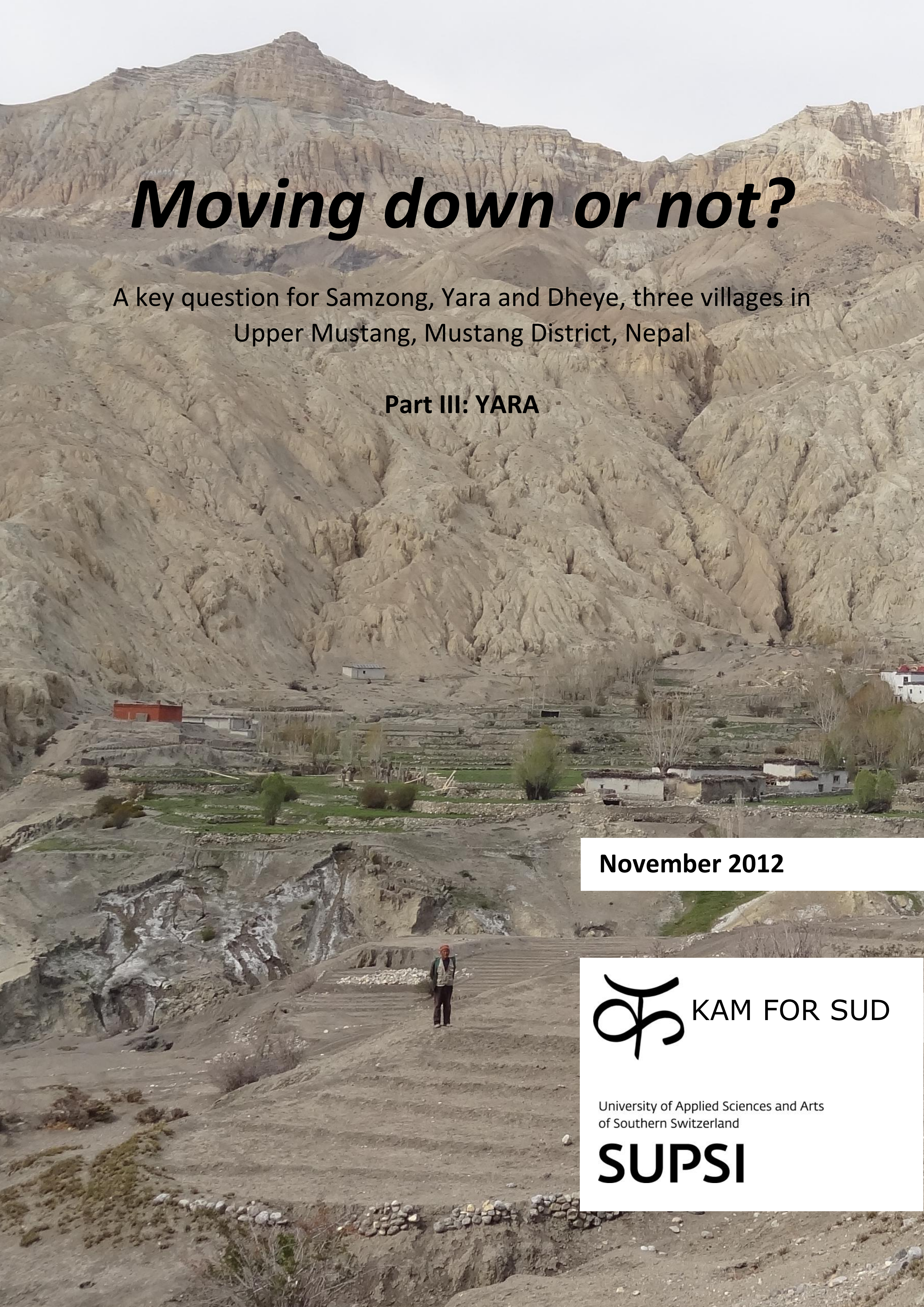


Moving down or not?

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

Part III: YARA

November 2012

KAM FOR SUD

University of Applied Sciences and Arts
of Southern Switzerland
SUPSI

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

Moving down or not?

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

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

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

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

Kam For Sud (KFS)

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

jointly with the

University of Applied Sciences of Southern Switzerland (SUPSI)

www.supsi.ch

and in collaboration with the

Lo Mustang Foundation (LMF)

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

Imprint:

Title photo:	Rigzin Dorgee standing on a field which was cut off from water supply several years ago. The lowest dwellings in Yara, situated on the right valley side on top of a large landslide, are visible. Below the cultivated fields, signs of soil erosion due to percolating irrigation water can be seen. Behind the red Gonpa the school is located, which is, together with the Gonpa, particularly endangered by the landslide's dynamics (photo: 11/05/2012, Daniel Bernet)
Date:	30/11/2012
Place:	Avegno, Switzerland
Pages:	52
Appendices:	10

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 short synthesis.

Yara, subject of the report at hand, located about 7 km east of Charang in a remote valley, consists of 22 nuclear families and totals 114 inhabitants including 40 permanent migrants. Though only 14 families own a certain amount of fields by themselves, most of the villagers depend on subsistence agriculture complemented by stockbreeding. The latter, together with other accessory economic activities, generates monetary income which is crucial because the agricultural output can only partially cover self-sufficiency.

The climate in the region with yearly precipitation rates around 200 mm and less is extremely dry and cold, manifesting itself in an almost desert-like landscape. Agricultural activities in Yara are low productive and almost solely dependent on the perennial flow of Puyung Khola. The river drains a non-glaciated catchment area of 51 km^2, which is expected to be linked strongly to snowmelt. Due to climate change, the temperatures in Upper Mustang are expected to rise 6 °C to 10 °C in winter and 4 °C to 10 °C during monsoon period at the end of the 21st century, relative to the reference period at the end of the 20th century. This drastic change in temperature, together with insignificant changes in precipitation volumes will lead to a considerable spatial and temporal decrease of snow cover. Furthermore the predominant diurnal winds in Mustang valley are expected to increase in magnitude, leading to enhanced dust and sand deposit on snow and glaciers, resulting in even higher melt rates. Consequently, the perennial flow of Puyung Khola is expected to decrease in the future.

The predominant problem in Yara is the combination of insufficient water availability and inefficient irrigation supply systems. All surface water is currently allocated, so that a change in the river regime is directly affecting irrigation amounts and consequently agricultural yield. Another concerning issue is the fact, that the whole settlement together with its surroundings is located within a huge landslide subjected area. Related movements have led to abandonment of numerous houses, while many others are fractured. Furthermore the school and the 15 years-old Gonpa are at eminent risk, due to their proximity to open trenches.

In terms of supply management, the considerable constant water losses associated with the open, earthen transport channels should be decreased by installing additional plastic pipes. This technology is considered to be most suitable, since the pipes are low-cost, manufactured in Nepal itself, simple to install and maintain, and above all, flexible enough to adapt to differential settlings and soil deformations. The use of rigid waterproofing measures such as masonry work and concreting is strongly discouraged. Also, the permeability of the reservoir bottom should be decreased for example by applying a layer of clay in order to reduce percolation. Since infiltrating water is generally accelerating landslide movements, all measures reducing water losses have valuable side-effects. The allotment of additional sources such as groundwater abstraction and use would need to be further investigated, since it is not practiced in Upper Mustang. Additionally, non-constructive measures are proposed in order to mitigate the effects of the inefficient traditional irrigation scheme. In terms of demand management it seems possible for the community of Yara to implement measures aimed at reducing the demand, which is a crucial aspect in finding sustainable responses to the water crisis as explained below.

Concerning the geological setting, it is generally possible to settle on landslides associated with low displacement rates, which is the case for Yara. If a house is damaged beyond repair, the corresponding dwelling should be rebuilt in a place unaffected directly by morphostructures. For that purpose, a map indicating such areas of low deformations has been elaborated. Concerning the school and the Gonpa which are at eminent risk, they are recommended to be relocated. In the meantime, the buildings should be evacuated in case of prolonged rainfall events, which are generally accelerating landslide movements.

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 or not.

There are no simple apparent means to allot additional water sources, while in general water availability is expected to decrease in the future. Therefore, the sole application of supply management measures will procrastinate, but not solve the current problems in the long run. 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 sustainable adaption strategies by further diversifying the economic activities (demand management). Therefore, it is concluded to be appropriate for Yara to “Stay” at the current location. Considering the high level of uncertainty about future socio-economic and climatologic conditions, it is impossible to predict, if these 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.

Glossary

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

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

Abbreviations and acronyms

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

Acknowledgements

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

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

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

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

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

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

Antonio Galli
President of Kam For Sud

Preface

Unlike the two other studied villages Samzong and Dheye, the community of Yara has neither an identified nor an acquired relocation site, with which the current location could be compared to. Therefore, the comparison of two future states “Move” and “Stay” cannot be done as for the two other studied villages. Consequently, for Yara the ultimate question of this study “moving down or not?” addresses whether the village is advised to think about “Moving” in the future, or if it is possible to mitigate the current problems and challenges in a way, that to “Stay” is appropriate, reasonable and sustainable.

In order to lead the reader comprehensibly through the report, it is structured as follows. First some background information are presented (chapter 1), followed by embedment of the whole study in the local context (chapter 2). Yara with its characteristics and related difficulties at the current location are outlined in chapter 3. With what means the current situation of Yara could be improved in situ, is discussed in chapter 4. Based on the previously elaborated option “Stay”, the study comes up with the answer to the central question of the study “moving down or not?” (chapter 5) followed by the final conclusions (chapter 6).

1 Introduction

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

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

1.1 Background of this study

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

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

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

1.2 Study objective

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

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

1.3 Methodology

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

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

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

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

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

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

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

1.4 Resources

The reports are based on the following resources:

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

1.5 Location

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

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

The three studied villages are all located in the restricted area (section 2.1) of Mustang District (Figure 1.2). Yara lies about 7 km east of Charang on an elevation of around 3650 m asl and belongs to the Zurkhang Village Development Committee (VDC). The village is situated on the right[1] riverside of Puyung Khola. On the left riverside further downstream, just before the Puyung Khola merges into the Kali Gandaki, Zurkhang village is located. On the other side of the junction, Dhee is situated (Figure 3.12 in section 3.4.2). At this location, an all-season pedestrian bridge leads over the Kali Gandaki.

---

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

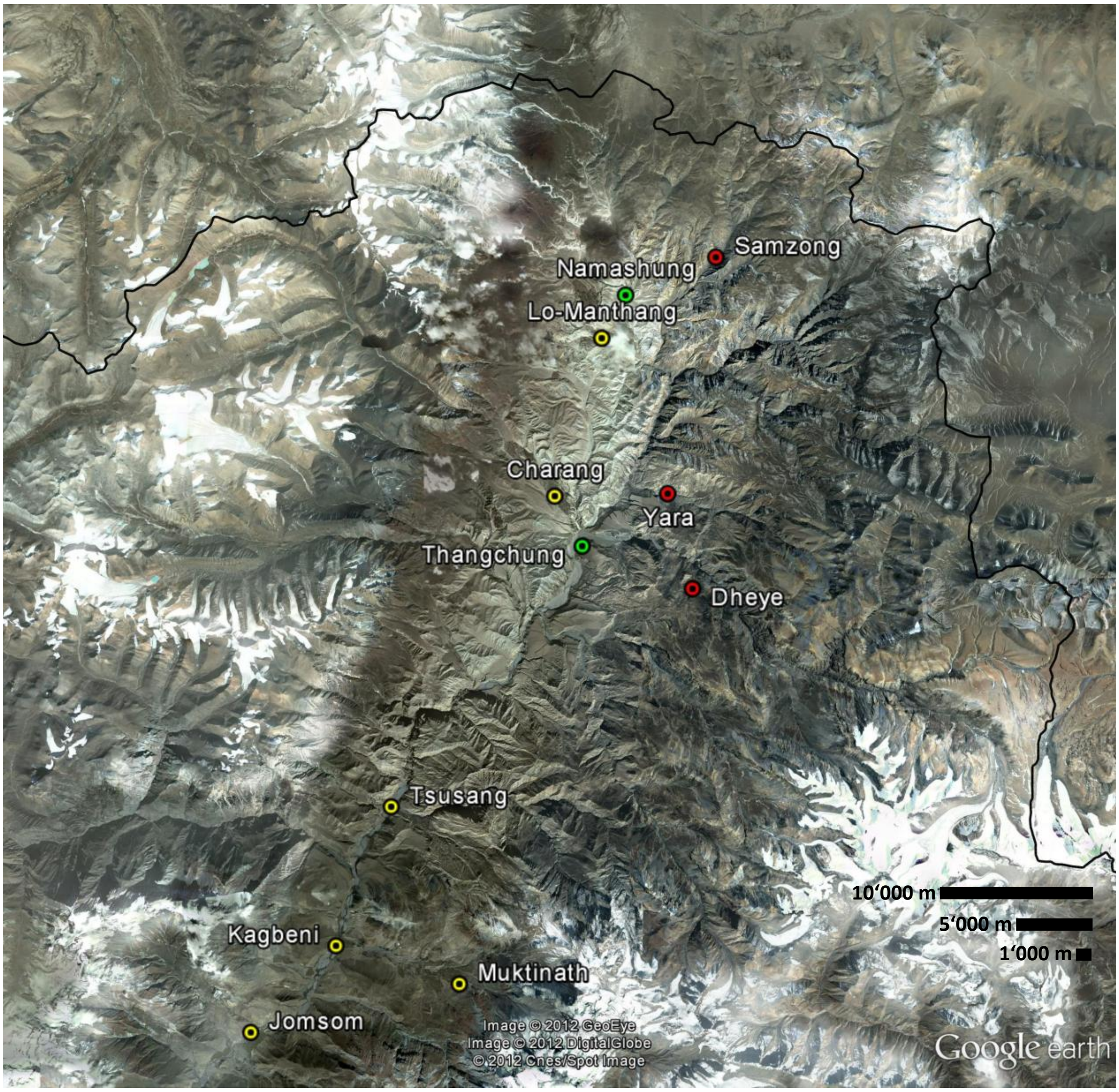


Figure 1.2: Overview of Upper Mustang. The main villages are indicated by yellow points, the studied villages are highlighted with red dots and the possible new locations of Samzong (Namashung) and Dheye (Thangchung) respectively are shown in green. The Chinese-Nepalese border is shown in pink, north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

From Zurkhang, a track ridable by tractor is leading mostly through the Puyung Khola riverbed to Yara and from there on the right valley side further up to Ghara, another village located at a higher elevation. The trackhead in Zurkhang is only accessible for about four months during the dry season, when tractors can ride through the riverbed of Kali Gandaki due to the low discharges during this period.

The village is also of interest for tourists, since Yara is located on the path leading to Dharmadha Kunda, a Hindi pilgrimage site reachable in about two days by foot. On this route, Yara is the last[2] village before reaching the destination and acts as a start and end point for a trip thereto. Additionally, Luri Gonpa, a tiny but extraordinary Monastery, located high up in a very steep rock wall, is reachable in about two hours by foot.

---

[2] Basically, Ghara would be marginally closer to Dharmadha Kunda, since Ghara is reachable from Yara in about an hour by foot. However, Ghara is located higher up on the valley side and is therefore slightly off the normal route.

2 Contextualization

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

2.1 Administrative setting

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

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

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

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

2.2 Institutional setting

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

2.2.1 Inherent characteristics

Collective decision making

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

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

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

Importance of social structure

It is important to recognize the central role of the social structure in the villages of Upper Mustang. For example, the discussions during the field visits in 2012 about possible relocations clearly underlined the fact that the unity of the communities (“staying together”) was considered to be of upmost importance. The interviews have shown that a strong common responsibility and solidarity (which is lost in western societies to some degree) seems to have survived in the high Himalayas, likely through cultural and religious influences and maybe also due to the difficulties that the population must face daily.

2.2.2 Funding of local projects

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

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

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

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

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

2.2.3 Institutional setting as an opportunity

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

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

2.3 Demographic setting

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

2.3.1 Mustang District

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

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

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

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

2.3.2 Upper Mustang

Headquarter of the DDC of Mustang District is Jomsom. Geographically and historically the District is subdivided into two sectors: Upper Mustang, with 5’395 inhabitants in 2001 and

Lower Mustang, with 9’130 inhabitants in 2001 (CBS, Kitazawa and Kayastha 2012)[3]. Apparently, more current data disaggregated on VDC level are (not yet) available.

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

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

According to CBS’s data (Kitazawa and Kayastha 2012), the seven VDCs counted 1’171 HHs in 2001. As a comparison, during the field visits in 2012, 53 HHs were counted in the three studied villages (Samzong, Yara and Dheye) together and 22 in Yara alone. Of all 1’171 nuclear families in Upper Mustang 301 (26 %) declared to have other economic activities other than agriculture, in particular in sectors such as trade and business (76, 7 %) and services (179, 15 %) according to the CBS (Kitazawa and Kayastha 2012). In Upper Mustang, the large majority of nuclear families dedicated to agriculture own land and livestock. Consequently they practice cultivation and stockbreeding.

2.4 National performance of Mustang District

A study undertaken jointly by the CBS and the International Center for Integrated Mountain Development (ICIMOD) came up with a comparative analysis based on development indicators in the 75 Districts in Nepal (CBS / ICIMOD 2003). According to the “Overall Composite Index” based on data from the 2001 census, Mustang occupies the 19th rank[4]. The “Poverty and Deprivation” indicator places Mustang 33rd and 17th in the “Socioeconomic and Infrastructural Development Indicator.” The position of Mustang District is particularly delicate with regards to the indicator “Per Capital Food Production” where it is placed 60th with only 2’196 kcal per day. However, in terms of number of living animals per family, Mustang with about 20 animals per productive unit is ranked first among the 75 Districts. Also the ratio “Percentage of Irrigated Area” related to total operational agricultural land area is high in Mustang (82.62 %, 6th rank). This demonstrates the crucial importance of water supply with regards to agricultural activities in Mustang.

---

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

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

3 Current situation in situ

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

3.1 Socio-economic and institutional aspects

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

3.1.1 Demographic aspects

Based on the field survey, the village is composed of 22 nuclear families and a total population of 114, among which 53 are male and 61 female. Out of the total 114 people, 40 (35 %) are permanently living outside of Yara. These permanent migrants rarely come back to Yara, if at all. Opposed to that, most of the inhabitants move towards the lower regions of the valley or even further south often engaging mobile trade during the winter months. This is a form of seasonal migration, which is quite typical for the area. Only a few remain in the village during the winter.

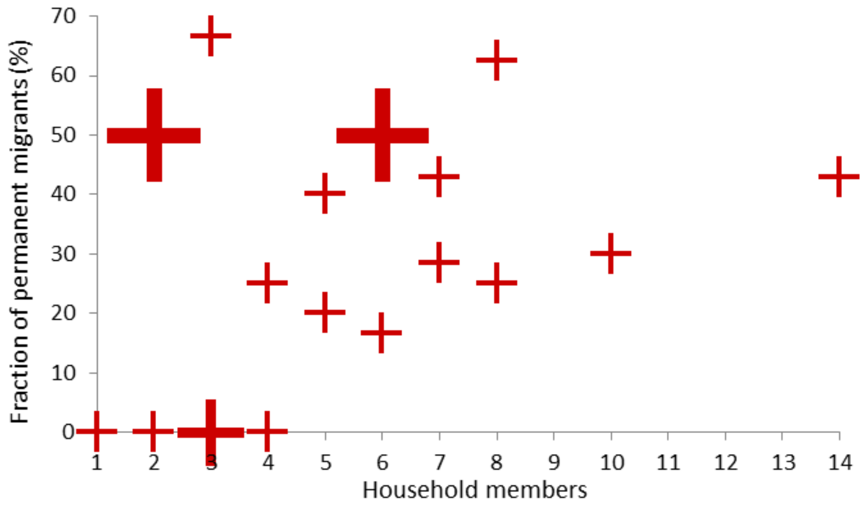


Figure 3.1: Scatter plot between the numbers of HH members against the fraction of permanent migrants of the corresponding family. The small sized crosses correspond to a single HH, the medium to two families and the large one to three HHs with the same characteristics (e.g. six HH members of which 50 % are permanent migrants).

Most of the permanent migrants are studying at distant schools (Lo-Manthang, Pokhara, Kathmandu or India). As depicted in Figure 3.1, the size of the family does not seem to be correlated with the percentage of permanent migrants. However, the demographic structure exemplifies that some of the HHs with a total number of four or less members are all living in Yara (at least during the bigger portion of the year) without including any permanent migrated family members. On the other hand, a varying fraction of all families with totally five or more members is living permanently elsewhere. In any case, it is difficult and it may be delusive to draw a conclusion from the data due to very small sample size.

The average age of the permanent migrants (17 y) is a lot lower compared with the residents (37 y). The former group consists mostly of teenagers and school-aged children, whereas the latter is constituted by adults and young children (Table 3.1). This represents a considerable risk for the future demographic stability of the village, since the young migrants will return less likely after their studies because of the strong attraction of local, regional and even national centers (e.g. Lo-Manthang, Jomsom, Pokhara, and Kathmandu). Subjectively, such centers present major earning opportunities and better material living conditions as it seems.

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

	Permanent migrants	Residents	Total
Number of family members	40	74	114
Average age	17	37	30
Standard deviation	8	21	20

3.1.2 Institutions and local competences

The institutional structure of the village appears to be very weak. There is no governmental body, building, police quarter and neither a health post present. A small school exists, but at the time of the field work, only few children were going to school.

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

In Yara, there is apparently not a person with informal leadership characteristics present who would be able to plan and implement strategies on mid to long term horizons. Consequently, the dependence from external supports is quite evident.

3.1.3 Economic activities and income

Economic activities are mostly limited to subsistence agriculture, strongly prejudiced by the scarce irrigation water, and to stockbreeding (goats, cows, horses and sheep). Based on the socio-economic survey, the average yearly income per nuclear family is about 90’000 Nepalese Rupees (NPR), but ranges from a minimum value of 5’500 (HH constituted by 2 people including 1 permanent migrant) to 450’000 NPR (7 family members including 2 permanent migrants). Though the income is visibly unlike from family to family, the references given by the people have to be interpreted with care, since the data could not be verified and are expected to be very unreliable.

Though almost all families practice agriculture (to a varying degree), not all of them own the fields they are working on. Of the total 22 HHs, 14 are land owners, 6 work on somebody else’s fields and 2 HHs are not engaging in agricultural activities altogether. Safe one family, all land owners each possesses a field area, expressed in the local surface measure, between one and two Ghalto. One HH owns only one field measuring about 0.1 Ghalto.

In total, the population of Yara owns 29 horses, 31 cows, 78 sheep and 1223 goats. In fact, one of the main economic activities that allow generating additional income is to sell animals and/or their fur. For instance, the market value of a goat corresponds to about 6’000 to 7’000 NPR.

The families’ incomes do not seem to have a clear correlation with the number of family members and owned goats (Figure 3.2). However, it has to be noted, that the quality and reliability of the data could not be verified. It is not possible to exclude strategic answers or underestimations, influenced by the sensitiveness of the issue for instance. Also, 3 out of the 22 HHs did not indicate their total yearly income.

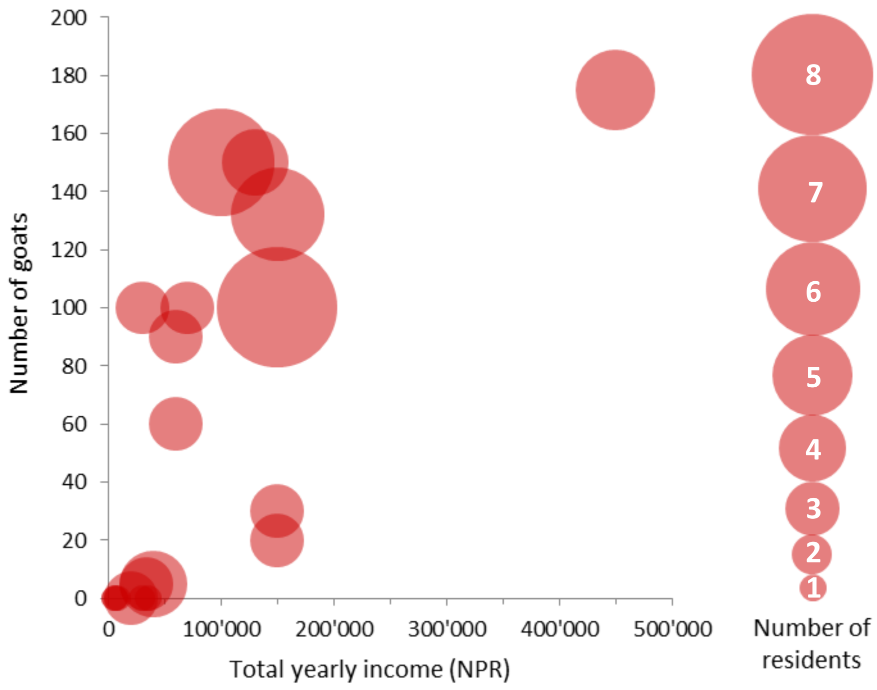


Figure 3.2: Scatter plot of the total yearly income and the number of goats per family. The size of the circle indicates how many family members are still living in the corresponding HH in Yara, meaning that they are not permanent migrants.

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, which is practiced by almost half of all families.

Other activities executed by numerous families include workmanship in construction, agriculture or other paid labor.

Yara is the only one of the three studied villages, which is, at least seasonally, accessible by a track. Furthermore it provides touristic accommodations, namely a guesthouse with attached campground and another separate camping site. Both provide accommodation mainly for tourists or pilgrims visiting Dharmadha Kunda or Luri Gonpa, two local attractions (section 1.5).

The touristic offer further diversifies the range of income generating activities. At least two households, 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.

The range of income generating activities is even further widened by individuals partly working as a health helper, manufacturing and selling horse equipment, producing handicraft, running a small shop or operating a tractor transport service.

3.1.4 Perception of the main problems faced by the community

During the socio-economic survey each of the 22 households were asked to identify three main issues about which they are most concerned and to rank them according to severity (Figure 3.3). With this data, the three main issues mentioned by the Yara community were identified:

- Priority 1: Lack of irrigation water
- Priority 2: Lack of fodder and pasture land along with many others (Figure 3.3)
- Priority 3: Broken mill

Some families were concerned most about not owning land for themselves (4), about food supply (2), landslides (1) or lack of electricity (1). The majority however (12) identified the insufficient irrigation water as the main threat.

As depicted in Figure 3.3, the second issue the HHs of Yara are concerned about is widespread. The lack of fodder and pasture land was mentioned thrice, while eleven other issues which were brought up, were only mentioned once or twice.

Also the range of issues which were mentioned with third priority is large (Figure 3.3). However, out of the families who identified three concerns (15), 5 mentioned the solar mill as a problem, because it had been out of order during the field visit. All other issues were mentioned by two or one family each.

On the bottom line, this analysis shows, that the largest concerns of the community is focused on the insufficient water supply. Interestingly however, out of the six families which do not own land, four are more concerned about land property than insufficient water supply. Generally, the most concerning issues with lower priorities are very wide-spread.

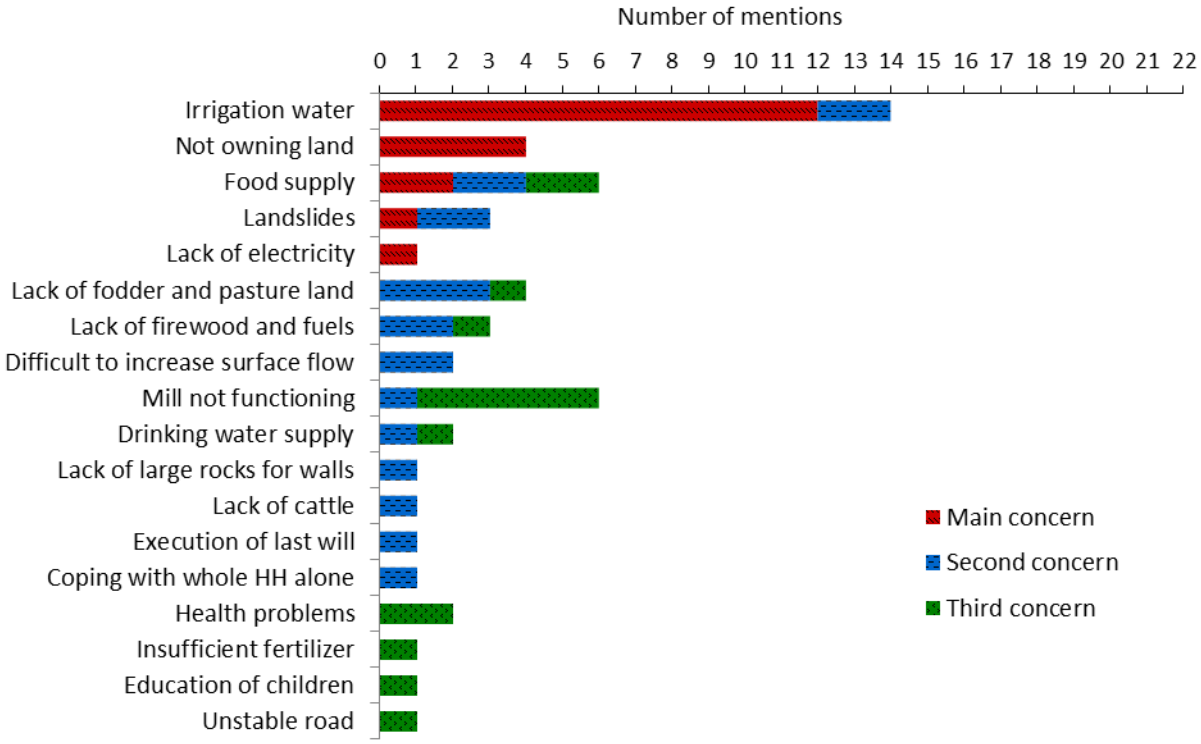


Figure 3.3: Visualization of the survey related to the identification and ranking of three main issues about which each of the 22 HHs are most concerned. Note that two families abstained from choosing altogether and five families identified less than three main issues.

3.2 Housing

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

3.2.1 Settlement layout, spatial organization and density

Yara (Figure 3.4) lies about 7 km east of Charang and is situated on the right riverside of the Puyung Khola. A deep gorge which is not carrying any perennial water cuts through the village (Figure 3.5). Most of the houses are located on the right bank but a small group of houses is occupying also the left bank.

The settlement is composed by five groups of houses, the largest is situated at the center, just above the right bank of the ditch, the second largest is located south, on the other side of the trench, one is situated southwest, another northeast, whereas the smallest including the school and the Gonpa is found in the northwestern section of the village (Figure 9.1 in appendix A.1).

Figure 3.4: Yara seen from the left riverside of the Puyung Khola. Yara is located on the right riverside (photo: 05/07/2012, Daniel Pittet).

Figure 3.5: View of the central area of Yara from south. In the foreground the ditch dividing the village can be seen. In the center the sector of the village most affected by geological instability is shown. Many houses have been abandoned which can easily be identified by the earthen color in contrast with the white colored occupied houses (photo: 02/07/2012, Daniel Pittet).

There is an earthen track access to Yara. From Zurkhang up to Yara it is mostly routed through the riverbed of Puyung Khola. From Yara it leads to Ghara (about 2 km distance) through the right valley side.

The salient characteristic of Yara related to territory setting is that it is located on a large landslide affecting the geological stability of the whole area (chapter 3.5). Consequently, numerous houses were damaged, of which many have been abandoned over the last decades (Figure 9.1 in appendix A.1). In fact, there are currently 18 houses completely abandoned (excluding the old Gonpa) and 8 houses that are currently used as cowsheds or for storing fodder, while only 5 among the houses that were already built before 1973 are still occupied as dwellings (out of a total of 22 HHs). Most of the abandoned houses are located at the center and south part of the village (appendix A.1).

The public amenities are a preliminary school (built recently in the northwest sector near the new Gonpa), a community hall, a mill powered by solar energy and a new Gonpa (the old Gonpa was located in the most affected sector by landslide in the center of the village and has been abandoned). Additionally, there is a big Chörten in the east side of the village and several smaller ones dispersed in the surroundings (appendix A.1).

The footprint of the settlement, including the buildings, abandoned houses, nearby compounds, squares and public areas, but excluding the fields, covers 1.69 ha[5], corresponding to a density of 67 inhabitants per hectare.

The surrounding fields cover an area of 11.74 ha among which 10.56 ha are presently cultivated and 1.18 ha are not used or used for other purposes such as grassland, trees, brick manufacturing. There are a fair amount of trees (mostly Populus Ciliata, locally known as Bhote Pipal; Figure 3.4), planted mainly along the irrigation channel crossing the village longitudinally (section 3.4.4). The wood of the cultivated trees are mostly used for construction purposes, namely their trunks for beams and their branches for roofing (section 3.2.3)

3.2.2 Characteristics of housing

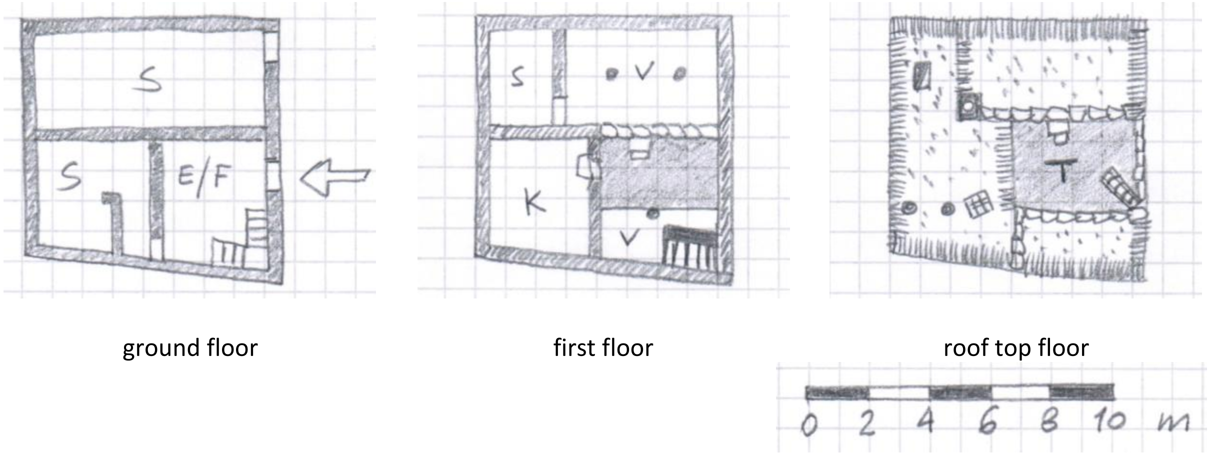
The spatial organization of the dwellings in Upper Mustang is greatly varying depending upon size, available space, need and means of the HH and proximity to other houses. However, there are some typical elements that are found in most cases, as discussed in the following.

The dwellings are generally rather compact with access to the rooms through a central courtyard and systematically accessible flat. Generally, the houses are surrounded by compounds for animals fenced by stone walls, in case enough space is available. About half of the houses in Yara have two stories, including a ground and a first floor, whereas the other dwellings are composed by the ground floor only.

---

[5] Measured with Google Earth Pro

Three houses, each representing a typical small, medium (Figure 3.6) or a large house respectively, were measured in Samzong and are fully presented in Figure 9.2, Figure 9.3 and Figure 9.4 in appendix A.2.



ground floor first floor roof top floor

Figure 3.6: Representation of a dwelling from Samzong taken as a reference for a typical medium sized house (abstract of Figure 9.3 in appendix A.2, hand drawings: 30/06/2012, Daniel Pittet).

The comparison of the three before mentioned typical house types in Table 3.2 illustrates the variations of house compactness and land use (footprint). 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).

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

Table 3.2: Size and compactness of three typical house types of different sizes. The whole drawings of the corresponding houses are presented in Figure 9.2, Figure 9.3 and Figure 9.4 in appendix A.2.

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

[a] Considers footprint without compound

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

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. The vertical access is generally supplied by very simple ladders constructed by excavating a wooden trunk accordingly. In some cases more elaborate wooden stairs for accessing the first floor are provided.

The socio economic survey has also allowed collecting data on the houses' compositions, illustrated by Figure 3.7. The corresponding data can be found in Table 9.1 in appendix A.3.

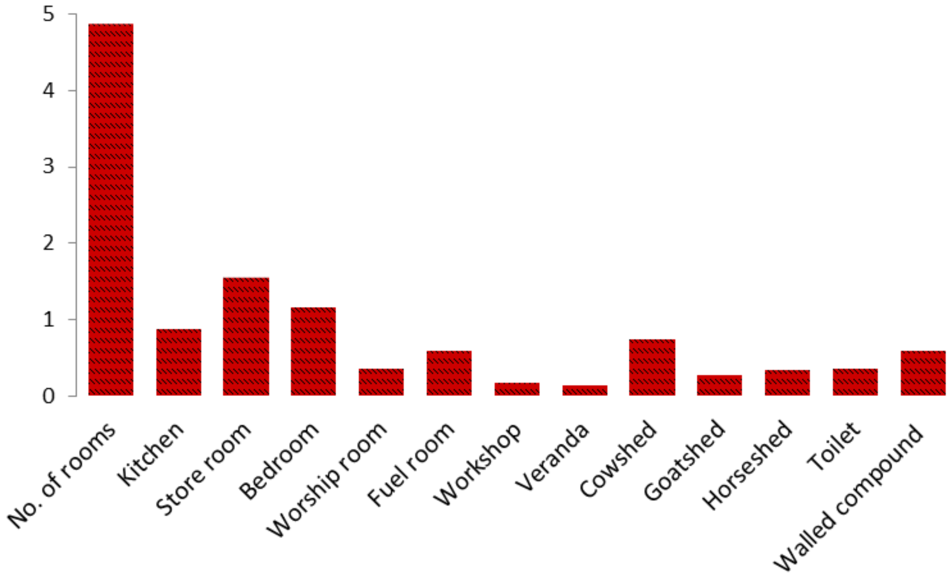


Figure 3.7: Average house composition of Yara based on the socio-economic survey undertaken during the field visits.

The number of rooms per house varies from 1 to 9 with an average value of about 5 (Table 9.1 in appendix A.3). Generally every house has one kitchen but in numerous cases (9 out of 22), the kitchen is also used as a sleeping space or exceptionally as a workshop or veranda. Safe in 3 dwellings, all houses have store rooms varying from 1 to 4 in numbers with an average value of about 1.5. All houses accommodate bedrooms, though in 7 cases they are shared with the kitchen as mentioned before. Fuel rooms and walled compounds are present in more than half of all HHs, which averages to 0.59 rooms per HH for both categories. Worship rooms, toilets and horsesheds all share a value of about 0.35. Workshop rooms, verandas and goatsheds are rather marginal (0.28) while cowsheds are more common (0.75).

3.2.3 Construction technology, systems and costs

Housing technology

The foundations are made of stones that are also used for the lower part of the walls in some cases. The walls are made of hand-made crude soil blocs of about 40 x 20 x 12 cm (Figure 3.8), laid out with soil mortar and covered with lime plaster. The walls are reinforced around the openings (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 3.8). 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 3.8: 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).

Construction systems and maintenance of the houses

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

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

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

Construction costs

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

Table 3.3: Estimated average cost for a standard house with 4-5 rooms in Samzong, which is considered to be representative for Yara as well. The values are based on a community meeting with representatives of 14 out of the total 17 HHs on 27/06/2012.

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

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

3.2.4 Issues and problems related to housing

In Yara, the condition of housing is very much linked with the particularities of the geological setting (chapter 3.5). In fact, the geologically generally instable area has deteriorated an important part of the built assets of the village. Many houses have been abandoned (section 3.2.1) and many others are more or less seriously affected by the phenomenon and present fissures in their walls. The socio-economic survey revealed also, that the people of Yara consider the location as relatively risky, namely because they feel a certain fragility of their houses in particular in case of heavy rainfall.

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

3.3 Climatic and meteorological setting

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

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

3.3.1 Climatic setting

According to Rohrer (2012a) Mustang's climate "(…) is characterized by a cold, windy and dry climate." Very generally speaking, it seems that it is getting even drier. This circumstance is exemplified by the many abandoned agricultural fields that could be seen walking through Upper Mustang. Based on satellite information from 1990 and 1984, Kostka (2001) identified and visualized agricultural areas including abandoned portions in a thematic map (Figure 9.1 in appendix B.1). Looking at more recent satellite imagery with Google Earth for instance, it becomes apparent, that the abandoned field areas have been further increasing over the last decades. Though this tendency may have different reasons, it is very likely that there has been an ongoing reduction of water availability during the last century. This is also supported by the accounts of the interviewed locals. In addition, this tendency of "Upper Mustang becoming drier since decades" has also been expressed by G. Miehe, a specialist of Tibet's climate (G. Miehe 2012, pers. com.).

In general, the climatic setting appears to be spatially highly variable. As a neat example thereof, clouds were producing very local precipitation in Upper Mustang in 1978, vertically distinctively delimited (Figure 3.9).

Figure 3.9: Local precipitation west of Samar produced by clouds which were formed by the uplifting air masses flowing upwards through the Kali Gandaki valley. Neither the valley bottom, nor the mountain tops, which were under the influence of an overlying high pressure system, received any snowfall. The picture was taken from Thorung Peak (6140 m asl) in northwestern direction (photo: 13/11/1978, Giovanni Kappenberger).

3.3.2 Air temperature

Actual trends of air temperature

Reliable meteorological data over longer periods are not easy to find in Nepal. Analysis of such data has to be done with care therefore. Nevertheless, according to Rohrer (2012a) a general warming trend over the last roughly three decades can be identified by comparing two different temperature interpolations (Figure 9.8 and Figure 9.9 in appendix B.3). The magnitude of the warming trend is questionable, as the two interpolations show inconsistencies, but roughly the warming seems to amount 1°C over the last 30 years in Mustang (Rohrer 2012a).

Future trends of air temperature

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

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

3.3.3 Wind

The winds of the Mustang region are heavily influenced by the pressure fields forming over India and Tibet. The very strong diurnal winds (Figure 3.10) are well known and described in many articles, books and guides. As in most valleys, winds blow up or down, but not perpendicular to the valley axis.

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

Figure 3.10: Riverbed of the Kali Gandaki between Jomsom and Kagbeni. The heavy afternoon wind is visibly suspending and transporting a lot of sand and dust particles (photo: 19/10/2011, Giovanni Kappenberger).

Present wind patterns

As mentioned before, a particularity of the Kali Gandaki valley is that it is subject to quite unique diurnal wind both in terms of magnitude and asymmetry between night and day (Figure 3.11). 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).

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.

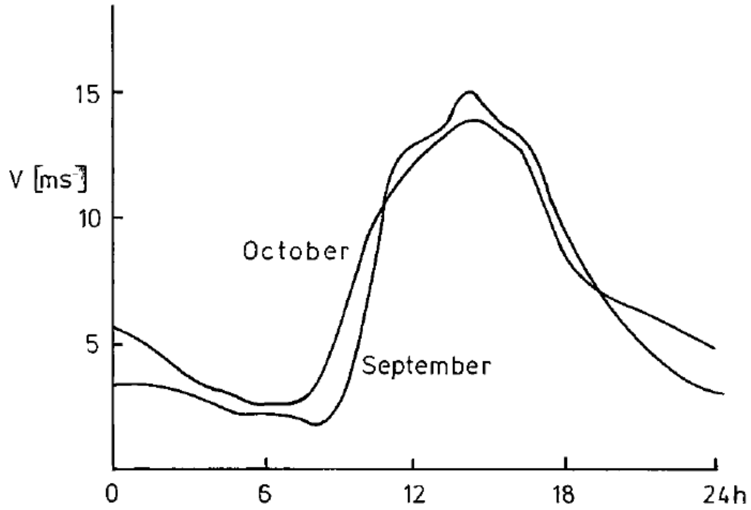


Figure 3.11: Graph illustrating monthly mean values of the hourly mean wind speed V (m/s) as observed in Kagbeni in September and October 1990 at a height of 30 ft, taken from (Egger et al. 2000).

Future wind patterns

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

As a consequence of the increasing winds, more dust and particles are transported and ultimately deposited (confirmed by B. Neininger 2012, pers. com.). Deposition on snow and glacier surfaces lead to a decrease of albedo and therefore to enhanced melt rates. This has major implications for future water availability, since the latter seems heavily dependent on snow and ice melt (section 3.3.4 and 0).

3.3.4 Precipitation

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

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

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

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

Average precipitation

Rohrer (2012a) states:

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

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

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

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

[a] Practical Action (2009)

[b] 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 3.5).

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

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

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

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

In Samzong the reported values differ by more than twofold. The discrepancy might partially be due to the placement of the gauge RS3 on an insufficiently open roof. Furthermore, important differences can be explained by the irregularity of convective precipitation events. In

Yara one reading is larger than the other two, while in Dheye, the readings are matching nicely.

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

Actual trends of precipitation

The analysis of the data records[6] 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 9.10 and Figure 9.11 in appendix B.4.

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

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

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

Future trends of precipitation

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

---

[6] 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

3.4 Water resources

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

3.4.1 Water demand

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

A range of drinking water demand per capita in a similar context is given by Wacker and Fröhlich (1997). The drinking water demand covers domestic activities such as cooking, drinking, washing of clothes, personal hygiene etc.

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

Description	Value range
Total inhabitants (excl. permanent migrants)	$P_p = 74$
Daily drinking water demand per capita[a] (l/p/d)	$d_d = 15 – 40$
Daily drinking water demand (l/d)	$D_d = d_d \cdot P_p = 1'110 – 2'960$
Required water flow during 24 hours a day (l/s)	$Q_d = D_d/(24 \cdot 3'600) = 0.013 – 0.034$

[a] Taken from Wacker and Fröhlich (1997)

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

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

Description	Value
Total population (incl. permanent migrants)	$P_t = 114$
Cultivation area per person[a] (m^2/p)	$a = 1'000$
Required cultivation area (m^2)	$A = a \cdot P_t = 114'000$
Daily irrigation area based on a 14 days cycle (m^2)	$A_i = A/14 = 8'143$
Irrigation intensity[a] ($mm/m^2 = l/m^2$)	$d_i = 38$
Required water flow during 24 hours a day (l/s)	$Q_i = d_i \cdot A_i/(24 \cdot 3'600) = 3.5$
Required water flow during 12 hours a day (l/s)	$Q_i = d_i \cdot A_i/(12 \cdot 3'600) = 7.1$

[a] taken from Wacker and Fröhlich (1997)

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

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

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

3.4.2 Water sources

The draining area of Puyung Khola in Yara measures roughly 51 km^2 (Figure 3.12). The lowest point of the corresponding catchment lies at 3550 m asl and reaches up to 5921 m asl. The headwaters are not glaciated so that the perennial flow of the river is strongly linked to the precipitation during the monsoon season and especially to the snowfall during winter.

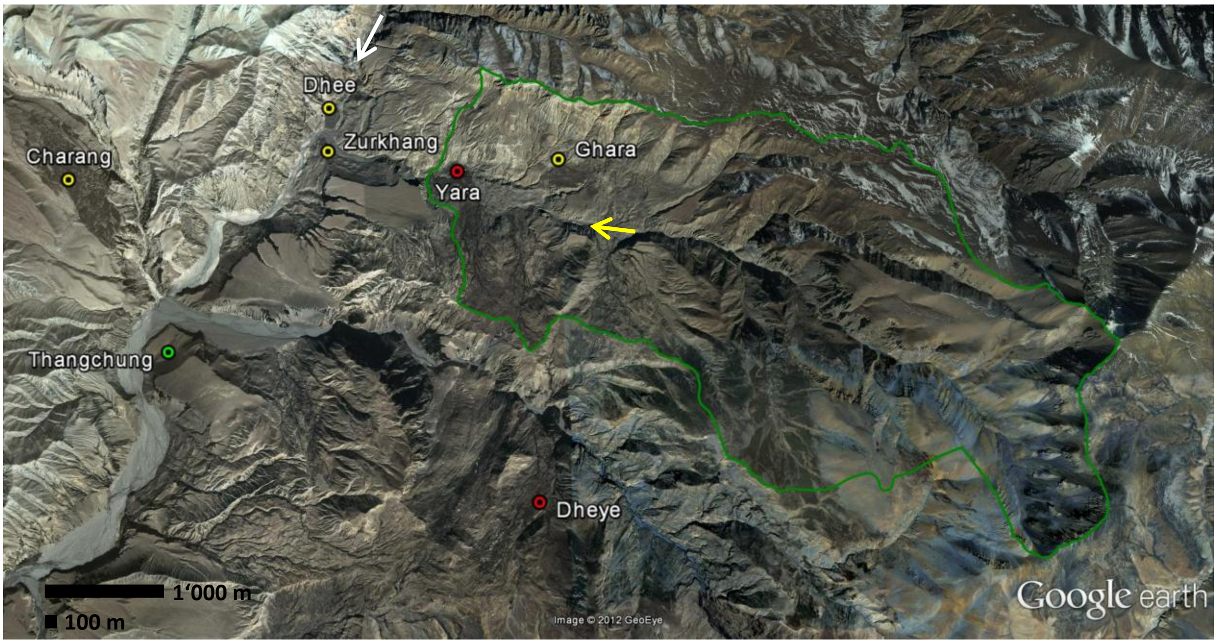


Figure 3.12: Catchment of Puyung Khola (green polygon). The studied villages Yara and Dheye together with Dheye's relocation site Thangchung as well as other villages in the vicinity are indicated. The flow direction of the Puyung Khola is indicated by a yellow, and the one of the Kali Gandaki, the main river in Mustang valley, by a white arrow. North direction is ↑ (source: Google Earth Pro, accessed 27/11/2012).

The Puyung Khola drains through steep chutes before entering a much less sloping section just above the locally well-known Luri Gonpa. The headwaters itself could not be visited during the field work. However, the area generally shows signs of carstic formations which are likely the reason for several springs observed in the section between Luri Gonpa and Yara. The springs are certainly contributing to the perennial surface water flow. Their yields decrease towards the end of the dry season or even fall completely dry. The river flow of the Puyung Khola however has never been observed to fall dry (so far).

3.4.3 Water regime

The closest river gauging station to Yara is located in Jomsom about 45 km southwest measuring Kali Gandaki's discharge. At this point the Kali Gandaki has been joined by numerous glacier-fed catchments. The correlation between the Kali Gandaki and the Puyung Khola is therefore expected to be very small. In addition, the available data are not very reliable according to the DHM, which is collecting and selling the data. Therefore the analysis concerning the water regime is mostly based on observations on site and their interpretations.

Monsoon precipitations lead to high discharges which can likely reach manifold of the lowest flows. In general the soil has a rather high permeability. The mountain slopes of the lower headwaters show very little signs of surface erosion. Either most of the precipitation falls in form of snow and is melted slowly thereafter or all the water infiltrates quickly so that only little sheet flow is created.

The precipitation certainly recharges the groundwater storage to a certain degree which is probably contributing to the perennial flow of the Puyung Khola especially during monsoon and post-monsoon. The effect of recharged groundwater during the monsoon on the surface flow in spring remains unclear. Particularly due to the rather carstic formations in the headwater, the dynamics are difficult to qualify without further studies.

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

3.4.4 Water supply

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

Drinking water supply

The drinking water is abstracted about 1 km east of and less than 100 m above the village. The water of a small spring, which has been shifting over the years led to the construction of three different concrete intake structures. It can be expected that also the newest chamber is going to be unsuitable in the future, since a rather large portion of the spring has considerably shifted again. The spring is situated on the right riverbank of the Puyung Khola and is protected against erosion of the river by gabion structures.

From the abstraction chamber the water is routed to a tank situated above the village. The water is transported within a plastic pipe with an inner diameter of 4.5 cm. The pipe is mostly buried underground so that only a few sections are visible.

From the collection tank, the water is distributed to five different tabs distributed within the village. From the five tabs, three are working fine, one is only sometimes yielding water and one is completely dry.

The people fill their so-called toms (35 and 5 l canisters respectively) at the fountain and bring them to their houses to satisfy their domestic water demand. By means of a survey, the demand was estimated to 20 l/d per capita or 1502 l/d, which is within the range of the estimated water demand (section 3.4.1). The water is mostly used for cooking, drinking, and personal hygiene. Most sheep and goats are lead to the river to drink, whereas cows and horses are brought to the taps. Their consumption could not be quantified. The clothes are either washed at the taps or within the irrigation channels. In any case, the drinking water pipeline supplies a sufficient amount of water, which is also perceived in this way by the people of Yara.

Irrigation supply systems

Due to the very low precipitation rates in terms of total amount, but also in terms of timing (section 3.3.4), agricultural activities are almost solely dependent on the surface flow of the Puyung Khola and particularly on how much can be captured.

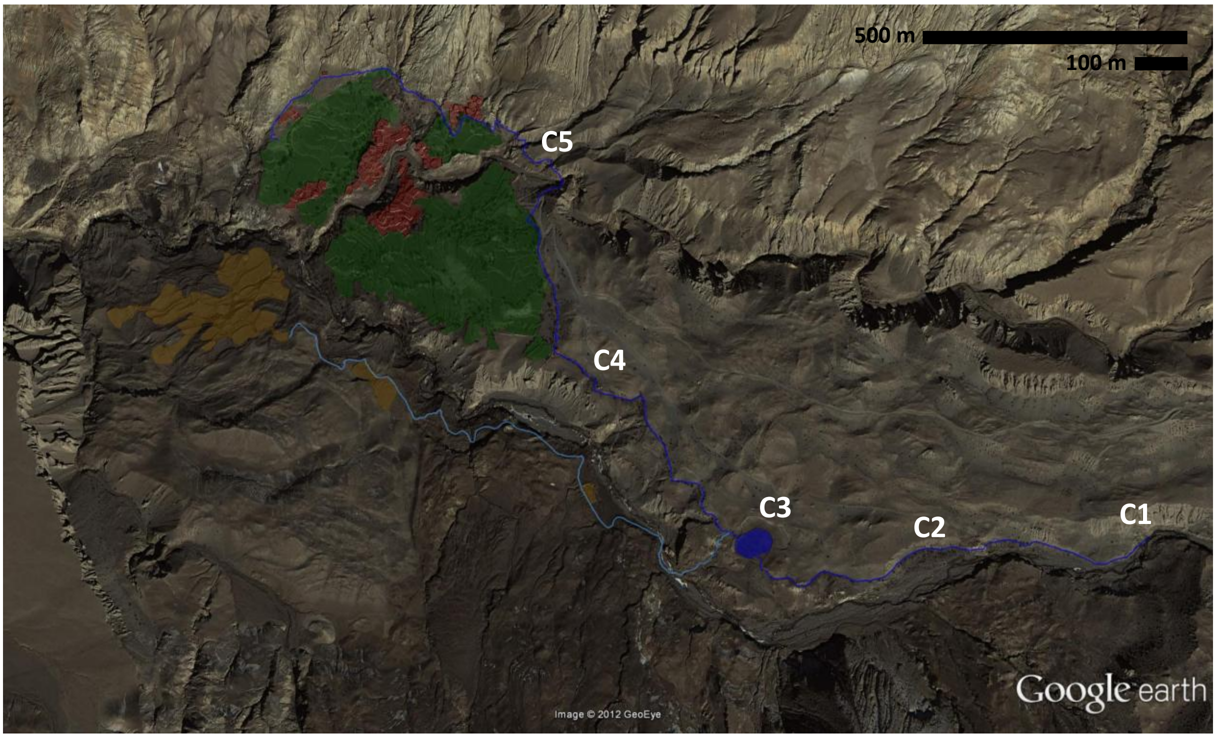


Figure 3.13: Google earth view of Yara and its surroundings indicating the abandoned (light blue) and the irrigation system in use (dark blue). Yara's settlement areas are dyed in red, the agricultural area in abandoned field area in orange. The number codes correspond to different sections of the irrigation systems further described in Table 3.8. North direction is ↑ (source: Google Earth Pro, accessed 27/11/2012).

The (upper) abstraction could never capture all water, so that the residual flow was taken in further downstream and directed to fields located on the left riverside of the Puyung Khola. The corresponding irrigation system consisted of open earthen channels of about 1.2 km length (Figure 3.13). Reportedly, two landslides took place within the past five years which damaged the irrigation channels of the agricultural area on the left riverside beyond repair.

Consequently, all corresponding fields had to be abandoned (Figure 3.13). These fields had been cultivated as long as the people could remember.

Table 3.8: Summarized description of the functioning (C) and the abandoned (D) irrigation system in Yara. The corresponding sections of each system are indicated in Figure 3.13.

Section	Unit	Length / Volume	Description	Main issues
C1	Water abstraction		Handmade construction, made of locally available rocks, mud and earth to abstract the water	➢ Damaged and/or destroyed during high flows of Puyung Khola ➢ Reconstruction frequently necessary
C2	Reservoir supply channel	790 m	Mostly hand-dug, open, earthen channel, partly piped, connecting water abstraction with the reservoir	➢ Channel runs along steep hillsides which are subject to instabilities ➢ Spillage and damages require frequent maintenance ➢ Hand-dug channel subject to constant losses due to seepage ➢ Infiltration accelerates landslide movements
C3	Reservoir	1200 m^3	Reservoir with side-walls formed by piled up rock, mud and earth, cemented outlet which can be opened and closed by inserting a cloth ball	➢ Excavation of accumulated particles necessary each year ➢ Subject to constant losses due to seepage ➢ Infiltration accelerates landslide movements ➢ Under observed conditions, all water accumulated during the night is released in in the morning, so that in the afternoon the abstracted water simply flows through the empty reservoir
C4	Main transport channel	520 m	hand-dug, open, earthen channel, connecting reservoir with field level distribution channels	➢ Hand-dug channel subject to constant losses due to seepage ➢ Infiltration accelerates landslide movements
C5	Channel delivering right village side's agricultural area	1170 m	hand-dug, open, earthen channel, including several piped gully crossings to transport irrigation water to the right village side	➢ Hand-dug channel subject to constant losses due to seepage ➢ Infiltration accelerates landslide movements ➢ Gully crossings subject to frequent maintenance due to leaking and erosion damages ➢ Constant losses along the long transport line heavily reduce yield towards the end of the distribution channel

The villagers would like to reactivate the damaged channel to cultivate the corresponding fields. The hydrogeological field assessment revealed however, that the renewed cultivation would lead to further acceleration of the large landslide on which the fields are located (section 3.5.1). The reactivation of the currently abandoned fields is therefore strongly discouraged.

Nowadays, only the irrigation system supplying all fields on Puyung Khola's right riverside is in use. Figure 3.13 indicates different sections of the system, which are further described in Table 3.8. A detailed description of the systems can be found in (Bernet 2012).

Local water shortage mitigation practices

Yara's people engage in a traditional procedure, being practiced for at least 25 years, aimed at increasing the surface water flow. About 1.2 km upstream of the water abstraction, next to a large deposit of fine sand, clay and mud, the people dig a channel into the riverbed in mid-February within one day each year. This practice does not result in higher surface water flow further downstream, but the water collects in the channel, which is crucial for the next steps of the procedure. When the perennial water within the river starts to recess, the villagers try to prevent the water to flow underground. From each of the 14 HH owning fields (section 3.1.3) somebody is sent to abstract soil (Figure 3.14) and put it to each side of the running surface water.

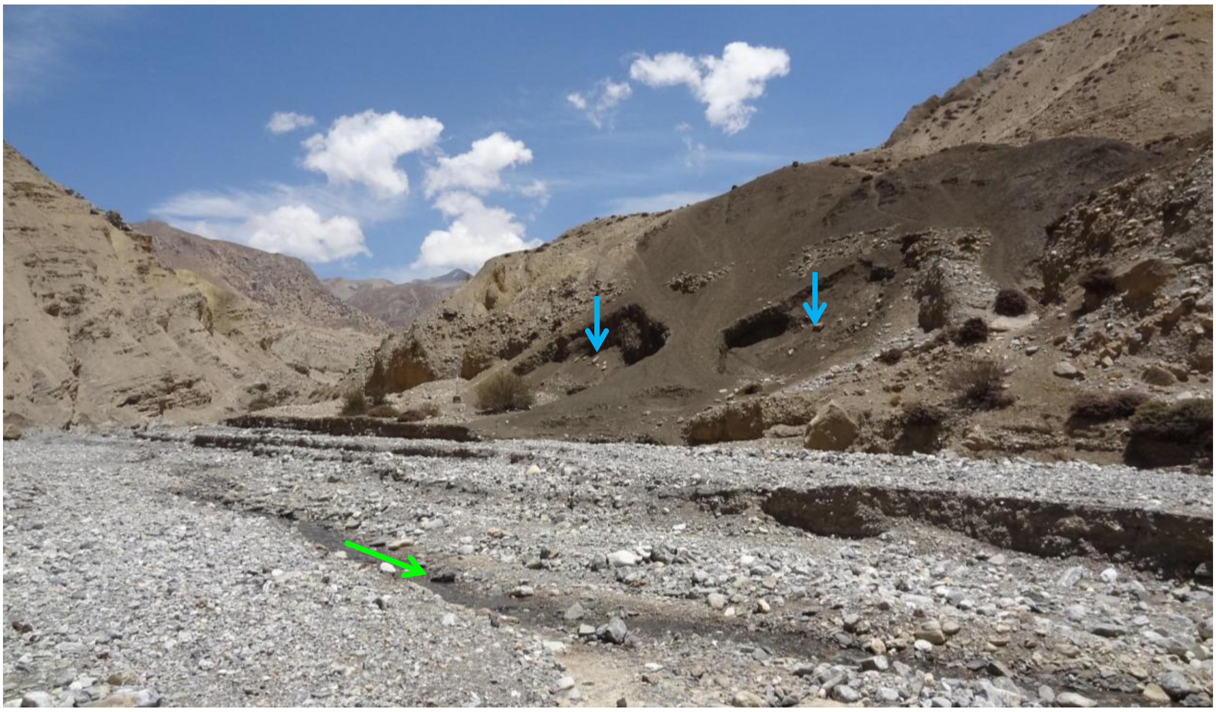


Figure 3.14: Site on the left riverside of Puyung Khola (green arrow), from which a vast amount of soil, consisting out of sand, mud and clay, is abstracted and applied to the river to prevent subsurface flow. The excavation of soil, being practiced for many years, has left clearly visible marks (blue arrows).

This laborious task is continued for about 11 days. Based on the villager's accounts, it was estimated, that a total of almost 10'000 baskets, amounting to approximately 10 tons of soil, are applied each year. The water mobilizes the fine particles and transports them along. Apparently, pores of the underlying are clogged so that the water flows mostly over ground thereafter.

After applying the soil, the water flow is said to slightly increase further downstream, but the observations could be biased. The effects have never been quantified in detail. Although, the procedure is most likely not resulting in adverse effects, it might as well be that the desired increase of surface water yield is negligible. It is thinkable, that the water which is dis- and reappearing along the course of the Puyung Khola at numerous places, would naturally surface in the area of the abstraction and is indifferent towards the upper section where the application of soil is reportedly preventing the water to become subsurface flow.

In the scope of this study, it was not possible to study the effects and reasonability of the described time-consuming and laborious practice in more detail. In any case, as long as the effects of this traditional procedure are not proven scientifically, an advice cannot be given.

Irrigation scheme

To prepare the fields for the winter, the fields are irrigated and fertilized at the beginning of November. After the winter, in the beginning of March, the fields are plowed and the crops are sown. Seven days after seeding the fields are irrigated for the first time. The order in which the HHs are given their daily turn to use the water distribution system is drawn by lot early each year. As there are 14 HHs owning fields, a full round takes 14 days.

One day is not sufficient to irrigate all fields for HHs with large agricultural areas. Therefore it usually takes two full rounds until all fields were at least irrigated once. Consequently HHs owning less land can irrigate their fields more often.

After conclusion of the first rounds, a pause of about three weeks is inserted. Thereafter all fields are irrigated at least twice after which another break of about two weeks follows. Afterwards the fields are irrigated without pause according to the drawn order.

During such pauses during which irrigating fields is not allowed, usually only part of the available surface water is abstracted. The captured water is mostly used to water the trees in and around the village (section 3.2.1).

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[7] was measured and put into relation.

The simple indicators presented in Table 3.9 exemplify that the abstracted water would be sufficient to supply the whole cultivated area with 6 mm of water each day, provided a lossless distribution system. During a HH's turn, the corresponding average field area could be supplied with roughly 80 mm. As a whole turn takes 14 days, each field could potentially be

---

[7] 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.

irrigated with 80 mm every 15 days. Compared to the postulated demand of 38 mm each 15 days (section 3.4.1), the potential supply is more than double. Likely, this can mostly be attributed to the fact that the irrigation systems are subject to very large losses.

The losses differ spatially and temporally and could not be quantified in the scope of this project. Furthermore the regularity of irrigation may vary, since the systems are prone to failure due to spillage, erosion etc. and are time as well as labor-intensive to maintain as described in the following section.

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

Description	Value
Number of HHs owning fields	14
Total cultivated area (ha)	10.6
Average cultivated area per HH (ha/HH)	0.75
Total abstracted water (m^3/d)	603
Abstracted water per total cultivated area ($l/m^2/d$ = mm/d)	5.7
Approximated irrigation depth[a] (mm/HH/d)	80

[a] The total abstracted water is divided by the average cultivated area per HH. 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.

Main issues related to the irrigation systems

From a water availability and management point of view, the difficulty is that the resources are fully allocated during most times. The surface flow of Puyung Khola therefore determines the amount of water which can potentially be used by the villagers not presenting any unallocated resources acting as a buffer or security during dry years.

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

As the water availability is limited and is smaller than the water demand for irrigation purposes at times, the efficiency of the irrigation systems is a crucial issue. The distribution systems are subject to constant losses such as seepage and evaporation, and local losses such as leakages. Furthermore, infiltration can lead to an undesired acceleration of the underlying landslides (section 3.5.1).

Mainly during monsoon period, concentrating rainfall crosses the section of the channel connecting the abstraction and the reservoir. The section is frequently damaged, be it by erosion of the soil downhill or by spillage the open channels. The necessary repair works, as well as overall maintenance of the irrigation system, are laborious and tedious tasks.

The non-durability of the water abstractions poses a challenge to the inhabitants of Yara. The yearly high flows of Puyung Khola during monsoon season frequently damage or even destroy the abstraction. As long as the abstraction is not reactivated, the fields cannot be irrigated.

3.5 Geological conditions

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

3.5.1 Geologic hazard setting

The valley of Puyung Khola is strongly affected by landslides that affect both the right and left flanks. In particular, at the right side of the river a huge Deep-seated Gravitational Slope Deformation (DGSD) is present affecting the slope on which Yara, as well as Ghara are located. The deformed area is characterized by a series of scarps and counterscarps affecting mainly the medium and lower part of the slope. The DGDS covers an area of about 1.5 km^2 with limestone and marly limestone outcrops in decimetric layers dipping towards northwest, which belong to the Tibetan-Tethys zone (B. R. Adhikari and Wagreich 2011).

The middle and lower part of the slope are marked by accumulations from rotational and translational landslides. Figure 3.15 shows the inventory landslide map of the valley between Yara and Ghara visualizing the presence of more than twenty rotational sliding bodies of different styles and states of activity, inventoried according to the International Varnes Classification (Varnes 1978). In the westernmost part, located west of Yara (Figure 3.15, #1), the hummocky morphology is due to rotational rockslide movements. Evidences of the current activity are numerous visible scarps and open trenches affecting this area, which is crossed by the footpath leading from Dhee to Yara. Also the tractor road along the river is influenced by the landslide. Numerous mass movement instabilities and rockfalls are proof for the landslide’s activity. In particular, along the Puyung Khola close to Yara numerous traces of past landslide events are visible. In some cases accumulations from past landslides probably closed the valley completely forming dams.

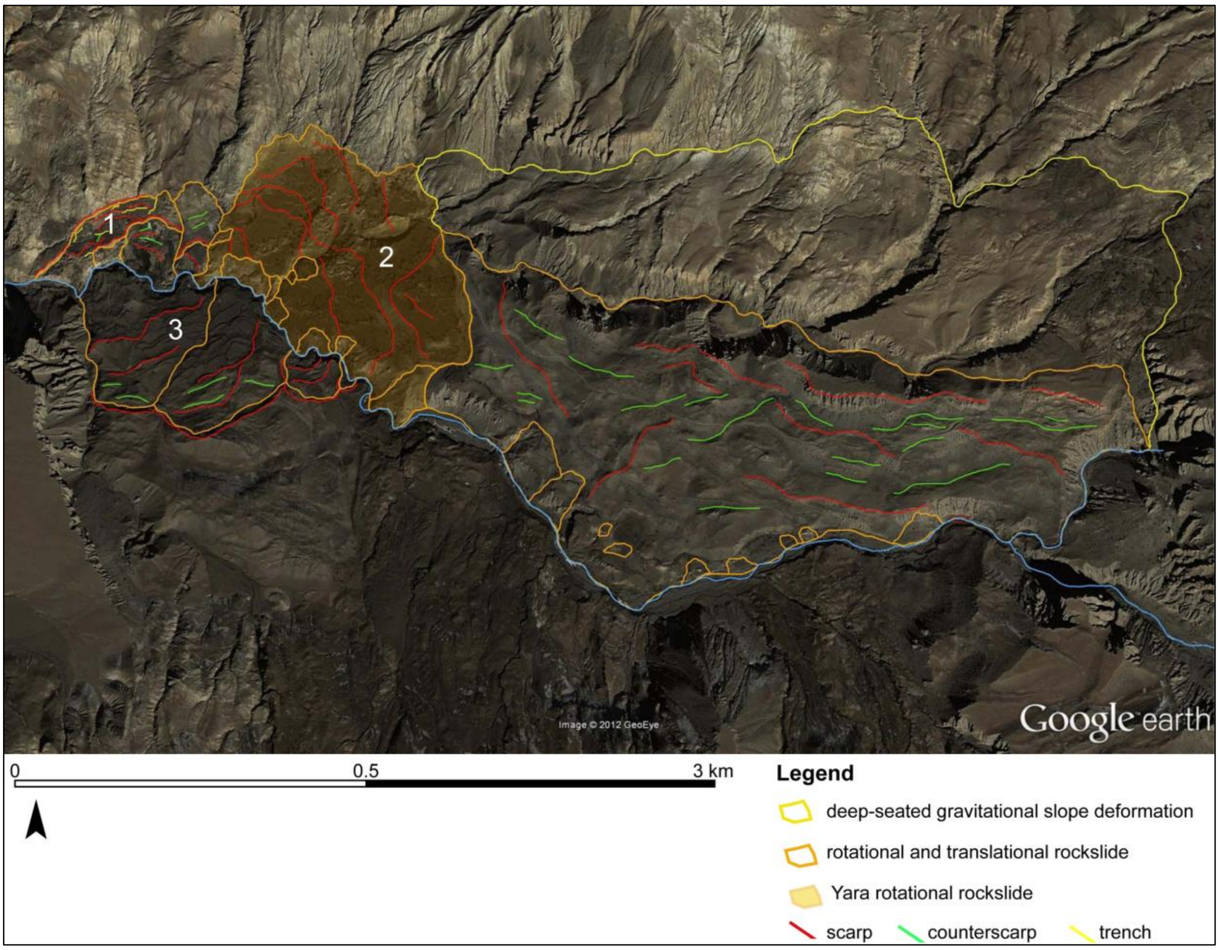


Figure 3.15: Landslide inventory map of Yara, located on the right riverside of Puyung Khola, highlighted by the blue lines. The numbers indicate areas which are referred to in the following paragraphs (source: Google Earth Pro, accessed 08/08/2012).

Yara's settlement areas including the surrounding fields on the right riverbank are affected by a deep rotational landslide that, according to the observations in-situ, appears to be still active (Figure 3.15, #2). Other minor landslides affect the toe of the slope along the irrigation channel (Figure 3.17).

Also the left flank of the Puyung Khola valley is affected by an active rotational slide (Figure 3.15, #3). The associated movements have destroyed essential parts of the irrigation channel supplying water to the fields located on the left riverside. Consequently, the corresponding fields had to be abandoned about five years ago (section 3.4.4). Due to the present activity of the landslide it is not recommended to reactivate these fields. Irrigation of the concerned agricultural area could further increase movements and trigger the collapse of the front of the landslide. In such an event, the Puyung Khola could be dammed, besides the thread of a sudden flood, it could also adversely affect the landslides on the right valley flank.

A detailed map of the landslide on which Yara is situated, is shown in Figure 3.16 indicating all recognized morpho-structures including scarps, counterscarps and trenches. The deep rotational landslide affects an area of about 0.2 km^2 and involves a fractured and weathered rock mass. The depth of the sliding plane is estimated to be 30 to 50 m below the village. In the lower part of the slope the landslide material shows geotechnical characteristics, which are similar to a cohesive soil. The sliding surface which outcrops at the base of the slope nearby the riverbed is formed by an over-consolidated clay gouge due to the cataclastic fragmentation of the rock mass.

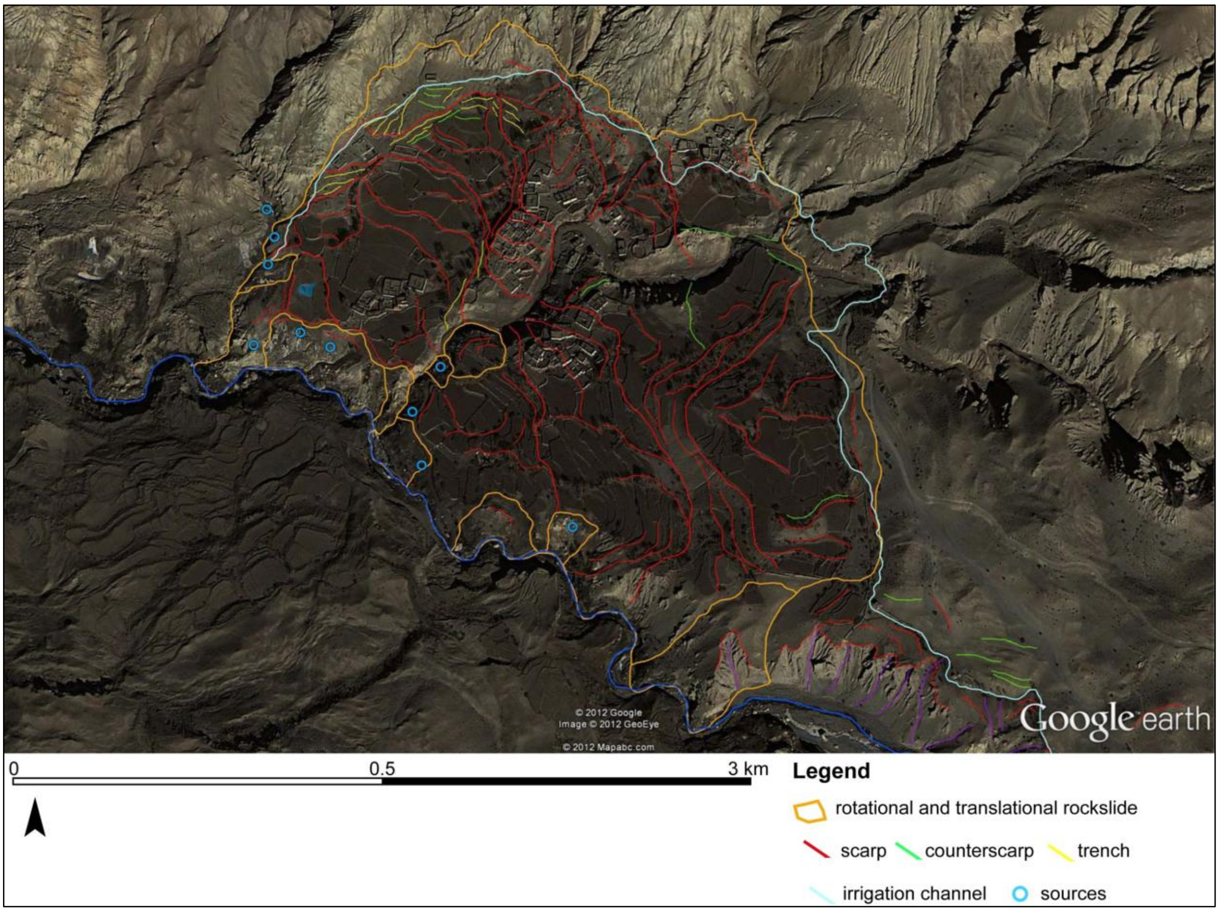


Figure 3.16: Detailed landslide map of the Yara including the surrounding field areas. The dark blue line highlights the Puyung Khola (source: Google Earth Pro, accessed 08/08/2012).

Two sectors are separated by a deep gorge corresponding to a small ephemeral riverbed (Figure 3.18 and Figure 3.5 in section 3.2.1). The erosion from seasonal floods locally affects the gorge cliff which exposes loose conglomerate and weathered chaotic rock mass.

The western sector is generally more active. In the upper part of the slide a series of northeast trending open trenches are present. The Gonpa, which was newly built about 15 years ago, as well as the school (Figure 9.1 in appendix A.1), are located close to these open trenches and both show cracks in the walls. The middle and lower part of the slope is characterized by a series of scarps that have a height of about 1 to 10 m. The differential shear strain along these structures have destroyed and damaged many dwellings in the lower part of the village's center (section 3.2.1 and Figure 9.1 in appendix A.1).

The eastern sector appears to be generally less evolved. Consequently this area can probably be characterized by lower associated movements compared to the western sector. Nevertheless, several scarps affecting mainly the fields just below the irrigation channel have been recognized (Figure 3.17).

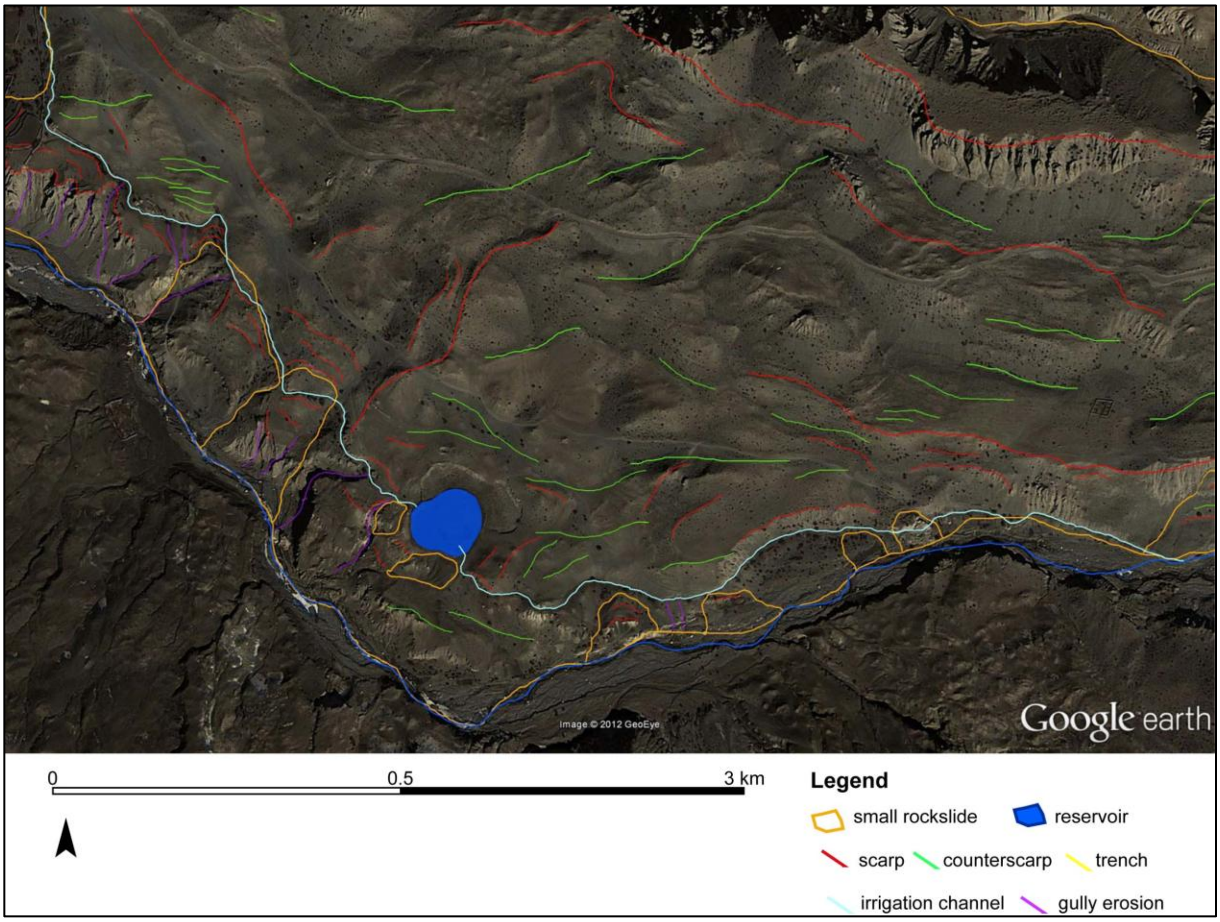


Figure 3.17: Inventoried Instabilities along the irrigation channel abstracting the water from the Puyung Khola (dark blue line) and transporting it to the fields located around Yara (source: Google Earth Pro, accessed 08/08/2012).

In general numerous houses show cracks and damages as a result of the landslide activity, which are corresponding with the mapped morpho-structures in Figure 3.16. All morphological evidences associated to the spatial distribution of damaged structures confirm a present activity of the landslide. The associated rate of movements is estimated to be in the order of a few centimeters per year. The activity is clearly visible at the toe of the landslide, where the landslide body covers recent alluvial sediments along the sliding surface. This type of landslides may be subject to considerable accelerations in case of severe rainfall events.

The cause of the landslide can be related to the alteration of the rock masses caused by water infiltration along preexisting tectonic structures (i.e. faults). Rainfall could increase the pressure of ground water and thus increase the movements. Local witnesses say that after only two days of rain, new cracks on the ground can be observed. Irrigation water can also have an important effect on the landslide kinematics. Because of the high permeability of the landslide body the irrigation water easily infiltrates, increasing the ground water pressures and effectively increasing the rate of movements. This effect is well demonstrated by the presence of very small active slides in correspondence with the water sources observed at the front of the landslide just below the irrigated fields (Figure 3.16). These tiny slides are associated with faster kinematics.

3.5.2 Goods at risk

The following goods are directly affected by the movements of the landslide:

- Irrigation channel
- Houses
- Fields at the landslide front

Figure 3.17 in section 3.5.1 illustrates that the irrigation channel is affected by several instability phenomena consisting of small landslides, scarps and gully erosion. In particular landslides and gully erosion show a retrogressive behavior. With the progression of the phenomena in the future, the irrigation channel will be affected directly. Additionally, infiltrating water from the mostly earthen channels also tend to accelerate these instabilities.

Regarding the settlement, many houses show fractures as a result of landslide movements. In particular, houses near or across the mapped morpho-structures are subject to future damages. Above all, the school and the Gonpa are susceptible to adverse effects of movements, since they are located along a series of trenches that may seriously damage the structures during prolonged rainfall events (lasting longer than 2 days).

As mentioned in the preceding section, the deep gorge separating Yara is susceptible to erosion. Namely, during severe rainfall events the water concentrates within the gorge and tends to erode especially the right bank in the center of the village (Figure 3.18).

Figure 3.18: Gorge cliff within Yara exposing loose conglomerate and weathered chaotic rock mass. The gorge cuts through the village separating it into two parts. As can be seen, the bottom of the gorge accommodates the track to Ghara (photo: 04/07/2012, Daniel Bernet).

4 Possible ways of resolving the problems in situ

The present overall situation of Yara is critical, as outlined in the preceding chapter 3. In this chapter strategies and measures are discussed, which aim at ameliorating the current situation of the village.

4.1 Mitigating issues related to housing

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

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

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

4.2 Water shortage mitigation strategies

As discussed in section 3.3.2, the expected significant rise of temperatures together with the rather irrelevant change in precipitation volume in the future, will lead to a heavy reduction in snow cover, both spatially and temporally. As the perennial river flow is believed to be fed mainly by snow melt during the dry season (section 3.4.3), it will adversely affect water availability in the future.

4.2.1 Water stress mitigation by supply management

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

Allotment of other water sources

As the current water source – the perennial river flow – is expected to be reduced largely in the future, the exploitation of other sources such as groundwater might be envisioned. However, little is known about the potential of tapping groundwater in the given context. In fact, the groundwater abstraction and use is reportedly not practiced in Upper Mustang. Furthermore, with a decline of snow cover, the groundwater resources are expected to decline similarly. To counteract this, methods to augment groundwater resources, such as water retention and infiltration could be thought of. Such methods do not seem suitable for Yara however, since increased infiltration could also lead to an acceleration of landslide related movements. Nevertheless, groundwater abstraction and use could be an option, but the potential thereof would need to be further investigated.

Loss reduction by constructive measures

As the allotment of other water sources seems difficult, ways to mitigating water shortages should aim at using and in particular also transporting the currently available water more efficiently. These range from reducing constant and local losses of the irrigation systems to installation of additional storage volume for better utilization of the available water.

For reducing the considerable constant losses associated with the water transport from the abstraction to the fields, the installation of additional plastic pipes should be envisioned. 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 due to mass movements associated with the prevalent landslides in Yara. 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 in the given context.

Furthermore, an intubation of the irrigation channel is gravely limiting infiltration, which is desirable related to the ambient landslide. In areas close to the instabilities, it is recommended to reinforce the embankment downstream of the channel using gabions.

The area would be spacious enough to accommodate increased water storages. Additional reservoirs could be built and/or the existing one could be enlarged. However, the capacity would have to be increased immensely to effectively be less dependent on the perennial flow. In the current configuration (section 3.4.4), the reservoir is 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, including the following:

- Feasibility of storing water throughout the winter, addressing issues related to freezing and melting of the stored water
- Puyung Khola's dynamics and yield during the non-growing season
- Possibilities to waterproof reservoir, or at least to reduce seepage to an acceptable level
- Threats and challenges of a reservoir built in an area subject to immense active landslides
- Quantification of losses such as evaporation

Concerning the existing reservoir, it is suggested to envision a waterproofing of the reservoir bottom, not only to reduce losses, but also to reduce percolation enhancing the landslide's movements. An idea is to apply a layer of clay, which is practically impermeable. It would have to be studied however, where such material could be purchased, how it should be applied and whether such an intervention is performing as desired in the given context.

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.

The observed presence of numerous springs in and around Yara (Figure 3.16 in section 3.5.1) might be an indication for inappropriate irrigation. Therefore, an optimization of the water use on a plot level could be envisioned. The plots should receive neither too much nor too little water and if possible in a most suitable interval. Rather than taking the amount of HHs as a base for the irrigation scheme, the way the water is distributed should root in the inherent characteristics of the agricultural area, namely the soil and crop type, as well as growing period and meteorological conditions. In this way, the crops itself would become much more important which would likely result in an increased productivity.

4.2.2 Water stress mitigation by demand management

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

Another possibility would be to switch to different activities, consequently becoming less dependent on agriculture and overall reducing the water demand, which seems to be a feasible option for Yara. At present, the community exhibits clearly the largest range of economic activities between the three studied villages (section 3.1.3). 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.

4.3 Geological hazard mitigation strategy

The village of Yara has always been living with the landslide on which it is built. In general deep landslides with low displacement rates allow for man-made structures without serious damages. However, certain requirements must be respected in order to secure the safety of the settlement and its inhabitants.

Further damages of the houses are also anticipated in the future. In case of severe damages, it is recommended to relocate the corresponding houses to areas, which are not directly affected by morpho-structures. For that purpose a map indicating such areas of low deformations (green zones in Figure 4.1) was elaborated.

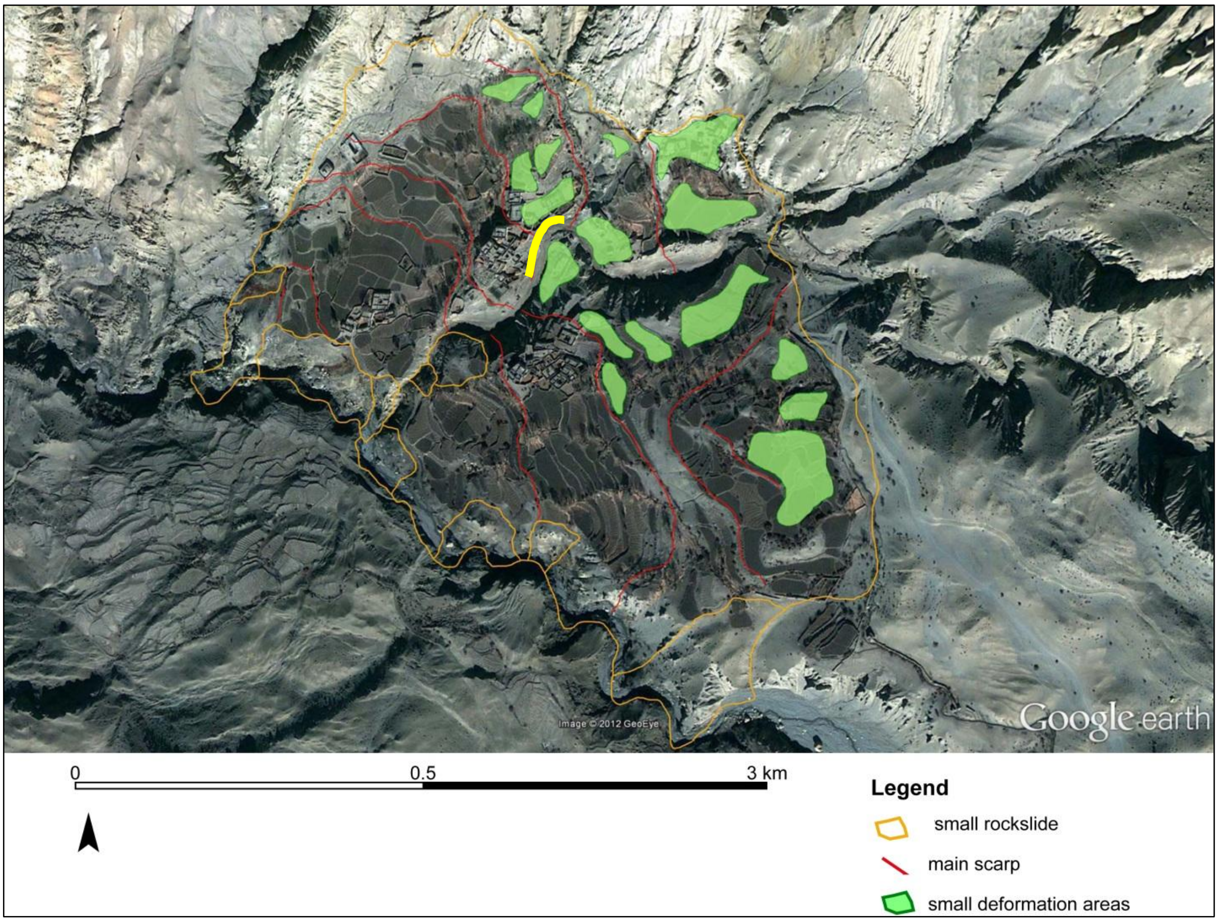


Figure 4.1: Small deformation areas shown as green surfaces are indicating possible spots favorable for relocating damaged houses in case of need. The bold line highlights the location where gabion structures should be placed in order to protect the cliff from further erosion damages (source: Google Earth Pro, accessed 08/08/2012).

The school and the Gonpa are at eminent risk. It is therefore recommended to relocate the buildings to an area associated with low deformations (Figure 4.1). In the meantime however, all persons should be evacuated in case of prolonged rainfall, meaning rainfall events lasting longer than two days.

Related to the erosion of the right gorge bank in the center of the village, it is recommended to place gabions at the base of the slope (yellow line in Figure 4.1).

5 Moving down or not?

The key question which needs to be answered in the scope of this study is: “Moving down or not?” 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. Instead of comparing the two different states “Stay” and “Move”, the focus lies only on the former. The question is, whether it is possible to mitigate the current problems and challenges in a way, that to “Stay” is reasonable and appropriate or whether the village should be advised to think about relocating in the future. It is important to note that the answer to this question is strongly linked to the considered time frame.

The most concerning issue in Yara is the combination of insufficient water availability and the inefficient irrigation supply systems. As mentioned in section 4.2.1, there are no direct means of increasing water availability. By means of supply management including constructive and operational means to improve water use efficiency, the water stress is relieved to a certain degree. However, the potential of such measures is limited and under constraint of the physically determined water availability.

The climatic and meteorological analysis (section 3.3) revealed that the water availability will clearly tend to decrease in the future, mainly based on the significant rise of temperatures together with the rather irrelevant change in precipitation volume and as a consequence thereof, the spatially and temporally reduction of snow cover. The latter is considered to be crucial for the perennial river flow and thus for the future water availability. Though associated with large variability, the decrease of water availability is expected to be a progressive process over the next decades and the following century.

Therefore, improving the supply alone (supply management) will relieve the community in the short term, but instead of being sustainable it will not present a long-term solution to the water problems.

In what time frame the community could be confronted with the same problems again, is very difficult to estimate. 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, which is associated with a particularly high water demand.

Therefore it is appropriate for Yara to “Stay” at the current location. 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.

6 Conclusion

Analyzing past, present and future trends of the water crisis in Yara, this study concludes that the water stress will even increase in the future. Possible water shortage mitigation measures were investigated. Though, in light of the decreasing water availability in the future, the problems could not be solved by improving the supply alone (supply management) in the long run. Only by reducing the demand (demand management) in conjunction with improving the supply, a sustainable solution might be feasible.

Holistically analyzing the possible future state "Stay," this study concludes that Yara has the potential to develop adaptation strategies to compensate the adverse present and future climatic conditions. Besides realizing supply management measures to increase the water use efficiency, demand management plays a central role, namely through a further diversification of the economic activities. In the course the community could become less dependent on agriculture and the associated high irrigation water demand could be lowered.

To mitigate the water scarcity, further planning and investigations are considered to be essential. In particular, the following issues need further elaboration:

- Feasibility of implementing non-constructive measures to use water more efficiently
- Implementation design of constructive measures enhancing water use efficiency
- Feasibility study to allot additional water resources such as groundwater
- Promote demand management measures

Additionally, the outlined mitigation measures concerning geological hazards (section 4.3) are recommended to be considered and implemented.

It is clear, that any constructive measures will require funds and aid from outside. The institutional structures as well as local competences do not allow a successful implementation of measures without support – be it in terms of funds and/or expertise – from outside.

However, it is suggested that the first step to improve the current situation in Yara should consist in realizing non-constructive measures. Though in the scope of this study their potential could not be quantified, they are believed to increase water use efficiency considerably. Moreover, such measures present the possibility for the community to take immediate actions independently from financial support. First, such engagement would demonstrate a positive attitude of the community to contribute as much as possible by themselves, even if it means to break with traditional irrigation schemes. This seems eminent for finding additional outside support. Second, the experiences could be monitored, the benefits and trade-offs could be quantified and a generic approach developed. The outcome thereof could possibly be transferred to other villages confronted with similar problems.

Finally, it has to be noted that as long as the relocation of Yara can be prevented with proportionate means, and the current location itself does not become disadvantageous, investments in the existing village should be considered worthwhile.

7 Bibliography

Adhikari, B.R., and M. Wagreich. 2011. “Provenance evolution of collapse graben fill in the Himalaya—The Miocene to Quaternary Thakkhola-Mustang Graben (Nepal).” *Sedimentary Geology* 233 (1–4): 1–14.

Adhikari, D., D. Shrestha, J.B. Adhikari, U.K. Shrestha, K.T. Sherpa, P. Gurung, and H. Tamang. *Upper & Lower Mustang, Trekking Map, 1:70’000*. Nepal Map Publisher Pvt. Ltd.

Ardito, S. 2012. *Dhe non deve morire*.

Ashfaq, M., Y. Shi, W. Tung, R.J. Trapp, X. Gao, J.S. Pal, and N.S. Diffenbaugh. 2009. “Suppression of south Asian summer monsoon precipitation in the 21st century.” *Geophysical Research Letters* 36 (1).

Bernet, D. 2012. *Moving down or not? Report of the first field visit to Upper Mustang in early May 2012*. Unpublished internal report. Tathali, Nepal: Kam for Sud.

CBS / ICIMOD. 2003. *Districts of Nepal, Indicators of Development, Update 2003*.

Central Bureau of Statistics. 2012. “National population and housing census 2011.” Data of the website http://census.gov.np/ accessed 28/09/2012.

Craig, S. 2004. “A Tale of Two Temples: Culture, Capital, and Community in Mustang, Nepal.” *European Bulletin of Himalayan Research (EBHR)*. EBHR 27 Autumn 2004: 11.

Egger, J., S. Bajrachaya, U. Egger, R. Heinrich, J. Reuder, P. Shayka, H. Wendt, and V. Wirth. 2000. “Diurnal winds in the Himalayan Kali Gandaki Valley. Part I: Observations.” *Monthly weather review* 128 (4): 1106–1122.

Gurung, D.R., A. Giriraj, K.S. Aung, B. Shrestha, A.V. Kulkarni, D.R. Gurung, A. Giriraj, K.S. Aung, B. Shrestha, and A.V. Kulkarni. 2011. “Snow-cover mapping and monitoring in the Hindu Kush-Himalayas.”

IPCC. 2007a. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Ed. S: Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

———. 2007b. “IPCC, 2007: Summary for Policymakers.” In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Kitazawa, H., and S. Kayastha. 2012. “Nepal Census 2011.” *Nepal Census Information Site*. https://sites.google.com/site/nepalcensus/ accessed 03/10/2012.

Kostka, R. 2001. “Nepal, Mustang, Map 1:50’000, Tsaran sheet”. Arbeitsgemeinschaft für vergleichende Hochgebirgsforschung, München.

Practical Action, Nepal Office, ed. 2009. *Temporal and spatial variability of climate change over Nepal (1976 - 2005)*.

Rohrer, M. 2012a. *Actual and future trends in precipitation and air temperature in Nepal and especially in Mustang province and during Monsoon - Part I*. Unpublished report. Metodat.

———. 2012b. *Actual and future trends in precipitation and air temperature in Nepal and especially in Mustang province and during Monsoon - Part II*. Unpublished report. Metodat.

Sharma, K.P. 2009. *Climate Change: Trends and Impacts on the Livelihoods of People*. Jalsrot Vikas Sanstha, Nepal Water Partnership Kathmandu, Nepal.

Stocker, T. 2010. *Water Cycle, Key Questions and IPCC AR5*. Unpublished report. NCCR Summer School.

Varnes, D. J. 1978. “Slope movement types and processes.” Ed. R.L. Schuster and R.J. Krizek. *Transportation and Road Research Board, National Academy of Science, Washington D.C.* Landslides: Analysis and Control (Special Report 176): 11–33.

Wacker, C., and U. Fröhlich. 1997. *Traditional Water Management System in Ladakh: Case study of Tagmachik village, factors of sustainability and adaptation to change and some observations on modern water development*. Zürich.

Zängl, G., J. Egger, and V. Wirth. 2001. “Diurnal winds in the himalayan Kali Gandaki valley. Part II: Modeling.” *Monthly weather review* 129 (5): 1062–1080.

Zurick, D., J. Pacheco, B.R. Shrestha, and B. Bajracharya. 2006. *Illustrated atlas of the Himalaya*. India Research Press.

8 List of figures

9 List of tables

A Housing

A.1 Settlement layout

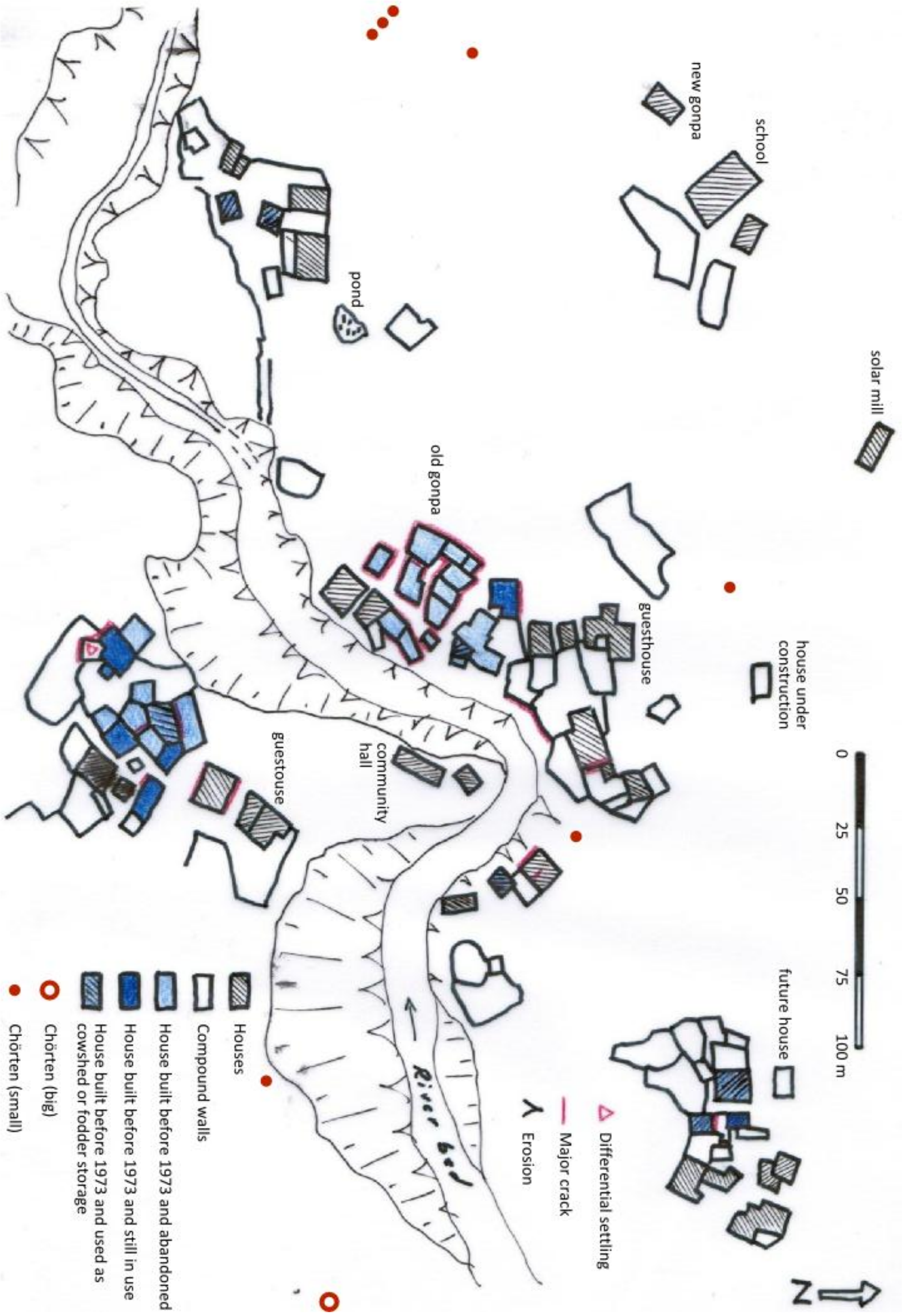


Figure 9.1: Schematic map of Yara (hand drawing: 02/07/2012, Daniel Pittet)

A.2 Typical house layouts

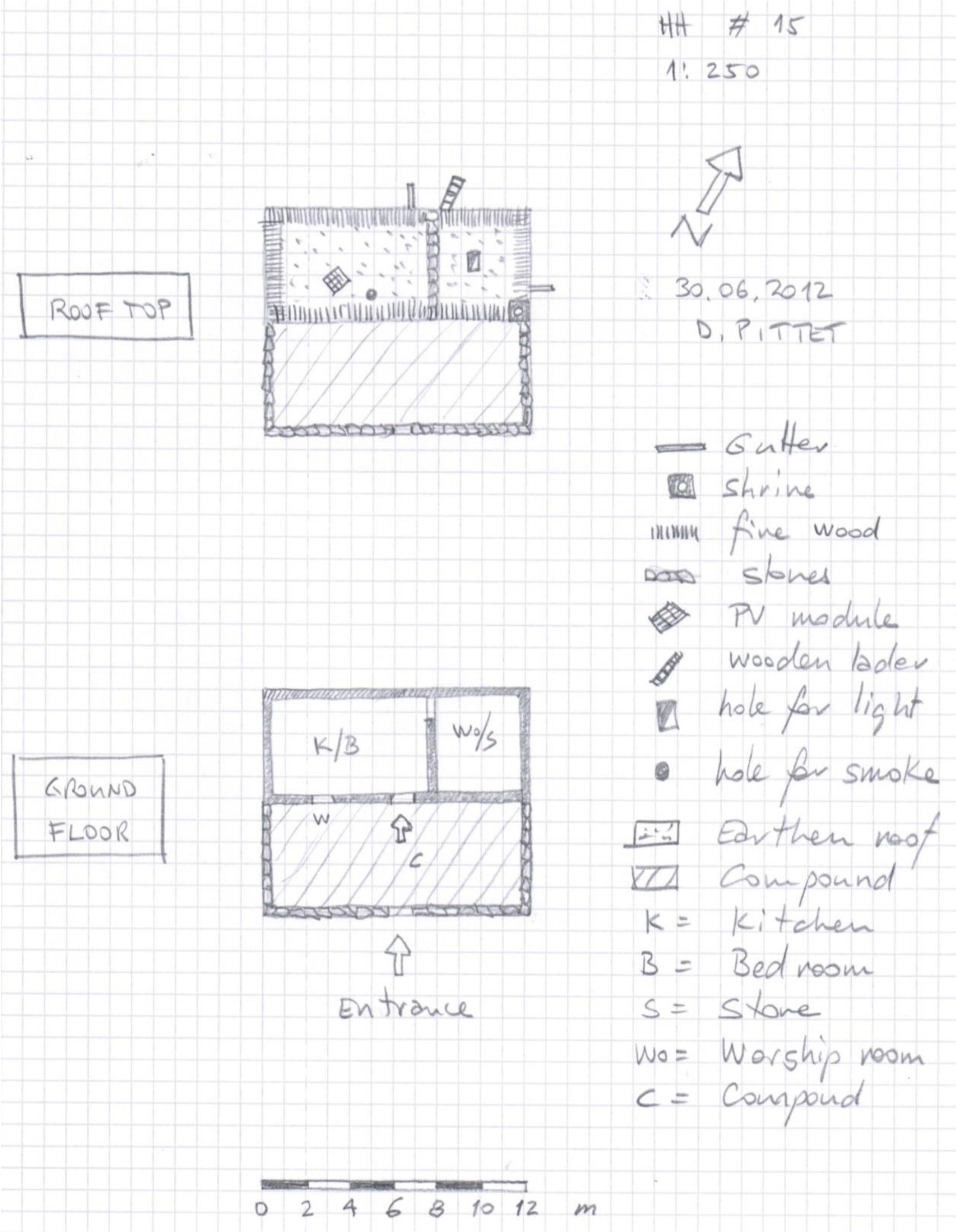


Figure 9.2: Representation of a dwelling from Samzong taken as a reference for a typical small house (hand drawing: 30/06/2012, Daniel Pittet).

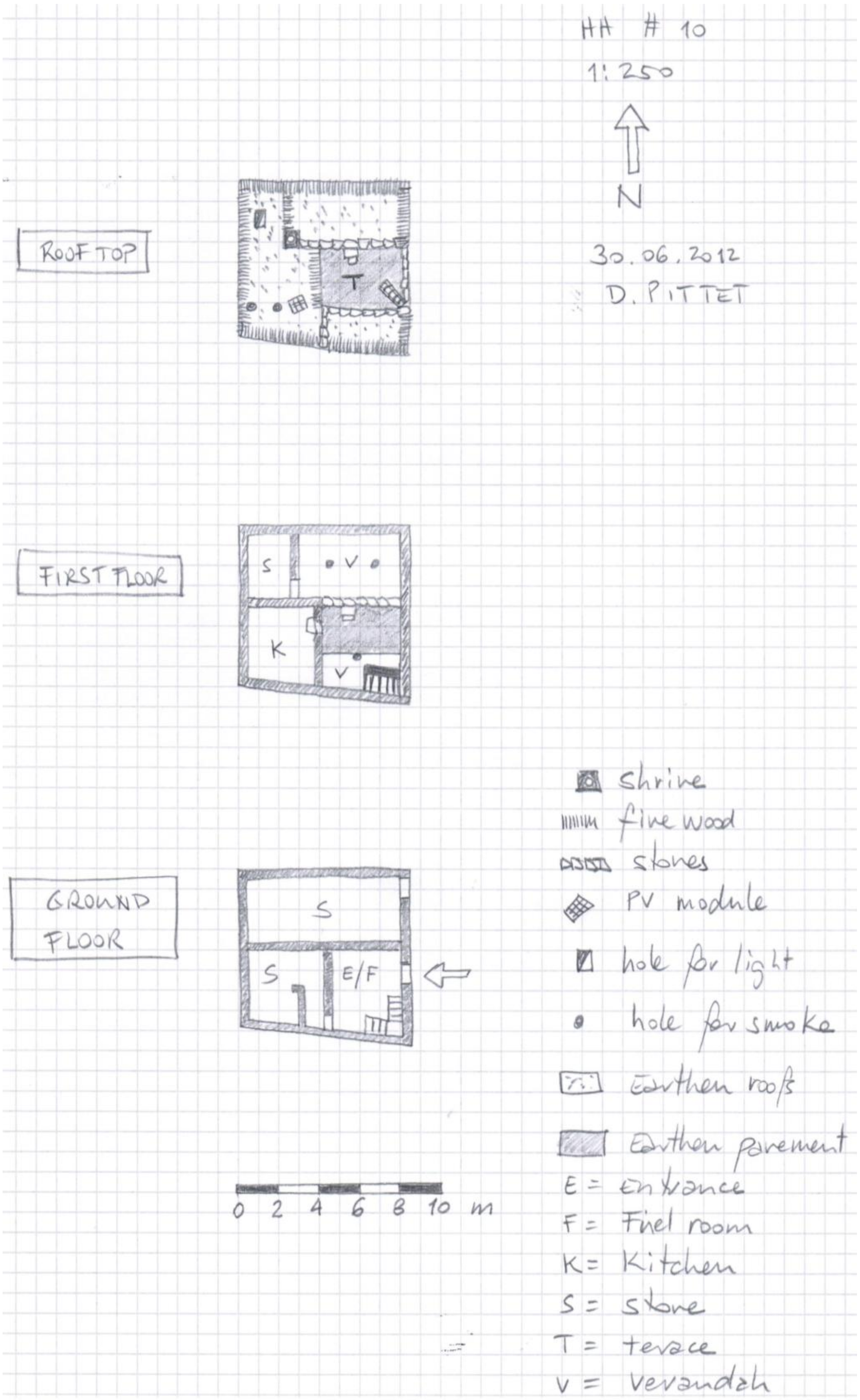


Figure 9.3: Representation of a dwelling from Samzong taken as a reference for a typical medium sized house (hand drawing: 30/06/2012, Daniel Pittet).

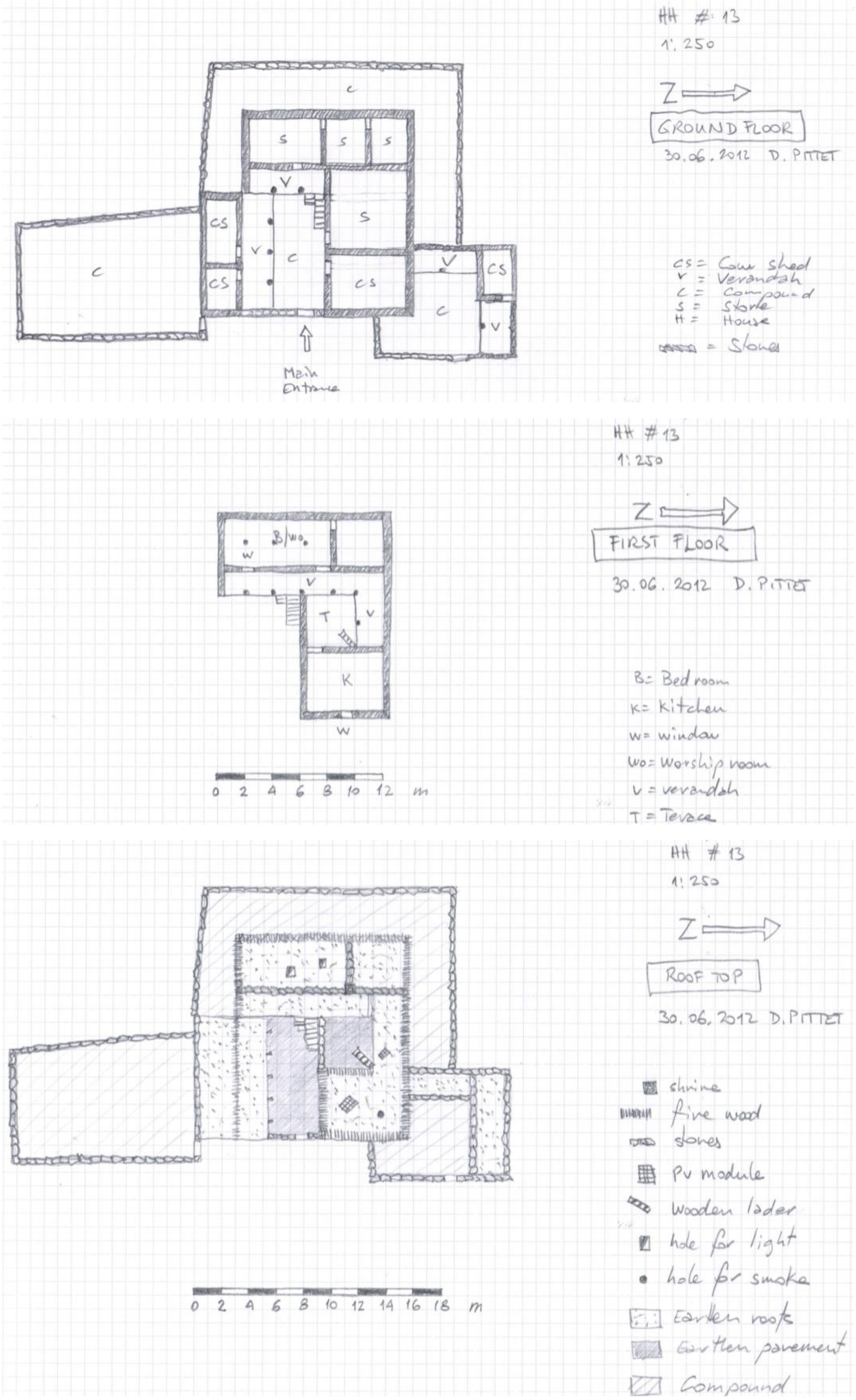


Figure 9.4: Representation of a dwelling from Samzong taken as a reference for a typical large house (hand drawing: 30/06/2012, Daniel Pittet).

A.3 House composition

Table 9.1: Composition of the houses in Yara. The fractions (0.5) indicate that the functions are shared in a same room (e.g. in HH number 5, the kitchen and one bedroom are in the same room).

HH number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Mean**
No. of rooms	**8**	**6**	**3**	**9**	**1**	**4**	**5**	**3**	**4**	**4**	**6**	**9**	**6**	**4**	**2**	**5**	**7**	**6**	**2**	**2**	**4**	**7**	**4.86**
Kitchen	1	1	1	1	0.5	1	1	0.5	2	1	0.5	1	1	0.5	0.5	0.5	1	1	0.5	0.5	0.5	2	**0.89**
Store room	4	0	1	4	0	1	2	1	0	1	2	3	2	1	1	1	3	1	1	1	2	2	**1.55**
Bedroom	1	5	1	1	0.5	1	1	1	2	1	2	2	1	0.5	0.5	0.5	1	1	0.5	0.5	0.5	1	**1.16**
Worship room	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	0	0	0	1	**0.36**
Fuel room	1	0	0	1	0	1	1	0	0	1	1	1	1	0	0	1	1	1	0	0	1	1	**0.59**
Workshop	0	0	0	1	0	0	0	0.5	0	0	0	1	0	1	0	0	0	0.5	0	0	0	0	**0.18**
Veranda	0	0	0	1	0	0	0	0	0	0	0.5	0	0	0	0	1	0	0.5	0	0	0	0	**0.14**
Cowshed	1	0	0	0	1	0	0	2	0.5	0	4	1	1	1	0	1	1	1	0	0	1	1	**0.75**
Goatshed	0	0	0	0	0	0	0	0	0	0	1	0	0	2	1	1	0	0	0	0	0	1	**0.27**
Horseshed	1	0	0	0	0	0	0	0	0.5	0	0	1	1	0	0	1	1	1	0	0	0	1	**0.34**
Toilet	0	1	0	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1	0	0	0	1	**0.36**
Compound	1	0	0	0	1	0	1	1	2	0	1	1	1	1	0	0	1	1	0	0	0	1	**0.59**

B Meteorology and climate

B.1 Visualized cultivated and abandoned fields

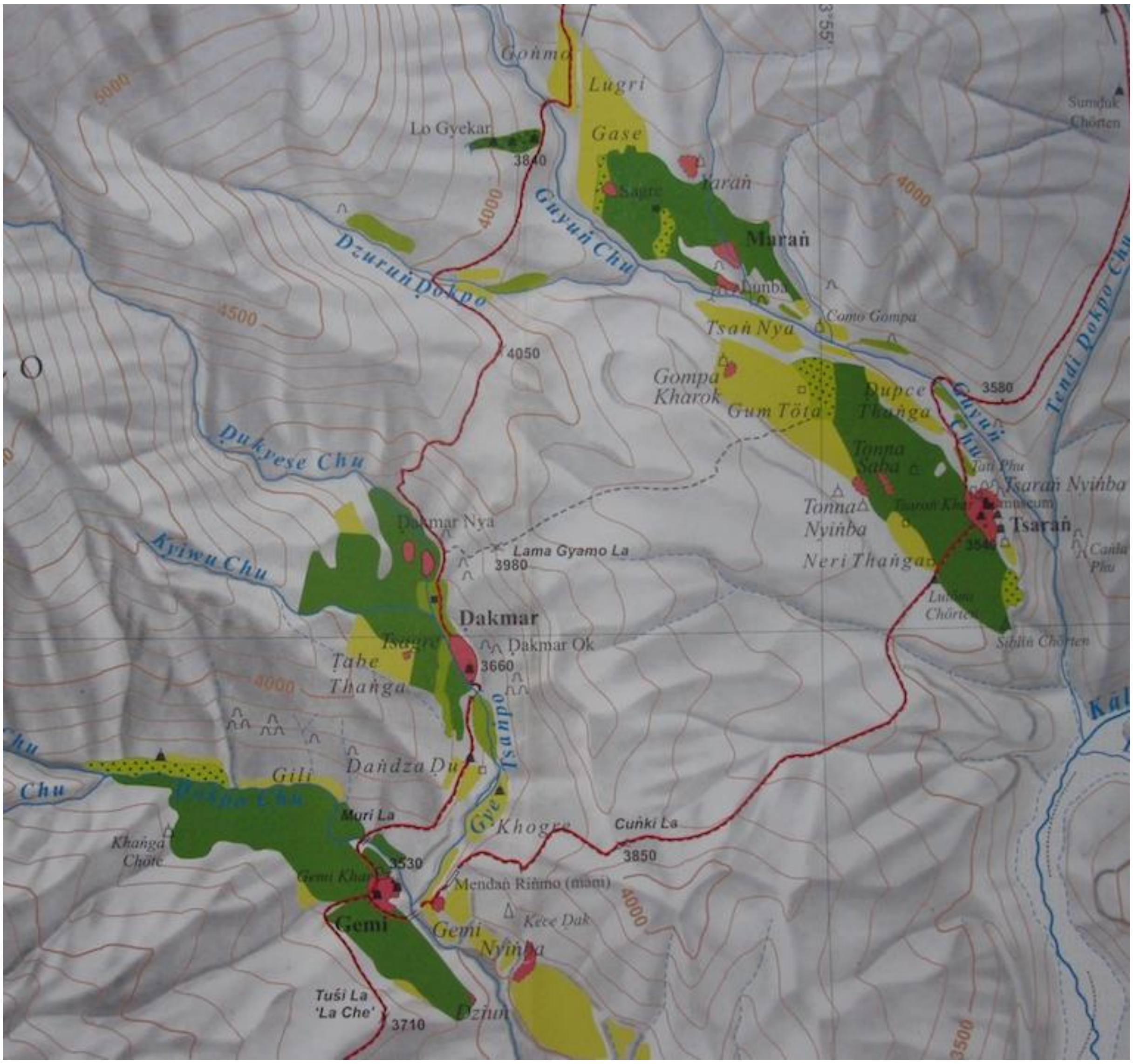


Figure 9.5: Abandoned fields (yellow-green) around Gemi (Ghami), Dakmar and Tsaran (Charang) on a thematic map of Upper Mustang by Kostka (2001), based on satellite information from 1990 and 1984. The dark green areas (including textured surfaces) indicate cultivated land. North direction is ↑.

B.2 IPCC scenarios

The Intergovernmental Panel on Climate Change (IPPC) present four different scenarios (Figure 9.6) in their fourth assessment report (IPCC 2007b), of which the intermediate scenario A1B is used in the analysis undertaken by Rohrer (2012a, 2012b).

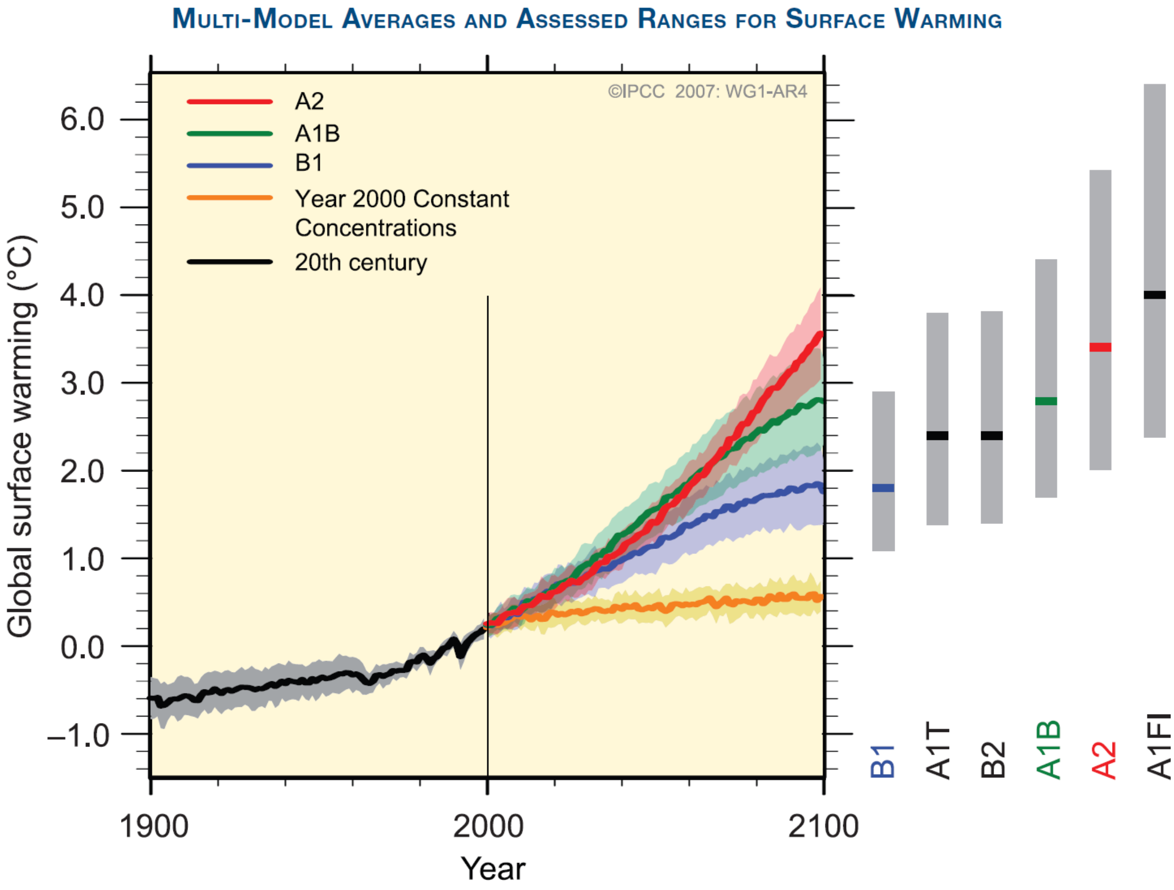


Figure 9.6: Multi-model averages and assessed ranges for surface warming, taken from IPCC (2007b): "Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios. The assessment of the best estimate and likely ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints."

For such scenarios (Figure 9.6), patterns for precipitation changes (Figure 9.7) are projected for instance (IPCC 2007b).

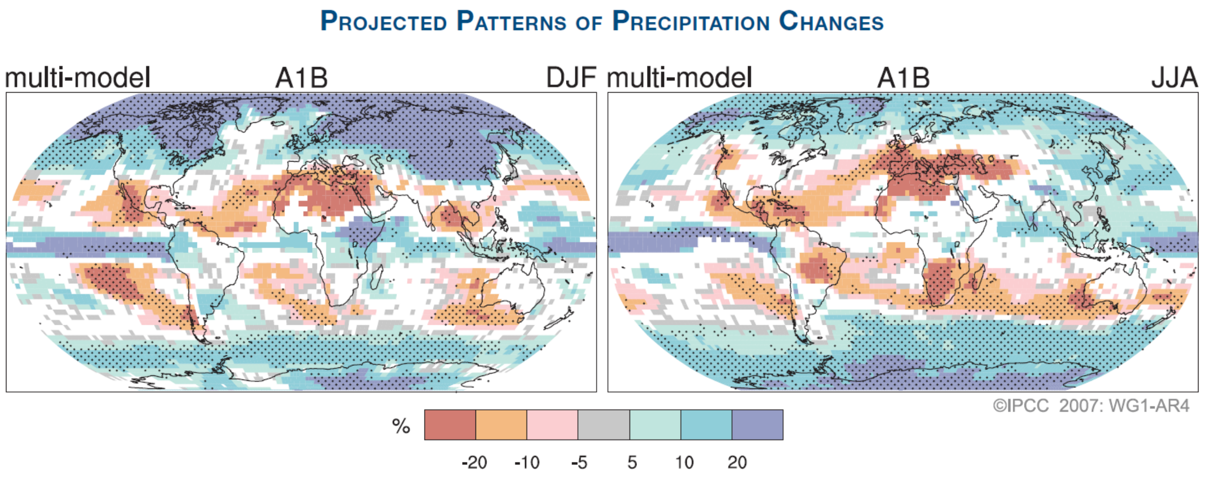


Figure 9.7: Projected patterns of precipitation changes, taken from IPCC (2007b): "Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change.

B.3 Temperature interpolations for Nepal

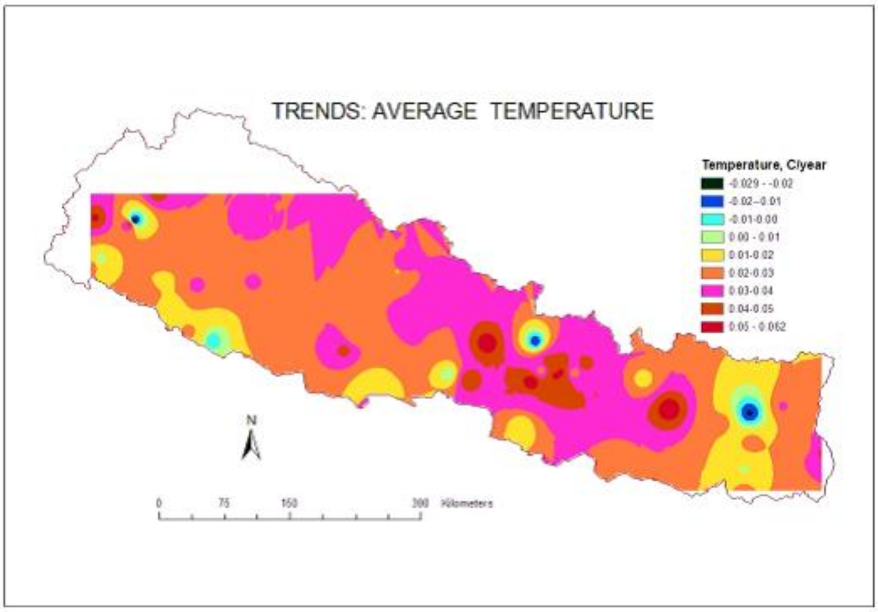


Figure 9.8: Trends of average temperature in Nepal in °C/year from 1975 to 2006 (Sharma 2009).

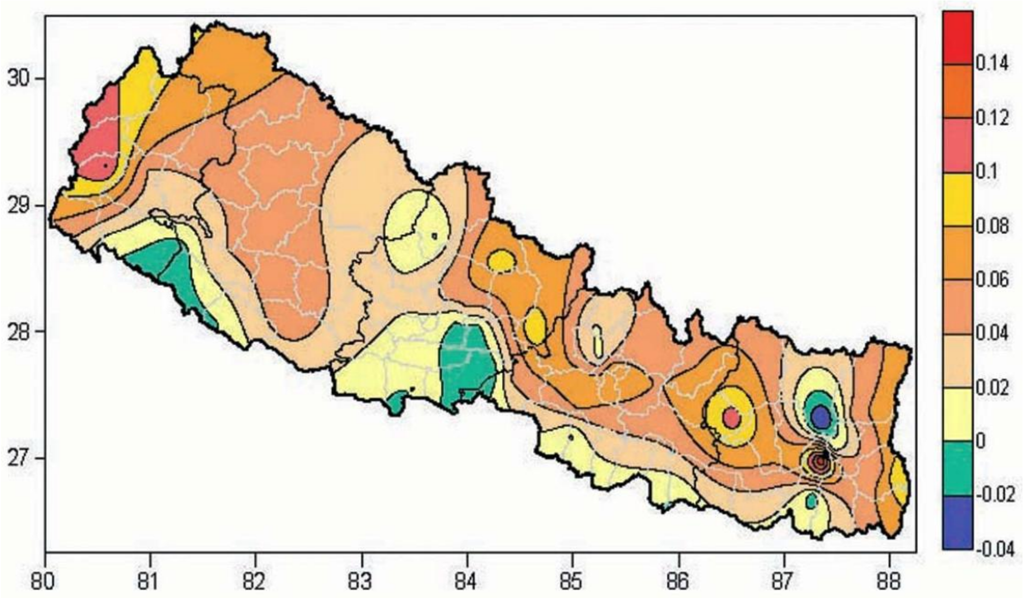


Figure 9.9: Trends of average temperature in Nepal in °C/year from 1976 to 2005 (Practical Action 2009).

B.4 Yearly precipitation sums in southern Mustang

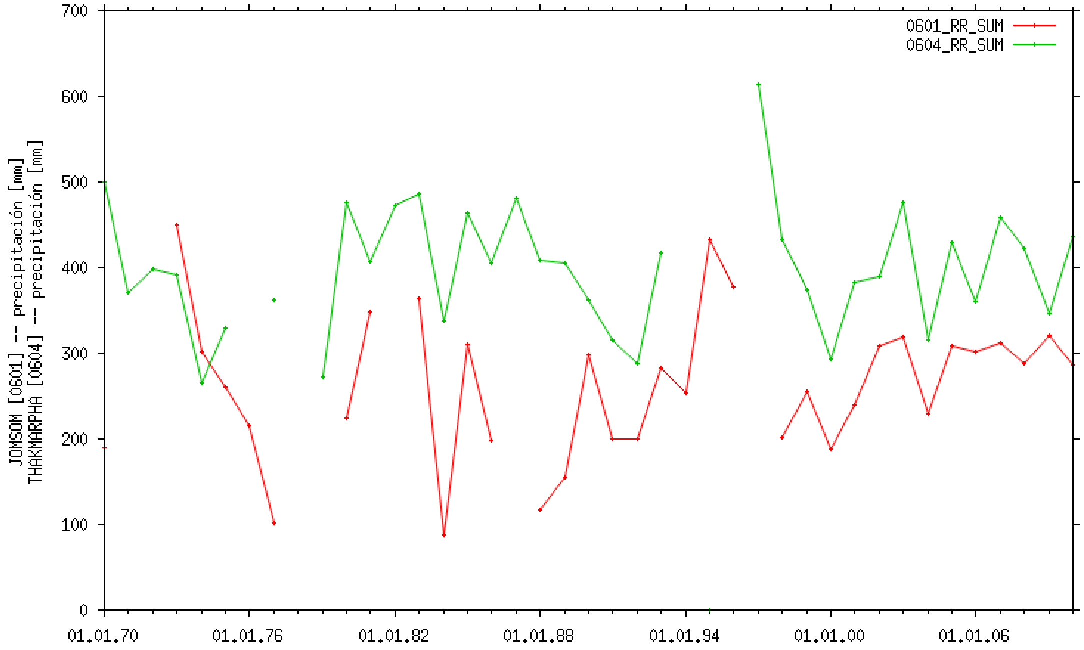


Figure 9.10: Yearly precipitation sums of the meteorological stations Jomsom (0601) and Marpha (0604), situated in lower Mustang showing no clear trend as shown and discussed in Rohrer (2012b).

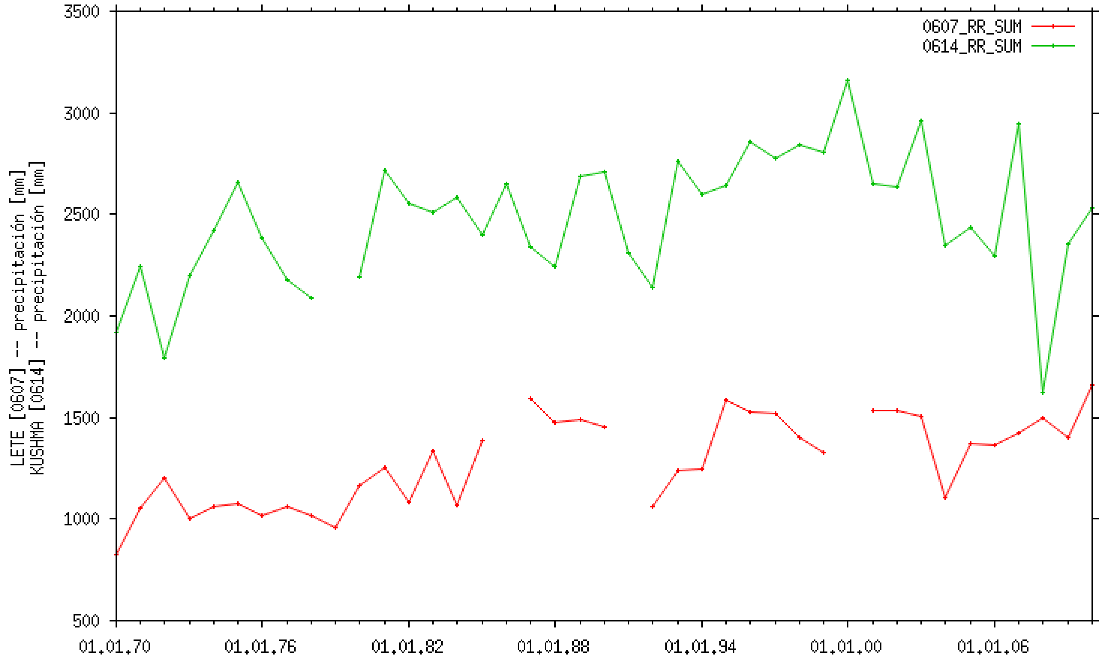


Figure 9.11: Yearly precipitation sums of the meteorological stations Lete (0607) and Kushma (0614) at the entrance of Mustang valley, situated in the south side of Annapurna showing an increasing precipitation trend which needs confirming however as discussed and shown in Rohrer (2012b).