Moving down or not?

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

Part IV: DHEYE

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:	Main public reservoir in the foreground storing the constantly abstracted water during the night for use in the fields the following day. Right below the main reservoir, other private reservoirs can be seen and on the left on lower ground the Dheye village is visible (photo: 15/05/2012, Daniel Bernet)
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In the following the members of the expert team are briefly introduced:

Kam For Sud

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

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

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

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

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

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

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

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

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

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

University of Applied Sciences of Southern Switzerland

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

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

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Executive summary

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

Dheye, subject of the report at hand, located about 10 km southeast of Charang in a remote valley, consists of 24 nuclear families out of which 10 have dislocated within the last decades, totalizing 157 people. During the field visits, 14 households were still living in Dheye amounting to 83 inhabitants including 22 permanent migrants. All, safe one family, own certain fields and depend on subsistence agriculture complemented by stockbreeding. The latter, together with other accessory economic activities, generates monetary income which is crucial because the agricultural output can only partially cover self-sufficiency.

The climate in the region with yearly precipitation rates around 200 mm and less is extremely dry and cold, manifesting itself in an almost desert-like landscape. Agricultural activities in Dheye are low productive and almost solely dependent on the perennial river flow within the valley. The river drains a non-glaciated catchment area of only 10 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 river flow in Dheye is expected to decrease in the future.

The predominant problem in Dheye is the combination of insufficient water availability and inefficient irrigation supply systems. All surface water is currently allocated, so that a change in the river regime is directly affecting irrigation amounts and consequently agricultural yield.

Possible measures improving the water supply (supply management) are aiming at reducing water losses, providing additional storage volumes or changing irrigation patterns to increase the water use efficiency. Nevertheless, the study has shown that in general the sole application of supply management measures will only procrastinate, but not solve the current problems in the long run. A significant reduction of the demand (demand management) does not seem to be an option for Dheye. The inherent characteristics of the village do not seem to allow a sufficient diversification of economic activities to become less dependent on agriculture, and thus reduce the related demand.

Another concern is the access path crossing an enormous active earth flow rather frequently inactivating the path, in which case an elongated detour has to be taken to reach the village. There are no apparent mitigation measures other than taking the existing alternative route in case the path cannot be used.

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

Thangchung, a plateau belonging to Dheye, elevated roughly 30-40 m relative to the confluence of the Dhey Chang Khola and Charang Khola with the Kali Gandaki, has been identified as a possible relocation site by the community of Dheye. It measures roughly 25 ha and is located 4 km southeast of Charang. Currently it is utilized by the community for livestock herding during the winter.

Due to the relative elevation of the plateau, the water supply is a very crucial issue requiring a technical solution. Basically, water from all three rivers merging right next to Thangchung could be tapped, but the Dhey Chang Khola seems most suitable for this purpose. In fact, the river drains an area of 366 km^2 of which 12 % is glaciated, amounting to a glacier volume of about 3.42 km^3. The glaciers are essential in terms of water availability, since the precipitation is stored and released slowly during the melting season. Due to the glaciers and the size of the catchment, the water availability is certainly sufficient for the current century. Due to the glaciation of the catchment, Chawale, a slightly elevated plateau of alluvial deposits below Thangchung, to the left of Dhey Chang Khola’s active riverbed, bears the risk of being inundated in case of a future GLOF or other sudden floods. In Chawale, the community of Dheye realized an orchard which is planned to be expanded heavily in the future.

The available space in Thangchung is certainly large enough to accommodate the relocated community including the recently dislocated 10 families, as well as an appropriate agricultural field area. From a natural hazard point of view a safety distance of 15 m from the constructible area to the escarpment should always be maintained to mitigate the risk of shallow landslides. From the foot of the steep hill slope delimiting Thangchung in southern and southeastern direction, which may be subject to rockfall and local debris flow, a safety distance of 20 m is recommended. Additionally, the plateau is exposed to the typical diurnal winds. Based on characteristics of the old settlement and habitat, a conceptual layout for the relocated settlement is proposed. It integrates space availability, modularity to account for the different means and desires of each family and measures to mitigating the adverse effects of wind exposure. Different technical solutions for supplying irrigation water to the fields and drinking water up to the elevated settlement are suggested, but they need further investigations. The prospects and difficulties of the relocation as discussed above constitute the state “Move.”

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

Glossary

Chörten	Stone made Buddhist monument
Dal	Soup made out of lentil, which is served with rice (Bhat) in the national Nepalese dish Dal Bhat
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
Saligram	Fossil
Tom	Plastic canisters with a volume of 5 or 35 liters
Zipu	Herb used as a spice for Dal

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

Abbreviations and acronyms

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

Acknowledgements

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

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

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

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

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

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

Antonio Galli
President of Kam For Sud

Preface

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

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

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

1 Introduction

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

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

1.1 Background of this study

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

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

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

1.2 Study objective

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

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

1.3 Methodology

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

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

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

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

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

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

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

1.4 Resources

The reports are based on the following resources:

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

1.5 Location

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

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

The three studied villages are all located in the restricted area (section 2.1) of the Mustang District (Figure 1.2). Dheye lies on a ridge at almost 4’000 m asl. The village is located more than 10 km southeast of Charang.

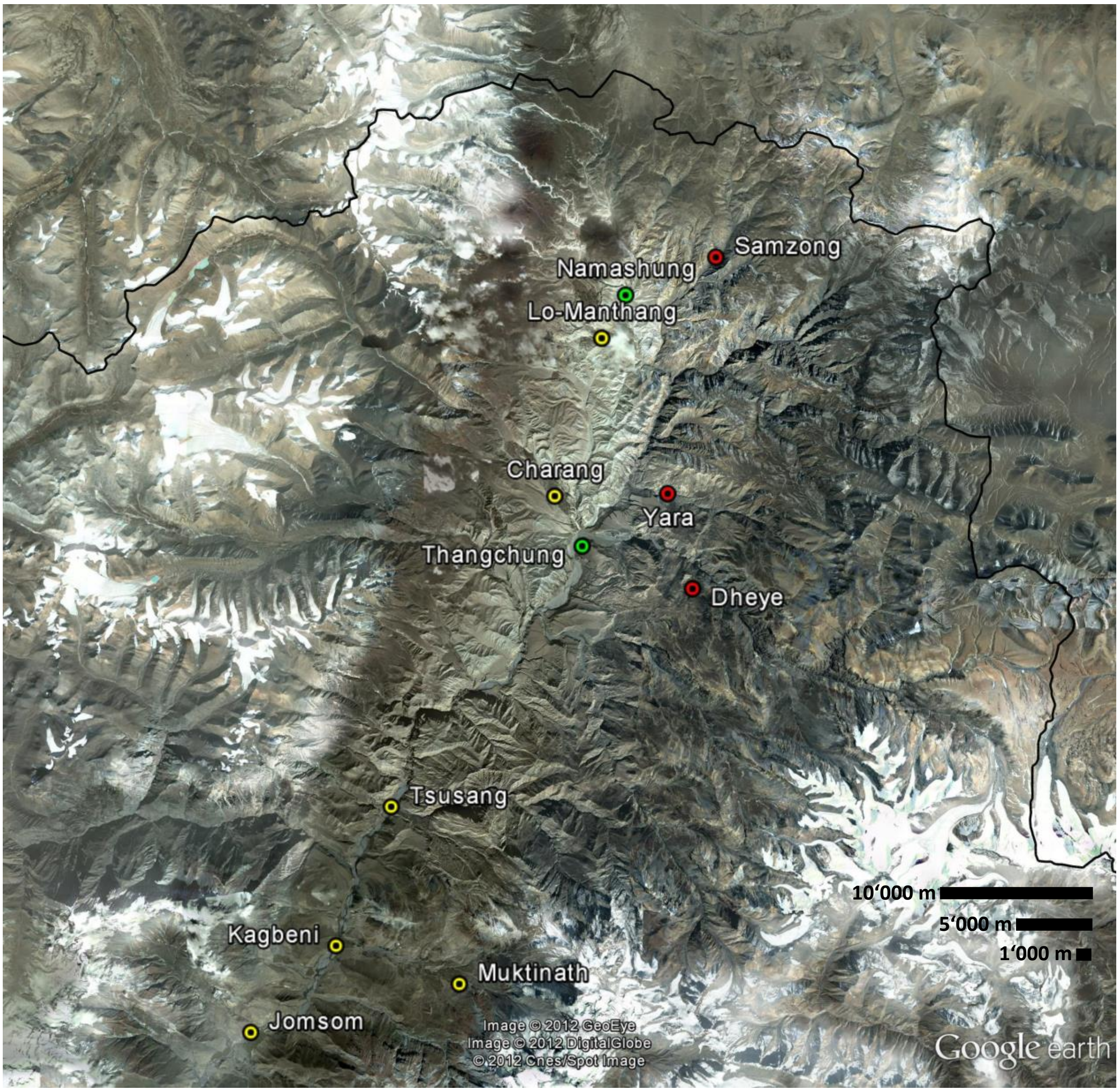

Figure 1.2: Overview of Upper Mustang. The main villages are indicated by yellow points, the studied villages are highlighted with red dots and the possible new locations of Samzong (Namashung) and Dheye (Thangchung) respectively are shown in green. The Chinese-Nepalese border is shown in pink, north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

Dheye belongs to Zurkhang Village Development Committee (VDC) and is accessible on foot only. From the confluence of the Kali Gandaki, Charang Khola and Dhey Chang Khola, the path leads through the floodplain of the latter river. A narrow gorge is passed and soon after the path rises up on the left valley side of the Dhey Chang Khola. The path crosses a section which is quite active in terms of landslides (section 3.5.1) and leads further up to the village. As the path is not accessible all year long due to the narrow section which cannot be passed during high flow of the Dhey Chang Khola or when the path is damaged by a landslide, there is an alternative, but longer path leading over the ridge.

2 Contextualization

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

2.1 Administrative setting

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

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

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

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

2.2 Institutional setting

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

2.2.1 Inherent characteristics

Collective decision making

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

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

These decisions are made outside of any formal framework and are seldom documented, as many of the villagers are illiterate. This practice seems necessary, since the institutional contributions are quasi absent.

However, the fact that the villagers are practically not supported in finding and implementing solutions for their apparent and pressing problems, bears the risk that non-optimal solutions are found, mainly due to the lack of professional elaboration and assistance. For appropriate and sustainable solutions, access to trustable and complete information is crucial. Furthermore, the taken decisions often miss a time dimension, meaning to say the planning horizon is dangerously short.

Importance of social structure

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

2.2.2 Funding of local projects

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

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

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

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

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

2.2.3 Institutional setting as an opportunity

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

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

2.3 Demographic setting

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

2.3.1 Mustang District

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

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

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).

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)[1]. 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 14 in Dheye 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[2]. The "Poverty

[1] 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.

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

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 Current situation in situ

In this section, all relevant and elaborated aspects about Dheye'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 Dheye.

3.1.1 Demographic aspects

According to T. G. Gurung (2011), Dheye has been consisting out of 24 HHs of which 10 have dislocated within the past two decades to Charang (2), Tsusang (4), Jomsom (2), Pokhara (1) and Kathmandu (1) respectively. However, the resettled families have maintained a rather strong connection to their origins, which for instance manifests itself with the participation in the development of a plantation next to the designated relocation site of Dheye village (section 5.1.4). As reported in T. G. Gurung (2011), the total population including the resettled families amounts to 157 including 74 women and 83 men. Presently, based on the field survey, the village is composed of 14 nuclear families and a total population of 99, among which 45 are female and 54 are male. Hereafter, the outlined demographic characteristics are considering only the remaining 14 HHs with their respective members.

Out of the total 99 people, 49 (almost 50 %) are permanently living outside of Dheye. These permanent migrants rarely come back to the village, if at all. Opposed to that, most of the inhabitants move towards the lower regions of the valley or even further south often engaging mobile trade during the winter months. This is a form of seasonal migration, which is quite typical for the region. Only a few remain in the village during the winter.

Most of the permanent migrants are studying at distant schools (Lo-Manthang, Pokhara, Kathmandu or India). There does not seem to be a correlation between the family size and the number of permanent migrants (Figure 3.1). However, it is difficult and it might be misleading to draw a conclusion from the data due to very small data sample size.

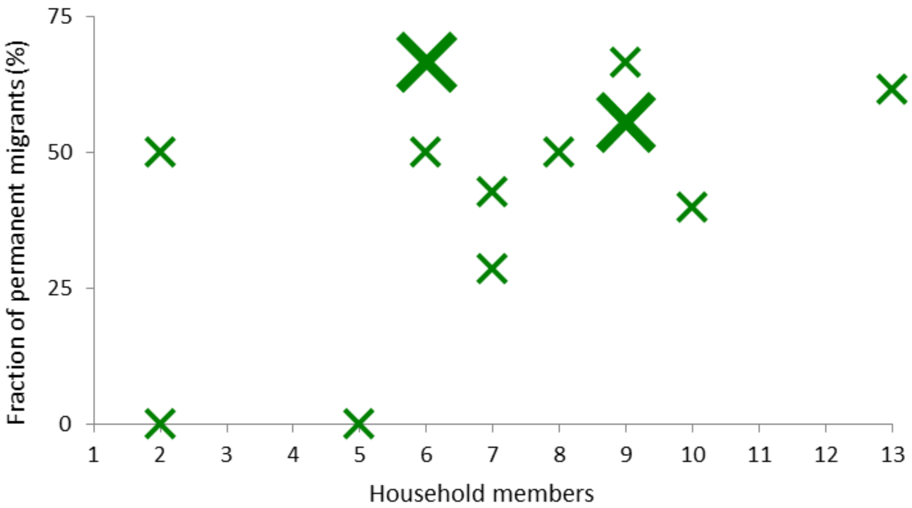

Figure 3.1: Scatter plot between the numbers of HH members against the fraction of permanent migrants of the corresponding family. The small sized crosses correspond to a single HH and the large one to two HHs with the same characteristics (e.g. two families with each six HH members and 67 percent permanent migrants).

The average age of the permanent migrants (16 y) is considerably lower compared with the residents (36 y). The former group consists mostly of teenagers and school-aged children, whereas the latter is constituted by adults and young children (Table 3.1). This represents a considerable risk for the future demographic stability of the village, since the young migrants will return less likely after their studies because of the strong attraction of local, regional and even national centers (e.g. Lo-Manthang, Jomsom, Pokhara, and Kathmandu). Subjectively, such centers present major earning opportunities, better material living conditions and a large overall attraction as it seems.

Table 3.1: Dheye'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	49	50	99
Average age	16	36	27
Standard deviation	7	20	18

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 with currently two teachers and eight students exists (T. G. Gurung 2011).

The management of the collective necessities is delegated to a traditional system based upon the roles of Ghenpa 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 Dheye, there are apparently persons with informal leadership characteristics present who are able to take initiatives in case of need. As a matter of fact, the engagement of the village in relocating to the land named Thangchung as well as the taken steps in generating additional income by establishing an orchard next to the relocation site (section 5.1), can be attributed to the initiatives of local leaders to a rather large degree.

Nevertheless, the dependence from external support, especially in terms of financial, technical as well as logistical support is quite evident. As expressed in chapter 2, there is practically no help offered for elaborating, planning and implementing crucial projects on a local scale due to the institutional weaknesses in Upper Mustang. Communities taking initiatives themselves are therefore mostly confined to their own competences in finding and implementing solutions for the current problems. In this way, non-optimal solutions are found, since the decisions are often based on limited expertise and know-how.

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 180’000 Nepalese Rupees (NPR), but ranges from a minimum value of 17’500 (HH constituted by 2 people including 1 permanent migrant) to 300’000 NPR (10 family members including 4 permanent migrants).

In Dheye, all but one family own a certain amount of land area. There is no agricultural land, which belongs to somebody living elsewhere. Land ownership is distributed in a rather uniform manner, with areas expressed in the local surface measure that vary between 1 and 4 Ghalto per nuclear family. Out of 14 families, only five have land areas below 2 Ghalto.

In total, the population of Dheye owns 34 horses, 57 cows, 25 sheep, 80 yaks and 1816 goats. In fact, the main economic activity that allows generating additional income is to sell animals and/or their fur. Monetary income is essential to assuring the subsistence throughout the year, since the output from agricultural activities alone does not suffice. Safe four HHs, all nuclear families own goats. The average number of goats per family is of about 76 with a minimum number of 65[3] and a maximum of 250. Taking the total population of 99, this amounts to 18 goats per capita. The market value of a goat corresponds to about 6’000 to 7’000 NPR.

[3] The minimum value is 65, not considering the four families which do not own goats at all.

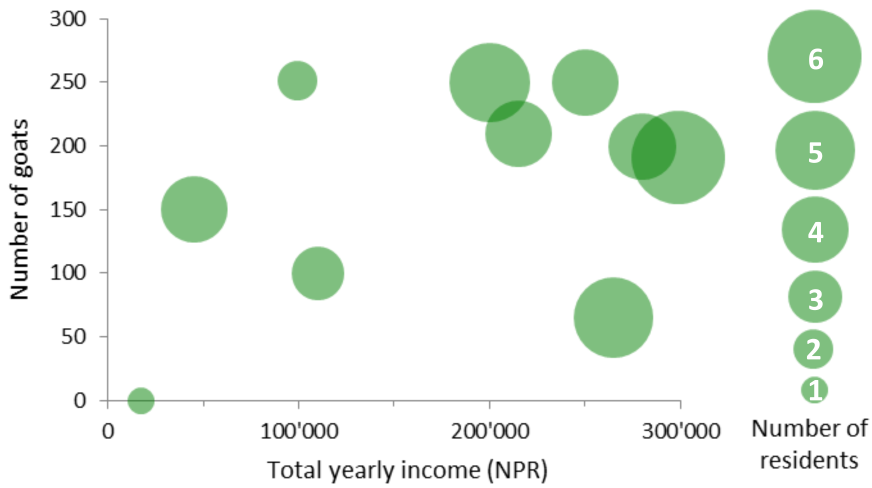

Figure 3.2: Scatter plot of the total yearly income and the number of goats per family. The size of the circle indicates how many family members are still living in the corresponding HH in Dheye, meaning that they are not permanent migrants.

The families' incomes do not seem to correlate with the number of family members nor the 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, four out of the 14 HHs did not indicate their total yearly income.

In Dheye there is no touristic infrastructure such as a lodge or a restaurant for instance. This could be partly due to the difficult access.

A quite common accessory activity to generate additional monetary income is collecting fossils, so-called Saligrams. They can be found in the region in high numbers and are sold to tourists. Another common activity is collecting Zipu, an herb which is sold as a spice for Dal.

3.1.4 Perception of the main problems faced by the community

During the socio-economic survey each of the 14 HHs were asked to identify three main issues about which they are most concerned and to rank them according to severity (Figure 3.3). With this data, the three main issues mentioned in the Dheye community could be identified:

- Main concern: Lack of irrigation water
- Second concern: Transportation / Food supply
- Third concern: Transportation / Lack of health facilities

There was one family which mentioned the isolated location of Dheye as the main issue. All other families (12) were concerned most about the insufficient amount of water for agricultural activities, whereas one family abstained from a vote.

As the second priority, food supply (3) and low crop yields (2) were mentioned along with the main concern about transportation issues (4). Insufficient irrigation water supply, the threat of wild animals, as well as the lack of firewood were only mentioned once.

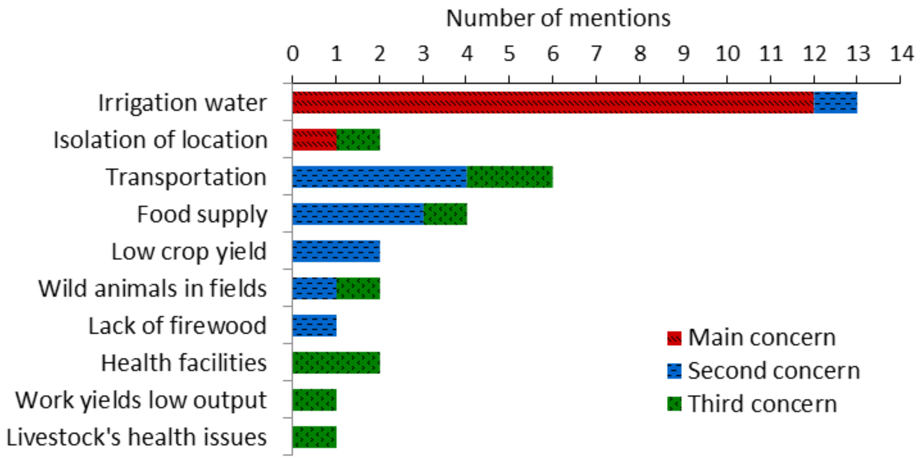

Figure 3.3: Visualization of the survey related to the identification and ranking of three main issues about which each of the 14 HHs are most concerned. Note that one family abstained from choosing and three families identified less than three main issues.

Also the third most concerning issue is greatly varying from family to family. Transportation and the lack of health facilities were mentioned by two families each. Unsatisfactory food supply, the isolation of the location, the threat of wild animals, the impression that the invested work is a loss of time and money, as well as concerns about the health of the livestock are mentioned only by one HH each, while five HHs did not qualify an issue with third priority at all.

On the bottom line, this analysis shows, that the most concerning issue is almost unanimously the insufficient irrigation water availability. With lower priority the most concerning issues are differing increasingly.

3.1.5 Willingness of the community to move

The relocation project is well accepted by the whole population of Dheye, as it has been initiated by the community itself. There is also a project proposal for the resettlement of Dheye village in Thangchung, the designated new location (T. G. Gurung 2011).

The survey revealed that related to the relocation site, the identified main concerns of the community is much more diverse (Figure 3.4) than for the current location (Figure 3.3). Clearly, main concerns are how the necessary irrigation water can be brought up to the elevated relocation site (section 5.4.4), with what means and workmanship the new houses could be rebuilt, how the corresponding funds could be provided or how the newly constructed orchard on the left riverbank of the Dhey Chang Khola could be flooded. Several other concerns are mentioned, but they are each mentioned by two HHs at most (Figure 3.4).

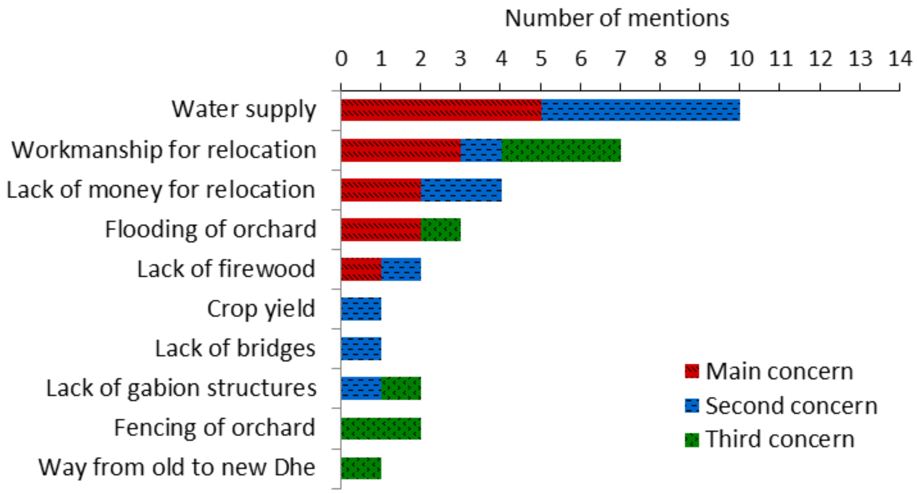

Figure 3.4: Identification and ranking of three main issues about which each of the 14 HHs are most concerned related to the relocation site of Dheye.

3.2 Housing

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

3.2.1 Settlement layout, spatial organization and density

The village of Dheye is located in a small valley along a slope oriented towards northwest and surrounded by fields (Figure 3.5). The settlement is composed by a compact main group of houses disposed linearly on the lower part of the slope towards north, while a smaller group is located nearby to the south and the school and mill are situated towards west, about 200 m from the main group of houses (Figure 10.1 in appendix A.1).

The footprint of the settlement, including all buildings, nearby compounds, squares and public areas, while excluding agricultural area, covers 1.18 ha[4] corresponding to a density of 84 inhabitants per hectare. The total agricultural area measures roughly 12.68 ha among which 10.39 ha are presently cultivated and 2.29 ha are currently not in apparent use or reserved for purposes such as pastureland or brick making. Considering the currently cultivated fields and the total population of 99 people, the cultivated field area pro capita is of 0.11 ha. There are a rather limited number of trees planted in the surroundings of the houses (Figure 3.5).

The public amenities are a preliminary school, a Gonpa, and a mill powered by solar energy. There is also a relatively important prayer wheels structure in the center of the village and several small Chörten, generally arranged in groups of three elements, dispersed in the surroundings (Figure 10.1 in appendix A.1).

[4] Measured with Google Earth Pro

Figure 3.5: Overview of Dheye seen from southwest (photo: 05/07/2012, Daniel Pittet).

3.2.2 Characteristics of housing

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

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. The majority of all houses in Dheye (about two thirds) have two stories, including a ground and a first floor, whereas the other dwellings are composed by the ground floor only.

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

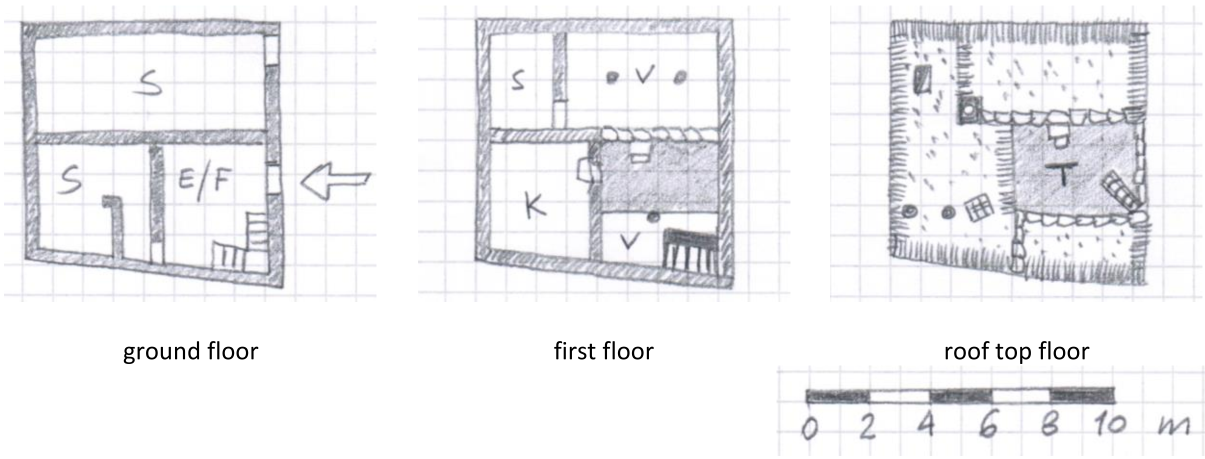

Figure 3.6: Representation of a dwelling from Samzong taken as a reference for a typical medium sized house (abstract of Figure 10.3 in appendix A.2, hand drawings: 30/06/2012, Daniel Pittet).

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 10.2, Figure 10.3 and Figure 10.4 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 10.1 in appendix A.3.

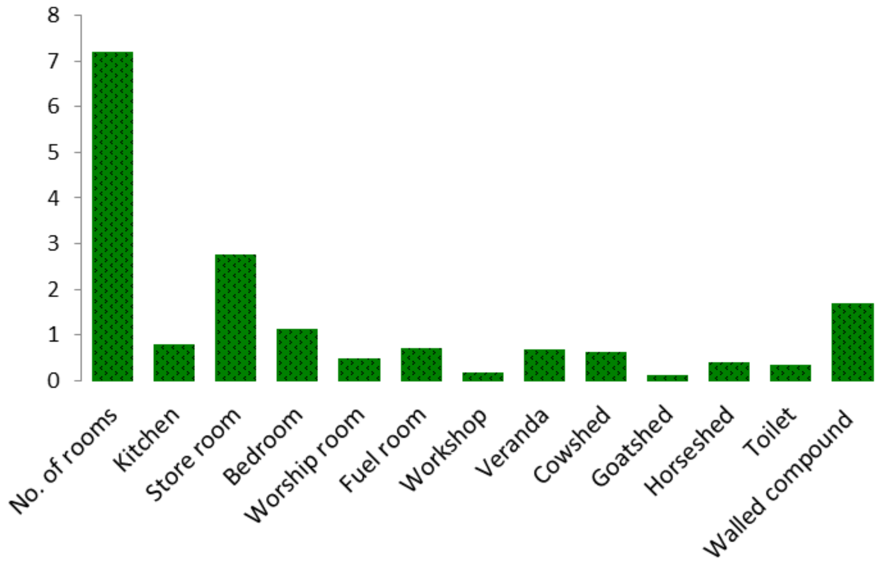

Figure 3.7: Average house composition of Dheye. The numbers indicate how many rooms are designated to the corresponding category on average per house, based on the socio-economic survey.

The number of rooms per house varies from 2 to 12 with an average value of about 7 (Table 10.1 in appendix A.3). Generally every house has one kitchen but in some cases (5 out of 14), the kitchen is also used as a sleeping place for instance. All houses have at least one and maximum 5 store rooms (average 2.8), which is the most frequently represented function overall. Also, all houses accommodate bedrooms (average 1.1), though in 5 cases the rooms have additional functions. Worship rooms are present in half of the houses, whereas fuel rooms and verandas are more frequent and workshop rooms are rather marginal. From all 14 houses 5 own a toilet as well. More than half of the HHs own a cowshed while 6 HHs have a horseshed. Goatsheds however are exceptional (2 out of 14).

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, laid out with soil mortar and covered with lime plaster (Figure 3.8). 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 3.9). The latter are covered with soil, in some cases mixed with ashes that assume the function of surfacing and water proofing of the slab and roof.

Figure 3.8: Outside view of a house in Dheye. The lower parts of the walls are made of stones whereas the upper parts are made of handmade earthen blocks, some of which are piled up on the right side of the house owner (photo: 06/07/2012, Daniel Pittet).

Figure 3.9: Inside view of a house in Dheye with earthen walls, wooden poles and wooden slab *(photo: 05/07/2012, 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 in Dheye should be comparable to those of Samzong. However, the cost of construction is influenced by the accessibility of the village, since the non-local building materials have to be transported to the construction site. As discussed in section 3.5, the main access path is rather frequently interrupted due to a quite active landslide. Additionally, the estimated construction costs reported in the project proposal for relocating Dheye to Thangchung (T. G. Gurung 2011) are sensitively higher compared with the indicative construction costs provided by the community of Samzong (Table 3.3). Mainly, the difference can be explained by the fact that the workmanship cost is not included in the estimate by Samzong's inhabitants and partly by the fact that there are no indications about the considered house size in the project proposal by T. G. Gurung (2011).

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

Table 3.3: Estimated average cost for a standard house based on two different sources. First, the costs for an average house with 4-5 rooms, estimated based on a community meeting with representatives of Samzong (14 out of the total 17 HHs on 27/06/2012) are presented. Second, the estimate provided in the relocation project proposal of Dheye village (T. G. Gurung 2011) is reproduced.

Description	Cost (NPR) *Estimate by Samzong's inhabitants*	Cost (NPR) *Estimate by (T. G. Gurung 2011)*
Workmanship of professional carpenter *1 month @ 500 NPR/day*	15'000	
Workmanship for unskilled works *Necessary labor provided by relatives and friends*	*Free for exchange of workmanship with relatives and friends*	*Quantified and included in total direct costs*
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	1'050'000

3.2.4 Issues and problems related to housing

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

Nevertheless, some houses, mainly in the lower part of the village, have cracks in their walls because of geological instability as outlined by the geological analysis of the site in section 3.5. However, the issue has never been mentioned as a potential problem by the community (section 3.1.4).

Another risk potentially threatening the buildings is related to the intensification of rainfalls in the region that has been observed and reported by Ardito (2012). According to this observation, some houses in Dheye village have undergone serious damages and even collapse of roofs during heavy rainfalls. Such an event could indeed be explained by an effective intensification of rainfall. In fact, an actual shift in precipitation patterns is neither supported nor contradicted by the climatic and meteorological analysis (section 3.3). 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 Dheye are confronted, it is crucial to put it into appropriate physical context. The past meteorological and climatic settings as well as future trends thereof have to be considered in order to qualify future prospects of the current settlement.

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

3.3.1 Climatic setting

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

In general, the climatic setting appears to be spatially highly variable. As a neat example thereof, clouds were producing very local precipitation in Upper Mustang in 1978, vertically distinctively delimited (Figure 3.10).

Figure 3.10: Local precipitation west of Samar produced by clouds which were formed by the uplifting air masses flowing upwards through the Kali Gandaki valley. Neither the valley bottom, nor the mountain tops, which were under the influence of an overlying high pressure system, received any snowfall. The picture was taken from Thorung Peak (6140 m asl) in northwestern direction (photo: 13/11/1978, Giovanni Kappenberger).

3.3.2 Air temperature

Actual trends of air temperature

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

Future trends of air temperature

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

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

3.3.3 Wind

The winds of the Mustang region are heavily influenced by the pressure fields forming over India and Tibet. The very strong diurnal winds (Figure 3.11) 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 3.11: 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 3.12). In the late morning upvalley winds take up and reach its quite extreme maximum after midday to decay later on and display typically only gentle breezes during the night (Egger et al. 2000).

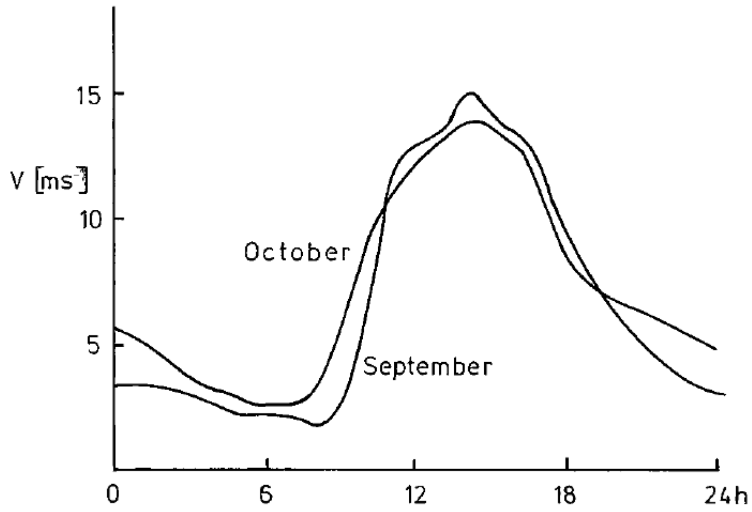

Figure 3.12: Graph illustrating monthly mean values of the hourly mean wind speed V (m/s) as observed in Kagbeni in September and October 1990 at a height of 30 ft, taken from (Egger et al. 2000).

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

Future wind patterns

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

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

3.3.4 Precipitation

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

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

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

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

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.

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

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.

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

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

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

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

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

[5] Data recorded and provided by the DHM

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 Dheye are described. Further details are reported in Bernet (2012).

3.4.1 Water demand

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

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

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

Description	Value range
Total inhabitants (excl. permanent migrants)	$P_p = 50$
Daily drinking water demand per capita[a] (l/p/d)	$d_d = 15 – 40$
Daily drinking water demand (l/d)	$D_d = d_d \cdot P_p = 750 – 2'000$
Required water flow during 24 hours a day (l/s)	$Q_d = D_d/(24 \cdot 3'600) = 0.009 – 0.023$

[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 range
Total population (incl. permanent migrants)	$P_t = 99$
Cultivation area per person[a] (m^2/p)	a = 1'000
Required cultivation area (m^2)	$A = a \cdot P_t = 99'000$
Daily irrigation area based on a 13 days cycle (m^2)	Ai = A/13 = 7'615
Irrigation intensity[a] ($mm/m^2 = l/m^2$)	$d_i = 35$
Required water flow during 24 hours a day (l/s)	$Q_i = d_i \cdot A_i/(24 \cdot 3'600) = 3.1$

[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 5.4.4). 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 the unnamed river draining the uphill area of Dheye measures 10 km^2 (Figure 5.6 in section 5.3.1). The lowest point of this catchment is at an elevation of 3872 m asl and reaches to a height of 5185 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.

A short distance upstream of the point of water abstraction, the river splits in two, whereas one branch dries out quickly further up. The other branch is host of the main spring which is located at an elevation of roughly 4500 m asl.

3.4.3 Water regime

The closest river gauging station to Dheye is located in Jomsom about 40 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 Dhey Chang 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. Heavy rainfalls during summer are expected to being mostly discharged as surface water. However, the rainfall recharges the groundwater storage to a certain degree which is probably contributing to the perennial flow of Dheye's river especially during monsoon and post-monsoon season. The effect of recharged groundwater during the monsoon on the surface flow in spring remains unclear.

The discharge in the Dheye's river 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 taken from a spring which does not drain into the Dhey Chang Khola, but to a neighboring tributary of the Kali Gandaki. The abstracted water is brought to a collection tank situated right next to the main irrigation reservoir, in which the tank's overflow is routed. The pipeline between the abstraction and the collection tank is about 3.25 km long and crosses a height difference of roughly 300 m.

Before winter, the pipes are emptied and the system is taken out of operation to prevent bursting of the. In spring the system is generally reactivated, which frequently involves locating leaks, cleaning of congested pipes etc. normally requiring about 12 mandays. During times the drinking supply system is not in operation, people usually take the water directly out of the irrigation channels which is far from optimal, since also the clothes are washed with the same water for instance.

It is notable that the villagers go through quite a lot of trouble to transport a small amount of water used for domestic uses from a place so far away. The villagers stated that first of all the quality is thought to be better. Second, the water would be considered as being wasted if it was not abstracted and third, the water brought from the other catchment is not in conflict with the irrigation water. These are important social aspects which have to be considered for the planning of the drinking water supply in case of resettlement of the village.

The people fill their so-called toms (35 and 5 l canisters) at the taps or the irrigation channel and bring them to their houses to satisfy their domestic water demand. By means of a survey, the demand was estimated with 18 l/d per capita (Bernet 2012) or 890 l/d, which corresponds to the lower limit of the estimated water demand (section 3.4.1). The water is mostly used for cooking, drinking and personal hygiene. In any case, the drinking water pipeline supplies a sufficient amount of water during its operation period, which is also perceived in this way by the people of Dheye.

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 Dheye's river and particularly on how much can be captured. In Dheye there are presently two different abstractions feeding one single irrigation systems bringing the water from the river to the fields.

The system is shown in Figure 3.13 indicating different sections of the system, which are described in Table 3.8. A detailed description of the systems can be found in Bernet (2012).

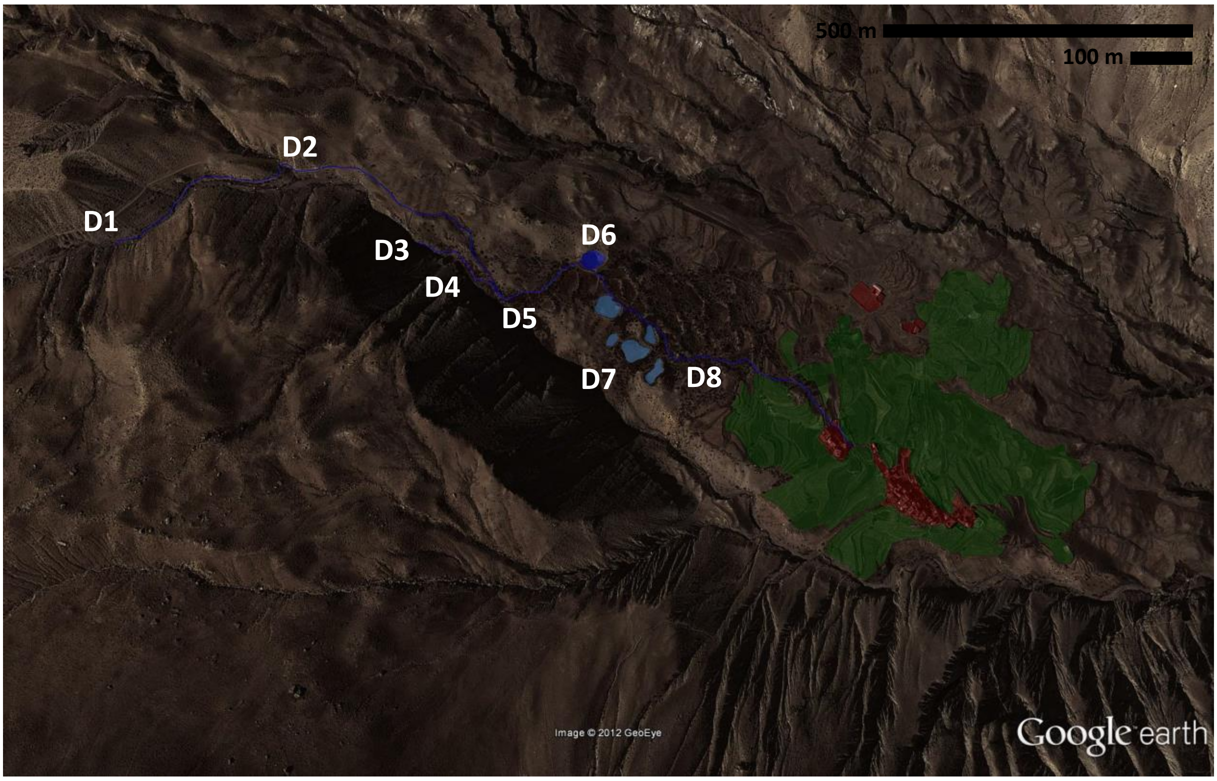

Figure 3.13: Google earth view of Dheye and its surroundings indicating the irrigation system. The red colored areas highlight Dheye village, the green colored area the agricultural area. The number codes correspond to different sections of the irrigation systems further described in Table 3.8. North direction is → (source: Google Earth Pro, accessed 27/11/2012).

Irrigation scheme

After the crops have been harvested at the end of the growing season, the fields are prepared for the winter. Usually in mid-October the fields are irrigated, fertilizer is applied and the land is plowed. One month later the fields are irrigated once again and left for the winter. In April the fields are plowed and the crops are sown according to the HH order, which is determined by draw early in the season. In the morning of the following day the fields are prepared with the help of member from all HHs. In the afternoon the corresponding fields are irrigated. During this time also the five private reservoirs are used additionally to the main reservoir for irrigating the fields.

Table 3.8: Summarized description of the irrigation system in Dheye. The corresponding sections are indicated in Figure 3.13.

Section	Unit	Length / Volume	Description	Main issues
D1	Upper water abstraction		Handmade construction, made of locally available rocks, mud and earth to abstract the water	➢ Damaged and/or destroyed during high flows of Dheye's unnamed river ➢ Reconstruction frequently necessary
D2	Upper abstraction channel	665 m	Hand-dug, open, earthen channel connecting water abstraction with conjunctive supply channel	➢ Hand-dug channel subject to rather large constant losses due to seepage through comparatively permeable soil
D3	Lower water abstraction		Masonry construction supported by mud and connected to PVC pipes	➢ Sometimes damaged during high flows of Dheye's unnamed river ➢ At least yearly maintenance necessary, mainly cleaning of the accumulated sediments in the collection chamber
D4	Lower abstraction channel	155 m	Mostly piped supply line connecting lower abstraction with the conjunctive channel	➢ Conjunctive use of lower and upper abstraction increases abstraction efficiency but might lead to lower overall yield (upper abstraction channel: large losses, but high flow; lower abstraction channel: little losses, but low flow)
D5	Conjunctive supply channel	130 m	Hand-dug, open, earthen channel connecting water abstractions with main reservoir	➢ Hand-dug channel subject to rather large constant losses due to seepage through comparatively permeable soil
D6	Main reservoir	750 m^3	Reservoir with sidewalls 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 considerable constant losses due to seepage through the comparatively permeable soil ➢ Is emptied within roughly half a day
D7	Private reservoirs (five pieces of different sizes)		Reservoirs with sidewalls formed by piled up rock, mud and earth, some have masonry outlets which can be opened and closed by inserting a wooden stick	➢ Excavation of accumulated particles necessary from time to time ➢ Subject to considerable constant losses due to seepage through the comparatively permeable soil ➢ Used by community until all fields were irrigated once, afterwards used as additional private water storage
D8	Main distribution channel	525 m	Hand-dug, open, earthen channel connecting reservoirs with distribution system on plot level	➢ Hand-dug, open, earthen channel connecting water abstractions with main reservoir

The prepared and irrigated fields are left for 40 days. Since for most of the 13 HHs owning fields it is not enough to irrigate all their fields during one turn, two rounds, amounting to 26 days, are needed until all fields received water at least once. Since each field is left for 40 days after it has been irrigated for the first time, there is a gap of 12 days. During this gap, the private reservoirs are refilled first. Starting from then, the water stored in the reservoir can be used by the corresponding owners for their personal use. The ones owning a private reservoir also have the largest land property and use the water storage for an additional source for irrigation water later in the season. Once the private reservoirs are full, the water is diverted to two ponds used for watering livestock. Reportedly these ponds dry out within just two weeks after filling them.

After the break, it is again the HH's turn which drew the first number in the lottery. At this time the fields are started to be irrigated for the second time. In this phase there are no breaks inserted anymore. As the dry season is evolving the water yield decreases. Consequently it takes more turns to irrigate the same number of fields compared to the early season. Therefore, the frequency by which a certain field is irrigated depends on the available water and the farmers' choice which of their fields should get irrigated at which time during the family's turn.

Released water for irrigation

The quantification of the water used for irrigation is not simple. It is seasonally, diurnally as well as spatially variable. Nevertheless the abstracted water was measured with very basic methods during the field visits (Bernet 2012). As a reference, the measurements during the second field visit were chosen. In addition the cultivated area[6] was measured and put into relation.

Table 3.9 exemplifies that the abstracted water would be sufficient to supply the whole cultivated area with 4 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 56 mm. As a whole turn takes 13 days, each field could potentially be irrigated with 56 mm every 14 days, which is slightly higher than the postulated demand of 35 mm (section 3.4.1). 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 observed yield of Dheye's river is expected to decrease further towards the end of the dry season.

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

Table 3.9: Indicators describing the water availability for agricultural activities in Dheye. The values refer to the measured water abstraction rate during the second field visit in the beginning of July 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 HH owning fields	13
Total cultivated area (ha)	10.4
Average cultivated area per HH (ha/HH)	0.80
Total abstracted water (m^3/d)	448
Abstracted water per total cultivated area ($l/m^2/d$ = mm/d)	4.3
Approximated irrigation depth[a] (mm/HH/d)	56

[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 river flow of Dheye's river 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 climatic behavior is particularly severe for agricultural activities in Dheye, 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. The situation of Dheye is even worsened by the small catchment area. It is rather surprising in the first place, that the yield is as big as observed given the size of the catchment.

As the water availability is limited and is smaller than the water demand for irrigation purposes at times, the efficiency of the irrigation systems is an issue. The distribution and storage systems are subject to quite large constant losses due to seepage through the comparatively permeable soil. There are many places in Dheye, which prove that reservoirs as well as the distribution system is leaking heavily, such as water accumulation in depressions downstream, thriving vegetation around the irrigation systems etc. Also local losses occurring mostly due to the fact, that the opened distribution channels on plot level cannot be or are not closed properly, are an issue.

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

A huge Deep-seated Gravitational Slope Deformation (DGSD) affects the left flank of the Dhey Chang Khola below the village of Dheye. The deformation (Figure 3.14, #1) affects a total surface area of about 8 km^2 covering heights from the crest at 4200 m asl to the riverbed situated at 3540 m asl. A series of scarps and counterscarps with heights of a few meters characterize the medium and upper part of the slope indicating a present activity. In the region a succession of limestones and shales whose layers are dipping towards north northeast and which belong to the Tibetan-Tethys zone outcrops (B. R. Adhikari and Wagreich 2011). A ridge of limestone and conglomerate splits the movement in two sectors but is also displaced by the deformation.

The western sector is characterized by more evolved kinematics. The movements involve mainly rock masses formed by shale. The eastern sector is generally less deformed and consists mostly of limestone. The front of the DGSD is dislocated by numerous landslides that show rapid kinematics.

Figure 3.14 shows an inventory map of the entire area reporting different types of landslides with different states of activity according to the international Varnes classification (Varnes 1978).

A large translational slide is present in the eastern sector (Figure 3.14, #1). Numerous east-trending scarps and counterscarps form a horst and graben-like morphology as a result of a creep-type dynamic. A complex rock/earthflow slide affects the upper part of the slope (Figure 3.14, #2). This slide affects loose clay material which is characterized of high plasticity. The lower slope is characterized by the presence of an enormous active earth flow (Figure 3.14, #3). This flow directly affects the access path to Dheye which is partly leading along the Dhey Chang Khola. In the melting season the river is carrying too much water so that a different, longer path has to be taken.

Dheye lies on the DGSD’s right border which coincides with the river from which the irrigation water is taken. Below the village a rotational slide affects the medium lower part of the slope. The houses do not appear affected from this phenomenon. However, the movements related to this landslide have most likely contributed to the abandonment of the lower field. Overall, there are few morpho-structures close to the lower houses of the village. During the field visit Dheye did not appear to be directly affected by the dynamic of the deformations.

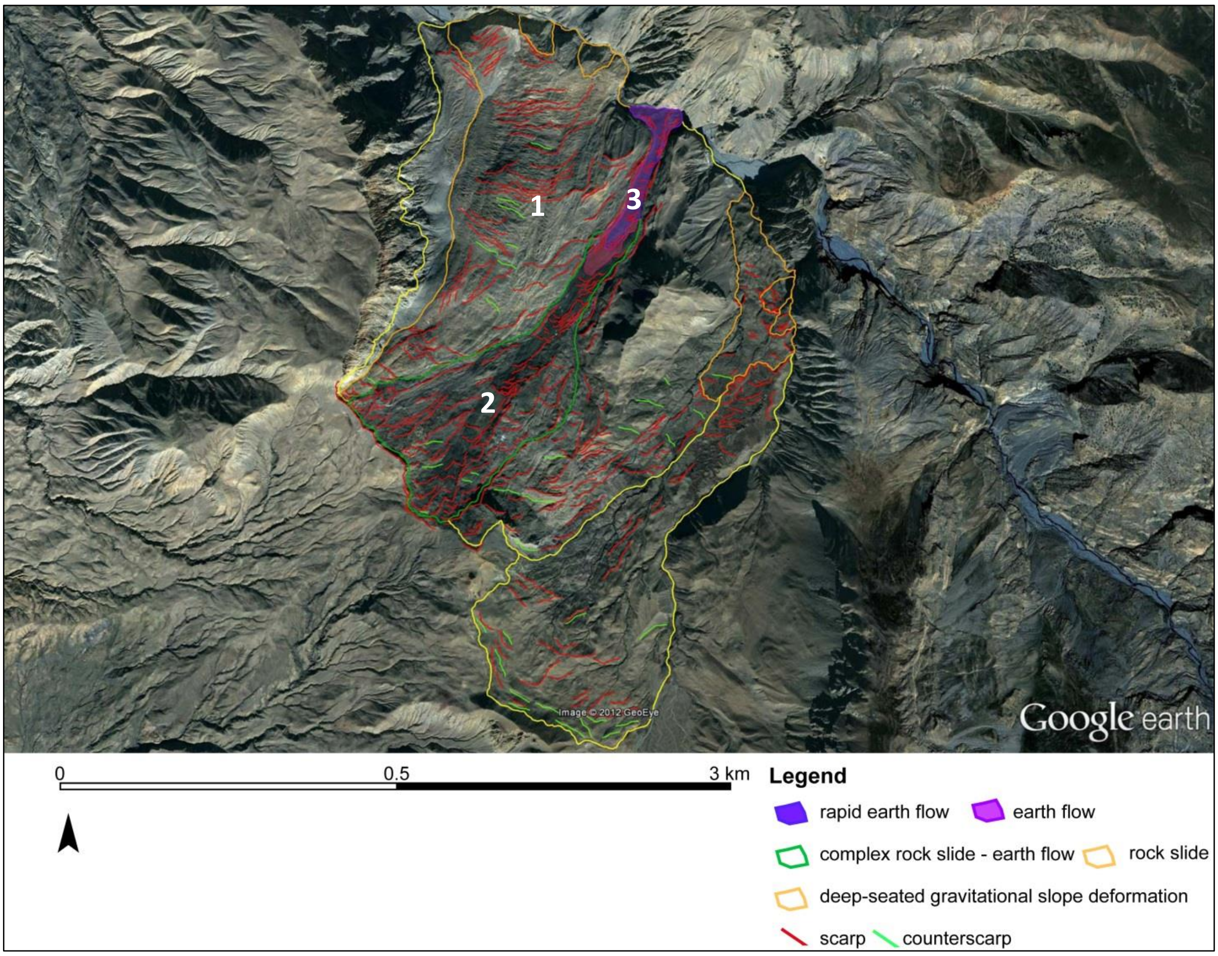

Figure 3.14: Inventory map of Dheye village including its surroundings (source: Google Earth Pro, accessed 08/08/2012).

3.5.2 Goods at risk

The winter access to the village, some fields and houses in the lower part of Dheye are at risk. In particular the path crossing the active earth flow (Figure 3.15) located at the toe of the DGSD is endangered (Figure 3.16). The high activity of this flow is highlighted by the presence of a horst and graben-like surface as well as numerous shear planes with abundant strike-slip kinematic movement indicators. During past events accumulating material has repeatedly interrupted the Dhey Chang Khola proven by historical Google Earth images as well as reported by locals who were witnessing at least two important events during the past 25 years. Reportedly, the military had to intervene to prevent a sudden flood after the Dhey Chang Khola had been dammed. Traces of a dam, which might go back to this particular event, are clearly visible upstream of the landslide toe. In the future, the possibility of further damming of the river cannot be excluded. In such an event, serious damage to any man-made structure in Chawale, which lies near the confluence of the Dhey Chang Khola and Kali Gandaki, could be caused.

Figure 3.15: Active earth flow at the toe of the slope (photo: Christian Ambrosi, 06/07/2012).

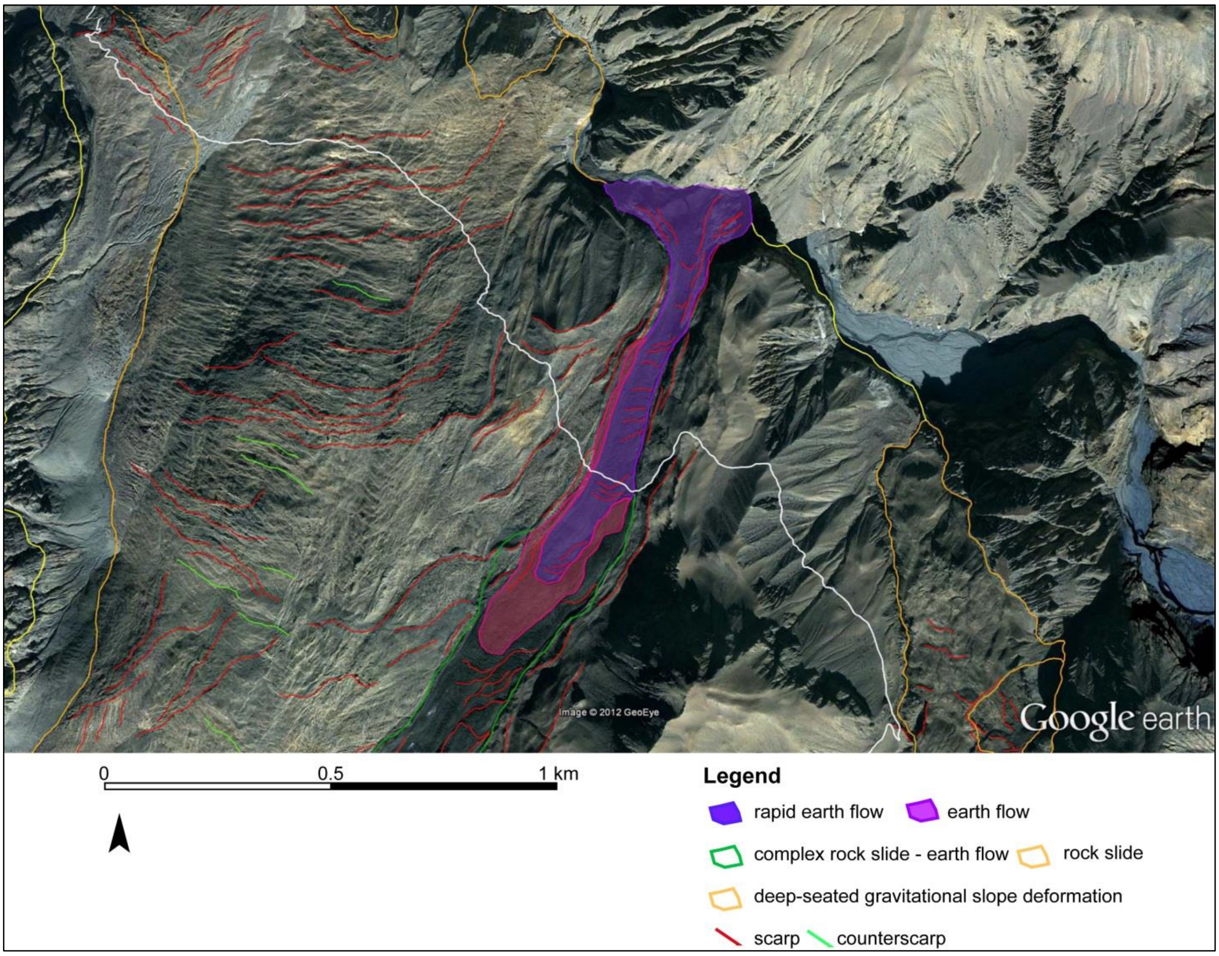

Figure 3.16: Earth flow below Dheye affecting the access path to the village (indicated in white) during the cold season (source: Google Earth Pro, accessed 08/08/2012).

Regarding Dheye village itself, there are no goods at imminent risk from landslide movements (Figure 3.17). In the future, the lower houses and fields could be damaged however by the retrogressive behavior of the landslide.

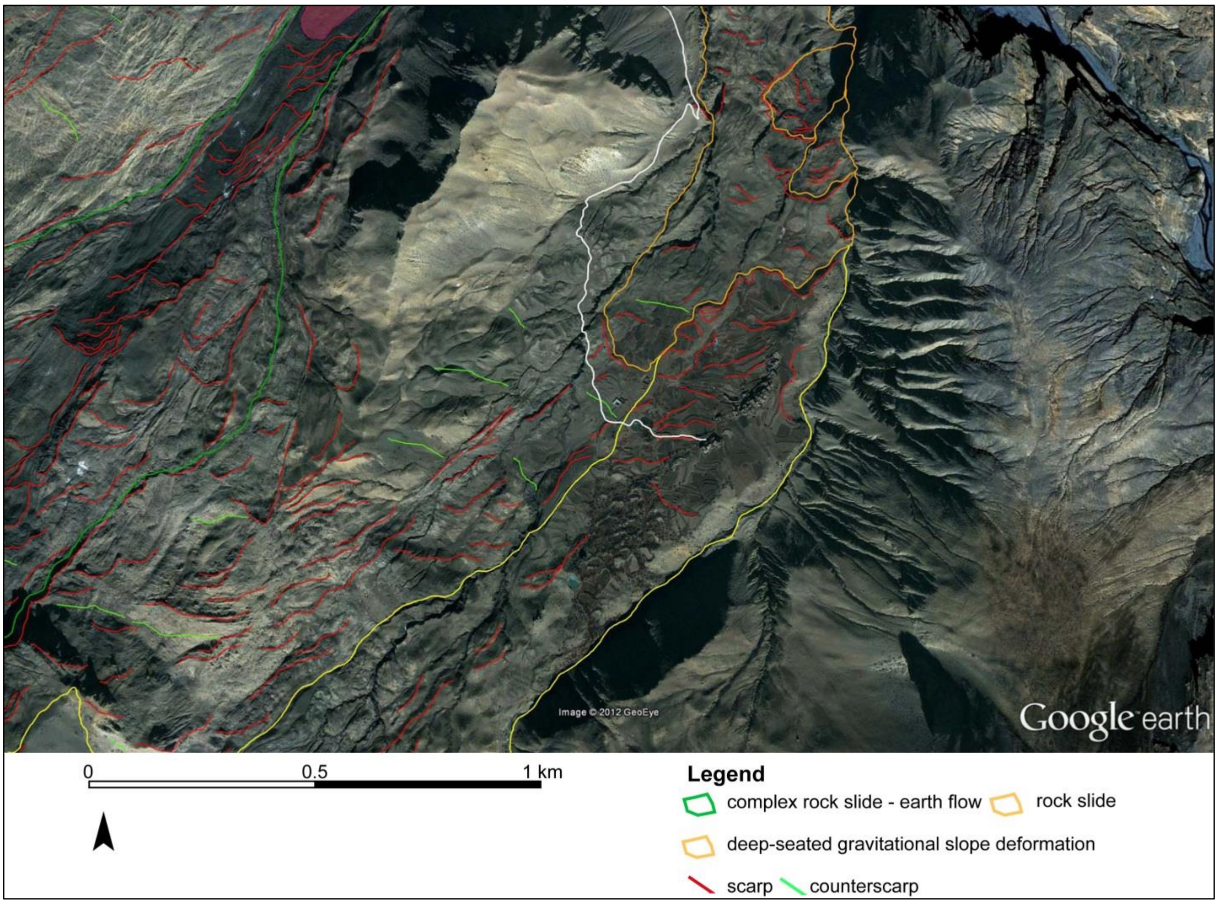

Figure 3.17: Landslide morpho-structures affecting Dheye village. The access path to the village is shown in white (source: Google Earth Pro, accessed 08/08/2012).

4 Possible ways of resolving the problems in situ

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

4.1 Housing fragility mitigation strategies

The geological analysis of the site (section 3.5) has shown that mainly the lower side of the settlement is threatened by geological instability which could cause cracks in some houses. About half of the already abandoned houses are located in this area (Figure 10.1 in appendix A.1). Consequently, the risk of cracks in the houses could be mitigated by avoiding to building new houses in this sector (lower part of the village). Regarding the few inhabited houses with cracks, they could be repaired by reinforcing the foundations or, for a longer term resolution of the problem, rebuilt in a more stable sector on the upper part of the village.

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

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

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

4.2 Water shortage mitigation strategies

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

4.2.1 Water stress mitigation by supply management

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

Allotment of other water sources

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

Loss reduction by constructive measures

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

The reduction of constant as well as local losses could increase the irrigation efficiency considerably. As observed during the field work, quite a lot of water accumulates in local depressions, or bushes and pasture are growing in the vicinity of the water supply system. This is clearly a sign of percolating and in this context lost water for irrigation.

Also, the efficiency of using both abstractions should be evaluated. By using two such installations, practically all surface water within Dheye's river is captured which is desirable from a water use perspective, of course. However, the upper abstraction diverts at least 80 % of the river's perennial flow. The corresponding abstraction channel is associated with large constant losses. The mostly piped lower channel on the other hand is not exploited nearly to its capacity and its advantages are therefore badly used.

For providing additional irrigation water storage, the area would be spacious enough, so that generally also large storage volumes could be realized. In that case, the water supply would be less dependent on the perennial flow of the river. During monsoon time or also in spring before the growing season starts, the storages could be filled for later usage. For planning and dimensioning such structures, the dynamics of Dheye's river as well as the feasibility of capturing overland flow would have to be studied in more detail. Also, the effects of such storage units on the hydro-geological setting, as outlined in section 3.5, would have to be paid due consideration. As mentioned before, infiltrating water could enhance the movements of the predominant DGSDs.

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

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

4.2.2 Water stress mitigation by demand management

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

Generally, another possibility would be to switch to different activities, consequently becoming less dependent on agriculture and thus overall reducing the water demand. However this does not seem to be an option for Dheye. The inherent characteristics of the village do not appear to allow a sufficient diversification of economic activities. Namely, all families depend on agriculture for self-sufficiency to a large degree, there is currently neither a road nor exploitable touristic potential.

4.3 Geological hazard mitigation strategy

From the geological point of view there is no need for risk mitigation measures. With regard to the winter access way, it is expected to be frequently damaged during future reactivation phases of the earth flow.

5 Considerations for a possible relocation

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

5.1 Taken steps towards relocation

The community of Dheye is put heavily under stress by the increasing lack of water, by the difficulties of accessing the village due to frequent damage of the path leading to the village (Gurung (2011) and section 3.5) and by other factors such as the remoteness of the village. The latter has adverse consequences in relation to access to education, health services and socio-economic opportunities. Dheye's community has already taken the following initiatives towards relocation of the entire village.

- Identification of a site for relocating both the settlement and the agricultural area
- Elaboration of a project proposal describing the relocation concept and costs
- Contact to local authorities and NGOs in order to ask support for the relocation process
- Construction of an orchard in Chawale

In the following sections, each issue is discussed briefly.

5.1.1 Identification of a relocation site

The selected site, called Thangchung, is located about 4 km southeast of Charang, on the opposite, left bank of the Khali Gandaki. It is a plateau, elevated roughly 30-40 m relative to the confluence of the Dhey Chang Khola and Charang Khola with the Kali Gandaki. The land of Thangchung falls already within the jurisdiction of Dheye village and is currently utilized by the community for herding their livestock during winter (T. G. Gurung 2011).

The plateau has a total useable area of no less than 25 ha. The layout proposed by the relocation project proposal (T. G. Gurung 2011) consists of 6 ha foreseen for the settlement (houses), 5 ha for public amenities and further expansions of the village and 14 ha for the agricultural area (Figure 5.1 and Figure 5.2). The mentioned areas consider safety distances to the scarp delimiting the plateau laterally in northeastern and northwestern direction, as well as to the foot of the steep slope in southern and southeastern direction (Figure 5.1). The scarp may be subject to shallow landslides, whereas the steep slope may trigger rockfall and local debris flow. All mentioned hazards can easily be dealt with by respecting a safety distance of roughly 15 m to the escarpment and at least 20 m to the foot of the steep hill flank respectively as exposed in section 5.5.

Due to the exposed characteristic of the plateau, the site is subject to the typical strong diurnal winds from southwest (Figure 5.1 and section 3.3.3).

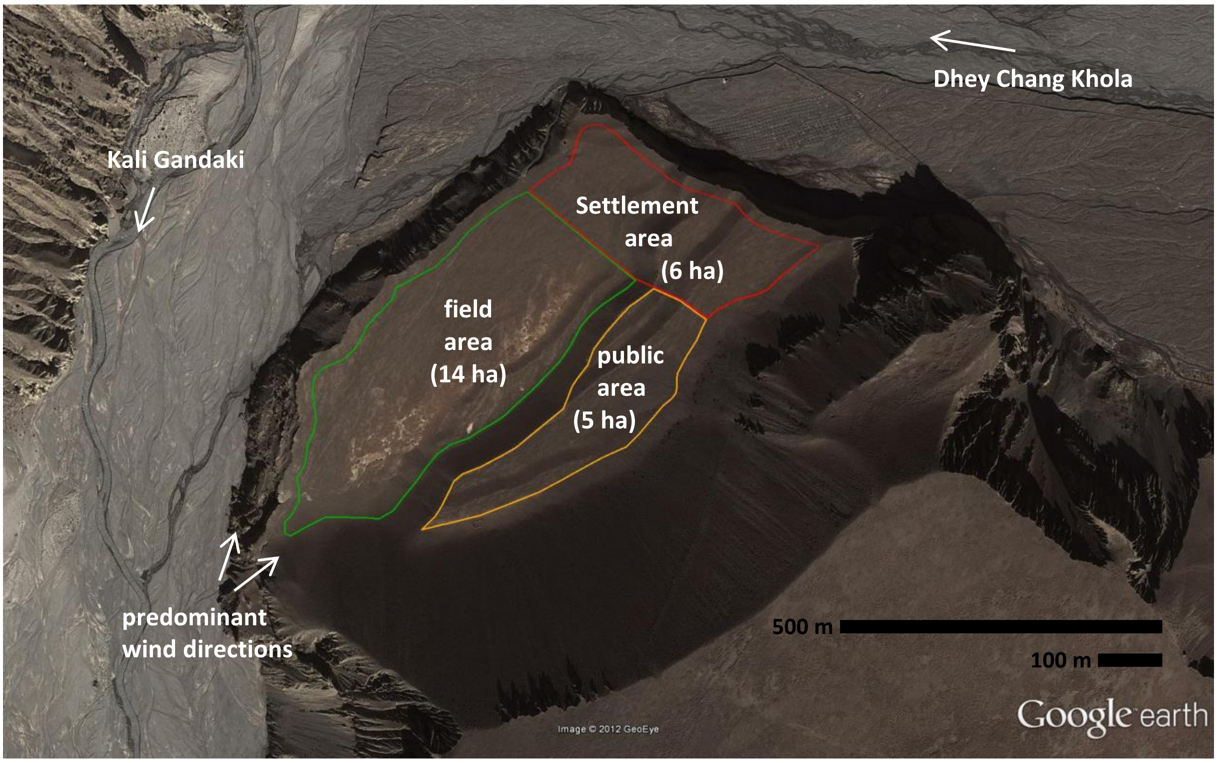

Figure 5.1: Satellite view of Thangchung, the land foreseen for the relocation of the settlement of Dheye. The spatial from Gurung (2011) is adapted. The settlement area (red) is designated to houses, the public area (orange) is reserved for public amenities and possible future expansion of the village. North of the settlement area the partially realized orchard can be seen. North direction is ↑ (source: Google Earth Pro, accessed 06/11/2012).

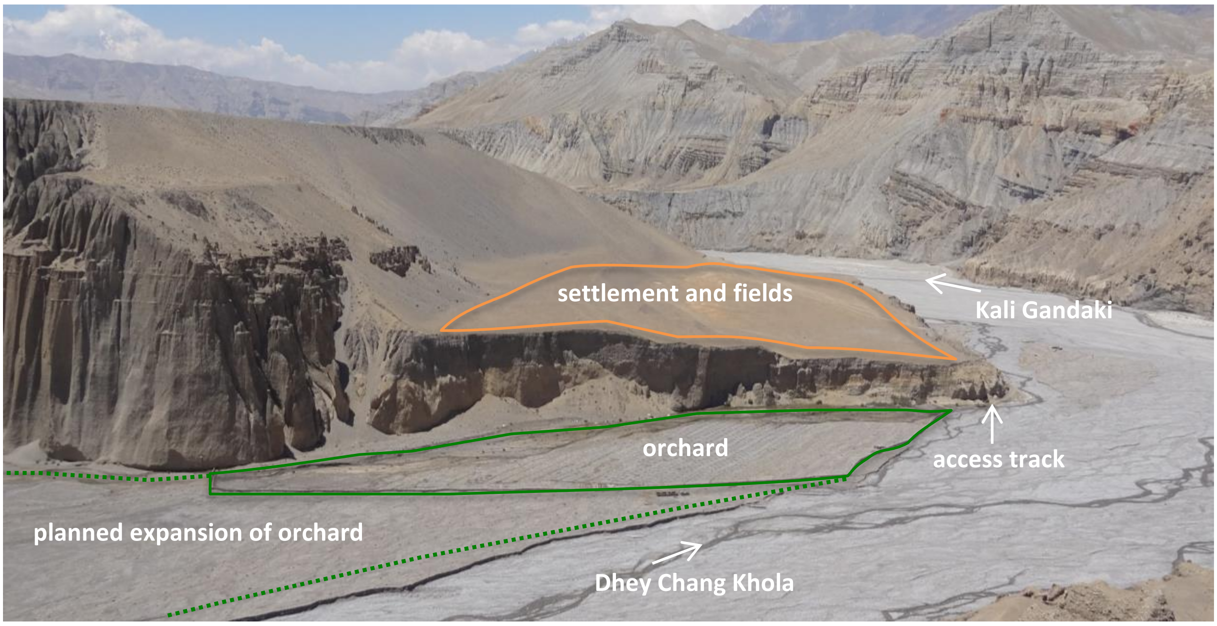

Figure 5.2: Thangchung seen from northeast. Below the designated relocation site (orange), an orchard has been realized (solid green), which is planned to be expanded extensively in the future (dotted green). A dirt track, recently realized, accessing the plateau is highlighted (photo: 13/05/2012, Daniel Bernet).

5.1.2 Elaboration of a project proposal for resettlement

The project proposal was prepared by Tashi Gyatso Gurung, a villager of Dheye, and includes a general presentation of the regional and local context, the major constraints and problems that the village is facing, a rationale for the resettlement and the concept of the relocation project with its main components (T. G. Gurung 2011). Furthermore it includes a budget for the whole resettlement as well as already carried out contributions mainly related to the orchard (section 5.1.4).

5.1.3 Contact to local authorities and NGO's for asking support

The relocation project proposal is being used as a reference document for soliciting the support of organizations such as WWF Nepal for instance. Both the VDC and the DDC were approached which in turn wrote a recommendation letter asking all concerned organizations to support the resettlement of Dheye village. Additionally, the VDC and the DDC financially supported the construction of the orchard, as described in more details in the following section.

5.1.4 Construction of an orchard in Chawale

To generate additional income, the construction of an orchard on the western end of a slightly elevated plateau named Chawale to the left of the active riverbed of Dhey Chang Khola was initiated a few years ago by the community of Dheye. The project proposal envisions the cultivation of whole Chawale, which covers a total area of roughly 50 ha. Up to present the following tasks were accomplished:

- Formation of cooperative involving at least one member from each HH for construction and management of orchard
- Purchase of dozer on loan for all task related to excavations and leveling
- Excavation of shallow holes for later planting of the tree seedlings
- Fencing of the eastern end of Chawale covering roughly 8 ha (16 %) with stone walls
- Purchase of apple and other fruit trees for later planting
- Plantation of seedlings in the shallow holes previously excavated by the dozer (Figure 5.3)
- Building of abstraction channel to direct water from the Dhey Chang Khola to the orchard
- Construction of a small stone hut for the employed caretaker of the orchard
- Building of a community hall next to the fenced plantation
- Installation of gabions forming spur dikes on the northwestern end of the orchard

Figure 5.3: Planted fruit tree seedling in a shallow depression excavated with the purchased dozer. Channels were dug into the alluvial deposits to be able to divert water to each of the planted seedlings. In the background the escarpment delimiting the designated settlement and agricultural area can be seen (photo: 13/05/2012, Daniel Bernet).

Additional to the financial contribution of the Dheye's inhabitants including the 10 dislocated families, the villagers invested a lot of workmanship to the project. Particularly the construction of the stone wall fencing the orchard was realized by the villagers themselves. Each HH was ask to participate in terms of workmanship and in case this was not possible, to pay a fee per missed labor day instead. As outlined in section 2.2.2, projects are not funded by local authorities as a whole, but rather in terms of possible yearly contributions. Different authorities including the VDC, DDC and ACAP along with others supported parts of the project financially but also with expertise and material to varying over the past few years.

The realization of the orchard and the planned future expansion thereof exemplifies the difficult project management within the framework of the local context with the institutional characteristics and their apparent weaknesses, as discussed in chapter 2 and section 3.1.2.

5.2 Housing

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

5.2.1 Layout and spatial organization of the relocated settlement

Inherent characteristics of the settlement area

In terms of space needs and availability, it is interesting to compare the values of the existing village with the new location (Table 5.1). Taking the spatial layout shown in Gurung (2011) as reference, the cultivation area would significantly increase. The total available settlement area would increase heavily, which results in a very small population density. Furthermore, the cultivation area per capita (0.09 ha/p) would drop even below the value in Dheye (0.11 ha/p) if the 10 resettled families (section 3.1.1) would return and settle down in Thangchung as well, as proposed by T. G. Gurung (2011). The outlined layout is therefore rather inefficient, which could be mitigated as exposed in the following section.

Table 5.1: Settlement and agricultural area related to the population for Dheye and Thangchung. The Settlement areas were measured with Google Earth Pro, the cultivation area in Dheye was estimated with Global Positioning System (GPS) measurements on site, the one in Thangchung with Google Earth Pro as well. The population is based on the socio-economic survey undertaken during the field visits. Note that the spatial layout of the settlement and agricultural area in Thangchung is adopted according to T. G. Gurung (2011) while considering appropriate safety distances to the escarpment and the foot of the steep hill flank (section 5.5). The numbers in brackets take the possible future population into account, in case the dislocated families return and settle down in Thangchung as well, as suggested by T. G. Gurung (2011).

Description	Settlement area[a] (ha)	Cultivated area (ha)	Total population (p)	Population density (p/ha)	Cultivation area per capita (ha/p)
Dheye *Current location*	1.18	10.39	99	84	0.11
Thangchung *Relocation site*	6.13	13.71	99 (157)	16 (26)	0.14 (0.09)

[a] As the public area (Figure 5.1 in section 5.1.1), measuring 5.09 ha, is intended to accommodate only public amenities and possibly future expansion of the settlement, it is not considered for the calculation of the population density.

Strategy to cope with the characteristics of the site

It is suggested to plan and possibly realize the settlement in a rather dense manner to have a large agricultural area available to accommodate possible further expansions. This is also in accordance with the aim of reproducing the way of life that is currently known in Dheye and to cope with the suggestion of protecting the village against exposure to strong winds. To take advantage of the wind protection measures of the village also the public buildings (Gonpa, community hall, school, youth club and mill) are suggested to be built in the same sector as the houses.

To use the available space more efficiently, the area could be partitioned in a different way compared to the proposal done by T. G. Gurung (2011). For instance, the lowest and largest level of the longitudinally slightly graded plateau could accommodate the agricultural area. The smaller upper steps could be used for the settlement and if possible and/or desirable for additional area shared by the community, such as gardens, trees or brick manufacturing.

Ideally, the settlement would be built on the small terraces, taking advantage of the grading for protection against wind. In any case, the issue of optimal site partitioning should be studied in more detail, particularly taking also other issues such as drinking and irrigation water supply into account. However, for the following elaborations, the land partitioning according to T. G. Gurung (2011) is taken as a reference.

The issue of exposure to strong wind has to be considered in the design of the settlement's layout and spatial organization in order to mitigate, as much as possible, the undesirable effects that wind can generate. A strategy is proposed which consists in using the settlement's boundaries (walls of the houses and compounds themselves) as a "wind barrier" in order to protect the open spaces. The concept is illustrated in Figure 5.4 and must respect the following rules (Gut and Ackerknecht 1993):

- Creation of a continuous wind barrier: Even small openings in the barrier placed in locations exposed to strong wind need to be protected in order to avoid local jet effects (very high speed winds created locally because of the creation of openings)
- Construction of a high wind barrier in order to increase the area of the protected zone beyond the barrier (this goes in accordance with the necessity of increasing the density using 2 story buildings for medium and large houses)
- Use of trees for mitigating the impact of wind

Figure 5.4: Conceptual layout of the relocated settlement in Thangchung (hand drawing: 14/09/2012, Daniel Pittet).

Proposed layout and spatial organization of the new settlement

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

This concept aims at providing a basic structure of the settlement's spatial organization allowing some flexibility in the use of space in order to consider the variations of needs and means of the different HHs. As proposed (T. G. Gurung 2011), it is assumed that the 10 families, which moved to other villages within the past decades (section 3.1.1), rejoin the community in Thangchung. Thus the proposition considers the realization of 24 houses and plots of the following dimensions (Table 5.2).

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

Description	Area (m^2)
Core house area *Maximum ground level area for core house including walls*	81
Compound area *Compound area including surrounding walls*	108
Extension area *Available ground level area for (future) extension of the core house*	81
Total plot area *Area of each plot (core house, compound and extension area)*	270
Public amenities area *Required area for a Gonpa, school, community hall, youth club and mill*	850
Total maximum built up area *Area for 24 core houses and public amenities*	4’738
Total ground area *Area for 24 plots including compounds and public amenities*	7’330
Total designated settlement area[a] *Allocated settlement area according to the proposal of T. G. Gurung (2011)*	61’320
Remaining free area *Not allocated, remaining free public area within settlement area*	53’990
Percentage of remaining public area *Remaining public area compared to total allocated settlement area*	88 %

[a] Available area adopted according to T. G. (Gurung 2011) while considering appropriate safety distances to the escarpment and the foot of the steep hill flanks respectively as exposed in section 5.5.

The principle of the concept consists in the supply of standard plots with modular possibilities of using the assigned constructible area. The standard plots of 270 m^2 are composed by 81 m^2 available for the core house, another 81 m^2 for possible house extensions and 108 m^2 of compound area that can be walled and could also be used for erecting livestock sheds (Table 5.2). If a house desires an area of more than 81 m^2 then preferably, the surplus area should be provided by adding a second floor on top of the core house. The available ground area for HH expansions should be used only after the second floor on top of the core house has been exploited. In this way as much land as possible is kept for other uses around the houses.

The sizes of the various components (core house footprint, compound area and area available for future extensions) correspond to the maximum areas at ground level. It does not mean that all houses will be of the same size as schematically represented in Figure 5.5. Some families will use only part of the available space for constructing smaller houses whereas others will use the additional space available for building extensions. It should also be possible for a family to buy surplus land for building larger houses. The construction of sheds for livestock is not outlined but such elements can be integrated in the space of the compounds and also by using part of the remaining public space in accordance with the community.

5.2.2 Considerations about house design

Local practices and characteristics

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

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

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

Housing strategy and concept

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

The concept has the advantage of being based on an equal plot division (the size of the plots are similar but the shape may vary as depicted in Figure 5.4) without impeaching the realization of houses of different dimensions and design and allowing various possibilities of further expansions, as presented in Figure 5.5.

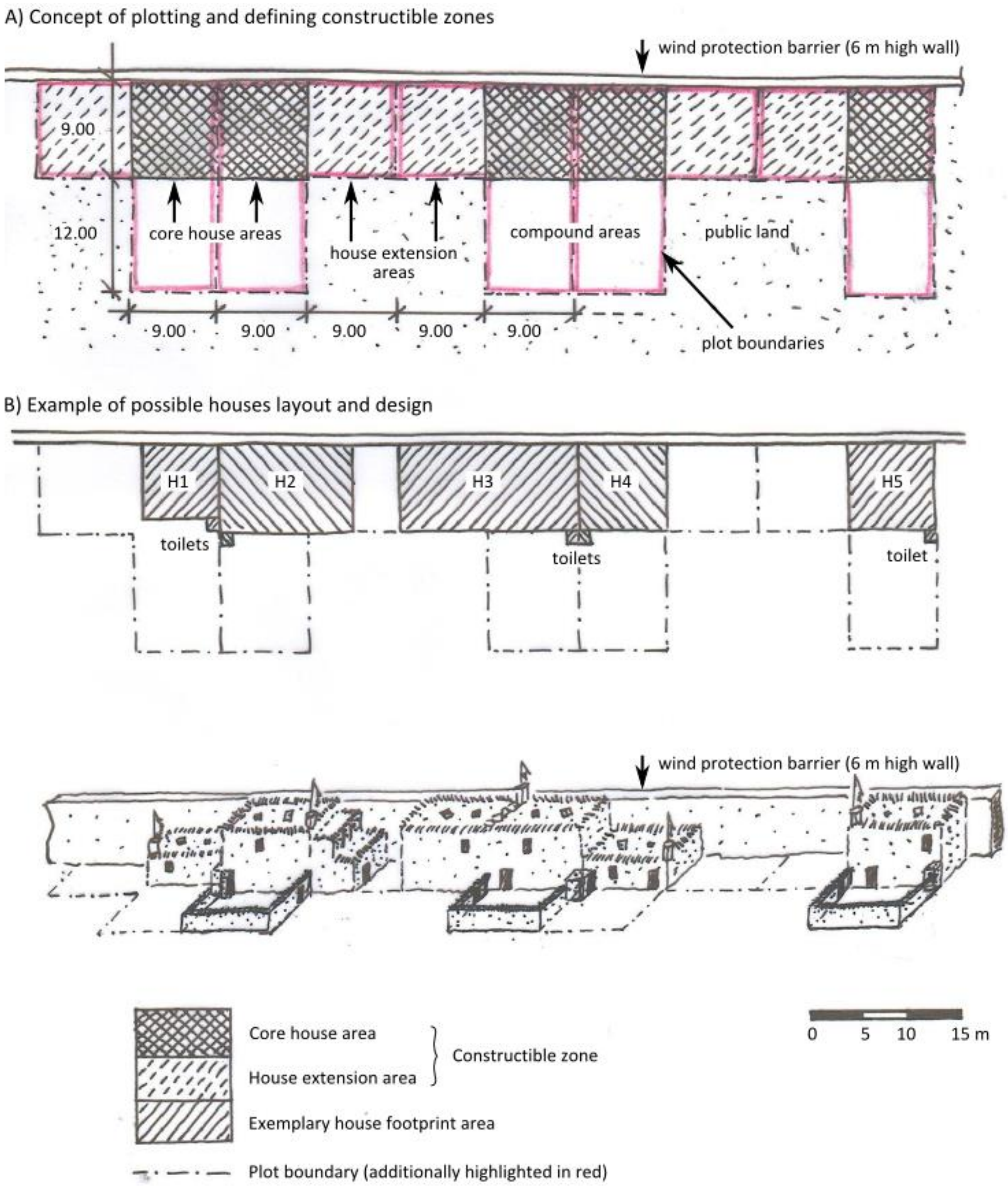

Figure 5.5: Housing concept of resettled Dheye (hand drawing: 04/09/2012, Daniel Pittet).

House design

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

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

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

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

Sensitively improving the thermal comfort of the houses would be rather challenging and costly and would imply a deep transformation of the housing technique and concept such as using passive solar energy concepts for instance. Besides, passive solar energy could also be used to create additional income and improve agricultural self-sufficiency. An example of the application of such techniques in a similar context is the successful implementation of 55 greenhouses in the Lahaul-Spiti District, India, by the social eco-travel agency Ecosphere[7]. The yield of vegetables would complement the agricultural output and surplus production could be traded on local markets. Such initiatives would certainly be interesting to be investigated and experimented at small scale in the framework of a complementary study. In the presented context, it goes beyond the scope of the study at hand.

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

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

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

5.2.3 Costs of relocation related to housing

Costs related to the relocated housings are rather difficult to estimate because they imply many different actors and the related operations include a lot of uncertainties and unknown data. Also many related activities do not have direct costs but consist in workmanship of the community itself. However, a rough estimate of the direct costs linked with the housing relocation processes is presented here. It is based on the experience of the LMF, as well as on the estimated costs reported in the relocation proposal (T. G. Gurung 2011). The estimate, summarized in Table 5.3, considers the (re)construction of 24 houses, public amenities as well as the construction of the wind protection barrier (wall, 6 m high and 340 m long). Note that the contribution as workmanship by the villagers was added as monetary post.

Table 5.3: Rough estimate of the costs of relocation considering only the portion related to housing, based on LMF's expertise, indications given by the community during the field visits and information taken from T. G. Gurung (2011)

Description	Cost estimate in NPR
Primary school	2'500'000
Gonpa	2'500'000
Community hall	3'500'000
Health service center	700'000
Mill *Only considers estimated construction costs, as all electrical equipment would be reused*	2'000'000
Youth club *Costs estimated based on costing of other public buildings*	1'500'000
(Re-) Construction of 24 houses *Including required materials and workmanship*	25'000'000
Construction of the wind barrier protection wall *Length = 400 m, height = 6 m: NPR 400/m in height and length*	960'000
Total direct costs *The cost of villagers' workmanships is not included*	38'660'000

5.2.4 Exposure of the settlement to natural hazards

Geological risks

As exposed in the section 5.5, shallow landslides along the escarpment towards the Kali Gandaki and the Dhey Chang Khola are expected which can easily be avoided by respecting a safety distance of about 15 m from the scarp to the constructible area.

Additionally, the slope which delineates the southern and southeastern border of Thangchung may be prone to rockfall. Since the whole hillside is sloped in the angle of deposition, loosened debris will merely roll or be transported down by accumulating water and deposit at the foot of the slope. Considering a safety distance of at least 20 m from the foot of the slope will respect necessary safety precautions.

Seismic risks

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

Consequently, the housing technology and house design including technical details such as connections between the wooden elements of the structure and the walls should be verified by experts before implementation in order to make sure that the structures are able to withstand foreseeable seismic solicitations. The National Society for Earthquake Technology-Nepal[8] is certainly a contact to be activated for such expertise.

5.2.5 Accessibility

In the monsoon season, when the larger rivers in Upper Mustang carry a lot of surface water, they are difficult or even impossible to cross without a bridge. In case no such crossing exists, from Thangchung, Charang is only reachable by crossing the Dhey Chang Khola (if possible), going up to Dhee, where an all-season pedestrian bridge is in place and from where Charang can be accessed. However, the Charang Khola still has to be crossed as there is no all-season bridge either. Reportedly (F. Devkota 2012, pers. comm.) a pedestrian suspension bridge crossing the Charang Khola is under construction financed by the government. At what time it will be completed remains unclear however.

Although the relocated village in Thangchung would be much closer to Charang, it would still be cut off during high flows of the rivers. A bridge over the Kali Gandaki (and also the Dhey Chang Khola if necessary) would greatly improve the situation in Thangchung in terms of accessibility. Due to the width of each of the three rivers joining in Thangchung, the bridge would have to be quite long. The narrowest spot is situated south of Thangchung with a minimal width of roughly 130 m. Whether an all-season pedestrian bridge was possible at this or another place needs to be investigated further.

5.2.6 Energy concept

A possible relocation also offers the possibility to implement a locally adapted, sustainable concept for energy provision, such as using wind or micro-hydropower for instance. As the water has to be brought up to the elevated plain of Thangchung, the excess water could

[8] www.nset.org.np

easily be used to produce electricity (section 5.2.5). However, in the scope of this study, such a concept is not elaborated.

5.3 Glaciers

Thangchung, the designated area for the planned relocation of Dheye is situated in a glaciated catchment. The glaciers play a major role, not only from a water resource point of view, but also related to present and future exposure to natural hazards. Although the settlement area itself is elevated and is therefore safe from any natural hazard triggered by the dynamics of the glaciers, the orchard situated on the left bank of the Dhey Chang Khola could be affected. Therefore the present state and future trends in glaciation of the Dhey Chang catchment have to be addressed.

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

5.3.1 Glaciation area and volume

Current state
The Dhey Chang Khola, which merges the Kali Gandaki and the Charang Khola next to Thangchung, has glaciated headwaters (Figure 5.6). Using Google Earth Pro, the current glaciation area could be approximated. Linearly segmenting the non-linear relationship between glacier area and its corresponding volume given by Huss et al. (2008), the glacier volumes could be calculated. In fact, the surface area of each distinct glacier mass was measured, and with the corresponding linearized relationship, the ice volume of each glacier piece could be approximated. In the end, the total ice volume was obtained by summing up the separately estimated volumes. In this way, the glaciated area of Thangchung was estimated to be roughly 45 km^2 with a corresponding total volume of about 3.42 km^3. Consequently, about 12 % of the total catchment area of Thangchung (366 km^2) is currently glaciated.

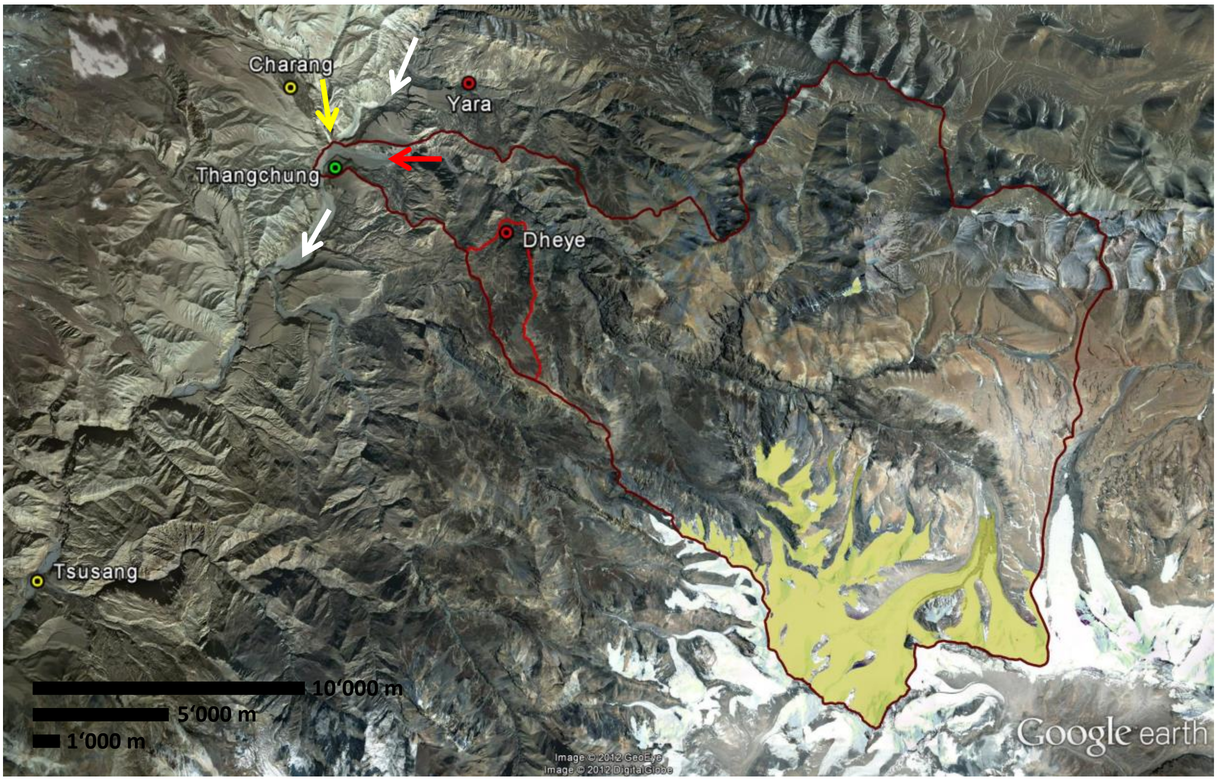

Figure 5.6: Catchment of the Dhey Chang Khola (dark red polygon). The glaciated area is dyed in yellow. The current location of Dheye is highlighted together with the corresponding catchment area (bright red polygon). Thangchung is situated close to the confluence of the Dhey Chang Khola (red arrow) and the Charang Khola (yellow arrow) with the Kali Gandaki (white arrows). North direction is ↑ (source: Google Earth Pro, accessed 27/11/2012).

Past and future trends

The direct comparison of the present with past glacier extent could not be done in the scope of this study. However, compared to the glaciated area in Namashung for instance, the catchment of the Dhey Chang Khola reaches to considerable higher elevations and the glaciers are more massive, underlined by the estimated volume of about 3.42 km^3. This suggests that the area will certainly stay (partly) glaciated within the current century.

Furthermore, "before-after" observations between 1978 and 2011 by Giovanni Kappenberger of glaciers seen from Thorung Peak revealed the following: Looking west into the mountain range above Samar which extends northwards to the glaciated catchments of Namashung, showed a very significant decrease in glaciation. This is in accordance with the decrease of the corresponding glaciers substantiated by satellite pictures in Bernet et al. (2012). From Thorung Peak looking east however, the corresponding glaciers, which are more massive generally, have retreated much less. It is certainly possible therefore, that the glaciers of the Dhey Chang Khola, which are situated only about 20 km northeast thereof, have decreased only slightly in a similar way.

5.3.2 Glacier Lake Outburst Flood potential

Past flood events

Generally, polythermal (or cold) glaciers, typical for this region, can develop hidden, inglacial lakes. Such lakes are neither commonly known nor well documented in literature, since they are often not visible, which makes it difficult to observe them and to study, understand and predict their behavior [9]. Apparently, meltwater enters the glacier and forms an internal lake, which can burst out and result in Glacier Lake Outburst Floods (GLOFs). Since these lakes are not well understood their risks are very difficult to assess.

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

Future events

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

Additionally, sudden flood events triggered by landslides which could dam the Dhey Chang Khola, are could also occur in the future (section 3.5.2).

In any case, extreme flood events, particularly sudden floods with flood waves, could endanger whole Chawale, the plain on the left of the Dhey Chang Khola close to the confluence with the Kali Gandaki, which is only slightly elevated relative to the active riverbed. Consequently, all constructions including orchards (section 5.1.4), buildings as well as the proposed water supply pipeline to Thangchung (section 5.4.4) will be potentially at risk for instance.

5.4 Water resources

The situation in Thangchung differs substantially from the old village of Dheye, particularly related to water availability. In the following the water demand is assessed, the characteristics of the catchment are described and recommendations for the water supply are presented.

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

5.4.1 Water demand

The water demand for the new location is considerably larger than the values assessed for the existing settlement (section 3.4.1), since a total population of 157 instead of 99 inhabitants are considered due to the wish to accommodate the ten recently dislocated families in Thangchung as well (section 3.1.1). For the domestic water demand an average value of 30 l/p/d within the presented range in Wacker and Fröhlich (1997) is taken. Therefore, the daily demand equals to 4710 l/d for the whole village of 157 people. It is recommended to install a tank able to store the daily demand, so that the abstracted water is buffered and can be used efficiently. The required water flow is therefore 0.055 l/s or 3.3 l/min to cover the domestic water demand including water for drinking and cooking purposes, as well as personal hygiene. The demand for washing clothes is excluded, since this could be done in the irrigation channels of the designated field area as is the local practice.

Analogous to the calculation of the irrigation demand in Dheye (Table 3.7) the required irrigation flow is elaborated for Thangchung. The only difference is that instead of a generic value of field area per capita the actual measured potential field area (13.71 ha) is considered. This value considers the available field area as outlined in T. G. Gurung (2011), respecting a minimum distance to the escarpment of 15 m and 20 m to the foot of the steep hill flank respectively (section 5.5). As the water flow during the night could be used for producing power for instance, the demand should be met by an unbuffered supply during an operation of roughly 10 hours per day. In this way, the required demand for agricultural activities in the field area of Thangchung is 13 l/s. Note that this demand is limited to the growing season including pre- and post-season, as outlined in section 3.4.1.

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

5.4.2 Water sources

Right next to Thangchung, the Dhey Chang Khola and Charang Khola merge with the Kali Gandaki. All catchments are glaciated and would generally provide the possibility to extract water for the desired purpose. However, for all three cases a technical solution is necessary, since Thangchung is elevated against the valley bottom, so that the provision by traditional water management systems such as earthen, hand-dug open channels is not possible. At this stage it seems easiest to tap the water from the Dhey Chang Khola. The feasibility of tapping water from the Charang Khola, by bridging the Kali Gandaki, or abstracting water from springs in the vicinity or the direct river flow and pumping it up to Thangchung would have to be studied further.

The draining area of the Dhey Chang Khola is roughly 366 km^2. The lowest point of this catchment is at an elevation of 3276 m asl. The highest point in the catchment is the Khumjungar Peak with a height of 6759 m asl. As exposed in section 5.3.1, the glaciated area measures currently roughly 44 km^2 which corresponds to a glaciated portion of 12 % relative to the whole catchment area.

5.4.3 Water regime

The perennial flow of Dhey Chang Khola is strongly linked to the melting dynamics of the glaciers in the catchment. Additionally precipitation during the monsoon season influences the river dynamics.

As an example, the measured discharge of the Kali Gandaki, as well as the precipitation, both measured in Jomsom, are shown in Figure 5.7. The dynamics of the Dhey Chang Khola are assumed to be similar[10] to the observed behavior of the Kali Gandaki in Jomsom. There is a low flow period during the winter months and heavily increasing flows during the melting season, even accentuated by the monsoon precipitations, which have a substantial fraction of rainfall due to the much higher associated temperatures during the season. On the other hand the precipitation events during winter are mostly in form of snowfall due to the low temperatures. This also explains that the discharge of the Kali Gandaki is not directly influenced by the corresponding precipitation events during the winter months (Figure 5.7).

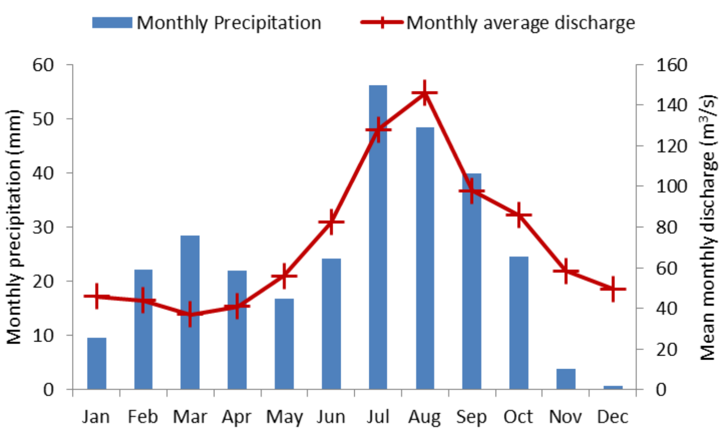

Figure 5.7: Measured average precipitation and discharge for the years 2002 to 2007 in Jomsom, Mustang (source: DHM, Kathmandu, Nepal. Discharge: station number 403; precipitation: station number 0601). Note that only the years 2002 to 2007 were considered, since the discharge records are very inconsistent in the preceding years. Also, the precipitation values are not representative for northern villages such as Dheye, since there is a large gradient from Jomsom northwards. Dheye appears to be substantially drier than Jomsom (section 3.3.4).

5.4.4 Water supply

Generally, one single system transporting all necessary water up to Thangchung is thinkable, but also two independent systems for drinking and irrigation water are possible. Additional-

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

ly, if a bridge over Kali Gandaki connecting Thangchung to Charang were to be built (section 5.2.5) the bridge could be efficiently used for transporting irrigation (and/or drinking water) to Thangchung. The different options have their inherent pros and cons, but in any case, the water supply system should be integrated into the whole resettlement plan and be elaborated as a whole, in order to use as many synergies as possible.

In the following possible water supply systems are discussed. Note that in the scope of this study, different options are only sketched. More detailed investigations and planning are required to evaluate the best possible solution and ultimately to implement it thereafter.

Domestic water supply

As observed during the field work separate supply systems for domestic and irrigation purposes are common. Though this makes sense from a water availability point of view, since the rather marginal domestic demand is often met by tapping springs which are less subject to annual flow variability, the implementation of such a scheme seems rather difficult in Thangchung. Nevertheless, different options are outlined in Table 5.4. The options vary in cost range, degree of technical sophistication, maintenance and operation requirements, supply security, social acceptance and other inherent aspects. As mentioned before, the different options would have to be elaborated in detail. It is important however, that the social acceptance of the system is given due consideration.

Irrigation supply system

The irrigation water could theoretically be taken from each of the three rivers Kali Gandaki, Dhey Chang Khola or Charang Khola to meet the water demand as mentioned in section 5.4.2. However, only abstracting water from the Dhey Chang Khola is considered in the scope of this study, as the feasibility of other options require further field investigations and are likely to be more difficult and costly to implement. In the following a possible way how to bring the water to the plateau of Thangchung is sketched.

Before the Dhey Chang Khola merges the Kali Gandaki, roughly 3 km upstream, the river passes a narrow cut. Just afterwards the valley opens up, where the river has dug a lowered active riverbed which is about 250 m wide. The left riverbank, named Chawale, is constituted by a 6 to 8 m high scarp consisting of alluvial deposits. Towards the junction the scarp is decreasing gradually in height.

Table 5.4: Qualitative assessment of different sources for the domestic water supply at Thangchung.

ID	Source	Way of transport	Issues	Pros	Cons
D1	Perennial flow of the Dhey Chang Khola	Pressure pipe (conjunctive use for irrigation and domestic purposes)	➢ Pressure pipe necessary (section 5.4.4) ➢ Required treatment of abstracted river water ➢ Operation, maintenance of water treatment ➢ Water very rich in particles during melting season ➢ Operation of system during winter ➢ System's (particularly water abstraction's) flood security	✓ Conjunctive use (irrigation and domestic purposes) economically reasonable ✓ Yield expected to be sufficient even during winter months ✓ Easier maintenance and operation, due to conjunctive use	× Direct river water abstraction and use not very well accepted by people × Water treatment requires technology which is uncommon in the area × Abstraction prone to flood damages × General exposure of the system to extreme flood events × Due to single system for domestic and agricultural purposes, not redundant in case of failure
E1	Perennial flow of the Dhey Chang Khola or Kali Gandaki	Pumping abstracted river water up to the settlement	➢ Same as D1 ➢ Operation and maintenance of technical installations	✓ Same as D1 ✓ Short transportation route due to direct pumping	× Same as D1 × Pumping requires power source (solar, wind, grid power)
F1	Present drinking water spring located in the Tangge Khola catchment	Pressure pipe including numerous pressure reduction basins	➢ Height difference (ca. 935 m) between abstraction (4315 m asl) and settlement (3380 m asl) ➢ Required length of roughly 9 km ➢ Freezing, bursting of pipeline ➢ Maintenance	✓ Expected good quality of spring water ✓ Tapping of spring water well accepted by the people ✓ Water abstraction not very susceptible to flood damages	× Intensive maintenance expected, particularly due to large expected length of the pipeline and big height difference × Operation in winter probably not possible × Pressure reduction basins required
G1	Spring below Charang	Pressure pipe, including few pressure reduction basins depending on exact location of the spring	➢ Kali Gandaki has to be crossed ➢ Farming in Charang might influence water quality ➢ Freezing, bursting of pipeline ➢ Location and yield of spring unknown	✓ Same as F1 ✓ Rather short, direct pipeline ✓ If pedestrian bridge over Kali Gandaki were to be built, easy accommodation of drinking water pipeline	× Crossing of Kali Gandaki difficult × Socially delicate issue, due to reported[a] differences between people of Charang and Dheye

[a] According to video anthropologist Fidel Devkota (F. Devkota 2012, pers. comm.), who wrote his master thesis (Devkota 2011) about climate change and its socio-cultural impact in the Himalayan Region and Dheye in particular, and is currently working on his PhD on a related topic.

In terms of normal flooding, the elevated valley bottom delimited by the before mentioned scarp seems to be safe from direct inundation. The floods could however erode the scarp, which might be a threat to any construction in Chawale close to the escarpment. Furthermore, exceptional floods (e.g. GLOFs or other sudden floods) could presumably overflow the elevated plain directly. Generally, the risk of flooding has to be studied in more detail, especially related to the construction of a sustainable, well designed water supply system.

Currently there is a water abstraction just after the Dhey Chang Khola passed the mentioned narrow cut. This abstraction is used to provide water to the orchard plantation. The abstraction (Figure 5.8) was dug with the purchased dozer (section 5.1.4) and transports the water on top of the elevated plain (Chawale) on which it is directed to the orchard.

At a safe distance from the scarp, but as high up as possible, part of the abstracted water could be captured. As the river water is rich in transported sediments, a settling basin should be installed to rid the water from most particles to make sure the following installations are not congested. From there, the water could be directed into a pressure pipe leading up to Thangchung (Figure 5.9). Thereby no pump is necessary, but one of the crucial parameters is the height difference between the inflow and the outflow of the pressure pipeline. During the field work, the height difference could not be evaluated in detail due to a lack of appropriate measuring devices (Table 5.5).

Generally, the bigger the actual height difference between the hypothetical start and end point of the pipeline is, the better. A measure aiming exactly in this direction has been completed in summer 2012. Into the northeastern corner of Thangchung a trench of roughly 8 m depth has been dug, which effectively increased the height difference.

At the end of the pipeline a small basin is recommended. From there, the water can be distributed to the field level with traditional, open, hand-dug, earthen channels.

As mentioned before, a settlement basin is suggested before the water is routed through the pressure pipe to prevent congestion[11]. Therefore, the water in Thangchung should already be of improved quality. Therefore, it would be quite easy technically to incorporate the drinking water supply. To enhance the water quality further and make it suitable for domestic uses, a simple, low-cost and easily maintainable bio-sand filter could be installed.

[11] Furthermore, a drain should be accommodated at the lowest part of the pipe, so that the pipe can be flushed and accumulated particles could be easily and effectively removed.

Figure 5.8: Existing water abstraction which is supplying the newly built orchard with water. The flow direction is indicated with the blue arrow. Due to high flow of the Dhey Chang Khola at the end of June, the intake was damaged and put out of operation. According to the local people, the intake will be reactivated in February next year. Thangchung, located roughly 2 km further downstream, is highlighted with an orange arrow (photo: 13/05/2012, Daniel Bernet).

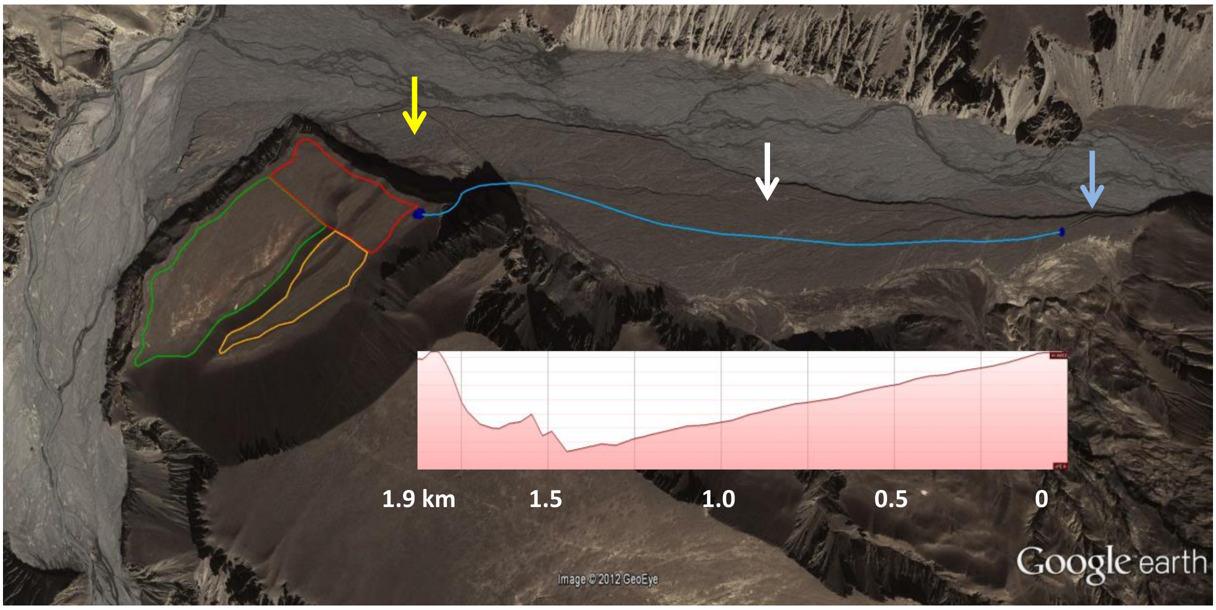

Figure 5.9: Possible location of the pressure pipe transporting the water from the existing water abstraction (blue arrow) to Thangchung (as shown in section 5.2.1, red polygon: settlement area; green: agricultural area; orange: area of possible future expansion). The longitudinal profile of the indicated pressure pipe is indicated as well. The first roughly 1.5 km are sloped evenly, thereafter the pipe is leading steeply up to Thangchung. The white arrow highlights the clearly visible elevated left riverbank named Chawale. Furthermore, the yellow arrow indicates the orchard just below the northern end of Thangchung, which has been realized this year (source: Google Earth Pro, accessed 09/10/2012).

Table 5.5: Comparison of the approximated height difference between the start and the end of the projected pressure pipe obtained with different measurement methods: A) Two altimeters measurements on 05/07/2012, whereas the mean of the two results is recorded here; B) Measurement with a hand-held GPS instrument by Hari Parajuli, a sub-engineer of the DDC; C) Google Earth Pro (GEP). To increase the height difference, a trench of about 8 m depth was dug in June 2012. The measurement with GEP does not account for this, therefore the resulting height difference is given in brackets (source: Google Earth Pro, accessed 09/10/2012).

	A) Altimeter	B) GPS	C) GEP
Height difference *Difference between in and outflow (m)*	33	17	6 (14)

Concerning the outlined pressure pipe, some simple hydraulic calculations were made (Table 5.6). Since the height differences (Table 5.5) could not (yet) be verified, the parameters were varied to get an idea about the resulting flow rates depending on the chosen parameter set. The calculations revealed that it is certainly feasible to bring up a sufficient amount of water to Thangchung by means of gravity assuming that the start of the pipeline is in fact located on higher ground than the end.

Table 5.6: Results from preliminary hydraulic calculations concerning the described pressure pipe supplying water to Thangchung. A water temperature of 4°C has been assumed, which gives a dynamic viscosity of $1.57 \cdot 10^{-6}$ m^2/s. The calculations were done according to Colebrook and White, as described in Bollrich (2007).

Parameters and variables	#1	#2	#3	#4	#5	#6
Height difference (m)	10	15	15	15	15	15
Pipe diameter (mm)	150	150	200	250	300	300
Pipe roughness (mm)	1	1	1	1	1	1.5
Total pipe length (m)	2’000	2’000	2’000	2’000	2’000	2’000
Resulting flow rate (l/s)	12	14	31	55	89	84

The results of the simple calculations summarized in Table 5.6 show that the most sensitive parameter is the pipe diameter. In fact, the total energy loss is increasing by the fifth power of the diameter if the latter is decreased (Gujer 2006). Therefore, choosing a small pipe will increase the losses immensely leading to a heavily decreased flow rate. Also the height difference is quite sensitive, as an increase of 5 m (50 %) led to a calculated increase of the flow rate of 17%. The roughness is less important, as an increase of 0.5 mm (50 %) resulted in a 6 % lower flow rate.

A necessary, more detailed study should focus on optimizing the hydraulics in terms of increasing the flow rate, while minimizing cost. As shown above, this is not a simple task as varying the diameter is very sensitively affecting the flow rate as well as the total cost, especially because the length of the pipeline is rather long.

Furthermore, it should be checked, if cheaper PVC pipes could be used. Given the length as well as the high associated water pressures, particularly related to opening and closing the pipe[12], iron pipes are likely much more suitable. Besides, the technical feasibility (especially focusing on the construction details of the steep scarp leading up to Thangchung), financing, operation and maintenance as well as exposure to and risk of natural hazards should be elaborated.

5.5 Geological considerations

Thangchung, the plateau overlooking the main valley at the confluence of the Dhey Chang Khola and Kali Gandaki River, is formed by well cemented gravel with blocks and boulders. In northeastern and northwestern direction, the plain is confined by a steep, 30-50 m high escarpment. The scarp may be subject to shallow landslides, so that the constructible area should come no closer than 15 m to the escarpment.

The plateau of Thangchung is delimited in southern and southeastern direction by a steep hill slope, inclined by the angle of deposition. Loosened debris could roll down or be transported by accumulating stormwater and be deposited at the foot of the slope. To avoid the threat of rockfall and debris flow, a distance of at least 20 m from the foot of the slope to the constructible area should be respected.

[12] Closing and opening a pipe of such length quickly creates so called pressure surges, which can surpass the hydrostatic pressure head by manifold. It is very important to account for this if a certain pipe is chosen.

6 Moving down or not?

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

6.1 Qualitative assessment

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

The following two hypothetical future states were compared:

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

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

6.1.1 Physical characteristics

Water availability
Water availability is considered the most important issue, in particular the availability for irrigation water, as it is the driver for agricultural activities, which is central for providing the (partial) subsistence of Dheye’s inhabitants. As the demand for irrigation water surpasses the drinking water demand by manifold (section 3.4.1 and 5.4.1), the former is much more critical. Even if no springs can be found the provision of drinking water is still possible by means of simple technical solutions, which aim at sufficiently enhancing the quality of river water for domestic use. In contrast, in case the water quantity which can be abstracted and used for irrigation is insufficient, there are no direct means to increment the water yield. As the drinking water demand might still be met even if the available water for irrigation is insufficient, the criterion of irrigation water availability weights most.

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

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

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

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

[a] Assuming that the water is transported to Thangchung by gravity flow in a pressure pipe

Water quality

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

At the new location, the drinking water may be taken from the perennial river flow or from springs (section 5.4.4). The former is of lower quality compared with the spring water transported to Dheye, because the river water is very rich in suspended particles. Also possible springs around Charang are expected to be of lower quality, because the spring is believed to be fed mainly by infiltrating, degenerated water used in the village. Therefore, the drinking water quality in Dheye is expected to be favorable.

6.1.2 Water supply systems

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

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

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

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

Irrigation water supply systems

The irrigation systems in Dheye are mostly traditional, including hand-dug, open, earthen channels. At a few places plastic pipes were installed to minimize losses. Overall the technical complexity is very low. In comparison, the provision of irrigation water to the elevated plateau of Thangchung with simple, traditional means is impossible. Comparatively complex systems, such as pumping or a pressure pipeline are necessary. Consequently, the associated initial costs are much higher for the state “Move”, so that in terms of technical complexity and initial costs, the existing system is preferable.

Comparing the irrigation system of bringing river water from Dhey Chang Khola to Thangchung, as described in section 5.4.4, with the existing system in Dheye, the exposure to natural hazards differs greatly. At the relocation site, the irrigation system is exposed to devastating infrequent floods (i.e. GLOFs other sudden floods, section 5.3.2). Though the existing open earth channels in Dheye are generally less durable due to their inherent erodibility, the irrigation system in Dheye is favorable, since the exposure to natural hazards is much lower. On the other hand, maintaining the technically more advanced system in Thangchung is likely easier and most importantly less frequent. However, in case the system fails, the repair thereof could be very costly.

Overall, the relocation seems therefore clearly less favorable compared to an ameliorated situation in Dheye related to the irrigation water supply systems.

Drinking water supply systems
The provision of drinking water to the elevated settlement area at the new location is not simple (section 5.4.4). Independent from the choice of water source (spring or river water; Table 5.4 in section 5.4.4), the supply system needs to be technically more advanced, also increasing the expected costs.

For comparison, the provision of drinking water by conjunctive use of the irrigation supply system, followed by a water treatment unit is taken as a reference. In this case, the system is also exposed to infrequent but devastating sudden flood events, due to the pressure pipeline routed along Chawale.

Though the existing drinking water supply system needs some time and effort to be reactivated after each winter, the maintenance tasks are expected to be less significant compared to the provision and particularly the treatment of river water in Thangchung.

Thus, the state “Stay” is preferable overall compared with the relocation site related to drinking water supply systems.

6.1.3 Geological risks

Both locations are safe from direct flooding, and are generally not exposed to severe geological risks. In whole of Thangchung, the exposure to geological risks is very small, in case the proposed safety distances are maintained (section 5.5). Since the settlement, as well as the agricultural area of Dheye, is situated on a DSGD, the risk of adverse effects is presumably slightly larger than the overall situation in Thangchung. Therefore, the state “Move” is somewhat better situated compared to the old location in terms of geological risks.

6.1.4 Socio-economic issues and ambient conditions

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

Access to public services
Due to the location of Thangchung, in particular being close to Charang, next to the wide riverbed of Kali Gandaki, which is used as a tractor path during low flow, are clearly improving the access to public services. Though the services are still very limited in Charang itself compared to more developed villages or cities in the country, it is still a quite significant enhancement due to the exceptional remoteness of Dheye.

Opportunities for economic activities and chances related to tourism
Particularly the fact, that Thangchung is situated along the transport route frequented by tractors during low flow season of the Kali Gandaki, offers the opportunity for the people to engage in other economic activities such local trade for instance. Also the possibilities of exploiting touristic potentials are far greater at the new location.

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

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

Communal cohesion
As could be observed during the field work, the intra-communal cohesion of Dheye is very high. Meaning to say, all the interviewed people prioritized the wish of the community above personal preferences. Furthermore, according to the relocation project proposal (T. G. Gurung 2011), the already dislocated families are supposed to rejoin the community (section 3.1.1). It seems very important for the people of Dheye that the community stays together.

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

Access to natural and energetic resources
The access to resources in general seems more favorable due to the proximity to other villages, the location next to a transport route and due to the much better physical accessibility. Only firewood might be more difficult to gather as the resource is scarce already and will become further stressed due to an increased competition after relocating. However, the former locations could still be exploited, even though the distances to the firewood sources as well as the transport routes will certainly increase. In any case, the scarcity of firewood

could also be counteracted by purchasing gas, which would be available easier due to the improved accessibility. Additionally it would be possible to increase the own wood production due to increased irrigation water availability.

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

6.2 Summary

From a strictly quantitative point of view (9 in favor of "Stay" against 8 for "Move" with 3 neutral qualifications) the relocation is rather neutral. However, as mentioned before, each issue weights differently, so that the quantitative summary is not representative. In fact, based on the preceding (section 6.1 and Table 6.1), the prospect of "Moving" seems favorable. In particular, the most important issue, namely the irrigation water availability is considerably better for the state of a relocated community in Thangchung.

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

Therefore, conclusively, the community of Dheye is recommended to resettle in Thangchung, by taking the issues elaborated in chapter 6.1 into account.

7 Conclusion

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

In general, a sound planning of the resettlement has to be envisioned in order to maximize opportunities and minimize the trade-offs. Along the same lines, further planning, as well as recommended further investigations is considered to be essential. Otherwise the resettlement may induce non-optimal or even adverse consequences. In particular, the unresolved issue related to the provision of water to Thangchung has to be mentioned. It is believed that the community would initiate the moving process, under the lead by the internal local leadership, by themselves once the best solution is identified and planned. Besides, other issues need further elaboration, as summarized in the following:

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

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

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

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

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

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9 List of figures

10 List of tables

A Settlement and habitat

A.1 Settlement layout of Dheye

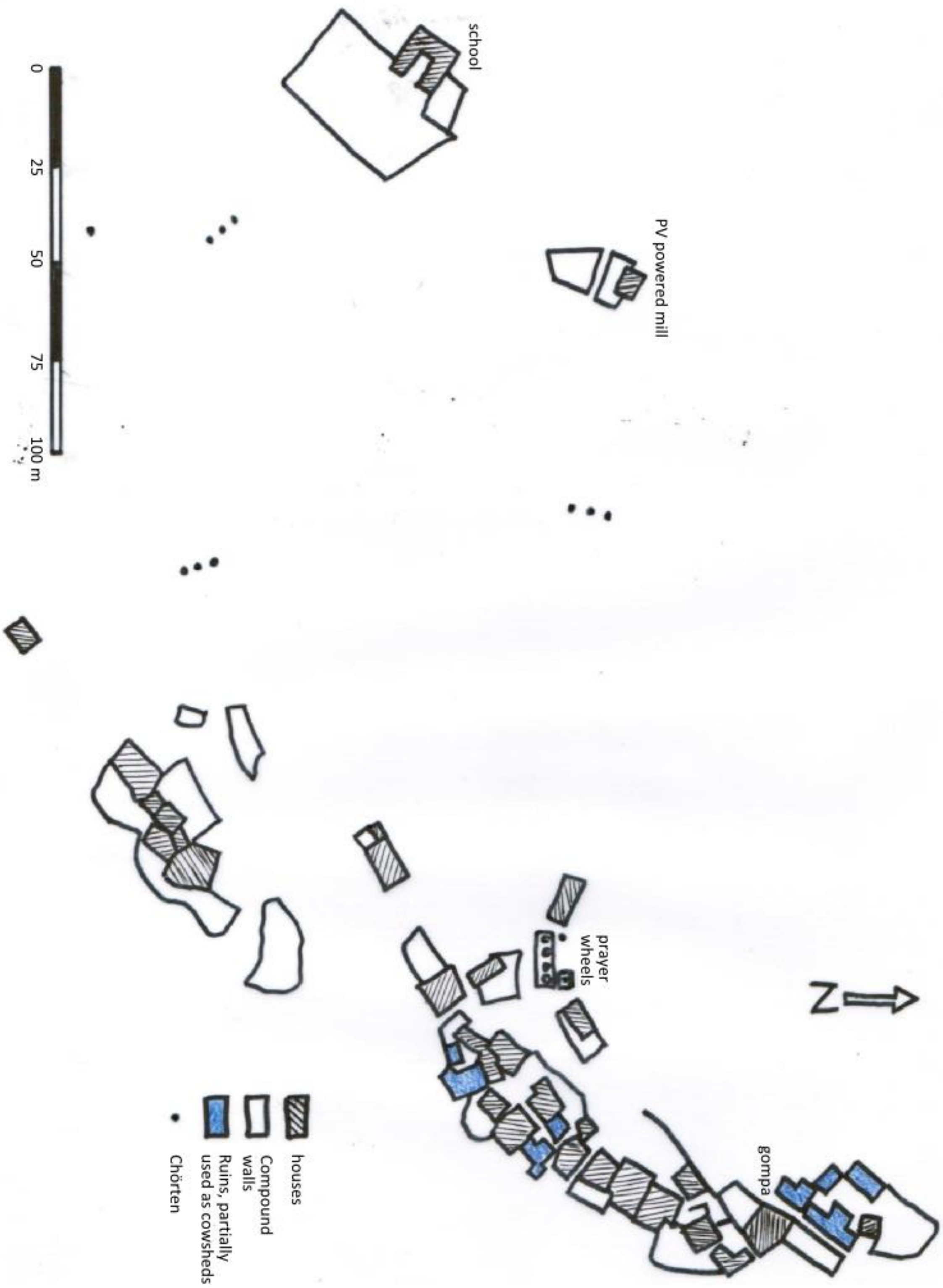

Figure 10.1: Schematic map of Dheye (drawing: 06/07/2012, Daniel Pittet)

A.2 Typical house layouts

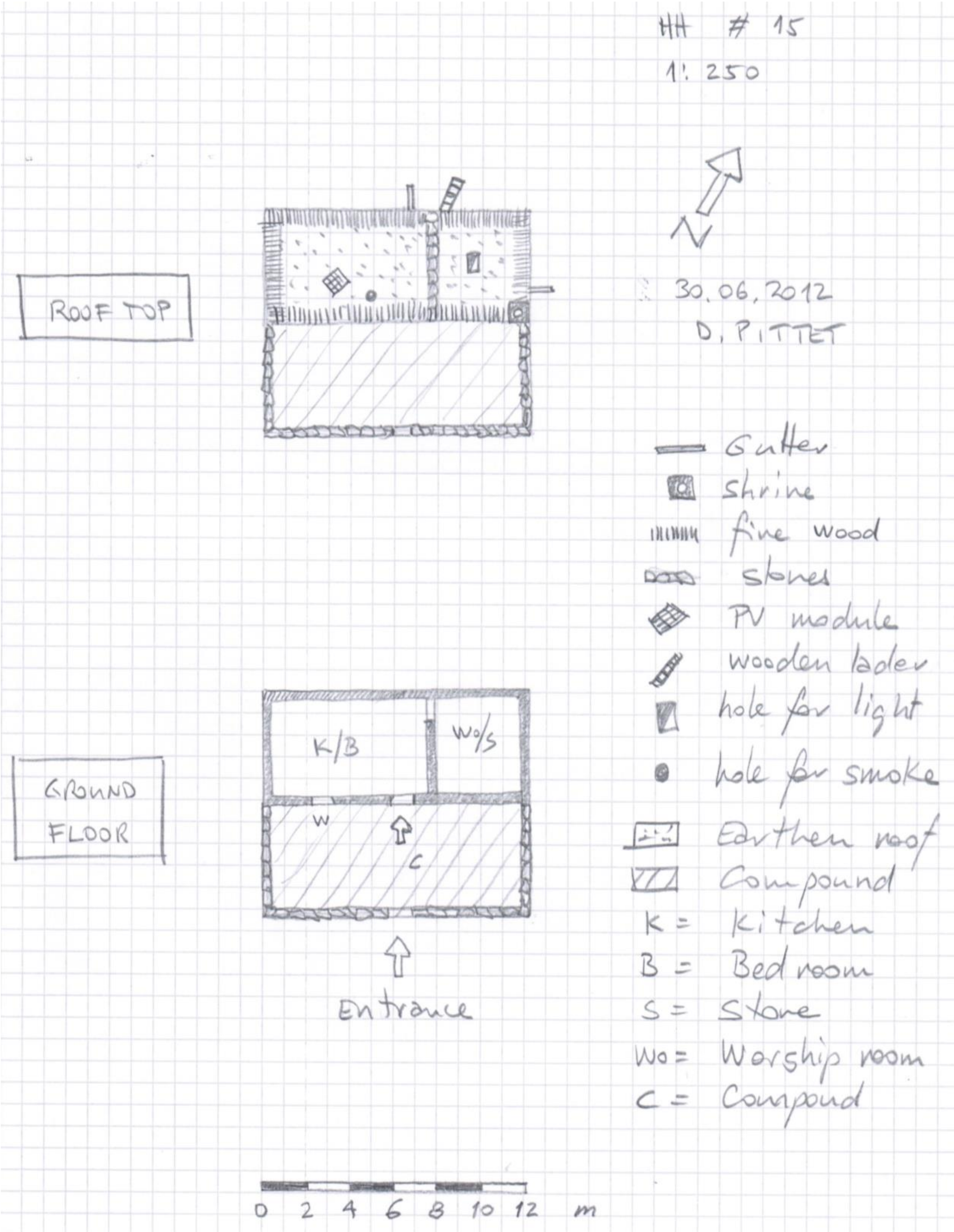

Figure 10.2: Representation of a dwelling from Samzong taken as a reference for a typical small house (hand drawing: 30/06/2012, Daniel Pittet).

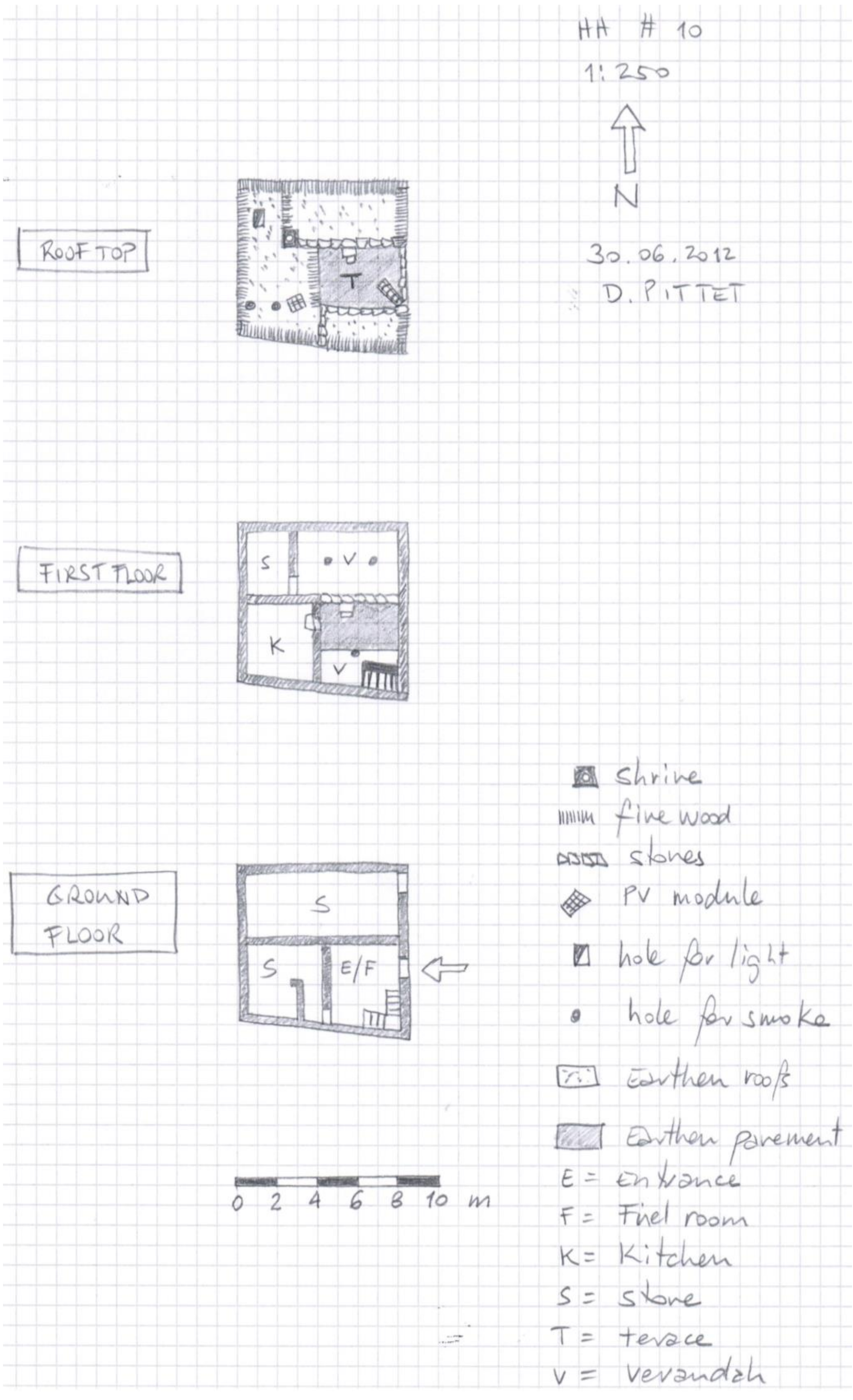

Figure 10.3: Representation of a dwelling from Samzong taken as a reference for a typical medium sized house (hand drawing: 30/06/2012, Daniel Pittet).

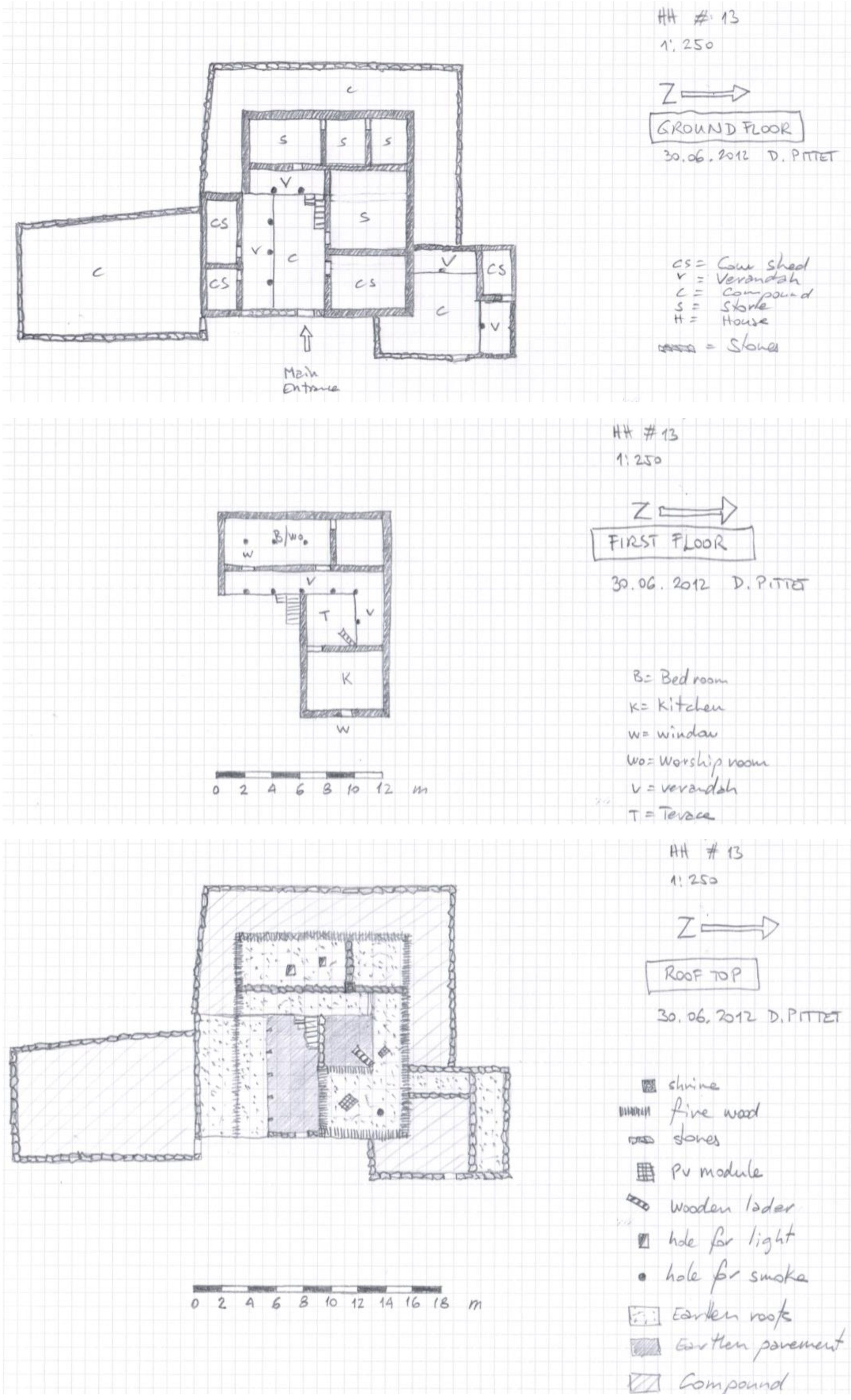

Figure 10.4: Representation of a dwelling from Samzong taken as a reference for a typical large house (hand drawing: 30/06/2012, Daniel Pittet).

A.3 House composition

Table 10.1: Composition of the houses in Dheye. The fractions (0.5 and 0.33) indicate that the functions are shared in a same room (e.g. in HH number 3, the kitchen, the workshop and the veranda are the same room).

HH number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean
No. of rooms	**5**	**10**	**10**	**8**	**10**	**11**	**4**	**4**	**6**	**2**	**3**	**11**	**5**	**12**	**7.21**
Kitchen	1	1	0.33	0.5	1	1	0.5	1	1	0.5	1	1	0.5	1	**0.81**
Store room	1	4	3	4	3	4	3	1	3	1	1	3	3	5	**2.79**
Bedroom	1	2	2	0.5	2	1	0.5	1	1	0.5	1	1	0.5	2	**1.14**
Worship room	1	0	1	1	1	1	0	0	0	0	0	1	0	1	**0.50**
Fuel room	0	1	2	1	1	1	0	0	0	0	0	2	1	1	**0.71**
Workshop	0.5	1	0.33	0	0.5	0	0	0	0	0	0	0	0	0.5	**0.20**
Veranda	0.5	1	0.33	1	0.5	2	0	1	1	0	0	2	0	0.5	**0.70**
Cowshed	1	1	1	1	0	0	1	0	0	0	1	1	0	2	**0.64**
Goatshed	0	0	0	0	0	1	0	0	0	0	0	1	0	0	**0.14**
Horseshed	1	1	1	1	0	0	0	0	0	0	0	1	0	1	**0.43**
Toilet	0	0	1	0	1	1	0	0	0	0	0	1	0	1	**0.36**
Compound	1	1	1	1	6	5	0	1	2	0	2	0	2	2	**1.71**

B Meteorology and climate

B.1 Visualized cultivated and abandoned fields

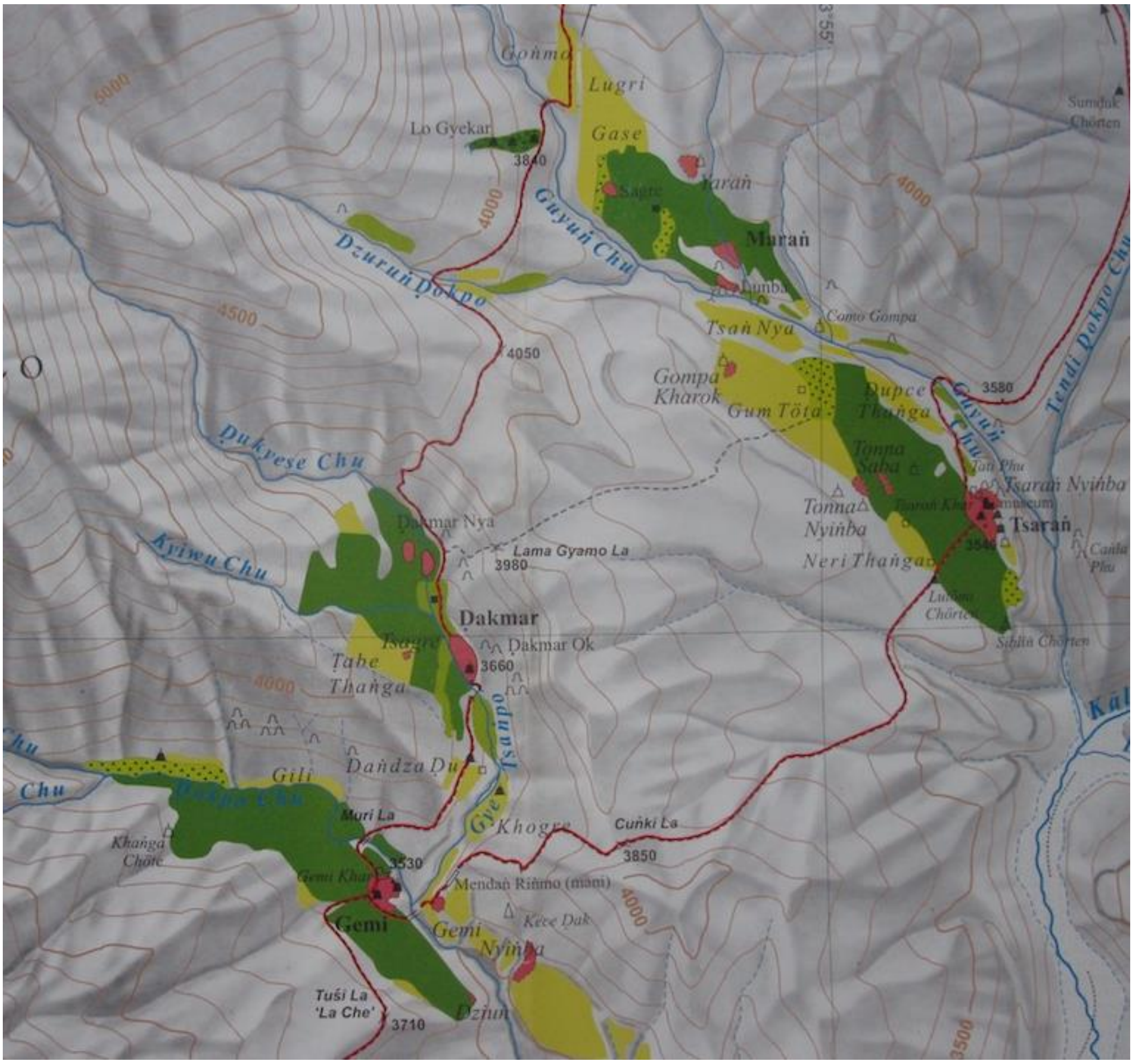

Figure 10.5: Abandoned fields (yellow-green) around Gemi (Ghami), Dakmar and Tsaran (Charang) on a thematic map of Upper Mustang by Kostka (2001), based on satellite information from 1990 and 1984. The dark green areas (including textured surfaces) indicate cultivated land. North direction is ↑.

B.2 IPCC scenarios

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

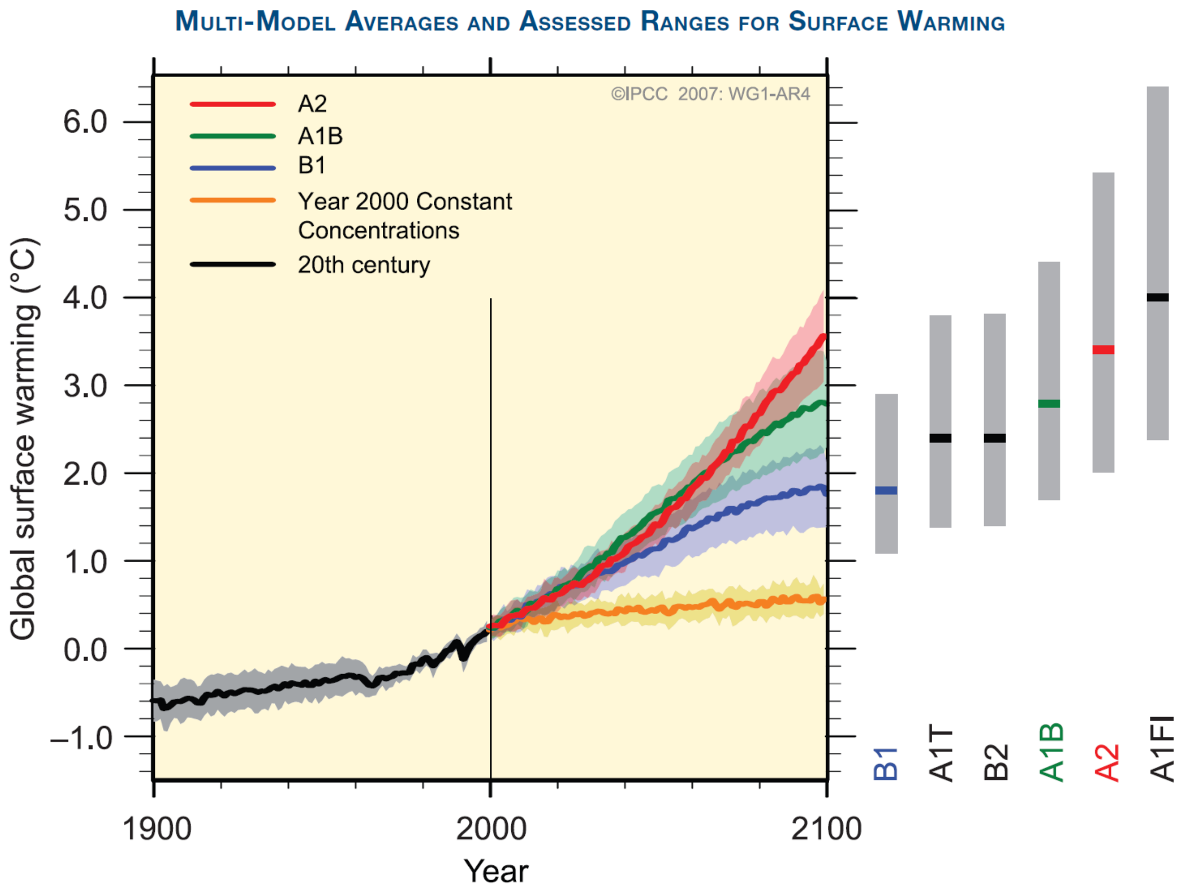

Figure 10.6: Multi-model averages and assessed ranges for surface warming, taken from IPCC (2007b): "Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1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

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

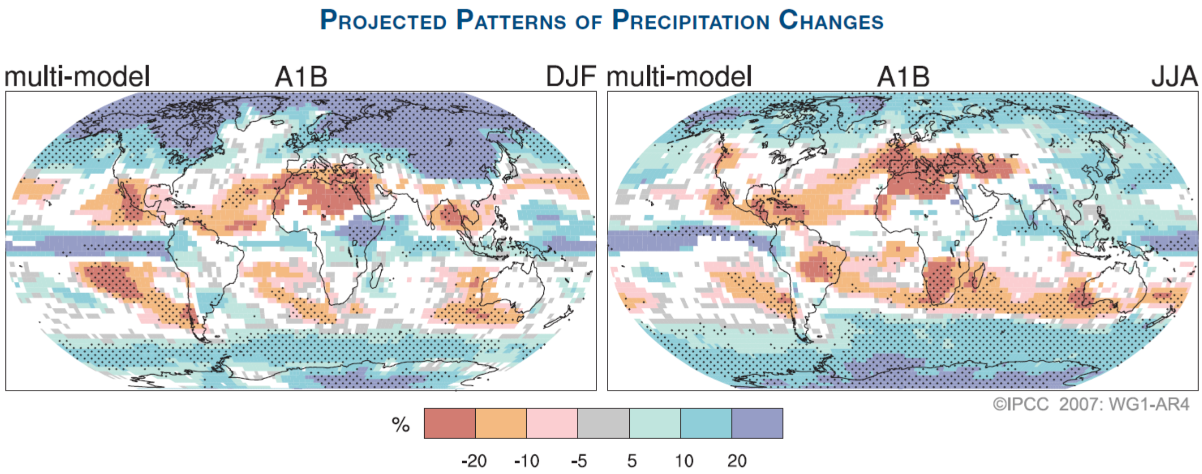

Figure 10.7: Projected patterns of precipitation changes, taken from IPCC (2007b): "Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right).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

B.3 Temperature interpolations for Nepal

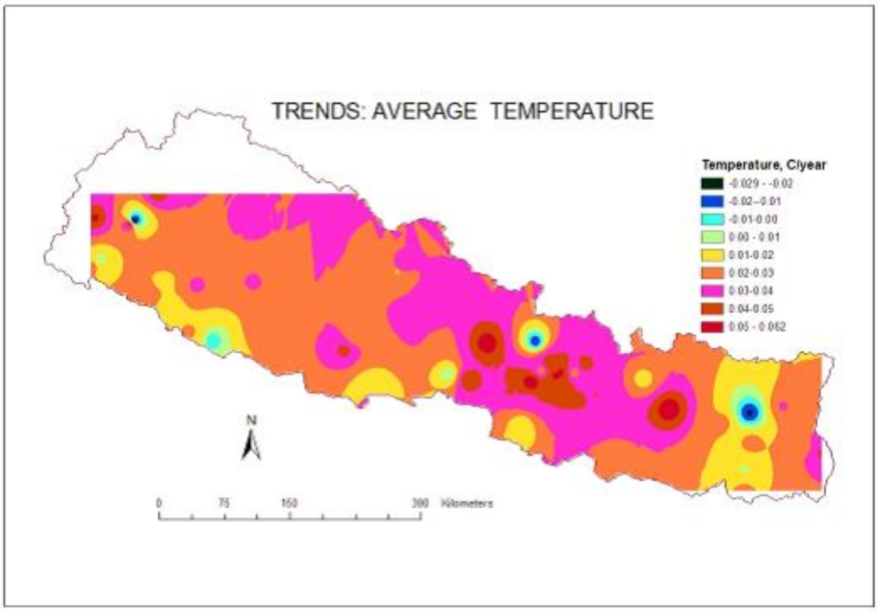

Figure 10.8: Trends of average temperature in Nepal in °C/year from 1975 to 2006 (Sharma 2009).

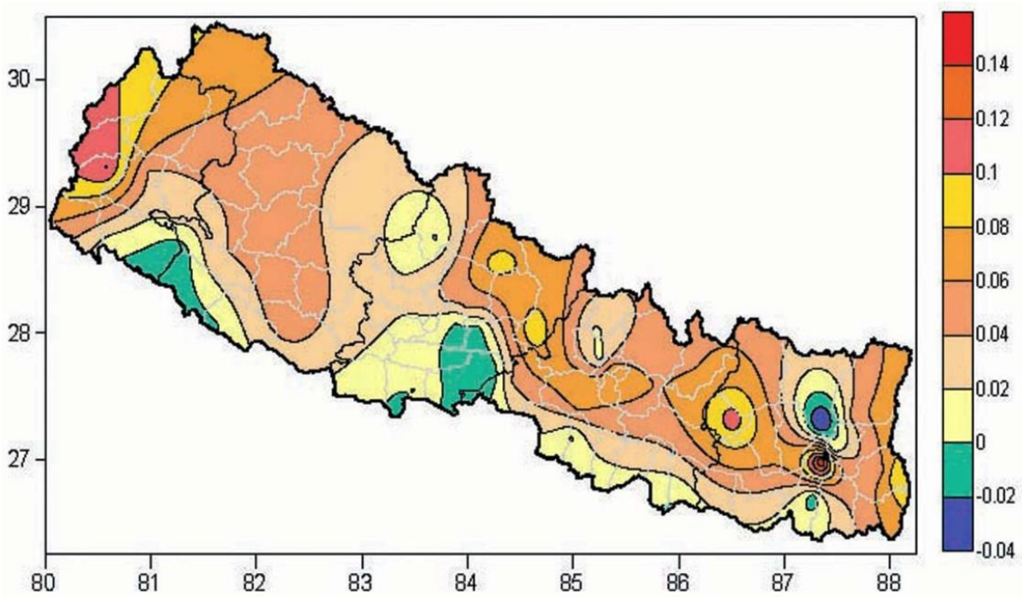

Figure 10.9: Trends of average temperature in Nepal in °C/year from 1976 to 2005 (Practical Action 2009).

B.4 Yearly precipitation sums in southern Mustang

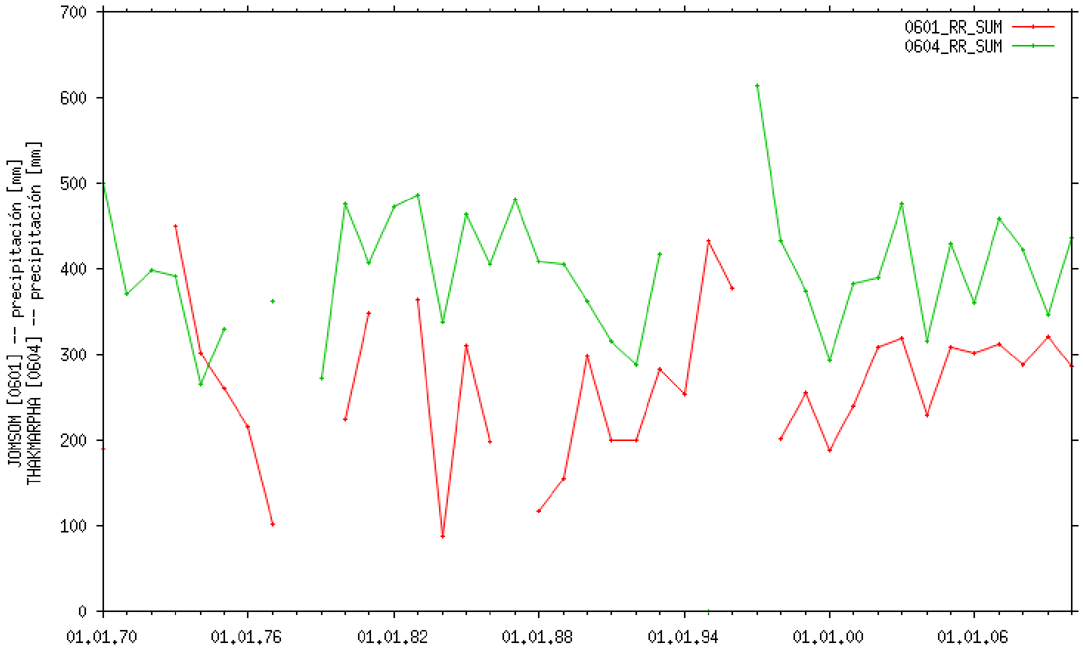

Figure 10.10: Yearly precipitation sums of the meteorological stations Jomsom (0601) and Marpha (0604), situated in lower Mustang showing no clear trend as shown and discussed in Rohrer (2012b).

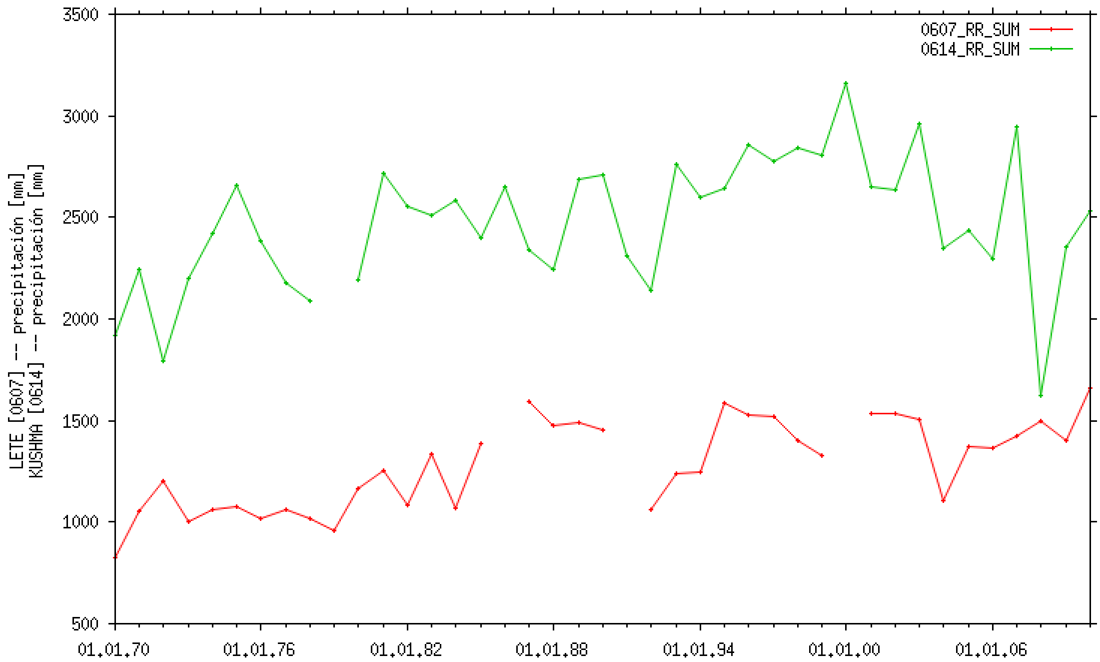

Figure 10.11: Yearly precipitation sums of the meteorological stations Lete (0607) and Kushma (0614) at the entrance of Mustang valley, situated in the south side of Annapurna showing an increasing precipitation trend which needs confirming however as discussed and shown in Rohrer (2012b).