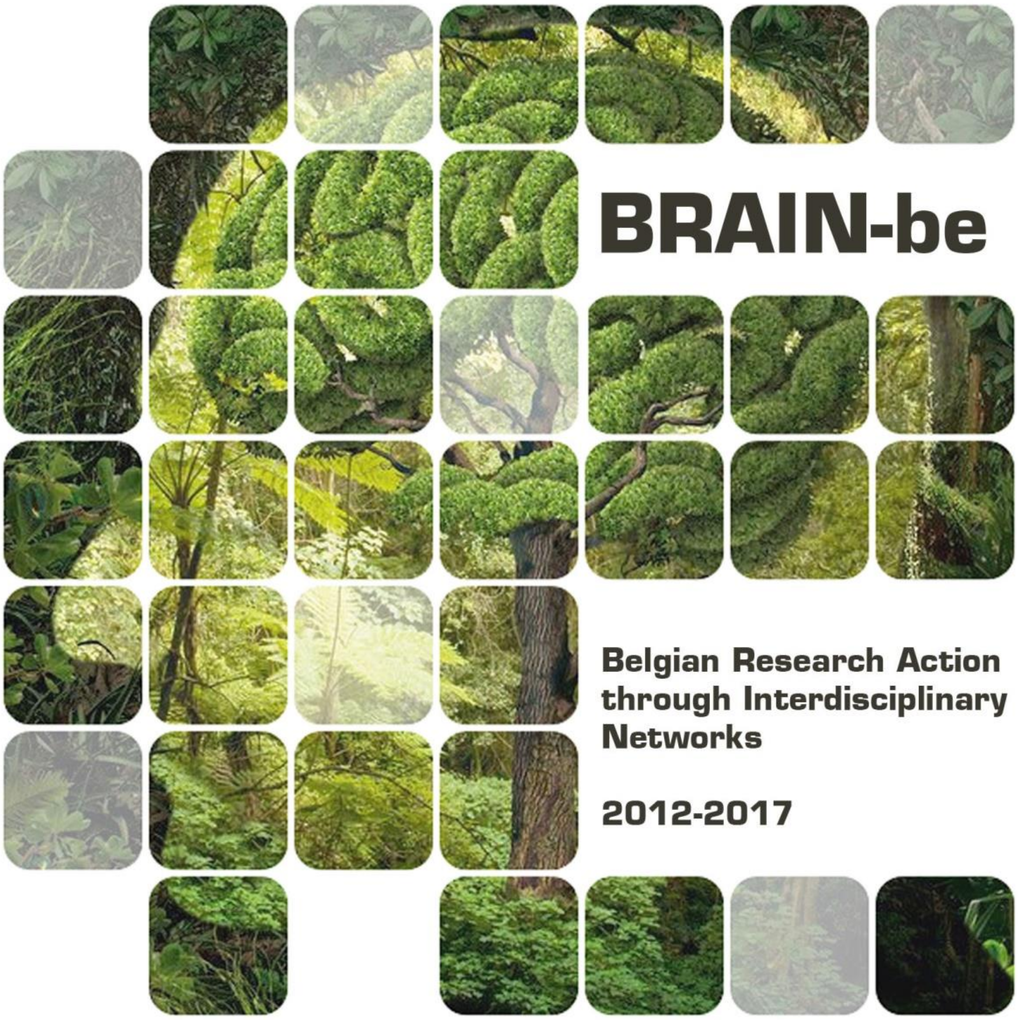


# AfReSlide

## Landslides in Equatorial Africa: Identifying culturally, technically and economically feasible resilience strategies

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NETWORK PROJECT

# AfReSlide

## Landslides in Equatorial Africa: Identifying culturally, technically and economically feasible resilience strategies

**Contract - BR/121/A2/AfReSlide**

## FINAL REPORT


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**TABLE OF CONTENTS**

**ABSTRACT**

Landslides cause significant impacts in many equatorial regions ranging from fatalities to damage to infrastructures and agricultural production. This problem is particularly acute in Equatorial Africa where landslide-prone environments are putting vulnerable populations at risk. However, in most of these regions little is known about the physical processes driving the spatio-temporal distribution and dynamics of landslides, the way they impact livelihoods of rural communities and how these are, or could be, mitigated using appropriate structural or policy measures. Here, we report on the results of the inter-disciplinary AfReSlide project which aimed at filling these gaps. We focus on four representative areas known for suffering from landslides in Uganda (Rwenzori Mountains, Mount Elgon) and SW and NW Cameroon (Mount Cameroon, Bamboutos caldera). Through a bottom-up approach in collaboration with the local communities via stakeholder meetings and participatory data collection approaches, we investigated how natural factors and human activities control the occurrence of landslides in space and time. Through extensive household surveys, we quantitatively analysed the socio-economic consequences of landslides and the role landslide played in land transactions. We developed a social multi-criteria evaluation with local stakeholders in order to identify risk reduction measures considered as cost-effective, technically efficient, culturally acceptable and adapted to the livelihoods of the vulnerable population. Such an analysis is crucial as it enables to provide practical recommendations for households and policy makers to mitigate landslide-related damages.

Key results of AfReSlide include detailed landslide inventories for the Rwenzori Mountains and Bamboutos caldera that serve as the basis to calibrate regional landslide susceptibility maps (Jacobs et al., 2016, 2017, 2018). An extensive literature review was accomplished to identify the currently implemented and recommended landslide risk reduction strategies in the tropics (Maes et al., 2017a). Currently implemented and potential resilience strategies at household and at policy levels were documented in the Rwenzori (Maes et al., 2017b). The households' survey highlighted a significant loss of income for farmers in the years following landslides (Mertens et al., 2016). It also demonstrated that farmers are generally well aware of their exposure to landslide hazards, but do not often feel empowered to implement simple risk reduction measures such as planting trees (Mertens et al., 2018). The management of the risk through decentralized risk management platform in Uganda (Maes et al. 2018), and risk zonation policy around the city of Limbe, SW Cameroon, were analysed critically based on focus group discussions with local actors. The multi-criteria analysis highlighted the need to give much more attention to local culture and livelihood practices before selecting disaster risk reduction measures. The findings from AfReSlide are not only of potential use in the target regions but also in other, similar environments.

**Keywords**: Landslides; Risk; Resilience; Equatorial Africa

# 1. INTRODUCTION

Landslides cause significant impacts in many equatorial regions. Their impact depends on their size and speed, the elements at risk and the vulnerability of these elements. This problem is particularly acute in Equatorial Africa characterized by mountainous topography, intense rains, deep weathering profiles, high population density and high vulnerability to geohazards. Every year landslides cause fatalities and result in structural and functional damage to infrastructure and properties. Losses from landslides are expected to increase in the future in response to the demographic pressure causing more development in landslide-prone areas (LSPA), deforestation and associated changes in land use and land cover, and the changing climate causing higher or more intense rainfalls.

Many studies investigated how natural factors and human activities control the occurrence or reactivation of landslides. These studies typically delivered susceptibility maps, but these are insufficient to lead to efficient risk management. In addition to accurate information on the spatial distribution and frequency of landslide, effective landslide risk reduction requires to quantitatively analyse the socio-economic consequences of landslides on household's livelihood and their influence of the land market, to consider the cultural representation of these disaster taking into account the local system of beliefs and to identify appropriate risk reduction strategies that are cost-effective, technically efficient and that are culturally acceptable and adapted to the livelihoods of the vulnerable population. Such an analysis also needs to consider the institutional and political context of the risk management. Such an integrated approach, involving the population exposed to the risk and stakeholders managing it through participatory methods, is crucial as it enables to provide practical recommendations to these end-users to mitigate landslides-related damages.

This project focuses on four representative study areas known for having suffered severely from rainfall-triggered landslides in Uganda (Mount Elgon, Mount Rwenzori) and SW and NW Cameroon (Mount Cameroon, Bamenda). These regions were already identified as landslide prone prior to AfR*e*Slide and some preliminary studies on landslides inventory and/or susceptibility had been carried out, while no information was available on the socioeconomic impact of landslides, the role of cultural beliefs in the interpretation of disaster nor on the implemented risk reduction strategies at household or policy level and their effectiveness. The AfR*e*Slide project followed a bottom-up approach where the specific research questions, the collected scientific data and research outputs were designed in collaboration with, and according to the needs of, the local communities and stakeholders via stakeholder meetings, organized from the start of the project in January 2014, and participatory data collection approaches.

Information on landslides is far more limited in Equatorial Africa compared to other continents. There are very few data at the continental and regional scale and it is difficult to have a clear picture of the total area affected. A key challenge and objective of AfR*e*Slide project was therefore to develop a methodology to identify appropriate risk reduction measures and policies this data-poor environment. The specific objectives of the AfR*e*Slide project were (Fig. 1-1): 1. to produce landslides susceptibility maps for four representative study areas; 2. to analyse the types of elements at risk (immaterial and material) and their exposure, and to develop a methodology to economically value the consequences, 3. to assess current and potential resilience strategies at household and at policy levels; 4. to analyse the cultural premises underlying perceptions of environmental threats, to describe land rights and land management, and to identify culturally acceptable resilience strategies;

5. to produce risk maps and provide a methodology to identify the most effective disaster risk reduction strategies.

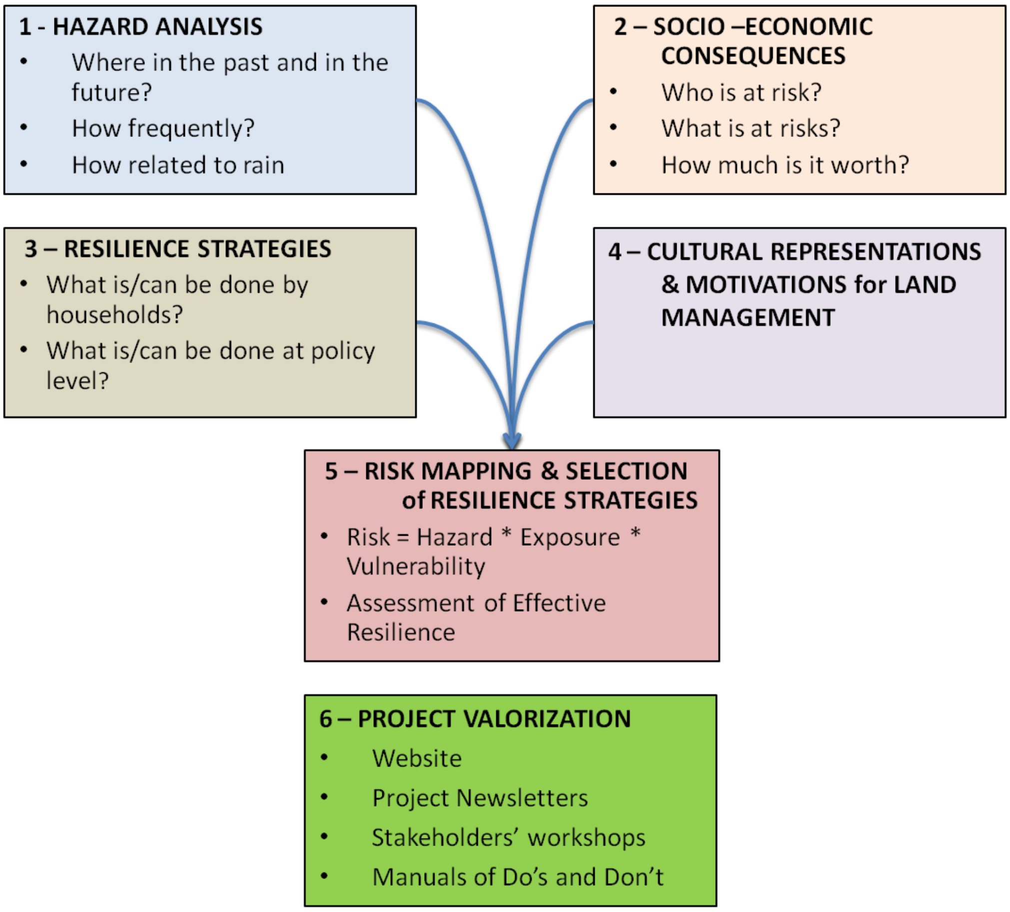


*Figure 1-1. AfReSlide Project structure*

AfReSlide project consists of six work packages (WPs). WP 1 focused on the inventory, characterization and modelling of the susceptibility of landslide based on the understanding of controlling factors. WP 2 focused on the socio-economic consequences and particularly on the elements that are at risk. It included the identification of all elements at risk and the economic valuation of the elements at risk and the potential damage or loss due to a landslides occurrence at a given element at risk. Based on the identification of major landslide impacts on agricultural lands, the research specifically focused on economically valuing the impact of landslide on farmers' income using data collected through household surveys and on the role of landslide in land transactions and unequal land ownership. WP 3 investigated the current and potential landslide risk reduction strategies, starting with a review of applicable measures in tropical countries and an inventory of those applied in the study areas. It included an analysis of factors controlling the willingness of households to implement specific strategies, as well as a critical analysis of the existing institutional framework and risk management policies implemented in Uganda and Cameroon. WP 4 focused on the cultural perspective: it is dedicated to the understanding of the environmental governance, the description of land rights, and the perception and management of landslides risk by cultural leaders and local communities. WP 5 then centralized and integrated the information produced in WPs 1 to 4. It proposed a preliminary method to map the risk and to identify the most suitable risk reduction strategies based on a multi-criteria analysis integrating the evaluation and perception of local stakeholders. The output of these research WPs were not only published in scientific papers but led to practical recommendations presented in a series of ten policy briefs and an educational poster. These policy-relevant outputs were presented to policy-makers, stakeholders and representatives of communities at risk, during an international conference held in Kampala in February 2018 and a series of district workshops. Other project coordination and dissemination actions (WP 6) included an active website and a biannual newsletter, stakeholders' workshops held at the start, mid-way and at the end of the project, as well as the development of a citizen-science network for data collection on landslide disasters in the Rwenzori.

The results of the AfR*e*Slide project were published in 10 scientific publications in peer-reviewed international journals, several other articles being in a final stage of preparation. The three PhD researchers active in the AfR*e*Slide project (Jacobs L; Maes J., Mertens K.) defended successfully their thesis in the first half of 2018. AfR*e*Slide led to additional collaborations with other researchers active in the same or nearby regions of Africa on complementary topics (e.g. Monsieurs et al. 2018). The project was also broadcasted in several popularizing articles and at many scientific conferences reaching various scientific communities from the earth and natural hazard sciences, to the development economics and anthropology. It further enabled to establish strong research collaborations with the Mountains of the Moon University (University) and Dschang University (Cameroon) whose researchers conducted joined field work with AfR*e*Slide researchers and benefited from training and investment in local rainfall station network. These collaborations open the scope to new development and research projects with additional funding (e.g. VLIR UOS).

This report provides a succinct summary of the actions and achievement of the AfR*e*Slide project. For further details on the research outputs, the reader is directed towards the scientific publications referenced as output of the project. The outreach actions and policy-oriented outputs (e.g. policy briefs) are shortly presented in the chapter 6 – Dissemination and Valorisation, but all of these can be accessed on the AfR*e*Slide website: afreslide.africamuseum.be.

## 2. STATE OF THE ART AND OBJECTIVES

### WP.1. Landslide hazard

Landslides are identified as an important geohazard worldwide, responsible for loss of life, economic disruption and destruction of infrastructure. The reduction of landslide risk is directly dependent on our ability to identify landslide-prone regions and understand the processes at play, a basic requirement for disaster risk reduction. In tropical, data-scarce regions, especially in developing contexts, this is severely hampered by a general lack of studies on natural hazards and landslides in particular (Gariano and Guzzetti, 2016; Jacobs et al., 2016a; Maes et al., 2017). Yet, low-income countries are the most affected by natural hazards with five times more fatalities per 100,000 inhabitants than in high-income countries in the past 20 years (UNISDR/CRED, 2016). Particularly for landslides, the highest toll on human life is expected in the Global South (Kirschbaum et al., 2010). In equatorial Africa, the situation is aggravated by an ever-increasing population pressure, as it is one of the regions with the highest population increases globally (United Nations, 2017). In addition to this, the frequency and/or intensity of rainstorms, a common trigger for landslides, is expected to increase in this region due to the effects of a changing climate (Gariano and Guzzetti, 2016).

This chasm between the expected increase in landslide hazard and exposure and a lack of understanding of landslide processes in Equatorial Africa motivates our study of landslide hazards in this region in particular. Therefore, the objective of WP 1 was to obtain, in a data-poor context, reliable estimations of the rainfall-triggered landslide hazards for the four selected study areas, representative of the landslides in Equatorial Africa. In the original proposal, attention was drawn to major challenges for the assessment of landslide hazard in the context of Equatorial Africa including the lack of reliable data on landslide occurrences themselves and the lack of ancillary data allowing a predictive model of landslides in space and time. Therefore, the objectives of this WP were - not only – to provide case-study assessments, but also to develop techniques and approaches that can be applied to similar environments where data availability and access to the terrain is limited. The Rwenzori Mountains in Uganda is selected as the main study area to develop and test these procedures as they embody a large diversity of landslides, triggers, land use and climatological gradients.

A first task within this WP1 was the construction of landslide inventories and collection of ancillary datasets for the study areas of interest. Constructing landslide inventories for regions in equatorial Africa is particularly challenging, indicated as well by the virtual absence of these regions in global landslide inventories. By combining archive study, field work and remote sensing approaches, we provide inventory approaches that can be applied to similar data-scarce environments in the tropics.

Secondly, WP1 aimed to provide susceptibility models able to predict the spatial probability of landslides on local to regional scales for different types of failures, distinguishing deep-seated and shallow landslides. This was mainly envisaged to be obtained through statistical modelling although physically-based models would also be tested. Landslide susceptibility maps, whether produced through statistical or mechanistic models, are extremely scarce in Equatorial Africa. A recent review by Reichenbach et al. (2018) shows that only a handful of susceptibility assessments are available in Equatorial Africa. This is largely a consequence of the lack of landslide information and inventories in these regions as well as the lack of reliable ancillary data needed to derive sound statistical relationships between the occurrence of landslides and geo-environmental conditions. Therefore, within this WP a strategy was developed to optimally exploit landslide- and ancillary data.

A final task of this study was landslide hazard analysis through the construction of rainfall-intensity-duration curves identifying the rainfall conditions after which landslides could occur and as such improving their predictability. For equatorial Africa, no precedent of this type of assessments exists as information on landslide timing is virtually non-existing. In addition to this, reliable rainfall data at a sufficient spatial and temporal resolution was not available for the four selected study areas. Although intensity-duration thresholds were not (yet) derived, the work done in this WP of the Af*Re*Slide project enabled the installation of dense rainfall station networks in the Bamboutos Caldera (Cameroon) and the Rwenzori region (Uganda) and a methodology based on citizen-science reporting was developed to collect detailed data on the timing and location of new landslides.

In summary, within the Af*Re*Slide project, several methodological procedures are developed to collect systematic, high-quality data, optimize the use of available datasets, and construct reliable susceptibility models at local to regional scale. These methods are extensively tested in the Rwenzori Mountains and often also applied to the other focus areas of the Af*Re*Slide project. These can furthermore be extrapolated to the other study areas within the project and similar data-poor contexts on the African continent or elsewhere.

**WP.2. Socio-economic consequences**

Besides investigating where and when a landslide might occur, it is important to study what are the impacts of landslides. The original objectives of WP2 were to identify and value elements at risk in the four selected study areas of Uganda and Cameroon. In the first months of the project these objectives have been refined and adapted to the local context and relevance for local stakeholders and researchers. During refining of the objectives, we gave special attention to (1) maximizing synergies and interactions with the other WP’s; (2) address research questions which really matter both for the local people and for the current lacunae in literature.

Regarding the study areas, it was therefore decided to focus most work on the Rwenzori region in Uganda. We decided to measure the impact of landslides in a rural environment, rather than in an urban context like in Limbe, because very little was known about the impact of landslides in rural areas in the Global South: except for some reports on losses of lives, nothing was known about the on-site consequences of landslides for farmers in the Global South. We elected the Rwenzori mountains as the prime study area, rather than the Bamboutos in Cameroon or Mount Elgon in Uganda because the Rwenzori was the focus area of WP1, providing the possibility for synergies between the work in WP1 and WP2. The Rwenzori mountains were very interesting because of its high population density, rural character and high, but unreported, frequency of both small and large landslides. Additionally, a study on the intentions to resettle away from landslides was implemented in the Bamboutos caldera in Cameroon.

During a first extensive field mission in the Rwenzori region we identified the potential elements and households at risk, as well as the potential impacts of landslides for household welfare and wellbeing. We thereby made use of participatory social science research methods. After exploratory fieldwork in the whole region, we selected one Sub-County in the Rwenzori region as a pilot study for assessing landslide risk in a data-poor region in the Global South. All physical elements at risk were identified as well as valuated in economic terms through field work and remote sensing approaches. It became clear very early in the process that the major direct impact of landslides in the Rwenzori region was related to their consequences for household income, through the loss of crops, and livelihoods, rather than damages to infrastructure and loss of human lives (Mertens *et al.*, 2016). Indirect and intangible impacts were related to the consequences of landslide risk (rather than the actual occurrence of landslides) for human behaviour and local land markets.

The valuation of a statistical life through the aggregation of individuals' willingness to pay for fatal risk reduction, which was an initial objective of the project, did not seem appropriate for the Rwenzori region. First, the hired PhD student had ethical problems with valuing life. Secondly, due to the very low incomes and close to subsistence livelihoods, estimates of willingness to pay for lives would have resulted in very low values, which would not reflect the importance farmers seemed to attribute to the presence of landslide risks in their decision making. Third, the number of lives lost due to landslide seemed very limited in the region.

A detailed review of literature moreover indicated that very little was known about (methods to measure) the consequences of landslides for rural households in the Global South. While studies in Western countries typically look at damages to infrastructure and houses (e.g. Corominas et al., 2014) such studies in the Global South would provide very little, and non-interesting results. Landslides have very little absolute costs, because of the low value of local infrastructure and limited revenue of smallholder farmers. Standard methods to measure costs in Western countries, such as hedonic pricing and substitution cost method, are ill-adapted to the local context of thin markets and poor infrastructure. We therefore concluded that the consequences of landslides would best be measured by comparing income and economic decision making among affected versus unaffected households. More specifically, we aimed at measuring (1) the relative consequence of landslide occurrence for household income and livelihoods; and (2) the consequences of the presence of landslides for (economic) decision making in the region.

The latter, of course, includes decisions farmers take to reduce their exposure to landslide risk, i.e. resilience measures. These risk reduction measures have indirect consequences for household income and local livelihoods. They therefore both fit into WP2 on the socio-economic consequences of landslides and in WP3 on the resilience strategies. While the objective and methodology for studying these 'consequences' are reported under WP2 in this report, the results on the impediments to adoption and the consequences of these resilience strategies for individual households are discussed under both WP2 and WP3. In particular, we report an analysis of elements at risk (including households) in the Rwenzori region, as well as the results of a choice experiment on intentions to resettle in the Bamboutos region under WP2.1. An estimation of the impact of landslides on household income in the Rwenzori region is reported under WP2.2. Consequences for decisions about planting trees, as well as for preferences regarding land transactions are reported under WP3.1.

The purpose in our research has been to innovate in two different ways: (1) the object of study, being the (in)direct impact of landslides on rural farmers in the Global South and (2) the methods that are used, being a combination of concepts and methods from environmental and social sciences.

**WP.3. Resilience strategies**

The international disaster risk management agenda has been driven by the United Nations International Strategy for disaster risk reduction (UNISDR), first through the disaster decade in the 1990s, then the Hyogo Framework for Action (HFA) in 2005 and recently the Sendai Framework for disaster risk reduction (SFDRR) in 2015. This recent SFDRR has renewed the international focus on reducing risk of disasters (UNISDR, 2015b). Investing in disaster risk reduction (DRR) was identified as one of the key priorities. Disaster 'risk' is defined as 'the potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period' (UNISDR, 2009: 9), while 'hazard' refers to the natural event itself that may affect different places singly or in combination at different times (Wisner et al., 2004). According to UNISDR (2009: 10), DRR is 'the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through (i) reduced exposure to hazards; (ii) lessened vulnerability of people and property; (iii) wise management of land and the environment; and (iv) improved preparedness for adverse events'. Especially for low-intensity, high-frequency events like landslides, DRR is considered the most cost-effective option to limit the negative impacts of disasters (Mechler et al., 2010). Since the HFA in 2005, the international DRR community is increasingly viewing disaster risk management as a governance issue (Bamutaze, 2015). More generally, risk governance is defined as 'the totality of actors, rules, conventions, processes and mechanisms [...] concerned with how relevant risk information is collected, analysed and communicated and how management decisions are taken' (Renn and Walker, 2008: 4).

As a first step in the DRR component of Af*Re*Slide, it was relevant to first analyse what is currently being recommended and implemented globally to support research and investment in DRR (UNISDR, 2015b). A hazard for which such a review of risk reduction (or mitigation) measures was still lacking was landslides. As the scientific literature on landslides is rapidly increasing (Gutiérrez et al., 2010; Wu et al., 2015), it is important to maintain an overview. The first objective of this WP3 is therefore to document which measures are recommended and implemented globally and which potential pitfalls the implementation of such DRR is facing. Although such overview is certainly relevant for the entire world, we decided to limit the study area to the tropics because this region shares several similarities, including similar climate (and climate change effects) and population pressure. A meta-analysis of recommended and implemented measures may certainly help in identifying the next steps to contribute to long-term landslide risk reduction. Since 'the totality of actors [,…] are concerned" (Renn and Walker, 2008: 4), the first objective of WP3 also includes the identification of specific grass-root resilience strategies. We therefore later on concentrated on identifying resilience strategies, such as planting trees and social norms to limit exposure to landslides, that exist in the Rwenzori region.

As disaster risk management is increasingly viewed as a governance issue, the second objective of WP3 is to assess specific landslide risk reduction policies and their implementation. Therefore we investigated two case studies of disaster policy for landslides in Uganda and Cameroon that are often recommended and implemented according to our literature review. We decided to focus on both rural (Rwenzori Mountains, Uganda) and urban (Limbe city, Cameroon) settings to have as diverse contexts as possible. The first policy is the implementation of disaster platforms for landslide risk reduction in Uganda, which is a risk reduction strategy that is promoted by the international treaties (HFA and SFDRR) and translated into national policies. The second policy is the implementation of disaster risk zonation policy in Cameroon, which is a risk reduction strategy that is promoted by scientists (Maes et al., 2017a) and policy-makers globally (UNISDR, 2015). Lessons learnt from our case studies might be illustrative for disaster governance for other natural hazards and in other countries, notably for those that endorse the international agenda for DRR and that are ruled by semi-authoritarian regimes. These studies attend to a well repeated call for empirical cross-scale disasters analysis (Adger et al., 2005; Baker and Refsgaard, 2007) and to a re-politisation of disaster research (Pelling and Dill, 2010).

**WP.4. Cultural representations and motivations for land management**

The goal of WP 4 is to understand the community dynamics and their relationship to land, their environment and its hazards. WP 4 is dedicated to the understanding of the environmental governance, the description of land rights, and the perception and management of LS risk by leaders and local communities. Rural communities and urban neighbourhoods have been identified for anthropological surveys. However, time was missing to made an in-depth study of initial targeted regions in Cameroon and Uganda, so selected case studies for WP 4 only focused to the Rwenzori region in Uganda.

Key informants have been surveyed to identify the leadership structure, in particular leadership involved in environmental hazards, and to determine land rights and land management in case of land readjustments due to unpredictable events such as LS. Portrait has been made of the traditional leadership structure, particularly the leadership involved in land rights and hazards management. It appeared that traditional leaders involved in land rights tend also to be involved in the way local communities cope with “the invisible” (cultural beings such as spirits), supposed to be responsible for disasters in many cases. The survey tested the perception of the hazards relative to other environmental threats, customs and cultural responses to hazards and to natural events in a broader sense. The research focused on relationships, customs and habits of the people related to their land and assessed the cultural perception by the local communities of the contrasted risk reduction strategies identified in WP 3.

The survey allowed to identify and describe cultural premises and representations related to natural hazards, the extent of solidarity networks and the leadership structure (political, religious, family), focusing on leaders involved in coping with natural disasters and involved in the reorganization and renegotiation of land rights and uses after a hazard. The survey described the symbolism and cultural explanations for natural disasters and their role in cosmologies, and figured out to what extent earthquakes and LS are perceived as a form of communication of the land with the living. It showed that cultural practices related to the land (such as divination techniques) play a crucial role in the construction of social and personal identity.

Local customs were taken into account to conduct the interviews and the necessary cultural precautions recorded for use by the other project partners. Cultural findings related to the intervention of the invisible (spirits) in the way local communities deal with environmental threats and other disasters have been particularly useful to that matter and have been taken into account to set up the stakeholders meetings.

**WP.5. Risk mapping and selection of resilience strategy**

Risk assessment remains considered as the first step towards disaster risk reduction (DeGraff, 2012). Producing a risk map was therefore also included in the original research proposal. As collecting data for all study areas would have taken too much time, we decided to focus on one specific sub-county in the Rwenzori Mountains to construct the very first risk map of the Rwenzori Mountains. The first objective of this WP5 was therefore to quantitatively assess the risk of landslides in Mahango sub-county. Therefore, we integrated the different aspects of landslide risk, i.e. the landslide hazard, the exposure and the physical vulnerability of elements at risk. As this pilot study was a first attempt, we only focussed on the physical vulnerability and not the social vulnerability. WP2 and 5 clearly show, however, that the latter should not be underestimated. The landslide risk was assessed in one sub-county to provide results on the potential loss due to landslides expressed in monetary values which could then be used in decision-making at sub-county level.

The recent Sendai Framework for Disaster Risk Reduction (DRR) promotes the investment in DRR, but is vague on how to identify appropriate DRR measures. Decision support systems are increasingly being used for DRR, especially in relation to natural hazards like flooding, fire and earthquakes (Newman et al., 2017). For the specific case of landslides and other natural hazards, there is a lack of scientific evaluation data for selecting DRR measures, e.g. in the form of cost-effectiveness, cost-benefit or multi-criteria analyses (Newman et al., 2017).

The second objective of WP5 is therefore to develop a feasible methodology for identifying (in)appropriate DRR measures. With ‘appropriate’, we mean that the measure is adapted to local conditions. As the appropriateness of DRR measures depends on many variables, including foremost the hazard characteristics (e.g. type of movement), the elements exposed (e.g. location of critical infrastructure), and their respective vulnerability (e.g. coping capacity of inhabitants), it becomes clear that selecting DRR measures is a complex process which involves a wide range of evaluation criteria and information sources (Newman et al., 2017). A common feature of decision support systems is the intention to provide information for supporting decision-makers in identifying problems and opportunities as well as taking decisions (Power, 2008). Such decision processes are referred to as multi-criteria approaches if specifically designed to evaluate a list of alternatives with the help of multiple criteria describing these alternatives (Dodgson et al., 2009; Huang et al., 2011), in this case, different DRR measures. For decision processes on DRR measures, Weichselgartner and Pigeon (2015) argue that, on the one hand, researchers still rarely consider the needs of potential users nor systematically produce directly usable risk information and, on the other hand, decision-makers hardly use the most appropriate available scientific information to make policy decisions. For this reason, decision support systems increasingly try to use participatory approaches (e.g. Barquet and Cumiskey, 2017), although its use remains scarce within the field of DRR (Newman et al., 2017). Newman et al. (2017) revealed the lack of decision support systems developed for use in African countries. The methodology is therefore tested in the Rwenzori Mountains region in West Uganda.

# 3. METHODOLOGY

## WP.1. Landslide hazard

### TASK 1.1. Landslide inventories and ancillary data collection

***Archive inventory***

The first objective was the construction of landslide inventories and ancillary datasets in the study areas of interests. Most highland regions in Equatorial Africa are absent from global landslide inventory databases, falsely giving the impression that these regions are not landslide prone. Because field information is scarce, as a first step, archive sources including newspaper articles, governmental and non-governmental reports, and internet sources were used to reconstruct a landslide inventory and as such disprove this initial deduction. For an overview of the data sources and treatment we refer to Jacobs et al. (2016a). The approximate location, date of occurrence and reported trigger was in the majority of cases available and thus included in the inventory. Impact information such as the number of fatalities, the number of persons that lost their house, the occurrence of infrastructural damage and damage to crops is also included in the inventory if reported in the source. Upon assembly of the historic inventory, it became apparent that debris-rich flash flood events are a second major type of disaster in the region. Because of the possibility that flash floods coincide with landslides, these events are included in the inventory as well.

***Field inventories***

Archive inventories provide useful first insights into the occurrence of landslides and their consequences in unstudied areas. However, for spatially explicit susceptibility models, accurate locations of single landslide events are required. In densely inhabited regions in the humid tropics characterised by persistent cloud cover, rapid vegetation growth and dynamic land use change of predominantly agricultural land cover, the mapping of landslides using optical remote sensing techniques can be severely hampered. Landslides masked by vegetation or tillage can still be recognized in the field through directions given by the inhabitants, who are best positioned to identify these events in their direct environment. Therefore, the construction of landslide inventories for our focus areas required extensive field work complemented by remote sensing optical imagery investigation. For the Rwenzori Region inhabited area (ca. 1,100 km$^2$), five representative study areas were selected, accounting for a total of 153 km$^2$. During the field surveys all landslides - regardless of their age - were considered. For most landslides GPS points at the head or in the depletion zone of the slide were taken. For some landslides however, an observation from a distance had to be made given the inaccessibility of the terrain. Google Earth imagery (2015) were used wherever possible to assist in mapping landslides if estimates of landslide geometry were difficult, i.e. for landslides mapped from a distance or if vegetation regrowth did not allow good observations. Each landslide is described in the field to allow classification according to Cruden and Varnes (1996). This inventory protocol includes parameters on size, depth, vegetation cover, estimated age, trigger and activity and is constructed to allow landslide mapping by a single person in poorly accessible areas (for more details we refer to Jacobs et al., 2016b). For the Rwenzori case-study, the landslide inventories are checked for their completeness. This allow to estimate the quality of the data, and enables comparison with other landslide inventories in different settings (Malamud et al., 2004). A detailed description of this methodology can be found in Malamud et al. (2004) and Van Den Eeckhaut et al. (2007). Once the landslide inventories are established, the factors which influence the occurrence of landslides can be analysed. We consider (1) controlling factors for the occurrence of landslides (or the preconditions) which determine slope stability and are mostly static in time; (2) preparatory factors which are dynamic in time and prepare the slope for failure and (3) triggering factors which actually trigger the slide (Glade et al. 2006). This methodology was also applied to the Bamboutos region (Cameroon) and the Mount Elgon region (Uganda). For the Limbe region in Cameroon, a landslide inventory was already available.

***Additional inventories and datasets***

For the Rwenzori region, a large portion of the area is covered by impenetrable National Park. The trans-boundary and remote character of the National Park render this area in particular scarce in both landslide – as well as ancillary data. Because of the homogeneous forest cover and the absence of human settlements, a remotely sensed landslide inventory and inventory of ancillary information including fault line position and position of glacial deposits and cirques was feasible. This was achieved by combined open source resources from Google Earth, SPOT6 (1.5m) resolution optical imagery, aerial photographs and the use of synthetic anaglyphs produced by combining topographic information of a TanDEM-X 5m resolution DEM and the SPOT6 images. This combined approach is, to our knowledge, never applied to a case-study in the tropics.

Around the peak areas of the Rwenzori Mountains, recent deglaciations are believed to cause several rock failures at altitudes between 4,200-5,000 m a.s.l. In this area, field inventories were also constructed, allowing for a localization of recent rock falls and debris flows. One large, recently re-actived rock fall initiating around the Mount Baker peak was surveyed in detail by UAV image acquisition which allowed to reconstruct a sub-meter resolution digital elevation model of the runout and depositional area.

### TASK 1.2. Landslide susceptibility

With regard to landslide susceptibility assessments both statistically-based techniques as well as mechanistically-based techniques are deployed. The former are elaborated and adjusted to fit data-poor contexts of equatorial Africa. The latter is more difficult to implement at larger scale given the larger data requirement and is therefore used to test single rock-fall outflows.

With regard to the elaboration of statistically based models, in first instance, pixel-based logistic regression models are optimized for the use of topographic data source, scale, resolution and process distinction. Secondly, we test the construction of alternative mapping units to also optimize the available landslide information, as to include also secondary sources of information. The mechanistic rock fall outrun model was applied to a recently re-activated large rock fall event initiated at the top of Mount Baker, a formally glaciated peak of the Rwenzori. By acquiring high resolution topography through drone imagery, we show that simple mechanistic models can assist in reconstructing complex rock failures in remote settings. The Rwenzori Mountains were the key study area for extensive testing of these methodologies because of (1) the lack of any information on landslide occurrences, (2) the large area of interest, requiring the consideration of several spatial scales and (3) the diversity of landslide processes, requiring tailored approaches. Therefore, these approaches are elaborated upon below. For completeness, we also report that statistical landslide susceptibility assessments were performed for the Mount Elgon region (Broeckx et al., submitted) and the Bamboutos region (Cameroon, currently in the process of finalization).

***Optimization of a pixel-based landslide susceptibility assessment***

In first instance we tested the sensitivity of the broadly used pixel-based logistic regression model to model resolution, topographic data source, landslide type distinction and scale. Indeed, in studies using pixel-based landslide susceptibility models, the choice of model's spatial resolution is often motivated based on the resolution of the available datasets, with a preference for using the most finely gridded resolution possible. Only few studies compared different model resolutions (e.g. Catani et al., 2013; Tian et al., 2008). Additionally, various commonly available topographic information sources are rarely compared (e.g. Havenith et al., 2006). In the data-scarce setting of the Rwenzori Mountains, the selection of the most appropriate model resolution and topographic data source is particularly relevant. Here, to model landslide susceptibility, three different topographic information sources (SRTM, ASTER and TanDEM-X) are used at four different resolutions (10, 20, 30 and 90m). Apart from these effects, we also assess the dependency of the model on the spatial scale of the assessment. This is achieved by building models at the local level for individual case studies (ca. 20-43 km²) and at the regional level for all case studies combined (153 km²). The local scales are referred to as Mahango and Kyondo, Kabonero, Bundibugyo and Nyahuka. The model combining all case study areas thus makes use of the landslide data of all case studies, which combined are considered to be representative for the Rwenzori inhabited zone. Finally, the Rwenzori Mountains inhabited area hosts a diversity of landslide types which are expected to be controlled by a different set of explanatory variables. In this study we compare, on the regional level, the effect of separating landslide types between the deep-seated (depth of sliding plane > 3m) and shallow landslides (depth sliding plane < 3m). For more information on the model construction, sampling procedures, model evaluators and variable selection underlying the construction of the logistic regression models at the various scales and resolutions, we refer to Jacobs et al. (2018).

***The integration of heterogeneous landslide information for landslide susceptibility assessments***

The pixel-based logistic regression explained above resulted in the first pixel-based regional susceptibility map for the Rwenzori Mountains (described in section 4 of this report). Outside the inventoried zones used for the model calibration and validation, this regional landslide susceptibility model should be considered as the result of an extrapolation of a statistical model and thus we do not know how reliable the model is there. Despite that the model's validity outside the sampled areas can be questioned, this strategy of using a limited proportion of the terrain is often preferred because collecting landslide data over the whole terrain is labour intensive or too costly. Moreover, in those cases where landslide data is available for regional scales, this data collection is often done by several experts and constructed using a variety of input data or techniques. Heterogeneities in the type of data and uncertainties with regard to their spatial accuracy can therefore be substantial. Because for most landslide susceptibility assessments a homogeneous landslide dataset, often constrained to a portion of the terrain, is preferred, very few studies investigate the propagation of these uncertainties or the possibility of data integration of different datasets in a regional susceptibility assessment. This assessment can however be useful in extending the *de facto* surveyed area and therefore the reliability of the resulting landslide susceptibility maps.

Most of the quantitative landslide susceptibility maps, especially on supra-local scale are built using pixel-based statistical approaches. Other mapping units, such as terrain units, which represent the terrain not in grid cells but in geomorphological units, are rarely used on these scales. These mapping units, which are in essence spatial aggregations, can however help to reduce the propagation of uncertainties in the statistical model. Again, the Rwenzori presents a good case-study as, in addition to the polygon dataset used in the pixel-based assessment described above, two point-datasets are available where one point represents a landslide body, but is taken at an unknown location within that body, or in its direct vicinity (Table 4-1). We tested the ability of different mapping units to deal with these uncertainties related to an unsystematic point localisation of landslides and propose a method for combining polygon and point data within one regional landslide susceptibility model.

When using a combination of landslide polygon data and landslide point data, some methodological considerations need to be made, here handled within two components (Fig. 3-1). The choice of the mapping unit is expected to play a large role in the susceptibility assessment reliability with regard to the handling of data heterogeneity and spatial uncertainty. Here, we test two different terrain units: the grid cell and the slope unit. For the construction of grid cells and slope units, two different DEMs at two different resolutions are tested: a TanDEM-X at 10 m resolution and the SRTM at 30 m resolution. The construction of the TanDEM-X is described in Jacobs et al. (2018). The grid cells are thus directly extracted from these DEMs and are hereafter referred to as Pix10 and Pix30. The slope units are constructed following the reproducible optimization procedure proposed by Alvioli et al. (2016) through the *r.slopeunits* software.

*Tier 1: Unknown relative location of point samples: effect on model performance and stability.*

Spatial uncertainty related to the landslide point samples taken at an unknown location inside or in vicinity of the landslide body is expected to influence landslide susceptibility assessments to different extents according to the mapping unit. The point data set available for the Rwenzori Mountains is only one of many potential samples of the true landslide extents or their immediate vicinity (Fig. 3-2a). To mimic the potential range of uncertainty related to a point selection from polygons, a repeated random sampling of polygon data is therefore applied. Hereby, several different sets of landslide input layers (n=100) are generated, each containing one randomly sampled point per landslide (Random Sample from Polygon, RSP). Additionally, to account for the possibility that the centroid of the affected plot does not lie within the landslide body (Fig. 3-2a) but in its vicinity, the polygon is extended with a 50 m buffer, after which the random sample is taken (Random Sample from Polygon with its Buffer, RSPB). The ensemble of these selected point datasets is therefore a proxy for the potential uncertainty resulting from simplifying the polygon dataset by a random-point representation and can be compared to a baseline model where landslides are represented by their depletion centroid (DC).

For both pixel-based as well as slope unit-based approaches the 100 RSP and RSPB samples are fed into the logistic regression model, run for each mapping unit. The three methods of landslide representation (RSP, RSPB, DC) and two sets of pixels (Pix10 and Pix30) and two sets of slope units (SluTDX and SluSRTM) thus result in 12 different model strategies. This procedure allows a direct comparison between the pixel – and slope unit-based approaches as to the suitability of a random point selection to provide robust modelling results. The selection of variables used for the logistic regression is based on findings from earlier research (Jacobs et al., 2017a; 2018) and are limited in number in order to facilitate a straightforward interpretation of the resulting models (Steger et al., 2016, Zêzere et al., 2017). They include lithology, elevation, slope gradient, topographic wetness index, sine and cosine of the aspect, tangent – and profile curvature. For the slope units the average and standard deviation of the topographical variables are considered. The consideration of the latter can result in an increase of model complexity. Therefore, the slope unit-based models are also run without the consideration of the standard deviation of the topographic variables.

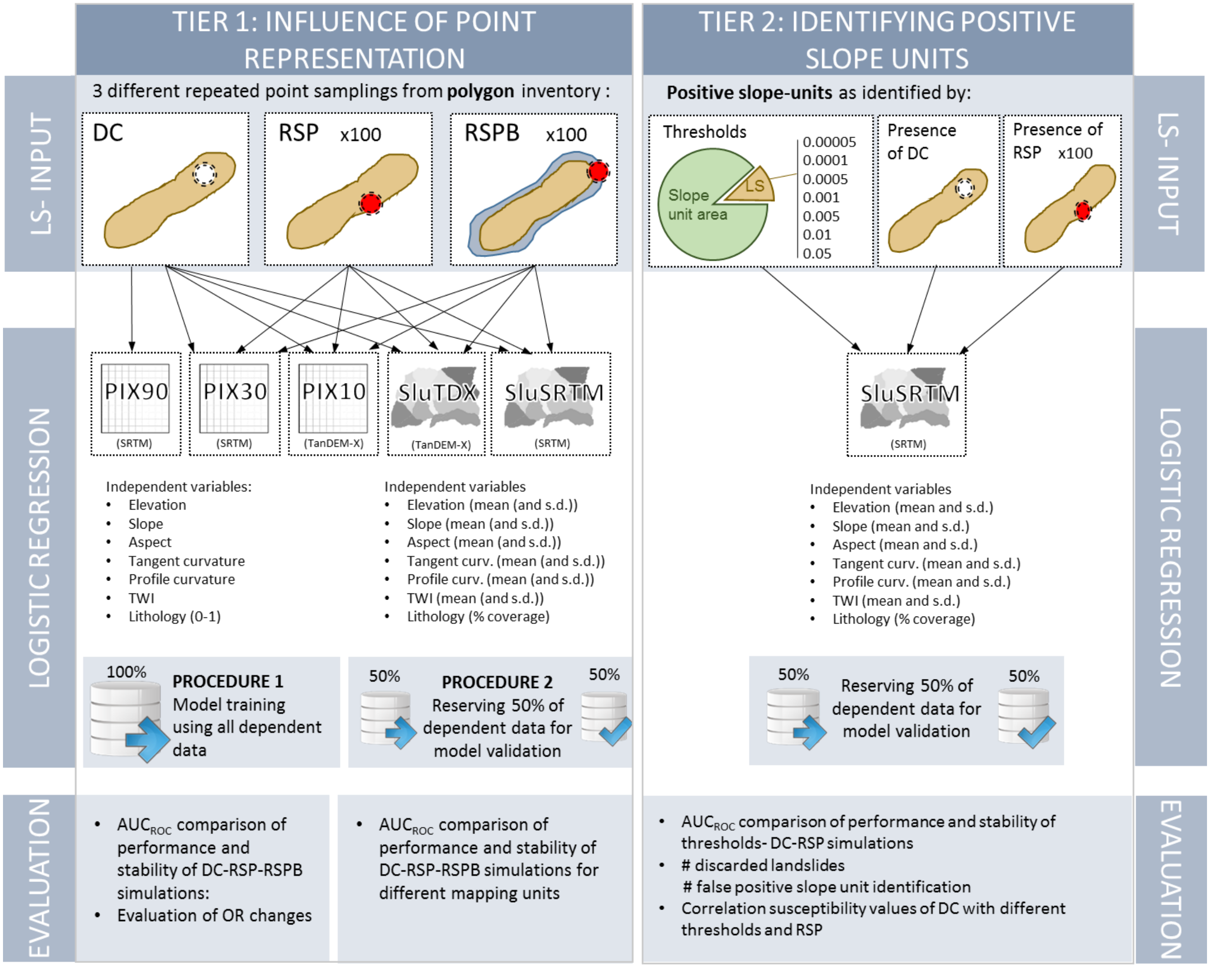


*Figure 3-1. Two-tier methodological scheme to evaluate the best use of point datasets (component 1) and the effect of the identification method when using polygon datasets (component 2).*

### *Tier 2: Identifying landslide prone mapping units when using polygon datasets*

The second methodological component consists of deciding when a mapping unit is identified as landslide-prone when considering polygons. When the landslide is only represented by one point, as is the case in the first methodological component, mapping units can only be positively identified (i.e. containing a landslide) based on the criterion of absence or presence of a landslide point within the mapping unit. When dealing with entire polygons, the applied strategy to identify the landslide-prone mapping units depends on the considered mapping-unit. The selection of the centroid of the depletion zone as applied in the first component is one of the most common techniques where the landslide is represented by only one representative pixel, avoiding spatial autocorrelation (Jacobs et al., 2018). The investigation of the effect of different methodologies to identify landslide-prone slope units has received much less attention and it is therefore the focus of the second methodological component.

Some authors propose the use of a threshold of exceedance representing the fraction of area of the slope unit covered by landslide polygons (Guzzetti et al., 2006; Rossi et al., 2010). It appears that the identification of a threshold entails a trade-off: when selecting a large threshold, small landslides will not lead to the identification of a landslide-prone slope unit (Fig. 3-2b) while too small thresholds could lead to false positives by wrongly identifying slope units caused by an accidental exceedance of the landslide polygon boundary over the slope unit boundary (Fig. 3-2c). The latter can be due to both an error in the delineation of the landslide boundary as well as errors in the slope unit boundary as the latter's positional accuracy is bound to the accuracy and resolution of the underlying DEM. Here, three different approaches are suggested to identify landslide-prone slope units. Firstly, seven different thresholds ranging from 0.00005 to 0.05 are tested in order to identify the best trade-off maximizing the ability to identify slope units containing small landslides whilst minimizing false positives. Secondly, the repeated random sampling (n=100) of one point per polygon, i.e. the RSP simulation in component 1, is used, where the presence or absence of the randomly sampled point within a slope unit serves as a binary identifier for assigning positive slope units. This method will by default also recognize small landslides and will predominantly select the slope unit where most of the polygon surface area is located. Finally, the depletion centroid (DC) of the landslide polygon is used as a binary identifier.

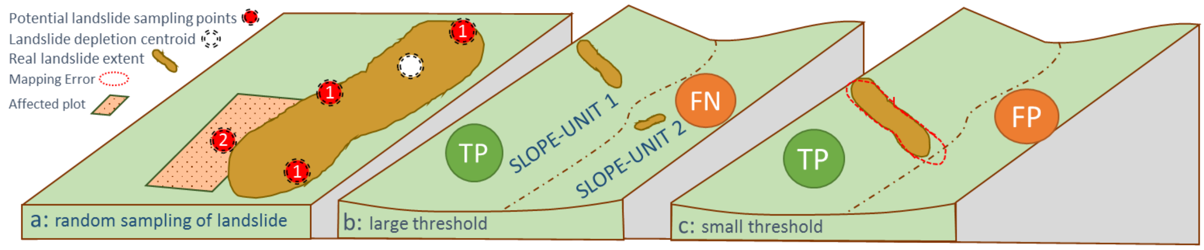


*Figure 3- 1. a: Potential landslide point representations (1) and (2) illustrate possible samples from the two point datasets, b: Discarding of small landslides when using a large threshold as an identifier for positive slope units resulting in False Negative slope units (FN), c: Identification of false positive slope units (FP) when using a small threshold as an identifier for positive slope units.*

***Construction of a spatially validated regional landslide susceptibility map***

Based on the evaluation of the two-tier methodology, the final regional landslide susceptibility model is trained using the polygon data and spatially validated using the point data. This final model will also be evaluated in terms of its model performance. Because the origin of the point datasets, we cannot reliably say that this inventory approximates completeness, in other words, false positives in the validation stages can in reality represent mapping units positive to landslides, for which the false classification is related to missing data in the point dataset. Therefore, also the prediction rate will be considered (Guzzetti et al., 2006, Van Den Eeckhaut et al., 2009; Dewitte et al., 2010).

### TASK 1.3. Rainfall Intensity-Duration thresholds for landslide initiation

A global challenge for the assessment of landslide hazard for rainfall-triggered landslides is the lack of accurate data on the timing of landslide occurrences. This is particularly so in remote regions, especially in the Global South, including equatorial Africa, which is virtually absent from global landslide inventories and where no systematic registration of landslides occur, e.g. on national level. Furthermore, in these regions, the challenge is twofold: also data on the rainfall events triggering landslides is scarce due to the lack of dense rain gauge networks or a poor temporal resolution of the operational rain gauges. Within the AfReSlide project, both challenges were addressed. In 2014, a network of 10 tipping buckets automatically registering rainfall depth on hourly basis was installed. Meanwhile, after several long field campaigns, we understood that collecting temporal information on landslide occurrences was impossible without constant presence and data-collection on the field. Because it was not feasible to permanently have researchers present in the vast region of the inhabited Rwenzori Mountains, a network of citizen science reporters was established: the 'geo-observer network'. This crowdsourcing project, funded by a VLIR South-Initiative ('Enhancing community-based natural resources and hazard management in Rwenzori Mountains'), is a collaboration between Mountains of the Moon University (MMU) and the Vrije Universiteit Brussel (VUB) and was launched in February 2017.

One of the project's goals is to achieve a GIS database on natural hazards within the region, whereby the data is collected by local inhabitants, hereafter referred to as 'geo-observers' and the database is managed by MMU. The collection of data is done by using the KOBO Toolbox[1], an open access application that can be used on android smartphone devices that allows to use any self-prepared questionnaire. Within the VLIR SI project, questionnaires were built and data is collected for eight different natural hazards: floods, landslides, earthquakes, lightning, hailstorm, pest and diseases, drought and windstorms. Here, the focus lies on the collection of landslide data. Currently, 21 geo-observers are trained to recognize important natural hazards in their environment and report on them using tailored questionnaires in the KOBO application. The landslide questionnaire, much like the other deployed questionnaires, starts with general characterization of the hazard with a focus on timing, location (with the inclusion of the acquisition of a GPS point with the smartphone), pictures and estimates on length, width and depth. Afterwards attention is given to what was perceived as a triggering factor and which type of damage the landslide caused. Questions are built in a tree-like structure, i.e., a question describing damage to the road will only be asked if damage to roads was reported in an earlier question. After the completion of the questionnaire it is sent through mobile data to a server that can be accessed by any authorized user. The data on landslide data and location can then be coupled to the rainfall data collected in the nearest rain gauge(s).

**WP.2. Socio-economic consequences**

The methodology developed in WP2 is specially adapted to the context of a rural area in the Global South. It draws on social sciences methods that are being used in development economics, and combines these with spatial data on landslides and land use. Our methodology is therefore highly innovative for research on natural hazards, and applicable to many rural regions in the Global South. It essentially consists of (1) field work and remote sensing approaches to identify elements at risk; (2) a quantitative household survey on both affected and unaffected households (including exposed and non-exposed households) in order to be able to compare their income and behaviour; (3) a choice experiment to measure preferences and willingness to accept (not) to sell plots in landslide prone area; (4) statistical tools from development economics (regression analysis) to estimate the effects. Crucial points of attention here are related to the identification of causal chains.

**TASK 2.1. Identification of elements at risk**

The socio-economic data have been collected during three rounds of fieldwork between 2014 and 2016. Qualitative methods have been used during a fieldwork in the summer of 2014 to identify elements at risk in the Rwenzori region (Fig. 3-3). These methods include transect walks and interviews with key informants such as local officials, farmers and other rural entrepreneurs, social service providers, and members of civil society organizations. One sub-county, i.e. Mahango sub-county in Kasese district, was selected for further inquiry. Mahango sub-county is severely affected by landslides and reflect the diversity in livelihoods in the highlands of the Rwenzori Mountains. There are mainly two types of elements at risk observed on the field, the human infrastructures and the land cover respectively. For human infrastructures, a difference is made between public and

[1] http://www.kobotoolbox.org/

private infrastructures. The public infrastructures include all government buildings like the sub-county headquarters, health centres, schools, and community infrastructures like roads and water springs. The private infrastructures include houses, churches and trading centres. Most of these elements at risk, i.e. all public infrastructure, churches, and trading centres have been mapped with a GPS and their capacity estimated in the selected sub-county. The identification of the houses as well as the land cover have not been systematically mapped by GPS in the field but their location was achieved though satellite images analysis and field work. The used satellite images were SPOT 6 and ASTER.

The first step of this identification is to compose different classes based on visual interpretation of the images and Google Earth: houses, cropland, trees and pasture. The second step is to create training data for each class based on ground truth data and image interpretation. The training sites embody representative samples of the spectral signature of each class. The number of pixels digitalized should be equal to thirty times the total number of bands. The third step is the use of a pixel-based classifier to allocate each pixel of the satellite image to a certain class based on the most similar spectral signature. We used the maximum likelihood as it has proven to be a robust classifier especially for features presenting a normal distribution (Otukei et Blasche, 2010). Finally, once the image has been interpreted, the accuracy of the classifier is determined; a process known as validation. A common tool to assess the validation of a classification is to use a confusion matrix. To implement the confusion matrix new training sites, different from the ones used during the classification, are utilized. The new training sites are sampled based on ground truth data. For each validation pixel, the class allocated by the classifier is compared to the true class label. It allows to determine different types of errors such as the user and producer accuracies together with the kappa value and the overall accuracy. We refer to Schoonenbergh (2017) for more detailed information.

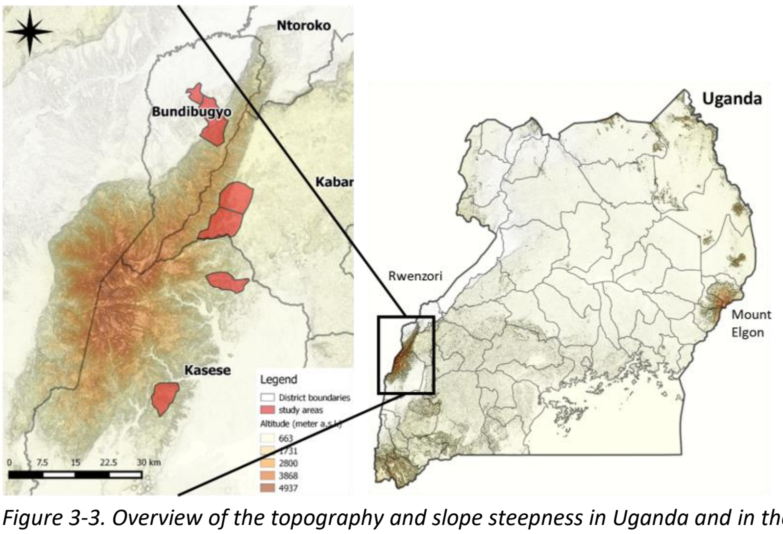


*Figure 3-3. Overview of the topography and slope steepness in Uganda and in the Rwenzori region. The Rwenzori mountains are located at the Western border of Uganda. Colours show the elevation range and darker areas have a steeper slope. The study areas are represented in red.*

### TASK 2.2. Valuation of the elements at risk

***Household survey in the Rwenzori Mountains, Uganda***

The data for the valuation of the elements at risk have been collected through a household survey. This survey also included data that were used for the assessment of household level resilience strategies. Some of these resilience strategies include changing ones' exposure by selling and buying land in- and outside landslide prone area. They would therefore fit both in WP2 and WP3. Out of practical reasons these data will be reported here, but one should bear in mind that they do not really aim at 'valuation of the elements at risk' in the strict sense. They rather study consequence of landslide risk in the broad sense, including changes in behaviour and land transactions that affect exposure to landslide risk. The results and recommendations derived from these data are presented under WP2.1, WP2.2 and WP3.1.

In the Rwenzori region two rounds of household surveys have been implemented, during which information was collected through questionnaires, an incentivized risk game, choice experiments and the mapping of houses and plots with GPS.

A first round of quantitative data was collected through face-to-face interviews on paper in January-March 2015. A stratified two-stage random sample of 461 households was implemented in 47 villages, of which 10 in Kabarole, 15 in Kasese and 22 in Bundibugyo (Fig. 3-3). Due to the low landslide density in Kabarole, fewer villages were sampled in this district. Interviews with the households lasted between three to four hours, including breaks. The questionnaires consisted of 13 sections covering questions on household demographics, land management and ownership, living conditions, agricultural production and marketing, experiences with landslides and other disasters, various income sources and social capital. GPS coordinates were taken in front of the house of each household, as well as on the corners of the plots, defined as a continuous piece of land owned or cultivated by the household.

A second round of data was collected through face-to-face interviews on tablets in August-September 2016. The same farmers were interviewed as in the first round, except for 48 households in Kabarole. These households were used for the training of the enumerators and the pre-test of the questionnaires. As such, a sample of 401 households in 41 villages was retained. This round of data collection aimed at eliciting prospect theory risk preferences (through an incentivised risk game, see further) as well as preferences for land transactions measured by means of a choice experiment (see further). Information on household composition and income was also updated. Also considerable attention was given to acquiring additional information at plot level. During this survey, plots were defined as continuous pieces of land that were acquired by the household during a same land transaction. This led to the identification of additional plots, which were mapped with GPS. Due to some problems in identifying and mapping the correct plots, only 75% of the 1040 plots could be located with certainty after this second fieldwork.

Risk preferences were elicited through a lab in the field experiment with real monetary pay-offs, as described in Tanaka et al. (2016). At the beginning of the interview in 2016 a monetary compensation of 3000 Ush (0.83 USD) was promised because the questionnaire was long and the mapping of the plots required some time and effort from the respondents. This is the equivalent of 93% of the average income per day per adult equivalent in our sample. At the end of the interview, the respondents were asked whether they would be willing to play a risk game. The expected value of this game was 5557 Ush (1.54 USD), making the total expected compensation for the interview 8557 Ush. Yet, as the risk game entailed a small chance of losses, a risk taking respondent with very bad luck would earn only 1215 Ush. Great emphasis was put on the fact that this would entail a loss of already earned money (i.e. 1215 Ush. instead of 3000 Ush.) rather than just a foregone income. As the money was not really given to the farmers before the start of the game, we do not know whether this was sufficient to ascertain that loss aversion was being measured. The rules of the game were made clear to the respondent before the start of the game and the risk game was only played with informed consent. A farmer refusing to play the risk game would just receive the 3000 Ush. Only 3 farmers refused to play the game, for religious reasons.

The risk game method consisted of presenting 35 choice sets with binary lotteries that involve gains and losses with different probabilities (Tanaka et al., 2016). After every interview, one of these choice sets was randomly selected to be played for real monetary pay-off. The advantage of this method is that it allows to identify risk aversion, loss aversion and overweighting or underweighting of small probabilities, as predicted by prospect theory (Kahneman and Tversky, 1979). Risk aversion (σ) measures the extent to which uncertainty decreases the utility of expected gains, while loss aversion (λ) does the same for expected losses. The curvature of the probability weighting function (α) is a measure for overweighting or underweighting small probabilities. Most people tend to overweight small probabilities (Kahneman and Tversky, 1979).

Choice experiments make use of the random utility theory, thereby assuming that the respondent makes a choice based on rational weighting of utility losses and gains related to the attributes of each choice (McFadden, 1973). An example of a choice card used during one of the choice experiments is given in Fig. 3-4.

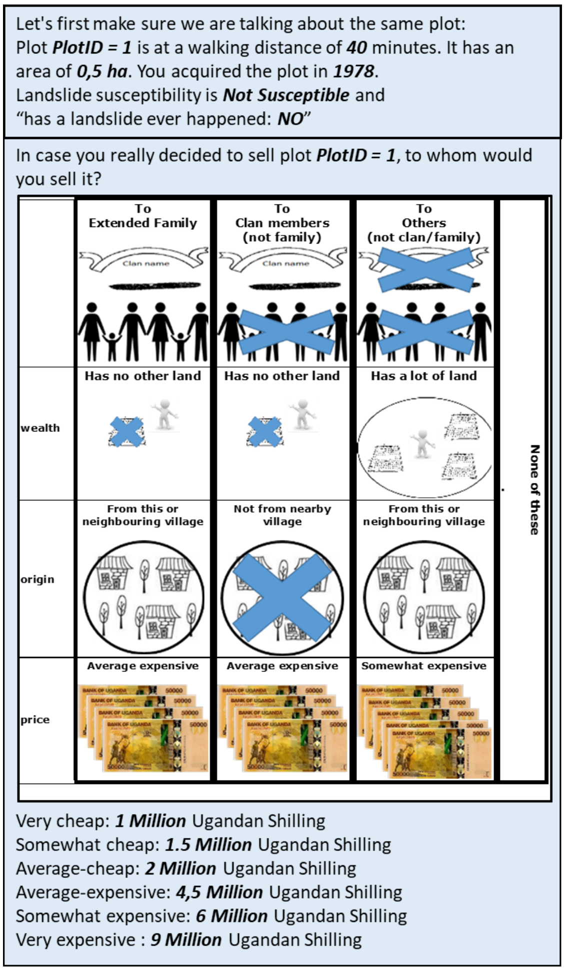


*Figure 3-4. Example of a choice card, as was presented during the interview in the Rwenzori region. The choice experiment was ran at plot level, so that each household head responded to several choice cards for each of his/her plot. The advantage of this method is that differences between different plots, including differences in landslides susceptibility, could linked to different preferences.*

The interviews were performed by students of Mountains of the Moon University (Fort Portal, Uganda), who received a 5 days training on how to implement a quantitative scientific survey. The students have been supervised by one of our PhD students. The interviews lasted on average 3-4 hours per household, including the time to visit at least one plot cultivated by the household.

During data analysis spatial information was extracted in GIS from a Digital Elevation Model (DEM) with a resolution of 30m, a geological map and the landslide susceptibility map that was produced through WP1 (GTK Consortium, 2012; Jacobs et al., 2018; USGS, 2014).

Data analysis was performed with Stata 15 software and aimed at identifying correlations between household characteristics and household income, exposure and behaviour. Ordinary least squares regressions, logit regressions and household fixed effects panel analyses have been run to identify these relations. The choice experiments have been analysed with multinomial logit equations.

***Valuation of elements at risk in one key sub-county of the Rwenzori Mountains, Uganda***

The data about the monetary value of elements at risk as well as the damage data for Mahango sub-county were collected during two periods: from July until August 2016 during the rainy season, and from January until February during the dry season. These data were collected through semi-structured interviews. These data gathered information about the structure of the different buildings and their related costs of construction and (potential) repair after being damaged by landslides. In total, 11 informants were interviewed (Table 3-1). The Living Standards Measurement Study-Integrated Surveys on Agriculture database, constructed by the Ugandan Bureau of statistics (UBOS) database, were also consulted to determine the monetary value of land cover. The main variables used are parcel name, GPS record of the parcel, the size of the parcel, the rent of the parcel and the crop types in the two cropping season and quantity of harvest sold, price of the harvest sold.

*Table 3-1: Description of the informants in 2016 and 2017 (Note: H=house, TC= trading center, CR= community road, DR= district road, WS= Water spring, SCHQ= sub county headquarters, CH= church, S= school; from Schoonenbergh, 2017).*

| Name | Profession | Other | Informant about… |
|---|---|---|---|
| | | ***In 2016*** | |
| **X1** | Unknown | Resident in Mahango village | H, TC, CR, WS |
| **X2** | Unknown | Resident in Mahango village | H, TC, CR, WS |
| **X3** | Builder | Resident in Mahango village | H, TC, CR, WS |
| **X4** | Senior district engineer in Kasese district | Unknown | H, DR, WS, SCHQ, S |
| **X5** | Unknown | Rich Donator in COU in Mahango village | CH |
| | | ***In 2017*** | |
| **X6** | Official constructor in Kasese town and Mahango sub-county | Resident in Mahango Village | H, WS |
| **X7** | Informal technician in Mahango sub-county | Resident in Buthale village | H, CR, WS |
| **X8** | Informal technician in Mahango sub-county | Resident in Mahango village | H, CR, WS |
| **X9** | Reverend, Financial manager of COU in Mahango sub-county | Born in Mahango sub-county | CH |
| **X10** | Senior District engineer in Kasese district | No data | DR, WS, SCHQ, SC, HC |
| **X11** | Water district engineer in Kasese district | No data | DR, WS, SCHQ, SC, HC |

Based on the different elements identified during the classification, the physical vulnerability of these elements is determined. Two different scenarios are made for simplification reasons. The first scenario consists of small damages. For human infrastructures, this means the damage can be repaired as it only concerns small cracks or partial destruction. For land cover, this means a part of the parcel production is destroyed and the entire harvest is lost. The second scenario simulates severe damages. Conceptually, it represents a maximal or pessimistic simulation of the damage occurrence. For all types of elements at risk this means complete destruction.

For the first scenario, two different methods are used depending on the function of the element at risk, i.e. human infrastructure or land cover. For human infrastructures, an initial value and final value is ascertained based on the following equation (Leone et al., 1996):

$$VI=(Value_{initial}-Value_{final})/Value_{initial}$$

where $VI$ equals the Vulnerability index; $Value_{initial}$ means the initial value of the object prior any damage; $Value_{final}$ represents the final value of the object after being damaged. The coefficient VI varies between zero and one.

The initial value of human infrastructures is estimated by the semi structured questionnaires (Table 3-4). As the interviewees revealed information that sometimes contradict themselves, a matrix was constructed to highlight which speaker seems more reliable. The criteria are based on the profession, the amount of details given with their answers and on the impressions of confidence of the interviewer. Also, additional data were available for the health centres in the form of official construction documents available at the education office of Kasese district. For the land cover, the initial value is calculated differently as construction costs are not applicable for this type of elements at risk. Here, the initial value is established based on the UBOS database. By crossing data, the average price of a certain land cover type per unit surface is calculated. For the final value, the method of the repair cost is applied to determine the human infrastructures' value after (potential) damage due to landslides (Kiremidjian et al., 2007). This method consists of valuating the element by its cost to rebuild in case of a certain type of damage (moderate or severe in this case). In Uganda information about the price of buildings is hard to obtain as no standard of evaluations like the current estate price or insurance statistics are available. Therefore, the method of the repair costs is deemed more appropriate. The damage to land cover is ascertained by calculating percentage of production value lost. This is obtained on the assumption that when a landslides covers a certain percentage of a land cover type, the production value lost is equivalent to the percentage of landslide coverage (Vranken et al., 2014). To determine that percentage, the most frequent damage occurrence per land cover type was calculated based on the household survey described in the previous paragraphs with the following equation: $D_i= n_i/N$. Where $D_i$ equals the scaled frequency occurrence of a damage intensity *i* of land cover type; $n_i$ is the occurrence of a certain landslide coverage *i* of land cover type; $N_i$ is the total number of land cover.

For the second scenario, the coefficient of vulnerability is always equal to one because in every case, the object needs to be totally rebuild to a new one. Therefore, only the initial value needs to be calculated. This value is calculated following the same procedures as for scenario one.

***Choice experiment in the Bamboutos region, Cameroon***

Additional to the work performed in the Rwenzori region, a short household survey and a choice experiment have been implemented in the Bamboutos region in Cameroon. This research, which fits into a master thesis of a student in bio-science engineering at the KU Leuven (Baert, 2018), aimed at identifying the conditions for voluntary relocation over a short distance outside landslide prone area. Studying voluntary relocation makes sense in the Bamboutos region because, in the past, farmers have already relocated outside the caldera to escape landslides. To our knowledge, this is one of the rare cases of voluntary relocation outside landslide prone area in a rural region in the Global South. An example of a choice card that was used in the choice experiment in the Bamboutos is presented in Fig. 3-5.

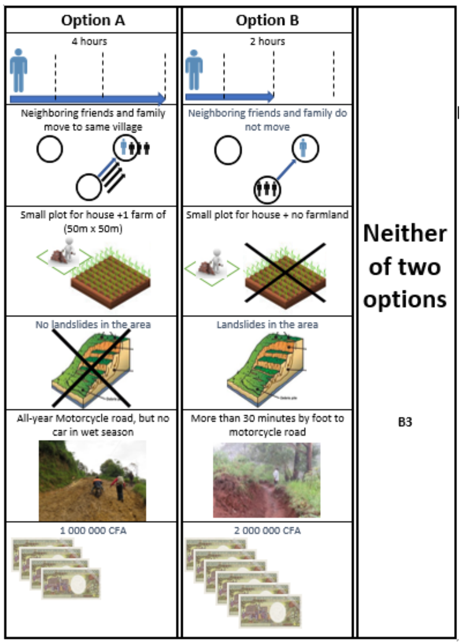


*Figure 1-5. Example of a choice card, as was presented during the interview in the Bamboutos caldera in Cameroon.*

## WP.3. Resilience strategies

### TASK 3.1. Assessment of household level resilience strategy

The first objective of WP3 is to review which landslide risk reduction measures are being recommended and implemented and what are the challenges for their implementation. In this study, we only considered countries for which (1) at least 50% of their land area lies between the tropical circles and (2) at least one inhabitant per year was exposed to either rainfall- or earthquake-triggered landslides, according to the Global Risk Data collected by the Norwegian Geotechnical Institute (NGI) for the Global Assessment Report on DRR (Giuliani and Peduzzi, 2011). This Global Risk Data is, to our knowledge, the most complete and consistent global dataset. It expresses the absolute physical exposure to landslides as the expected average annual population exposed (# inhabitants/year) and is based on the modelling of landslide susceptibility and population density (NGI, 2013). Of the 138 tropical countries, 99 met this second criterion and were considered for our review on recommended and implemented DRR measures for landslides (Table 3-2). For a full discussion of the included country and the possible errors in excluding small island states, we refer to Maes et al. 2017).

Scopus® (Elsevier B.V., 2015) was chosen as the search engine to select articles for the detailed review on recommended and implemented landslide risk reduction measures, because this search engine yielded the highest number of countries with publications and includes more social sciences-oriented publications besides natural sciences, which is deemed crucial for this research. Furthermore, Scopus produces more citation counts than WoS (Bergman, 2012; Falagas et al., 2007) and it has been shown to result in fewer inconsistencies regarding content verification compared to WoS and Google Scholar (Adriaanse and Rensleigh, 2013).

An inventory of peer-reviewed articles on landslides and landslide risk reduction, published between January 2005 and January 2015, was thus made using Scopus. The keywords and Boolean search criteria described below were applied to the 'title', 'abstract' and 'keywords' simultaneously. In order to analyse the literature on landslide risk reduction, we first searched for publications on landslides in general and then specifically publications on landslide risk reduction. For the landslide literature, we used the following keywords and Boolean search criteria: *<country name> AND (landslide* OR 'mass movement' OR 'mass wasting')*. For the landslide risk reduction literature, we used the same keywords and Boolean search criteria but added the terms *'prevention', 'management', 'mitigation', 'risk reduction'* or *'remediation'* in order to narrow down to DRR. Only peer-reviewed publications with English abstracts have been taken into account. Noteworthy is that 25% of the 536 publications concerns India. After detailed investigations, 154 out of the 536 landslide risk reduction publications were excluded because they were irrelevant for this research (e.g. articles on submarine landslides).

To classify the landslide risk reduction measures, we used the general DRR classification suggested by Twigg (2007). This classification consists of five components: (i) risk management and vulnerability reduction, (ii) governance, (iii) knowledge and education, (iv) preparedness and response and (v) risk assessment. 'Risk management and vulnerability reduction' contain all measures related to reducing the occurrence of landslide hazards, the vulnerability to landslides and the exposure to landslides. 'Governance' relates to institutional frameworks and policies on landslide risk reduction. 'Knowledge and education' consist of all measures related to awareness raising on landslide. 'Preparedness and response' comprise all measures dealing with early warning and emergency response. 'Risk assessment' includes all aspects of understanding landslide risk. These five components can then be further classified into specific risk reduction measures. The classification of landslide risk reduction has been the subject of much debate (Nadim and Lacasse, 2008). Here we used the classification of the SafeLand project to further divide the component of 'risk management and vulnerability reduction' in subcategories, since this was the most recent classification and since it was based on a comprehensive literature review (Vaciago, 2013). For a detailed description of specific landslide risk reduction measures, we refer to Twigg (2007) and Vaciago (2013).

Using this classification, the implemented and recommended landslide risk reduction measures in landslide-prone tropical countries were identified by screening the abstract and conclusions of the 382 collected publications on landslide risk reduction. With implemented landslide risk reduction measures, we understand specific actions and techniques that are mentioned in the article (not necessarily with detailed explanation) as currently being developed or operational. Similarly, with recommended measures we mean specific actions and techniques that are suggested as recommendations but not yet developed or operational in the country.

Finally, the bottlenecks for implementing landslide risk reduction measures have been identified by screening the abstract and conclusions of the 382 publications. After identification, these bottlenecks were classified into six sections based on our own judgement: i.e. scientific, political, social, economic, disaster risk management related and geographic bottlenecks. All categories are, however, not mutually exclusive.

### TASK 3.2. Assessment of policy level resilience strategy

The second objective of WP3 is to assess specific landslide risk reduction policies and their effects on DRR: i.e. disaster platforms in the Rwenzori Mountains of Uganda and disaster risk zonation in Limbe city of Cameroon. To assess the disaster platforms in Uganda, data were collected at three different politico-administrative levels: national, district, and sub-county (Table 3-2) during three months of field work in the summer of 2014. The chosen levels are the most relevant for disaster risk management, according to the 2010 National Policy on disaster risk management (OPMRU, 2010).

We combined three different data collection methods: i.e. semi-structured interviews, focus groups and collection of secondary data sources. The most relevant data to study the implications for disaster risk management of disaster network governance come from the focus groups, which were organized at district and sub-county level with key members of the respective decentralized platforms for disaster risk management. Information obtained through focus groups was triangulated with the other methods. Semi-structured interviews were held with key informants involved in disaster risk management. We chose to conduct focus groups because of their acknowledged contribution to policy analysis: stakeholders are enabled to participate in discussions and underlying power relations might be revealed (Kahan, 2001). The validity of the information was checked by transcribing and coding all semi-structured and focus group interviews (Corbin and Strauss, 2015) using NVivo (2012) software.

**Table 3-2.** Data collection methods for the different politico-administrative levels in the Rwenzori Mountains, Uganda (DDR = Disaster Risk Reduction; DMC = Disaster Management Committee).

| **Level** | National | District | Sub-county |
|---|---|---|---|
| **Location** | Kampala | Bundibugyo | Kirumya |
| | | Kabarole | Kateebwa |
| | | Kasese | Mahango |
| **Data collection methods** | 15 semi-structured interviews | 15 semi-structured interviews | 9 semi-structured interviews |
| | Secondary data: OPMRU, 2010; UNESCO- UNATCOM, 2014 | 3 focus groups with DMC's | 3 focus groups with DMC's |
| | | secondary data: budget allocations, development plans and disaster reports | secondary data: budget allocations, development plans and disaster reports |

To assess the disaster risk zonation in Cameroon, the case of Limbe city was selected. A qualitative research approach was used, based on four data collection methods: focus groups, semi-structured interviews, secondary data collection and a household survey. The data corresponding to the first three methods was collected in the summer of 2015 during five weeks of field work in Limbe and Buea; the household survey was conducted and analysed in the framework of Jeff Molombe's PhD research (University of Buea). Firstly, secondary data on Limbe city and risk zonation for landslides and floods were collected and analysed. These included national laws and orders, hazard maps produced by different projects, and urban development plans. Secondly, information on perception of risk zonation was gathered through 20 semi-structured interviews with representatives of local and national authorities, NGOs, scientists and citizens living in so-called 'risk zones'. Thirdly, seven focus groups were held, including one with local authorities (Limbe I) and six with local communities on the development and implementation of risk zonation policies. Three focus quarters with risk zones were selected for this: Unity Quarters, Mabeta New Layout and Mbonjo quarter (Fig. 3-6). For each quarter, two focus groups were held in order to enhance open discussion: one with women and one with men. Each focus group consisted of nine to ten participants. Fourthly, a household survey was conducted to compare the perceived evaluation of quarter facilities provided by the government, between citizens living inside and outside so-called ‘risk zones’ of Limbe. It consisted of 187 households sampled amongst several quarters in Limbe. A multi-stage sampling procedure was followed to select interviewed households. The stratified sampling technique started with categorizing the various quarters according to location, geophysical conditions and socio-demographic characteristics of residents, into six quarter types. For each quarter type the most representative quarters were sampled. Each sampled quarter was then subdivided into clusters, based on their relative population number to determine their sample size. Finally, households were selected from these clusters by a random sampling technique to ensure representativeness. The survey was answered by the household head of the selected household, or, in absence of the former, by another household member above 15 years old.

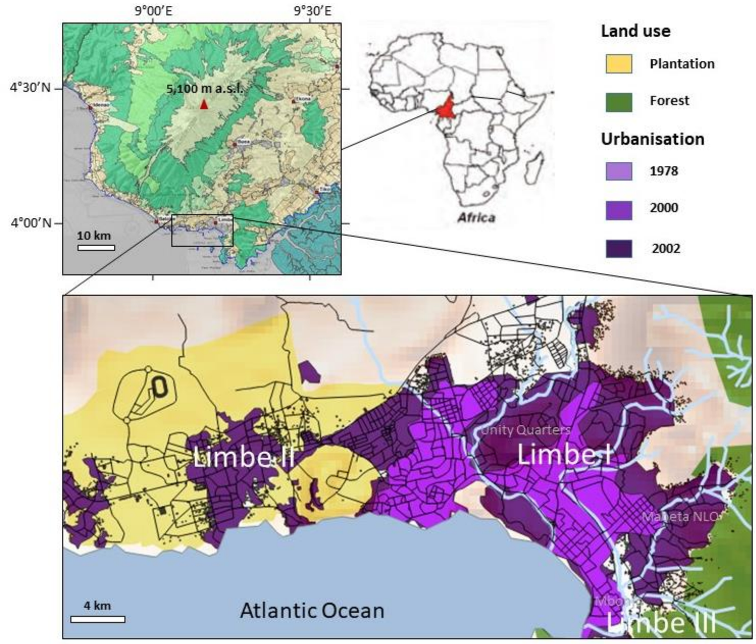


*Figure 3-6. Location of Limbe city in South-West Cameroon (Adapted from MIAVITA project, 2008 and OpenStreetMap, 2016).*

The validity of the collected information was checked by transcribing and coding all semi-structured interviews and focus groups (Corbin and Strauss, 2015) using NVivo. SPSS was used to analyze the survey data, applying both descriptive (i.e. frequency tables and percentages) and inferential statistical techniques (i.e. measures of association using Chi Square test of independence). In order to assess the consequences of the risk zonation policy on the exposure to natural hazards of people in Limbe, satellite images were analysed. For this analysis, buildings in Limbe were retrieved from OpenStreetMap Foundation (2016) and overlaid with so-called ‘risk zones’ from different studies in a QGIS environment.

## WP.4. Cultural representations and motivations for land management

### TASK 4.1. Description of cultural premises related to land and natural hazards

The community identified for the anthropological survey was the Bakonzo people, who have strong cultural incentives to live in the highlands and specific history, myths and representations inspired by this particular habitat. The Bakonzo people are also the major cultural group living in the Rwenzori mountains. To a lesser extent, other cultural communities have also been researched – in relation with Bakonzo customs and uses – in order to understand their mutual coping with cultural habits, especially those related to land boundaries settlement and land acquisition.

Four in-depth anthropological fieldwork stays have been set up in order to allow fluid participant observation to take place with the help of local households. The first fieldwork was dedicated to the building of a framework for the research: safe homesteads to stay within 3 locations (Mahango village, Ibanda parish and Bundibugyo) for the anthropologist and the 3 PhD students, rates for “appreciations” and daily fees to be given to informants, facilitators and important characters helping the research, means of transportation, contacts with the informants and general logistics. Coordination meetings with the cultural and political leaders have been organized in each targeted community before the beginning of the research in order to inform them about the research survey to identify possible informants. The anthropological survey was dedicated to three categories of informants and participators: the victims of LS and their extended family, traditional ritual specialists involved in rituals preventing or coping with disasters (omuthahwa), and cultural leaders related to land rights (isemalhambo, omukulhu wawulambo), including clan leaders and ministers of the royal family. The victims have been surveyed to determine to what extent their representations of the causes of LS – and natural disasters and misfortune as a whole – can find some cultural grounding, personally and socially (due to cultural leaders and specialists’ influence and pressure). As the “Bakonzo culture” has imperfectly been documented (only a few recent works are available), the perspective of publications coming out of the anthropological research is warmly welcome by the informants, helpers and facilitators

Some efforts have been made to learn the basics of lhukonzo, the language spoken by the Bakonzo, especially key terms related to disasters, traditional buildings, items and functions, and cosmology. The interviews allowed to assess the implication of the invisible in the local explanations for misfortune and to begin to draw a portrait of the cosmology of the Bakonzo. Two anthropological fieldtrips were dedicated to the continuation of the study of this complex cosmology and the relationships between the Bakonzo and the spirits/gods/invisible beings, as people constantly make connections between social life, the environment and the spiritual world.

A survey has been done about the moral components of ritual performance, tree planting and cultural leadership, as well as non-appropriate behaviors – especially in the mountains – often evoked as possible causes for disasters (e.g. once people misbehave uphill (murder, sex, and fighting), Kythasamba – the god of the snow mountains – can destruct them by lightning and send LS). The interviews have also investigated the influence of Churches over these beliefs.

A description has also been made of the land acquisition process, in particular traditional owners of the land (chieftain/isemalhambo, ridge leader/omukulhu wawulambo, sub-ridge leader/omusokyi) and their ritual functions (including the adjustments of land boundaries and the plants used for that purpose), as well as the payment of the traditional tribute to the omukulhu wawulambo.

### TASK 4.2. Definition of the local means customarily requested to face natural disasters

In order to describe land rights, land management and negotiations over land, environmental governance, leadership structure, interviews of a diversified panel of key informants (including spiritual and customary leaders) have been performed, focused on cultural representations, the actual application of land rights and the connection of land use to cosmologies and spiritual practices, both Christian and customary. The survey of key informants helped to identify and describe cultural premises and representations related to natural hazards, the extent of solidarity networks and the leadership structure (political, religious, family), focusing on leaders involved in coping with natural disasters and involved in the reorganization and renegotiation of land rights and uses after a hazard. In each community, a comparable panel of informants was interviewed with a balance between men/women, youngsters/elders, land owners/users, religious/medical specialists and victims. Local customs have been progressively unveiled and taken into account to conduct the interviews.

In Kabarole subcounty, some discussions have been organized with Batooro people about cultural trees and stories of important birds and bad omen provided by certain animals, as well as cultural reactions to disasters (hailstorms, rains and epidemics). However, connections with the invisible as regards disasters and calamities seem to belong to the past, unlike the Bakonzo people.

As WP 4 is also dedicated to the understanding of the environmental governance, the mechanisms involved in land boundaries settlement, and the perception and management of LS risk by leaders and local communities, the interviews also helped to describe the leadership structure (official and non-official), in particular customary leadership involved in environmental hazards such as healers, traditional leaders and influential personalities of Bakonzo kingdom, and to enlighten about land discussions and negotiations in case of land readjustments due to misfortune as a whole and unpredictable events such as LS. The survey also focused on the royal family of the Bakonzo (Omusinga Rwenzururu designates the kingdom). Meetings have been organized with the King of the Bakonzo Obusinga Rwenzururu Charles Wesley, the Queen, the Queen Mother - both of them being involved in important rituals - and several ministers for the kingdom. The King, considered the head of the spiritual power, gives the signal to launch rituals of major importance. The royal family plays a significant role in the Bakonzo struggle against natural disasters and misfortune. The Queen Mother seems to intervene through annual rituals ensuring fertility and prosperity among the Bakonzo, encouraging the communities to have twins.

During the work with cultural leadership, it appeared that leaders involved in “culture” are rarely the same as political leaders but work hand in hand with them in some contexts, notably to acquire a new land. However, young people tend to solicit the LOC1 (local political leader) and less often the *owukulhu wawulambo* (traditional owner, who culturally owns the whole land of the Bakonzo people). An attention has also been given to the role played by cultural heritage and sites such as Nyamutsule.

The survey also tested the perception of the hazards relative to other environmental threats, customs and cultural responses to hazards and to natural events in a broader sense.

We have noticed an enthusiastic welcome to the research. Many informants – victims of LS but also people whose activities are coping with misfortune – spontaneously showed up when they heard that a research was performed about LS under the angle of “the culture of the Bakonzo”.

### TASK 4.3. Assessment of the coping capacity

Six key informants (Eri Thembo Nyakango, Emmanuel Masereka, Johnson Kiryango, Mugume Mumbere Enos, Azoli Bahati, Joseph Mumbere) willing to cooperate on the explicitly cultural aspects of the research, have been selected among the cultural leaders, ritual specialists and people involved in the maintenance of traditional gardens – containing plants used for dealing with cultural beings supposedly responsible for natural and social disasters – and the traditional land boundaries settlement. The survey of these key informants aimed at precising and exploring already collected data related to Bakonzo myths and history, intercultural communication about land acquisition and resettlement, leadership structure and intertwining of the different levels, underlying tensions in land management and changes, Bakonzo personal and family values and, broadly speaking, cultural premises inspiring representations about natural hazards and misfortune in general.

The research tried to enlighten about existing cultural resilience strategies, the extent of solidarity networks and the cultural (but also political, religious, family) leadership structure, focusing on leaders involved in coping with natural disasters and involved in the reorganization and renegotiation of land rights and uses after a disaster. Some investigation was made about the help received by the victims and endeavours provided by different actors (families, neighbours, friends, government, Red Cross, other NGOs, Churches).

A special attention has been given to plants, bushes and trees traditionally used to cope with disasters (LS, lightening, thunder, floods, hailstorms, epidemics, bad omen, connection to rainbows, change of weather, also social disasters); around 60 plants have been identified to cause misfortune as a whole (the inventory is not complete yet). 36 plants are specifically connected to disasters, lightening, LS, earthquakes, epidemics, social and family issues. Interviews have been done with *abathahwa* ('healers' reknown to deal with cultural beings) to understand the way they are mitigating disasters and misfortune in general; detailed observations of their practices would be essential during further fieldwork.

A visit has been paid to Rudy Lemmens in Lira (in the North) about recent improvements of the Mpan'game (participatory tool to involve local communities into specific issues) and its adaptation to disasters and LS in particular. The purpose is to extend it beyond the Mpanga River with a new name: 'Village disaster preparedness game' (in luo, the language spoken here). Findings gave some insights to define possible – culturally acceptable – behaviours that could be adapted to increase resilience (materials and techniques used in architecture, reorganization of harvesting in function of rainfall), possible means to help the people to better accept LS occurrence (proximity with a health centre, psychological follow-up, teachers training) and possible incentives to arise the local civilians' intention to move or to adapt their usual behaviours after a natural disaster (support from an influent leader, cultural and ritual precautions to make new behaviours accepted, assurance of a livelihood or of a replacement land, presence of a family member, free housing, grant allowance).

## WP.5. Risk mapping and selection of resilience strategy

### TASK 5.1. Risk Mapping

The aim of this WP was to quantitatively assess the risk of landslides in Mahango sub-county in the Rwenzori Mountains. The final goal was to provide results on the potential loss expressed in monetary values by integrating the landslide hazard, and the exposure and physical vulnerability of elements at risk. Therefore, we used the landslide susceptibility assessment of Mahango sub-county as described in WP1. Second, the element at risk were identified in WP2. Third, the initial monetary value of each element at risk was assessed as well as its final value after damage, as described in WP2. Two scenarios of vulnerability were considered: one for small damage caused by landslides and one for full destruction. As such the damage ratio was determined. Finally, the three risk components were integrated by multiplying all components (Dai et al., 2002):

$$Risk(PL)= \sum_{i=1}^{I} E_i \; x \; V_i(P|L) \; x \; P(H_S) \; x \; P(H_T)$$

whereby, $Risk(PL)$ equals the potential monetary loss due to landslides damages and is expressed in Ugandan shillings per year (USH/year). $Ei$ equals the exposure of the element at risk *i,* expressed in monetary value (USH). $(P|L)$ depicts the coefficient of vulnerability of the element *i*. It ranges between zero and one and is a dimensionless unit. $(Hs)$ gives the probability of spatial probability of occurrence of a landslide. It ranges between zero and one and is a dimensionless unit. $(HT)$ corresponds to the temporal probability of landslide occurrence which is expressed per year (year-1). $I$ equals the number of pixels of elements at risk.

Several assumptions are made due to the limited data availability. First, the risk is determined only for direct impacts caused on elements at risk. Indirect impacts are usually determined for industrialized countries by estimating the disturbance of tourism, the business interruption (e.g. due to traffic interruption), the social costs (e.g. health problems post hazards), the environmental impact (e.g. water contamination by mud), loss of productivity due for instance to the destruction of crops (Papathoma-Köhle et al., 2011; Zêzere et al. 2007). Even in industrialized countries, the indirect impacts are often roughly estimated or simply ignored (Schuster et Highland, 2001). Hence, this approach is not applicable to remote areas with poor infrastructures and scarce data such as the Rwenzori Mountains region, despite the fact that stakeholders identified qualitatively indirect impacts occurring in the region (Kervyn et al., 2015). Second, the risk concerning people is not considered, e.g. in terms of injuries or fatalities. Already existing studies made in East Africa showed that landslides affect people by the loss or destruction of crops, the loss of soil fertility or the loss of house, but that casualties and physical impact on people are limited (Abebe et al., 2010; Msilimba, 2010). Third, no probability of damage is considered. It is assumed that when a landslide occurred, it automatically damaged the elements at risk to a certain level determined by the damage ratio.

### TASK 5.2. Toolbox for assessing resilience strategies

In this WP, we propose a social multi-criteria analysis (SMCE) to support decision-making for selecting appropriate DRR measures and to anticipate both uncertainty and value conflict. Therefore, we combine a two-phased participatory multi-criteria analysis (MCA) with two additional steps (Fig. 3-7). The latter includes an institutional analysis, i.e. identifying various actors involved in disaster governance, and a discourse analysis, i.e. interpreting the weighting of criteria, to ensure both public participation and transparency in the decision support process (see Maes et al., In press).

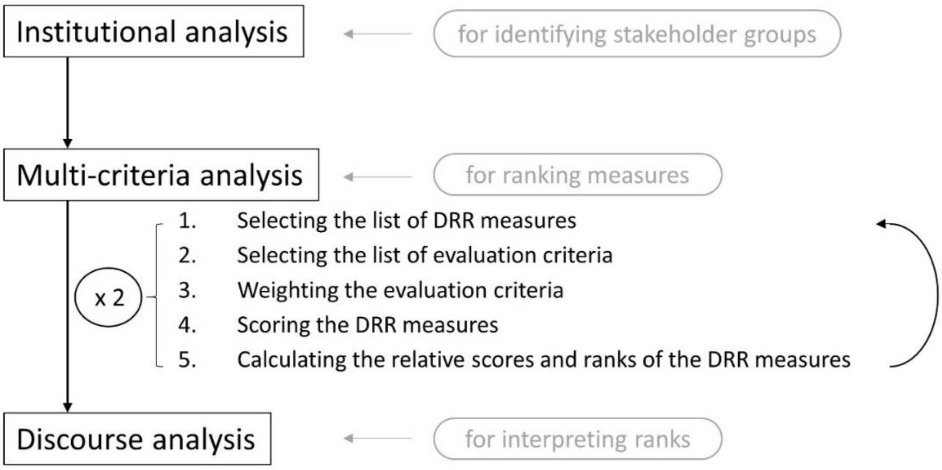


*Figure 3-7. The three steps in the proposed social multi-criteria evaluation: (1) institutional analysis, (2) two-phased multi-criteria analysis, and (3) discourse analysis (Note: DRR = Disaster Risk Reduction; Maes et al., in press).*

The first step in the SMCE is the institutional analysis, which involves an investigation of the disaster governance in a specific location. The primary objective of this analysis is to map the different actors relevant for disaster governance over various politico-administrative levels (Munda, 2004). This analysis allows an in-depth understanding of the socio-political context within which decisions are made concerning DRR. Moreover, it enables the identification of potential stakeholder groups at the various levels for the subsequent steps.

The second step is the two-phased MCA. MCAs have been widely proposed and applied to serve as a decision support system to deal with risks from natural hazards (Barquet and Cumiskey, 2017; Gamper and Turcanu, 2009; Newman et al., 2017; Smith et al., 2016). They are most often used to assess stakeholders' perceptions on evaluation criteria in order to rank different alternatives (Huang et al., 2011), in this case DRR measures. In contrast to cost-benefit analyses, MCAs are applied when these criteria cannot be expressed in monetary terms solely (Lim et al., 2005). The MCA process thus involves qualitative ranking criteria by a number of stakeholders according to their preferences and belief systems (Smith et al., 2016). A MCA has the possibility to assign levels of importance, i.e. weights, to each of the evaluation criteria. Weighting the criteria is based on the analytic hierarchy process (AHP), which uses 'pairwise comparisons' to compare criteria to one another (Saaty, 1990).

A novel approach is that we propose to apply this SMCE methodology in two phases. Applying several phases, also known as the Delphi method (Linstone and Turoff, 1975), allows for reaching more 'consensus', i.e. less variability of the individual stakeholder results from the average results of the stakeholder group. For both phases, the five subsequent steps to evaluate and rank DRR measures based upon stakeholder groups' perceptions are (Fig. 3-7): (1) selecting a set of DRR measures and evaluation criteria, (2) selecting a set of evaluation criteria, (3) weighing these criteria at the different criterion levels, (4) scoring the measures, and finally (5) calculating the relative scores for the measures by multiplying their scores on the criteria with the respective weight of these criteria and ranking them. A summary of the findings from phase one was presented to discuss with the relevant stakeholders during the second phase, allowing for feedback on the method, and 'anchoring' of the second phase scores around the average scores of the first phase.

The third step of the SMCE is the discourse analysis. Discourse analysis looks for patterns in the representation and interpretation of reality to understand people's worldviews (Van Dijk, 2008), or cultures (Bankoff et al., 2015). Contemporary explanations of culture consider culture as an array of discourses (Oliver-Smith, 2015). Critical discourse studies acknowledge the role of power dynamics in discourses and their implications for (re)producing reality (Wodak and Meyer, 2016). More specifically, the weights given by the various stakeholder groups are coupled to different discourses on disasters which are extracted from language use of each stakeholder group respectively and described in theory (e.g. Furedi, 2007; Manyena et al., 2011). This analysis is intended to interpret the final ranks according to the different locations, administrative levels and stakeholder groups.

This proposed methodology was tested in the two most landslide-prone districts of the Rwenzori Mountains: Kasese and Bundibugyo (Jacobs et al., 2017). Guided by the respective district officials (Kervyn et al., 2015a), the sub-county with the highest landslide intensity was selected for each of these districts. Within each of these sub-counties, one village that has been heavily affected by landslides was selected. Data collection was done in two phases in the summer of 2016 and the spring of 2017 (Table 3-3). Where possible the same participants were included for both phases. The (inter)national stakeholder group consists of 12 Ugandan and foreign (Belgium, Cameroon, Czech Republic) academics involved in landslide research. At district and sub-county levels, the most relevant representatives of the respective DMC members were selected, including government officials, NGO and private sector representatives, members of cultural institutions, and local researchers. At village level, separate meetings were held for a group of approximately 10 men and 10 women per village, including representatives of youngsters, elderly, disabled and people affected by landslides. This gender segregation was done to ensure open discussions. Each of the three steps of the SMCE, were based on different data collection methods (Table 3-4), including literature review, surveys, focus groups, semi-structured interviews and secondary data collection.

*Table 3-3. The politico-administrative levels, the respective geographical locations of the collected data and the number of participants, between brackets, in phase one and two. (Note: *including both men and women groups).*

| Level | (Inter)national | District | Sub-county | Village* |
|---|---|---|---|---|
| **Geographical location** | Uganda, Cameroon, Belgium, Czech Republic (12;9) | Bundibugyo (11;11)<br>Kasese (9;11) | Kirumya (9;12)<br>Mahango (9;9) | Nyangasa (10+12;10+12)<br>Mahango (10+10;10+10) |

*Table 3-4. Data collection methods for the different politico-administrative levels in the Rwenzori Mountains region (Note: SMCE = Social Multi-Criteria Evaluation; DMC = Disaster Management Committee).*

| Steps in SMCE | Data collection methods |
|---|---|
| Institutional analysis | Secondary data collection (including policy documents, scientific articles) and semi-structured interviews (WP 3) |
| Multi-criteria analysis | |
| 1. Selecting measures and criteria | Literature review (WP 2), field work (WP 3), and feedback from stakeholder groups in phase 1 |
| 2. Building a hierarchy model for the criteria | Literature review and feedback from stakeholder groups in phase 1 |
| 3. Weighting | Surveys in two phases with the (inter)national, the district/sub-county DMC's, and the village stakeholder group |
| 4. Scoring | Surveys in two phases with the district/sub-county DMC's |
| Discourse analysis | Literature review for (inter)national experts, and focus group and semi-structured interviews with district/sub-county DMC's and village stakeholder groups |

For the institutional analysis, actors involved in landslide risk reduction and their roles were identified based on secondary data and semi-structured interviews (Table 3-4). Secondary data included policy documents at various politico-administrative levels, reports of (inter)national organisations and scientific articles on landslide risk reduction in Uganda (e.g. Bamutaze, 2015; Jenkins et al., 2013; UNESCO, 2014). Semi-structured interviews were held with key respondents involved in DRR from national to village level. For the two-phased MCA, a different data collection method was used for each of the five steps (Table 3-4). For the discourse analysis, different qualitative methods were used depending on the stakeholder groups (Table 3-4). At district, sub-county and village level, focus group interviews were held with the respective stakeholder groups during the second phase of the MCA. Critical discourse studies are based on the assumption that power relations and worldviews of respondents are discursively manifested in their linguistic choices (Wodak and Meyer, 2016). Questions like ‘who or what can be blamed for losses due to landslides’, ‘what kind of problem are landslides’ and ‘how can this evaluation be used’, were discussed in detail. Answers to these questions were investigated through qualitative content analysis which tries to identify the (non-)use of key concepts and relate it to broader social, economic and political processes. Based on this content analysis, we linked the predominant criteria according to the weighting of the MCA to one of the three disaster discourses: hazard, vulnerability or fatalistic discourse (Furedi, 2007). For the (inter)national stakeholder group however, focus group interviews were impossible to be held for practical reasons. As disaster discourses have been discussed in scientific literature for international communities (e.g. Furedi, 2007; Hewitt, 2015; Manyena et al., 2011; Wisner, 2016), we linked the predominant criteria according to the weighting by the international stakeholder group to the dominant disaster discourse based on literature review.

# 4. SCIENTIFIC RESULTS

## WP.1. Landslide hazard

### TASK 1.1. Landslide inventories and ancillary data collection

***Archive inventory***

The archive inventory constructed for the Rwenzori Mountains contains 48 landslide or flash flood events, retrieved from all sources available of which 41 are landslides, 7 are flash floods or combinations of flash floods and landslides (Annex 1). The dataset ranges from 1929 to 2014 and all events except seven could be precisely dated; six out of these seven could still be situated in the month and year of occurrence. Most events could be located at the village or parish level, in some cases only a localization at (sub-) county or district level was possible. The inventory is published in Jacobs et al. (2016a). The archive study allows first insight into the consequences of landslides and flash floods in this region. They include loss of life, damage to or loss of buildings, loss of crops and livestock (Annex 1). This type of inventory construction can be applied to any data-scarce region within the tropics and outside, and shows that by devoting attention and focus to a specific region, in depth analysis of the same type of archive sources used for global landslide inventories can provide insights into whether landslides occur, where they occur, which trigger they have and what damage they cause for the population in regions absent in these global inventories.

***Field inventories***

Field mapping complemented with remote sensing image interpretation allows a detailed characterization of the landslide processes. The field inventory constructed for the Rwenzori is characterized by rates of completeness which are similar to, or outperform other examples of historical inventories (e.g. Malamud et al., 2004; Van Den Eeckhaut et al., 2007; Guzzetti et al., 2008). Due to fast vegetation regrowth, frequent cloud cover and the limited availability of remote sensing data, the identification of landslides on satellite images or aerial photographs would not allow reaching such high degrees of completeness. It is however important to highlight that field surveys do need to be done in a systematic way, not limited to observations from the road only. A full description of the field inventory procedure and its analysis can be found in Jacobs et al. (2017a).

This type of inventory construction was also applied to the Bamboutos and Mount Elgon. An overview of the mapped inventories is given in Table 4-1.  The inventory for the Mt Elgon area was completed in October 2016, in the framework of a VLIR-Team Initiative project (SURELIVE) in collaboration with BELSPO promoters J. Poesen and L. Vranken from KU Leuven. For the Bamboutos, a dataset of 666 landslides was constructed. Both the Mt Elgon and the Bamboutos inventories are currently under analysis, coupled to susceptibility assessments in these region (Table 4-1). The inventories constructed for the Rwenzori, Mt Elgon and Bamboutos region are among the most complete and detailed in equatorial Africa.

*Table 4-1. Overview of landslide (LS) data collected for the Rwenzori Mountains*

| *Study Area* | *Type of inventory* | *# LS* | *Data-type* | *Geographical coverage* | *Published* |
|---|---|---|---|---|---|
| ***Rwenzori*** | Archive inventory | 48 | Point data | Scattered over region | Jacobs et al. (2016a) |
| | Field Inventory (a) | 450 | Polygon data | Inhabited region | Jacobs et al. (2017a) |
| | Field inventory (b) | 469 | Point data | Inhabited region | |
| | Socio-economic survey (c) | 90 | Plot data | Inhabited region | Mertens et al. (2016) |
| | SPOT6 and Google Earth (d) | 770 | Polygon data | National Park | Jacobs et al. (2016b,c) |
| | Field inventory (e) | >50 | Polygon data | Peak regions RMNP | |
| ***Bamboutos*** | Field inventory | 666 | Polygon data | Bamboutos calderra | In prep. for publication |
| ***Mnt Elgon*** | Field inventory | 233 | Polygon data | Mount Elgon region | In prep. for publication |

***Additional inventories and datasets***

For the Rwenzori, the archive and field inventories are complemented by several initiatives leading to additional landslide data: 469 point data were collected in the framework of the VLIR SI project by Busitema University. Location of plots affected by landslides (from WP 2) complemented these inventories with an additional 90 GPS points of approximate landslide locations. These databases all focus on the inhabited region of the Rwenzori Mountains (i.e. in general below 2,200 m a.s.l.).

For the Rwenzori Mountains National Park, the construction of a regional landslide inventory based on Google Earth and SPOT6 imagery was completed (Table 4-1, Fig. 4-1). For the area around the recently deglaciated peaks, field surveys have allowed the delineation of 50 recent rock falls and debris flows (between 4,200-5,000 m a.s.l., Table 4-1, Fig. 4-2)). One major debris flow around the peaks of Mount Baker was surveyed in detail (Fig. 4-2), with a topographic reconstruction of the depositional area using UAV image acquisition (Samyn et al., 2017).

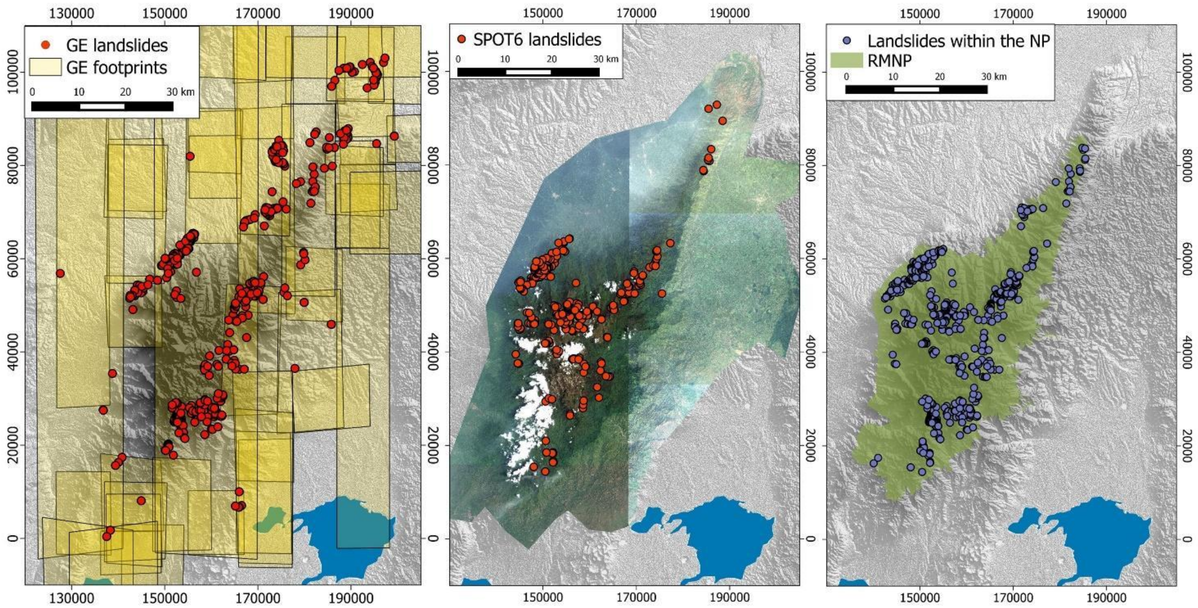


*Figure 4-1. Left: Landslides identified with Google Earth (GE), together with the footprint areas of the GE imagery used. Middle: landslides identified using SPOT6 imagery (Jan 2013). Right: GE and SPOT6 landslides occurring in the national park.*

With regard to the collection of ancillary data, a TanDEM-X 4.6m resolution DEM was constructed for the Rwenzori Mountains, in collaboration with the RESIST project. By combining this DEM and VHR SPOT6 imagery, synthetic anaglyphs could be constructed. Their analysis led to the identification of 275 faults, 15 glacial cirques and 62 moraine deposits. The smallest moraine deposit mapped by the stereo-viewing measured 48 ha. In comparison, the most detailed lithological map previously available containing polygons of moraine deposits (GTK consortium, 2012) only contained 33 deposits, the smallest measuring just below 80 ha. Furthermore, detailed fault maps or information on glacial cirques were previously unavailable.

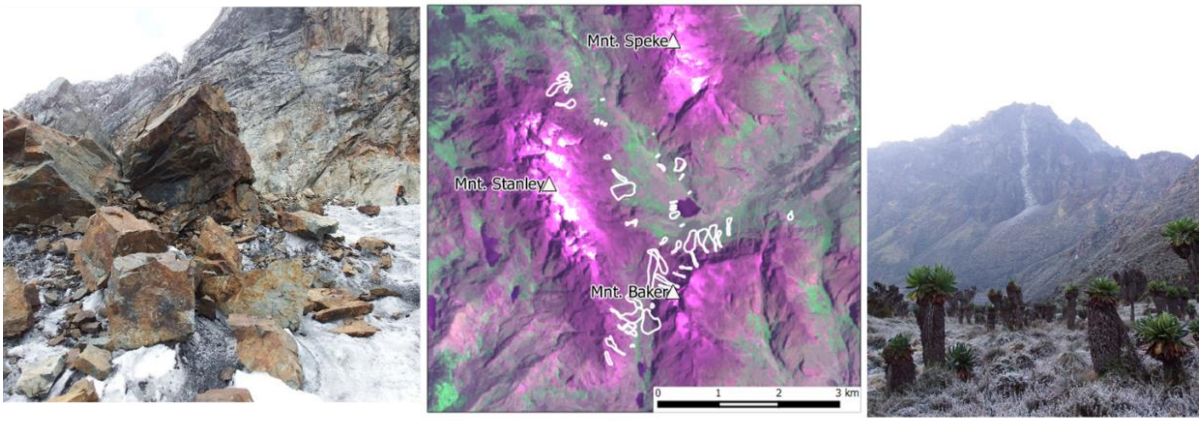


*Figure 4-2: Left: recent rockfall from deglaciated area around Mnt. Speke, Middle: polygon delination of recent debris flows around the peak areas of Mount Rwenzori, Right: Mount-Baker rockfall.*

### TASK 1.2. Landslide susceptibility

***Optimization of a pixel-based landslide susceptibility assessment***

Based upon our analysis for the Rwenzori Mountains inhabited study areas, it is demonstrated that a decrease of spatial resolution from 30 to 90 m in general decreased model performances (Table 4-2). An increase in resolution from 20 to 10 m however does not result in performance increases. This is in accordance with the concept of "optimal model complexity" where an increase in information does not necessarily improves the model performances (Grayson et al., 2002) but instead performances tend to reach an optimum after which increasing data availability does not increase or even decreases performance (Dewitte et al., 2010).

*Table 4- 1. Overview of the mean and standard deviation (S.D.) of AUCROC over 20 runs for the different model variants at each level. Selected model variants are marked in bold, values in italic indicate non-normally distributed samples (Shapiro-Wilk test, p<0.05). The null-hypothesis of homoscedasticity could only be rejected for the comparison of all variants in Nyahuka (p<0.05). Wherever applied, all non-parametric tests and the Welch-test confirm the results of the parametric tests and results are therefore combined here. Symbols indicate significant differences detected between variants.*

| | | TANDEMX10 | TANDEMX20 | TANDEMX30 | ASTER30 | SRTM30 | SRTM90 |
|---|---|---|---|---|---|---|---|
| REGIONAL | Mean $AUC_{roc}$ | 0.71 | 0.71 | 0.71 | 0.68 | **0.71** | 0.68 |
| ◊ / ○ / Δ | S.D. $AUC_{roc}$ | 0.01 | 0.01 | 0.01 | 0.01 | **0.01** | 0.02 |
| BUNDIBUGYO | Mean AUCroc | 0.70 | 0.69 | 0.70 | 0.63 | **0.70** | 0.65 |
| ◊ / ○ / Δ | S.D. $AUC_{roc}$ | 0.03 | 0.02 | 0.01 | 0.03 | **0.03** | 0.02 |
| NYHUKA | Mean AUCroc | 0.69 | 0.69 | 0.64 | 0.66 | 0.69 | **0.75** |
| ◊ / □ / Δ | S.D. $AUC_{roc}$ | 0.04 | 0.03 | 0.06 | 0.06 | 0.05 | **0.05** |
| KABONERO | Mean AUCroc | 0.75 | **0.78** | 0.76 | *0.75* | *0.75* | 0.69 |
| ◊ / □ / Δ | S.D. $AUC_{roc}$ | 0.05 | **0.04** | 0.03 | *0.05* | *0.05* | 0.05 |
| KYONDO /MAHANGO | Mean AUCroc | *0.71* | **0.73** | 0.71 | *0.68* | 0.73 | 0.66 |
| ◊ / ○ / Δ | S.D. $AUC_{roc}$ | *0.04* | **0.04** | 0.03 | *0.05* | 0.03 | 0.04 |

Significant difference *between all variants* (◊ at p<0.05)
Significant difference *between TANDEMX variants* (□ at p<0.05)
Significant difference *between all variants at 30m* (○ at p<0.05)
Significant difference *between SRTM variants* ( Δ at p<0.05)

Besides spatial resolution, the DEM source also influences the predictive power of the applied susceptibility model. The DEM based on optical imagery (ASTER) at the 30 m resolution never results in susceptibility models that significantly outperform those based on InSAR technology (SRTM and TanDEM-X) and on three levels, the SRTM30 and TANDEMX30 significantly outperform the ASTER30 variants (Table 4-2). This is supported by earlier comparisons of the SRTM and ASTER DEMs by Kervyn et al. (2008) who found that the ASTER DEMs have lower vertical accuracies and that they are affected by more small-scale noise and resulting apparent topographic variability than the SRTM DEM. Similar findings are also found by Guth (2010) and Li et al. (2013).

Nearly all local models outperform the regional model in terms of $AUC_{ROC}$ and prediction rate (Table 4-2). In general, by increasing the scale from regional to local level, more and more similar landslide processes are simulated within a single model. Because different landslide processes are controlled by different geo-environmental conditions, a downscaling to the local level can thus potentially result in a better performing model more tailored to the local conditions and sliding processes. Finally, we found that the separation of landslide types at the regional level allows to improve model skills for deep-seated landslides (up to an $AUC_{ROC}$ of 0.81) and to better understand the factors contributing to the susceptibility of shallow landslides. Shallow landslides seem to be more controlled by regional rainfall distribution and local runoff concentration in the landscape while a strong effect of the presence of rift alluvium influences the occurrence of deep-seated landslides. For more information we refer to Jacobs et al. (2018).

Based on the above results, a regional landslide susceptibility model for the inhabited Rwenzori region was constructed using a pixel-based logistic regression model with underlying SRTM topographic data at 30 m resolution. In the Bundibugyo lowlands (NW Rwenzori) we noticed an artefact as here, even at low slope gradient, medium to high landslide susceptibility values are assigned because of the occurrence of rift alluvium, strongly positively connected to landslides in the regional model (Fig. 4-3a). However, it could be expected that slopes below 5˚ generally do not favour the occurrence of landslides in these lowlands (Jacobs et al., 2017a). We therefore apply a correction considering a slightly more conservative threshold of 3°, below which susceptibility values are reclassified (Fig. 4-3b). This corrected landslide susceptibility map is combined with the rescaled population densities provided by UBOS (2003) (Fig. 4-3c) to produce a preliminary identification of landslide risk hotspots (Fig. 4-3d). From Fig. 4-3d, which shows where high landslide susceptibility co-occurs with a high population density, some zones can be isolated presenting apparent hotspots for landslide risk. Some of the most evident landslide risk hotspots such as the gently sloping Bundibugyo lowlands are not recognized as such by global assessments (Stanley and Kirschbaum, 2017). The risk hotspot map also allows to identify areas which appear to be very prone to landslides, but which so far have not been subject to landslide studies such as the South of Kasese district (Fig. 4-3d IV and V). Finally, the risk hotspot map clearly points out that the area around Kilembe, located in the Nyamwamba valley, appears to be a potential hotspot for landslide risk. This valley is also known for its flash flood risk (Jacobs et al., 2017a). Currently, the construction of a hydropower station in the Kilembe valley is ongoing. To which extent landslide and flood risks are taken into account in its design is unclear.

Recent research efforts have led to an increased availability of global, continental, and even country-specific landslide susceptibility maps, also for data-scarce regions such as equatorial Africa (Broeckx et al., 2018; Redshaw et al., 2017; Stanley and Kirschbaum, 2017). In contrast, local and regional susceptibility assessments remain particularly rare in these regions. For the Rwenzori Mountains, we found that the local susceptibility assessments are generally better suited for representing the site-specific controlling mechanisms of landslides and that the regional assessment is an added value compared to continental and global assessments. In parallel to smaller scale landslide susceptibility studies, adequate attention should therefore also be given to study landslide susceptibility on the local and regional level.

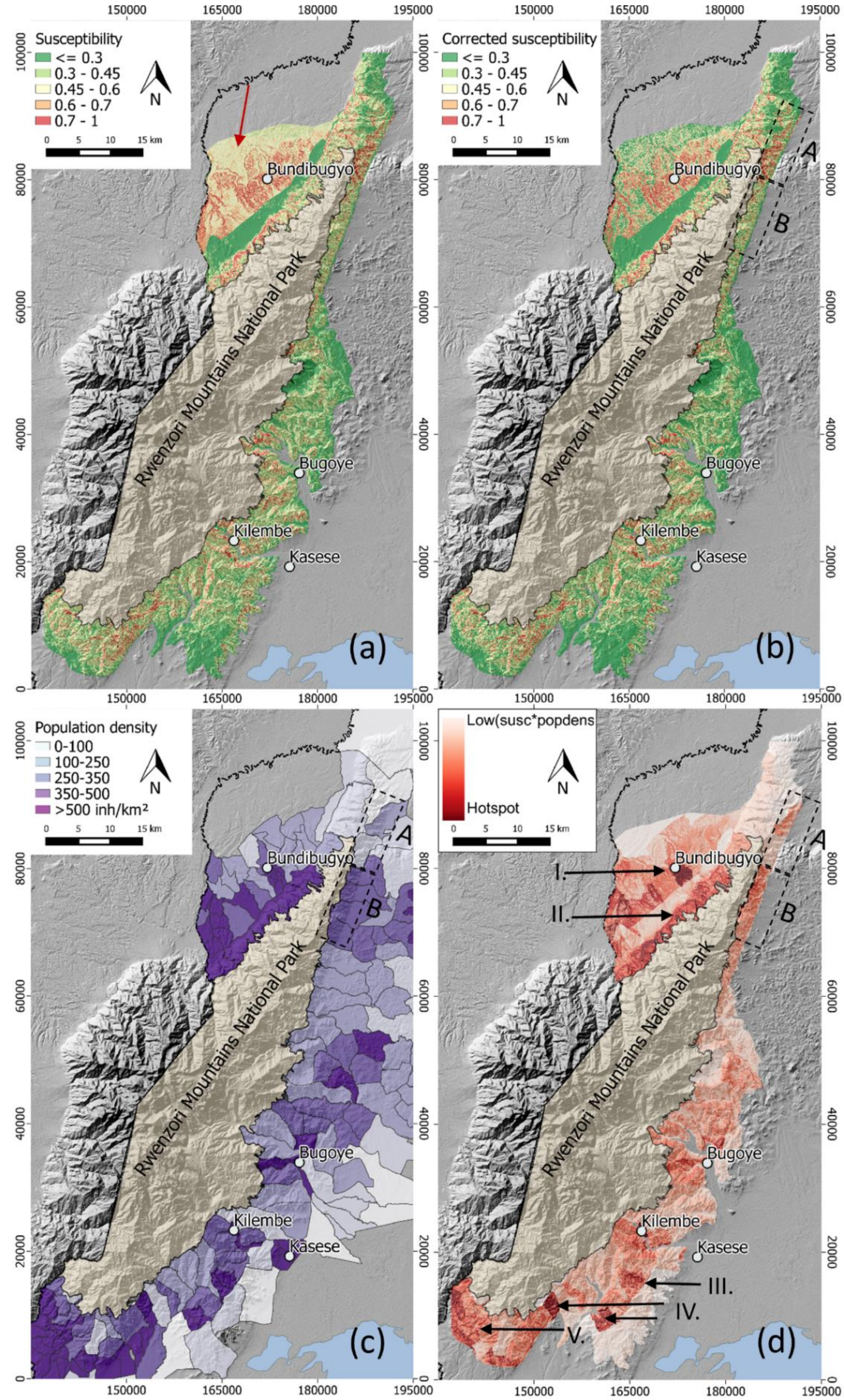


*Figure 4- 3 Landslide susceptibility (LS susc) and population density (pop dens) in the Rwenzori Mountains inhabited zone. a: landslide susceptibility (red arrow indicates artefacts in regional landslide susceptibility model), b: corrected landslide susceptibility, c: population density at parish level (source: UBOS, 2003), d: preliminary identification of landslide risk hotspots. A and B indicate polygons discussed in the text. I to V indicate particular hotspot locations elaborated in the text.*

***The integration of heterogeneous landslide information for landslide susceptibility assessments***

The above pixel-based assessment should be considered as an extrapolation of a statistical model in those areas outside the five surveyed zones. In order to include more sources of data, and therefore extend the *de facto* surveyed area, a methodology is developed to combine point- and polygon datasets (see section 3). These results are described below.

*Tier 1: Unknown relative location of point samples: effect on model performance and stability.*

We compare the different $AUC_{ROC}$ values obtained by using all mapping units (Fig. 4-4). In general, slope unit-based models have a higher performance in the DC, RSP and RSPB simulations. Without the use of the standard deviation of continuous variables as predictors in the slope unit-based models (SluTDX-noSD and SluSRTM-noSD), the fit decreases but remains significantly higher than in the pixel-based assessments (Fig. 4-4). With regard to the RSP simulations, a significant drop in performance compared to the DC simulations is only noticed for the pixel-based assessment at 10 m. Considering the RSPB simulations, significant drops in performances occur in the pixel-based assessment at both 10 and 30 m. The coefficient of variation (CV) in general lies lower in the slope unit based simulations than in the pixel-based ones, but all CV values increase in the RSPB compared to RSP simulations. The SluSRTM simulations have the least variance between runs.

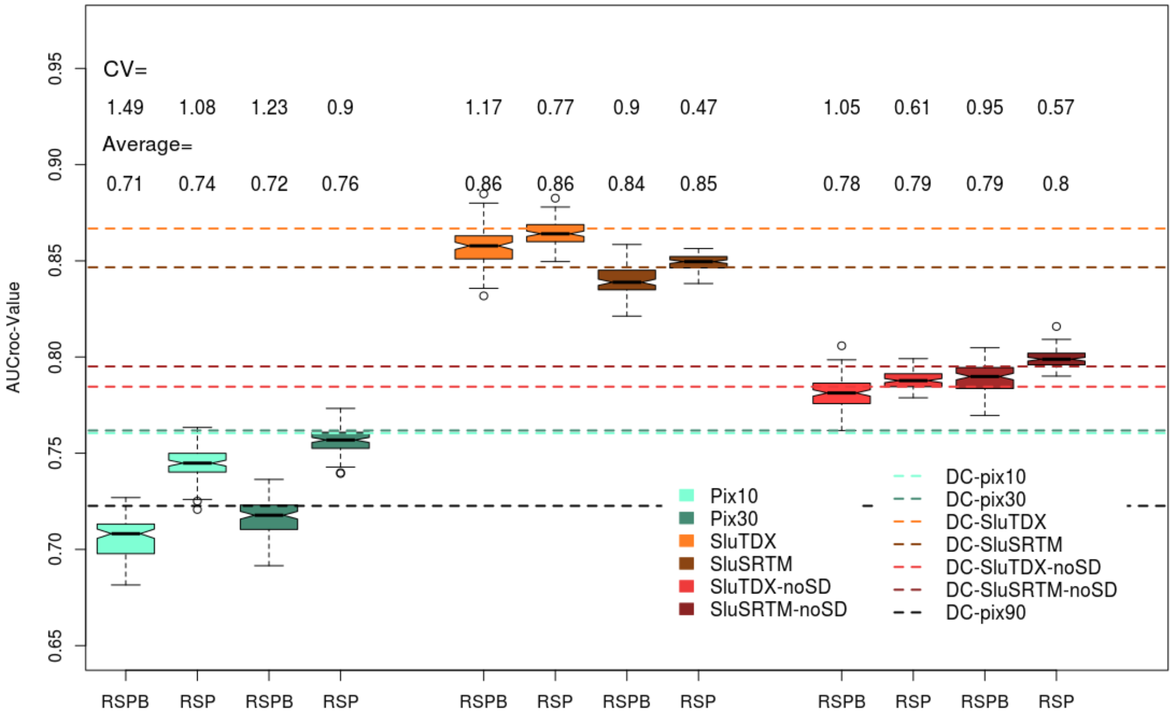


*Figure 4 -4. $AUC_{ROC}$ when sampling from the landslide polygon (RSP-pix10, RSP-pix30, RSP-SluTDX, RSP-SluSRTM) or from the polygon including its buffer (RSPB-pix10, RSPB-pix30, RSPB-SluTDX, RSPB-sluSRTM) together with the baseline performance (DC-pix10, DC-pix30, DC-SluTDX, DC-SRTM) where the logistic regression model is fed with the depletion centroids of the landslide polygons (dotted lines).*

*Tier 2: Identifying landslide prone mapping units when using polygon datasets*

Because the SluSRTM simulations result in stable susceptibility estimates regardless of the sampling method, this mapping unit is selected for the implementation of the second component. The $AUC_{ROC}$ and its standard deviation at the different thresholds and for the baseline (DC) as well as the random sampling (RSP) is displayed in Fig. 4-5. The number of positively identified slope units using the assigned threshold is given as well as the number of slope units falsely identified as positive on the basis of the threshold. The latter is checked manually by the same person who has constructed the inventory and are thus the result of an interpretation focusing on where an exceedance of slope unit boundaries by the landslide polygon is likely to be the result of either a mapping error of the landslide polygon or the limitations of spatial precision with which the slope-units could be delineated. In this case, the false identified slope units can be due to mapping errors of the landslide polygons but also due to the coarseness by which the mapping units are delineated. The average performance increases with decreasing threshold but saturates at thresholds equal or smaller than 0.001.

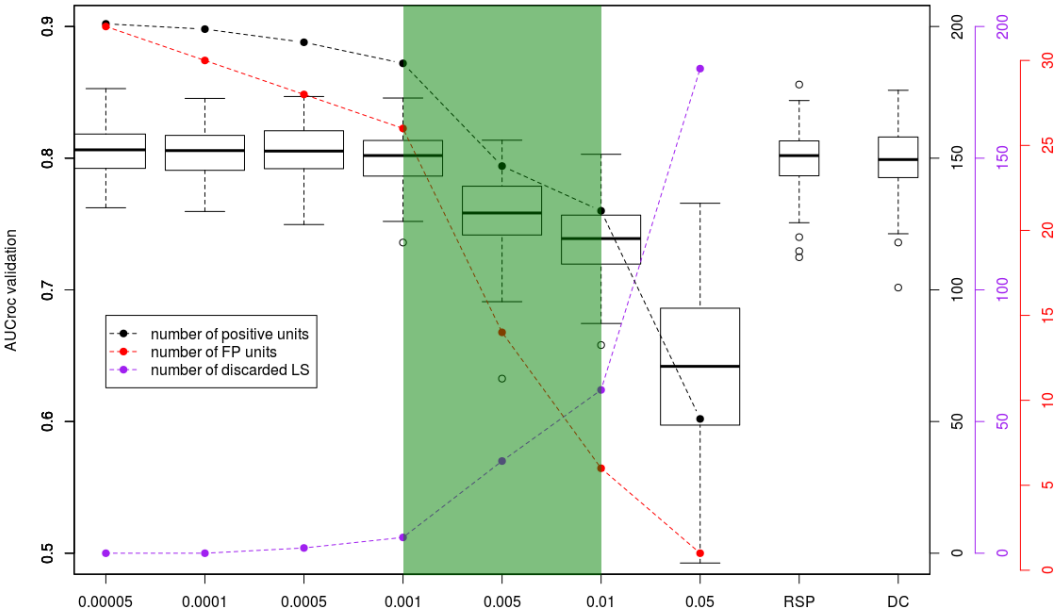


*Figure 4-5. $AUC_{ROC}$ values over 100 simulations of models at different thresholds, compared to the repeated random sampling (RSP) and the baseline model (BC). Blue dots indicate the number of discarded landslides as a result of the selected threshold, red dots indicate the number of false-positively identified slope units (FP), purple indicates the total number of positively identified slope units. Shaded in green is an illustration of a reasonable compromise between false positive mapping units and discarded landslides.*

With an increasing threshold the number of positively identified slope units decreases. This is a combined effect of an increase in the number of discarded landslides and a decrease in the number of false positive slope units (Fig. 4-5), i.e. reflecting the trade-off depicted in Fig. 3-2b and 3-2c. At thresholds higher than 0.001 a sharp decrease in false positive slope units occurs. The sharpest increase in discarded landslides occurs between 0.01 and 0.05. In this case, we want to minimize the number of discarded landslides and minimize the number of false positive landslide units whilst maintaining reasonable model performances. A threshold of 0.005 provides a good balance between number of discarded landslides and number of false positive slope units whilst providing a good model fit. The repeated random sampling procedure results in the overall highest $AUC_{ROC}$ values. In this case, the number of positive slope units depends on the random selection and therefore differs from run to run. Per definition, there are no discarded landslides in this approach as each landslide is sampled. The number of false positively identified slope units fluctuates between 0 and 7 (median=4) and thus performs better in the identification than any threshold that results in a reasonable number of discarded landslides (green shade Fig. 4-5).

***Construction of a spatially validated regional landslide susceptibility map***

Based on the results of the two-tier methodology elaborated above, a regional landslide susceptibility model was calibrated using the landslide polygons, whereby the repeated random sampling from the polygons is used to identify positive slope units and validated using the point dataset (Fig. 4-6). The mapping unit selected was the SluSRTM. The regional susceptibility model has an average $AUC_{ROC}$ of 0.76. A classical prediction rate curve depicts the cumulative fraction of total landslide area predicted by the fraction of the study area with decreasing susceptibility (Dewitte et al., 2010). However, because in our validation dataset we only have points to our disposal, we consider the cumulative fraction of positive slope-units predicted by the fraction of total area at decreasing susceptibility. We observe that over 75% percent of positive slope-units (i.e. those containing landslide points) are predicted by the 50% highest susceptible area (Fig. 4-6). For two areas within the region, i.e. Kabonero and Mahango, the regional pixel-based assessment from Jacobs et al. (2017b) is compared to the regional slope-unit based model constructed here. In general, although the nature of the terrain representation is substantially different in the two maps, the same spatial patterns can be observed, i.e. predominantly low and high-susceptible areas coincide in both maps.

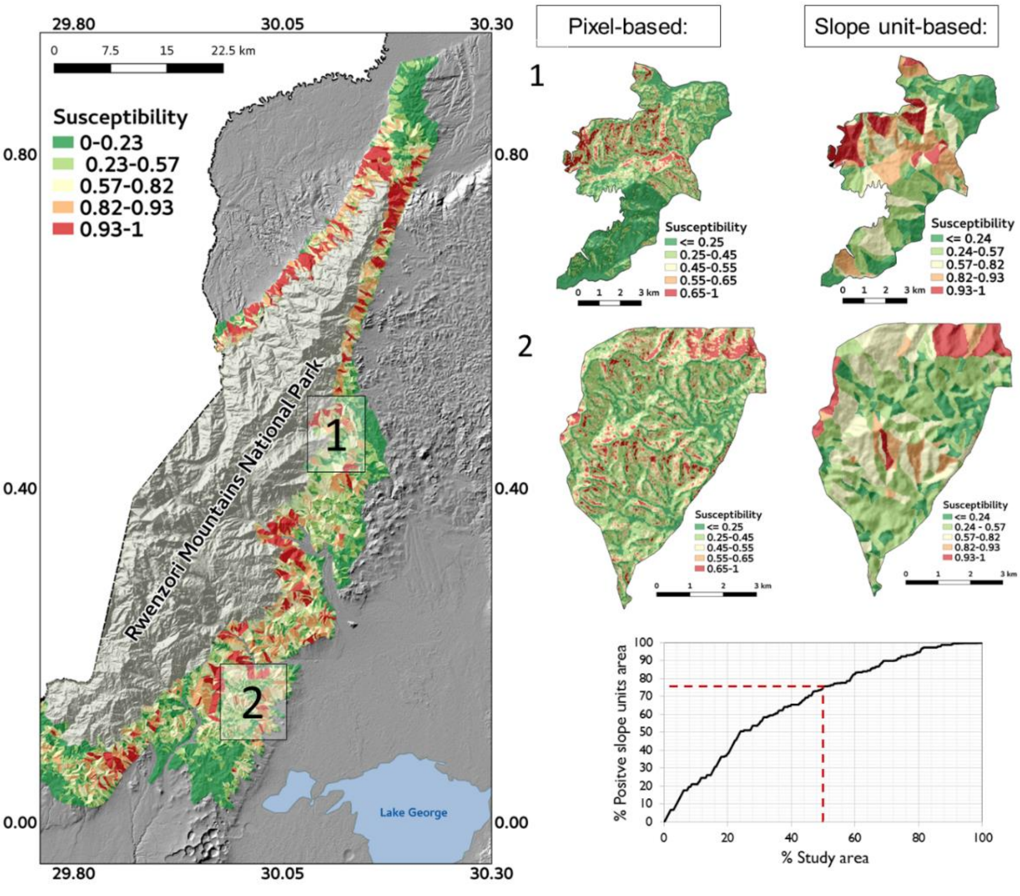


*Figure 4-6. Left: Regional landslide susceptibility map produced by training a logistic regression model using the RSP and validating using the point datasets, using the SluSRTM as mapping units. Right: comparison of the pixel-based regional assessment in Jacobs et al. (2017b) with the slope unit-based regional model (upper corner) for the Kabonero study area (1) and Mahango study area (2) and the prediction rate curve for the SluSRTM model (lower corner).*

With this study, we provide a two tiers approach to assess the impact of (1) spatial uncertainties related to point data sets and their propagation in landslide susceptibility mapping and (2) different methods for the identification of landslide-prone slope units when using landslide polygons as input data. We show that slope units outperform pixels regardless of their size when dealing with point datasets with unknown precise location within or in vicinity of the landslide. Secondly, when using slope units, we show that the choice on thresholds influences which slope units are considered positive and how many landslides are eventually discarded, and as such determines the performance and reliability of the resulting model. A threshold should thus be carefully selected. Alternatively, a random sampling within the landslide polygon body can result in well performing models with few false positive slope-units and whilst avoiding the discarding of small landslides in large slope units. This approach was applied to the Rwenzori Mountains inhabited highlands, but similar approaches can be used for any other case studies where point datasets or a combination of point- and polygon datasets are available.

***Application of diverse susceptibility mapping techniques to other AfReSlide study areas***

The pixel-based landslide susceptibility assessments were applied to the Mt Elgon region (Broeckx et al., submitted) and the Bamboutos region in Cameroon (reported upon in the yearly BELSPO report of 2016). Pixel-based susceptibility assessments were also applied to the Rwenzori Mountains National Park for which we have collected a landslide inventory data base (Table 4-1). The collection of ancillary datasets using the pseudo-anaglyph techniques applied using the SPOT6 and TanDEM-X datasets allowed the improvement of pixel-based susceptibility assessments (Fig 4-7). Both the moraine deposits and glacial cirques indicated by the stereo-viewing of the pseudo-anaglyphs are favouring the occurrence for landslides and this effect is found to be significant. This indicates that pseudo-anaglyph analysis is attractive on two levels: the direct digitization of polygons based on visual interpretation is more rapid and often more accurate than analogue interpretation of aerial photographs using stereoscopy. Moreover, aerial photographs are frequently unavailable in remote regions of the humid tropics. Although this research is still ongoing, we are able to demonstrate the use of synthetic stereo-mate production and subsequent geomorphologic interpretation allows to build unique datasets in these areas which are an added value for susceptibility assessments. This approach is particularly relevant for any other trans-boundary regions or other settings where data-availability is a major constraint.

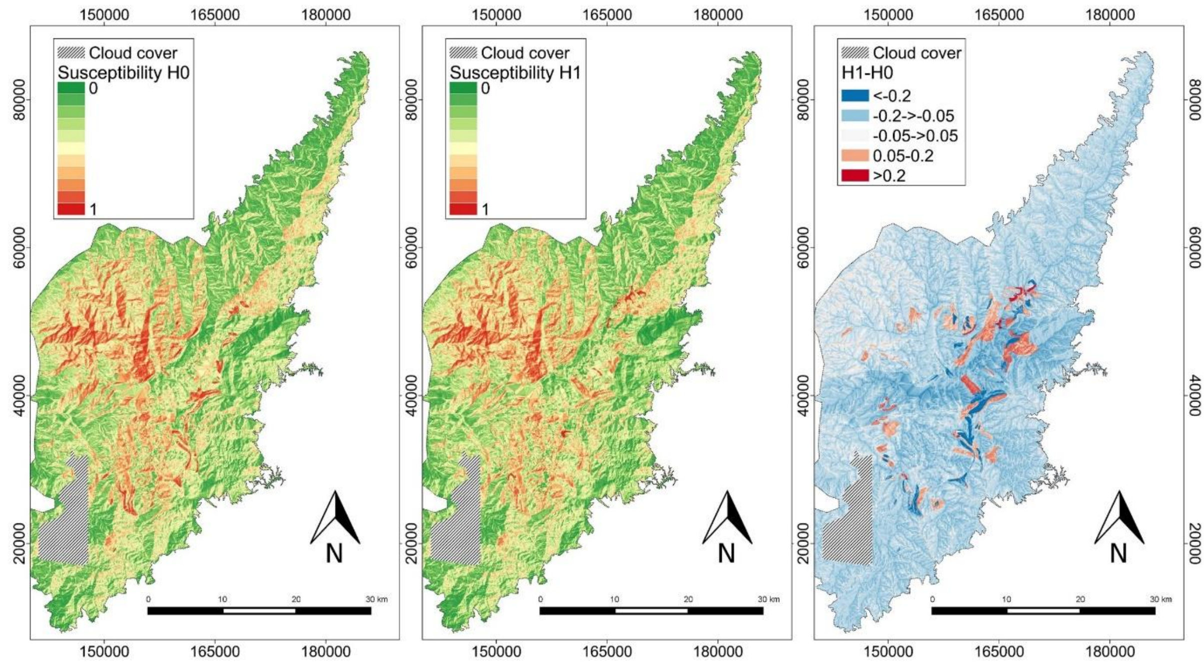


*Figure 4-7. Susceptibility maps with (H1) and without (H0) considering glacial cirques, glacial deposits and faults (Left = model H0, middel = model H1). Right is the difference between the two models (H1-H0).*

For the Mount Baker rock fall, described above, the mechanistic STONE model was applied to reconstruct the rock fall trajectory based upon detailed topographic reconstruction enabled through UAV image acquisition. The calibration and validation of the rock fall model is currently ongoing, but preliminary results show the added value of detailed topographic measurements compared to commonly available SRTM topographic data. An example of STONE output is given in Fig. 4-8. This approach shows that simple, but performant, mechanistic models can be constrained by the construction of detailed topographic data through UAV image acquisition. This allows to study major rock fall events in areas which are difficult to reach and where previous topographic data are of insufficient quality to drive a mechanistic model.

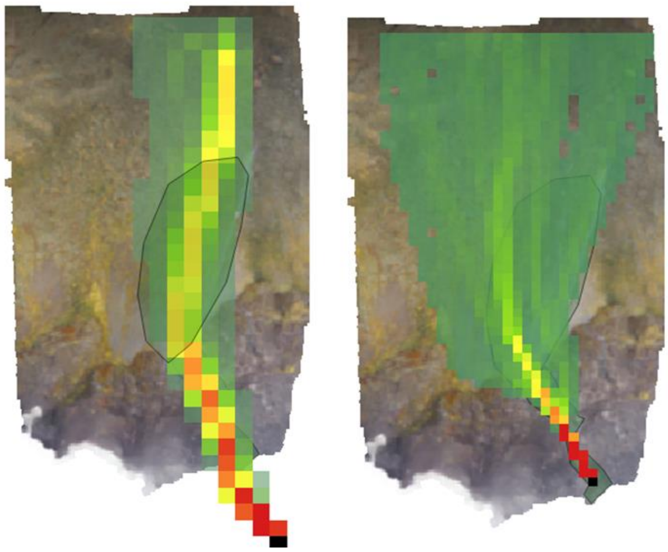

*Figure 4-8. Example of the STONE calibrations here illustrative of a varying resolution and DEM (DEM based on the digitization of a topographic map at 25 m on the left, DEM from UAV acquisition at a resolution of 13 m on the right) for the Mount Baker Rock Fall reconstruction*.

### TASK 1.3. Rainfall Intensity-Duration thresholds for landslide initiation

The network of geo-observers was initiated in February 2017 in the Rwenzori. Over the first eigth months of activity, 57 landslide reports were submitted (Fig. 4-9). Of these reports, 42 are reports of new landslides and 15 reports concern important reactivations of already existing landslides. All of the reports have pictures of the landslides. With regard to the timing of the landslides, of the 42 new landslide events, five were reported at least more than a week after the event, and thus a precise date is not entered in the report. In seven cases, the landslide is reported within the week, in 16 cases the landslide is reported one day after the occurrence and in 14 cases the landslide is reported the day of the occurrence. This indicates that most geo-observers are in direct contact with the inhabitants and soon get news of any new events in their neighbourhood. Most geo-observers report to have visited the landslides within the day after its occurrence.

As a first attempt to link the reported landslides to the rainfall conditions measured by the rain gauges, we focus on the landslides that were reported within a day of occurrence. At the time of report collection from the server (21st September 2017) the rain gauge data was collected up till June 2017. Therefore, we focus our attention on 10 landslide events that occurred before June 2017 in the vicinity of the Kilembe rain gauge (Fig. 4-9). Six landslide events were reported during the month of May 2017 and as a first assessment we assume the dates provided by the geo-observers are the actual dates of occurrences. The moving-window 24h cumulative rainfall during that month and the timing of the landslides is depicted in Fig. 4-10. All of these events were reported to be triggered by rainfall. If this is specified by the geo-observer, they receive a follow-up question asking whether the rainfall event triggering the landslide was a short-duration intense event (defined as a rainfall event with a duration of a few hours to max. 1 day) or whether the landslide occurred after a prolonged rainfall event (during more than 1 day). All but one of the Kilembe events were reported to have occurred after prolonged rainfall. This is in agreement with Fig. 4-10 where the first landslide occurs after several days of heavy rain.

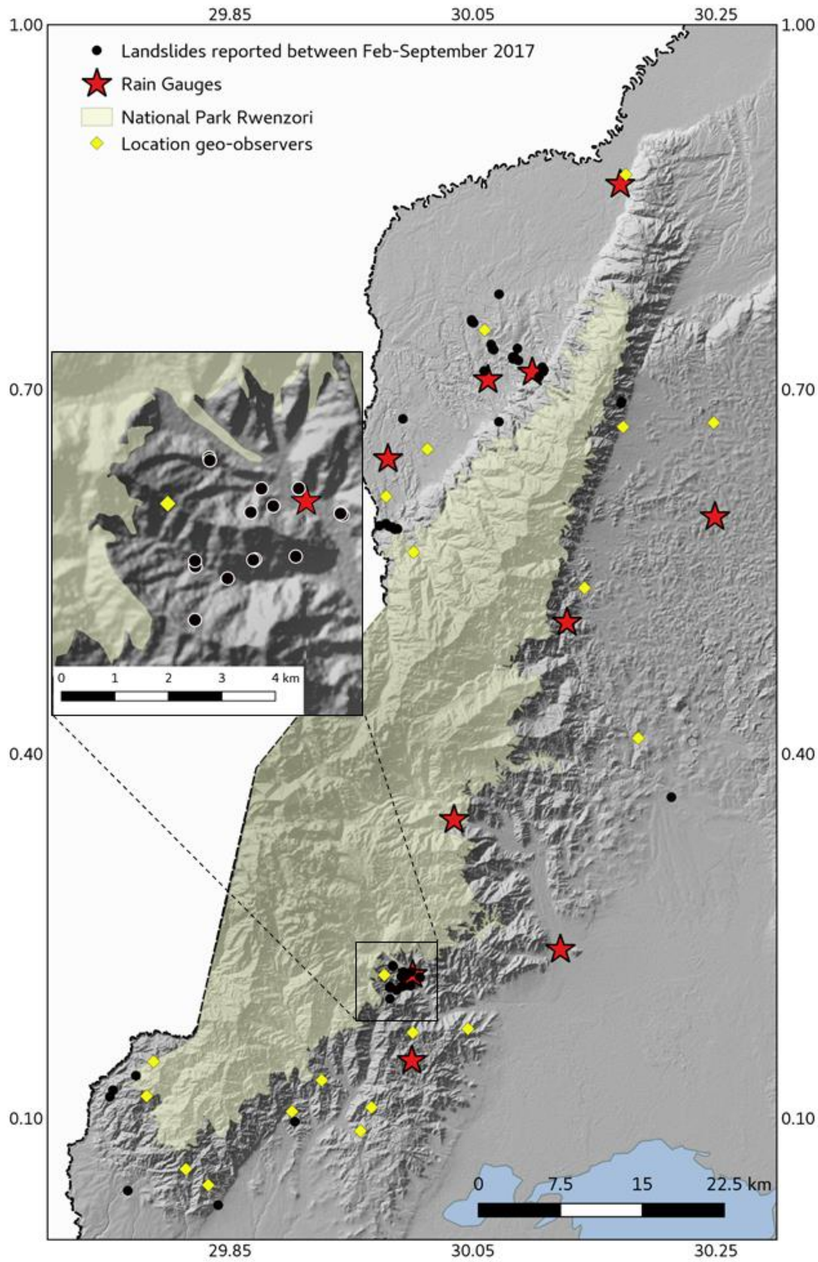


*Figure 4-9. Overview of the approximate geo-observer location as the centroid of the parish they are representing, rain gauges and reported landslides between February-September 2017, with a zoom of the landslides reported near the Kilembe rain gauge.*

Due to their direct contact with the inhabitants of their parish and their continuous presence in the field, the geo-observers have succeeded to collect more data on the timing of landslides in the Rwenzori in the first eight months of deployment than what was ever collected during field surveys in the course of the AfReSlide project. Although this project is currently still ongoing, we are positive this initiative will allow us to collect the necessary data to identify spatially explicit rainfall thresholds. Not only does this network allow to collect data that is essential for the understanding and characterization of those rainfall event capable of triggering landslides, it also collects and bundles data on the damage that these landslides cause in the affected parishes. This approach can act as a pioneer example for similar data-scarce, remote regions with poor accessibility.

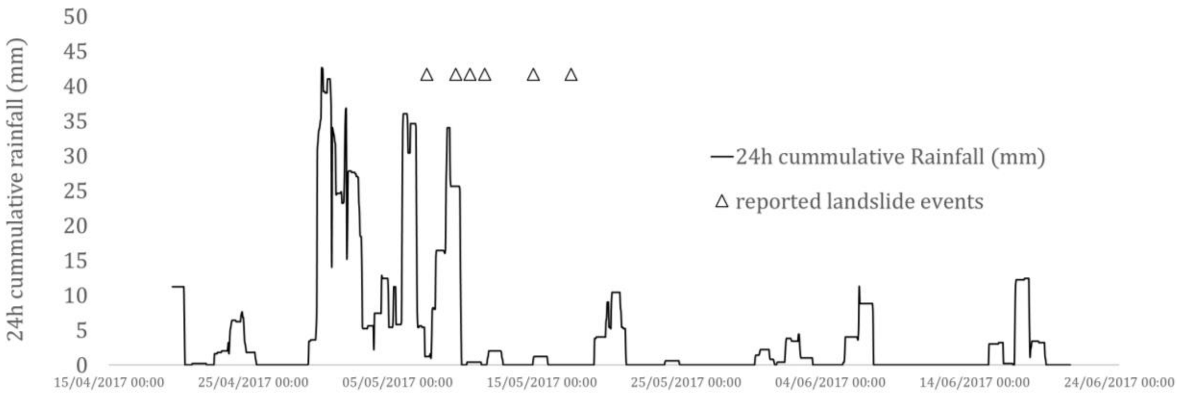


*Figure 4-10. Moving-window cumulative 24h rainfall from the Kilembe rain gauge and corresponding timing of six reported landslides*

## WP.2. Socio-economic consequences

### TASK 2.1. Identification of elements at risk

As previously mentioned the 'elements at risk' that have been identified and studied in the Rwenzori region are people and their fields and houses which can be destroyed by landslides. Not everyone is equally exposed to landslide risk. Within a region, there are pieces of land that are likely to have landslides and others that are landslide-free. Only those farmers that have land in landslide-prone areas are exposed to landslide risk. The exposure of a farmer to landslide risk is therefore determined by the type and amount of land s/he inherits and acquires over time.

We therefore investigated who is most likely to acquire plots in landslide prone areas and how this affects exposure to landslide susceptibility and risk. This is important because this allows us to identify the dynamic pressures that lead to the (re)production of disaster risk. An analysis of lifetime land holdings was performed for the farmers in our sample. We found that farmers do make use of land acquisitions to change their exposure to landslide susceptibility. In particular it is found that farmers that start off with plots that have a high landslide susceptibility are more likely to acquire plots with a lower susceptibility, while farmers that start with a plot that has a low susceptibility are more likely to acquire plots that have a higher susceptibility. This is schematically illustrated in Fig. 4-11. Additionally, it is shown that farmers that start off their career with larger plots or plots that have a lower exposure to landslide susceptibility do manage to accumulate land faster in the course of their life (schematic illustration in Fig. 4-11, and illustration with a polynomial smooth on our data in Fig. 4-12). These observations suggest that land transactions in our study area are equalizing in exposure and disequalizing in total land ownings over time. Yet, as shown in Fig. 4-11, over a lifetime the equalization in exposure is not completed, since the difference between initially exposed farmers and non-exposed farmers is still present after 30 years.

These results have allowed us to identify two different pathways for land acquisition in landslide prone areas. The two different reasons for land acquisition are related to differences in the availability of financial resources to the farmer:

1. First, farmers with limited resources have the majority of their land in landslide-prone areas because that is the only type of land they managed to acquire. It could be that they inherited land in a landslide-prone area or that they purchased such land because it was very cheap due to the high landslide probability. These farmers frequently have a limited amount of land and are more vulnerable to severe impacts of landslides.
2. Secondly, wealthier farmers might have both land with and without a high landslide risk. Over time, these farmers may buy plots in landslide-prone regions because these plots offer an interesting investment opportunity. As such they acquire land in landslide-prone areas to increase their land holdings. Obviously, these farmers are less vulnerable to falling into poverty when a landslide happens.

The distinction between the two groups implies that the consequences of a landslide depend on the availability of financial resources to the farmer. Farmers with more land and financial resources likely have a stronger ability to cope with the income shock due to a landslide than farmers who have limited land.

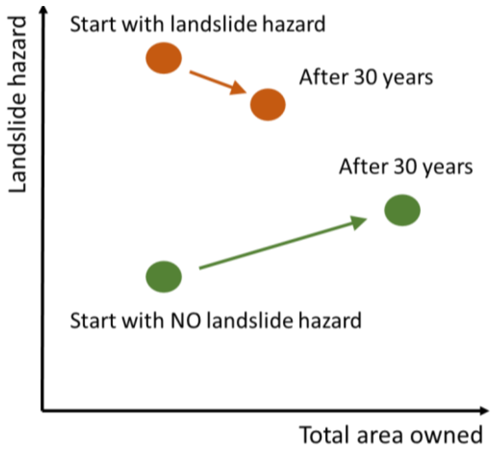


*Figure 4-11. Schematic illustration of how total land ownings and exposure to landslide susceptibility evolve over time for a same household in the Rwenzori region*

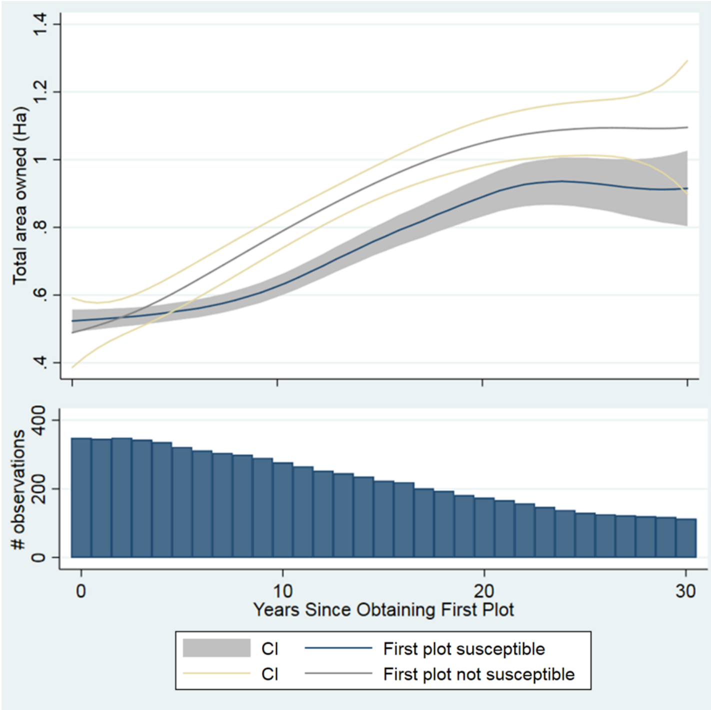


*Figure 4-12. Local polynomial smooth on the evolution of land holdings over the lifetime of farmers that started with a plot with a high landslide susceptibility and for farmers that started with a plot with a low landslide susceptibility (first panel). The second panel illustrates how many observations are being used for the estimation of land holdings at every point in time. Since the dataset contains farmers of various ages, the number of observations reduces with increasing recall time. This also explains the expanding confidence interval with increasing recall time. An epanechnikov Kernel function was used.*

The results of this study add to the literature on poverty traps in agriculture, whereby the rational decisions to minimize risk of falling below a certain income level are perpetuating inequality in land holdings. Previous studies used wealth as a proxy for risk of falling below a certain threshold, while we directly measure the susceptibility of facing a serious shock which can push farmers below such a level. As such we provide some concrete evidence on one of the mechanisms, i.e. exposure to natural hazards, that could be keeping farmers land poor, and hence probably also income poor.

The results nuances the findings of a previous study which suggested that land markets in Uganda decrease inequality (Baland et al., 2007). Our study highlights the importance of also considering land quality in studies about land markets and investments, rather than land quantity alone. Recognizing that processes driving inequality have nothing natural, like there are no natural disasters, more qualitative and quantitative studies are needed to further lay bare various mechanisms that can increase or decrease inequality.

Many studies on landslides tend to treat plots as given to the household and therefore fail to acknowledge the strong, endogenous processes that determine who is exposed to landslide susceptibility. The results of our study provide some evidence of the importance to consider the processes leading to certain levels of exposure as endogenous. A similar observation probably holds for erosion. This finding adds to the literature highlighting the importance of self-selection on the land market (Olbrich et al., 2012).

***Database on elements at risk in one key sub-county in the Rwenzori Mountains, Uganda***

The identification of elements at risk in one sub-county in the Rwenzori Mountains are presented in Fig. 4-13, including public infrastructures like roads, schools, water springs, sub-county headquarters and health centre III and private infrastructures like churches and trading centres.

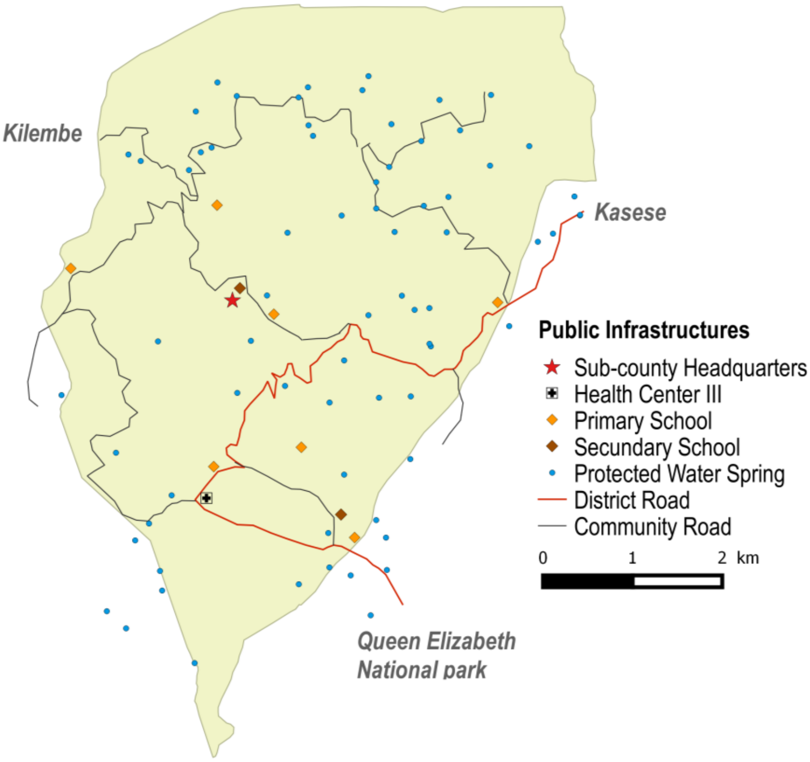


*Figure 4-13. Localization of the public infrastructures in Mahango sub-county (Schoonenbergh, 2017).*

The total surface of Mahango sub-county is approximatively 30km². Of this total area, croplands occupy the largest surface with 19 km² (64 %) of the total, scattered across the entire sub-county. Trees account for the second largest area with 5 km² (19 %), mainly located in the North and the West of the sub-county. Pastures represent 4 km² (13 %) and are situated in the centre and in the North of the area. Finally, human infrastructures represent only 4 % of the sub-county and are spatially dispersed in the entire area. After the automatic spectral classification, a post-classification was performed in a GIS software to add the human infrastructures into the classification. The identification of all elements at risk is depicted on Fig. 4-14.

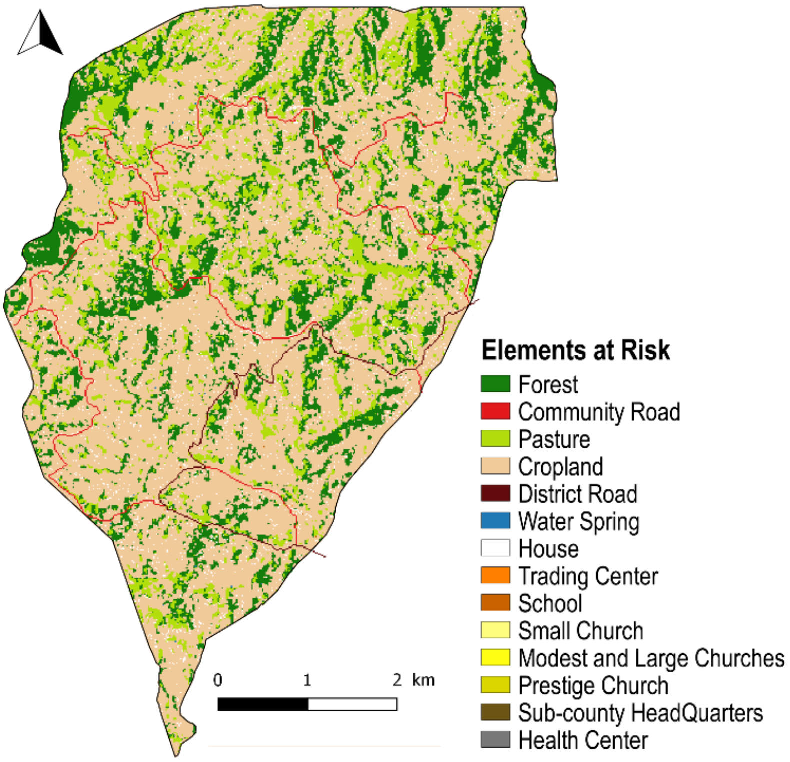


*Figure 4-14. Land cover post-classification cover of Mahango sub-county (Schoonenbergh, 2017).*

***Choice experiment in the Bamboutos, Cameroon***

The analysis on intentions to resettle in the Bamboutos was recently finalized (Baert, MSc thesis, 2018). Results suggest that the population in the caldera is aware of the danger of landslides and is therefore willing to resettle away from landslides. In general, there is a strong preference for resettlement programs that allow the neighbouring family to move along and that provide arable land. The majority of the respondents also value the presence of road infrastructure at the new location. Individuals with motorcycles show a preference for resettlement locations with paved roads, whilst respondents who have been negatively affected by landslides show a higher willingness to resettle in general.

Respondents with a larger acreage also show a higher willingness to resettle, appreciate resettlement locations that are closer to the original location and show a higher valuation for resettlement locations even if family moves to a different location. Poorer respondents, on the other hand, are less willing to resettle and attach most importance to whether their family can move along. Both groups show a preference for additional land. Surprisingly, financial support does not seem to be a prerequisite for resettlement. Appreciation for monetary compensation is heterogenous within analysed groups. This could be due to previous promises from authorities regarding financial support which were never fulfilled, thereby reducing the credibility of any program offering financial support for resettlement.

Finally, five obstacles to a successful resettlement were identified: lack of resettlement location due to population pressure, border dispute or administrative restrictions, cultural attachment to original location and cost of resettlement. This master thesis has led to a research manuscript which has been submitted to Land Use Policy and is currently under review.

### TASK 2.2. Valuation of elements at risk

***Landslide impacts on households in the Rwenzori Mountains, Uganda***

Landslide risks have both ex-ante and ex-post consequences. Ex-ante consequence derive from the presence of the risk and the influence this has on (the behaviour of) people living in its vicinity, as well as on the economy. Ex-post consequences derive from the realization of the risk (the occurrence of a disaster). We will call ex-post consequences “landslide impact”.

The direct impact of landslides in the Rwenzori region essentially goes through the impact they have on crops and on soil fertility in the region. By destroying crops and soil fertility, landslides cause income shock. An average loss of 20 % of income from agriculture has been observed among farmers in the year that follows the occurrence of a landslide (Table 4-2; Fig. 4-14). Due to long-term consequences of this shock and the likely loss of soil fertility, a sustained loss in income is found among affected farmers for two to three years after the landslide. This has serious and long-term consequences for the wellbeing of the farmers and their family members.

The severity of the impact on household income is highly dependent on the percentage of the land affected by a landslide (Table 4-2). It is therefore likely that households with more land or with many plots are more resilient towards landslides than households which have less land. These findings confirm and expand previous qualitative literature on the impact of landslides in Sub-Saharan Africa.

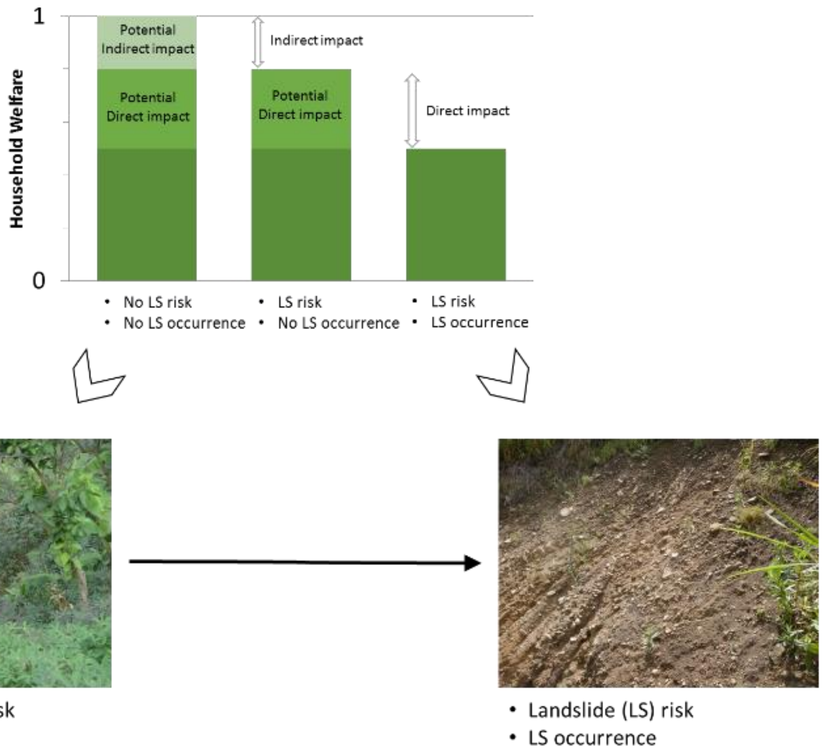


*Figure 4-14. Schematic overview of the impact of landslides (Mertens et al., 2016).*

In an attempt to compensate for income losses after a landslide, household members seek for self-employed activities or wage labour on other farms. The income obtained from these jobs does not fully compensate for income losses due to landslides, as total household income remained significantly affected by landslides. We found that members of households that had been affected by a landslide more than one year ago were not more likely to have a job than members of unaffected households. This suggests that jobs were abandoned once the emergency situation after the landslide had been cleared. We did not find indications of increasing transfers or remittances after a landslide. While remittances are considered to be an important method for households to reduce the impact of income shocks in developing countries, the households in our sample did not seem to have access to such a strategy after landslides.

The presence of a serious income shock after landslides, despite coping strategies like working on other peoples' farms, as well as the lack of access to remittances and credit, suggest that formal and informal insurance mechanisms in the region against landslides are insufficient or lacking. Since the support of neighbours and family is not enough to compensate for income losses, the affected farmers have to reduce their consumption. This has long-term consequences for welfare and wellbeing of the farmers and also puts stress on the overall community. 64% of the affected households in our sample mention that they faced hunger after the landslide, while 18.5% say at least one of the children of the household temporarily or permanently missed school due to the landslide.

*Table 4-2. Impacts of landslides, adapted from Mertens et al. (2016).*

| Equation number | (1) | (2) |
|---|---|---|
| Dependent variable | Log(Income agriculture) | Log(Income agriculture) |
| *Experience with landslides* | | |
| Landslide | -0.183** | |
| | (-2.00) | |
| % of land affected by most recent Landslide | | -0.00735*** |
| | | (-3.09) |
| *Control variables on productive capital* | Yes | Yes |
| *Control for human and social capital* | Yes | Yes |
| *Control for landslide susceptibility and location-specific covariates* | Yes | Yes |
| _cons | 4.950*** | 5.253*** |
| | (3.27) | (3.45) |
| Village FE | Yes | Yes |
| N | 450 | 450 |
| r2 | 0.445 | 0.452 |
| F | 6.897 | 7.187 |

***Valuation of elements at risk in one key sub-county in the Rwenzori Mountains, Uganda***

Concerning the valuation of elements at risk in Mahango sub-county, Uganda, the initial and final values were calculated based on the semi-structured interviews and the UBOS survey as represented in Table 4-3. Based on the initial values, the repair costs and the final values, the vulnerability indices were calculated for two scenarios: one that simulates small damage and another that simulates severe damages. The Vulnerability Index of scenario one (VIscen1) oscillates between 0.10 and 0.25 percent. The Vulnerability Index of scenario two is equal to one as the entire element is considered destroyed.

*Table 4-3. The elements at risk and their initial value (Million USH), repair cost (Million USH), final value (Million USH) and vulnerability indices for both scenarios (%). The main source of the information is given per type of element (Adapted from Schoonenbergh, 2017).*

| Element at risk | | Initial Value (Million USH) | Repair cost (Million USH) | Final Value (Million USH) | $VI_{scen1}$ (%) | $VI_{scen2}$ (%) | Source |
|---|---|---|---|---|---|---|---|
| *Public Infrastructures* | | | | | | | |
| District Road | | 15 per km | 2 per km | 13 per km | 0.13 | 1 | X4 |
| Community Road | | 1 per km | 0.1 per km | 0.9 per km | 0.1 | 1 | X7 and 8 |
| School | | 75 | 15 | 60 | 0.20 | 1 | X10 and 11 |
| Water Spring | | 1 | 0.2 | 0.8 | 0.20 | 1 | X6, 7 and 8 |
| SCHQ | | 200 | 26 | 174 | 0.13 | 1 | X10 and 11 |
| Health Center III | | 363 | 91 | 272 | 0.25 | 1 | X10 and 11, invoice of education office |
| *Private Infrastructures* | | | | | | | |
| House (4 rooms) | | 17 | 2 | 15 | 0.13 | 1 | X5 and 6 |
| Church | Small | 95 | 24 | 71 | 0.25 | 1 | X5 and 9 |
| | Modest | 120 | 30 | 90 | 0.25 | 1 | |
| | Large | 120 | 30 | 90 | 0.25 | 1 | |
| | Prestige | 150 | 38 | 112 | 0.25 | 1 | |
| Trading Center (8 rooms) | | 35 | 5 | 30 | 0.13 | 1 | Extrapolated from House |
| *Land Cover* | | | | | | | |
| Cropland | | 94.5 x 10-6 | NA | NA | 0.25 | 1 | UBOS |
| Trees | | 57.1 x 10-6 | NA | NA | 0.25 | 1 | UBOS |
| Pasture | | 84.6 x 10-6 | NA | NA | 0.25 | 1 | UBOS |

## WP.3. Resilience strategies

### TASK 3.1. Assessment of household level resilience strategies

***Global overview of recommended and implemented landslide risk reduction measures***

The first objective of WP3 is to document which landslide risk reduction measures are being recommended and implemented and what are the challenges for their implementation (Maes et al. 2017). Of all landslide risk reduction measures, ‘landslide risk assessment’ is by far the most implemented DRR component (57%), while ‘risk management and vulnerability reduction’ is the most recommended DRR component (38%; Fig. 4-15). ‘Landslide risk assessment’ is the most implemented component in all regions, but receives relatively more attention in Africa (72%), which might be attributed to the fact that landslide hazard research is still emerging on this continent and that governance remains a challenge for the implementation of other DRR actions (UNISDR, 2012). While ‘landslide risk management and vulnerability reduction’ is the most recommended component in all tropical regions, it receives somewhat less attention in Asia-Pacific (27%) as compared to Africa (40%) and Latin America (42%). Generally, implemented and recommended measures vary relatively little between different regions.

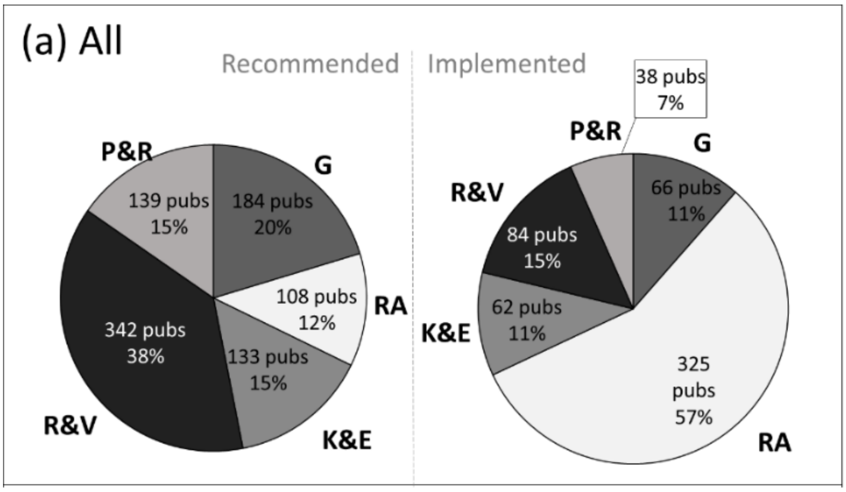


*Figure 4-15. Percentage of the number of publications on landslide risk reduction (# pubs landslide risk reduction) in Scopus for the period Jan. 2005 - Jan. 2015 that cite the recommended landslide risk reduction components (left column) and the implemented landslide risk reduction components (right column). (a) Total percentages of the number of publications reporting recommended (total number of citations is 709, reported in 225 individual papers) and implemented landslide risk reduction components (total number of citations is 461, reported in 245 individual papers). The same data for sub-regions can be found in Maes et al. (2017).*

Overall, 575 landslide risk reduction measures were cited as being implemented in 304 articles, while 906 measures were recommended in 279 articles (Table 4-4). Noteworthy is that the main focus of landslide research remains on ‘hazard’ assessment. This focus might be explained by the fact that disaster research is rooted in the natural sciences (Watts, 1983). Our review also indicates that implemented landslide risk reduction measures are dominantly focusing on the collection of ‘hazard’ instead of ‘vulnerability’ data. Of the 255 publications citing the implementation of ‘collection of hazard/risk data and assessment, 236 publications refer to the collection of ‘hazard’ data, while only 19 cite the collection of ‘risk’ data. This focus on understanding hazards in disaster research is, however, gradually shifting towards understanding vulnerability and loss of resilience to disasters (Manyena et al., 2013). Our review shows that this shift is indeed increasingly being recommended but not yet reported as implemented. Similarly, most publications focusing on the combination of both hazard and vulnerability, i.e. risk, are relatively new (69% of these studies were published in 2010 or later).

*Table 4-4. Number of publications (#pubs) in Scopus for the period Jan. 2005 – Jan. 2015 that cite implemented (I) and recommended (R) landslide risk reduction (LS-DRR) measures in tropical landslide-prone countries. According to Twigg (2007), 'early warning systems' are part of the preparedness and response component, while according to Vaciago (2013), these are part of exposure reduction measures and thus the risk management and vulnerability reduction component. As some publications cite several measures, a difference is made between the total number of cited landslide risk reduction measures (total # citations) and the total number of individual publications that cite landslide risk reduction measures (total # individual pubs) (NA means Not Applicable; Maes et al., 2017).*

| DRR component | Landslide risk reduction measures | | I | | R | | I/R |
|---|---|---|---|---|---|---|---|
| | | | #pubs | % | #pubs | % | |
| **Governance (G)** | | | 66 | 11 | 184 | 20 | 0.36 |
| | Policy, planning, priorities and political commitment | | 13 | 2 | 34 | 4 | 0.38 |
| | Legal and regulatory systems | | 1 | 0 | 14 | 2 | 0.07 |
| | Integration with development policies and planning | | 2 | 0 | 21 | 2 | 0.1 |
| | Integration with emergency response and recovery | | 3 | 0 | 3 | 0 | 1 |
| | Institutional mechanisms, capacities and structures; allocation of responsibilities | | 24 | 4 | 63 | 7 | 0.38 |
| | Partnerships | | 9 | 2 | 12 | 1 | 0.75 |
| | Accountability and community participation | | 14 | 3 | 37 | 4 | 0.38 |
| **Risk Assessment (RA)** | | | 325 | 57 | 108 | 12 | 3.01 |
| | Unspecified | | 8 | 2 | 31 | 3 | 0.26 |
| | Collection of hazard/risk data and assessment | | 255 | 44 | 59 | 7 | 4.32 |
| | Assessment of vulnerability/capacity and impact data | | 52 | 9 | 15 | 2 | 3.47 |
| | Scientific and technical capacities and innovation | | 10 | 2 | 3 | 0 | 3.33 |
| **Knowledge and Education (K&E)** | | | 62 | 11 | 133 | 15 | 0.47 |
| | Public awareness, knowledge and skills | | 11 | 2 | 62 | 7 | 0.18 |
| | Information management and sharing | | 31 | 5 | 35 | 4 | 0.89 |
| | Education and training | | 13 | 2 | 24 | 3 | 0.54 |
| | Cultures, attitudes, motivation | | 3 | 1 | 2 | 0 | 1.5 |
| | Learning and research | | 4 | 1 | 10 | 1 | 0.4 |
| **Risk Management and Vulnerability Reduction (R&V)** | | | 84 | 15 | 342 | 38 | 0.25 |
| | Unspecified | | 3 | 1 | 27 | 3 | 0.11 |
| | Landslide hazard reduction | Unspecified | 2 | 0 | 19 | 2 | 0.11 |
| | | Surface protection; erosion control of landslide-toe | 7 | 1 | 49 | 6 | 0.14 |
| | | Modifying the geometry and/or mass distribution | 2 | 0 | 13 | 2 | 0.15 |
| | | Modifying surface water regime | 15 | 3 | 39 | 4 | 0.38 |
| | | Modifying groundwater regime | 4 | 1 | 8 | 1 | 0.5 |
| | | Modifying the mechanical characteristics of unstable mass | 2 | 0 | 1 | 0 | 2 |
| | | Transfer of loads to more competent strata | 2 | 0 | 5 | 1 | 0.4 |
| | | Retaining structures | 12 | 2 | 22 | 2 | 0.55 |
| | Vulnerability reduction | Measures to improve capacities of people to cope with landslides | 7 | 1 | 21 | 2 | 0.33 |
| | | Measures to increase the resistance of critical infrastructures | 5 | 1 | 1 | 0 | 5 |
| | | Measures to stop or to deviate the path of landslides | 2 | 0 | 3 | 0 | 0.67 |
| | Exposure reduction | Measures to decrease number of elements-at-risk potentially affected | 16 | 3 | 121 | 13 | 0.13 |
| | | Relocation and migration | 5 | 1 | 13 | 2 | 0.38 |
| **Preparedness and Response (P&R)** | | | 38 | 7 | 139 | 15 | 0.27 |
| | Unspecified | | 1 | 0 | 21 | 2 | 0.05 |
| | Early warning systems | | 36 | 7 | 74 | 8 | 0.49 |
| | Risk transfer (Insurance) | | 0 | 0 | 10 | 1 | 0 |
| | Organisational capacities of and coordination by local communities | | 0 | 0 | 6 | 1 | 0 |
| | Contingency planning | | 1 | 0 | 14 | 2 | 0.07 |
| | Emergency resources and infrastructures | | 0 | 0 | 9 | 1 | 0 |
| | Emergency response and recovery by local communities | | 0 | 0 | 3 | 0 | 0 |
| | Participation, voluntarism, accountability | | 0 | 0 | 2 | 0 | 0 |
| | | Total # citations | 575 | 100 | 906 | 100 | 0.63 |
| | | Total # individual pubs | 304 | | 279 | | 1.09 |

***Bottlenecks for implementation of landslide risk reduction measures***

Despite the increased literature on landslide risk reduction measures (Gutiérrez et al., 2010; Wu et al., 2015), we show that the implementation of measures and their scientific documentation remains rather scarce in the tropics. Furthermore, the low implementation/recommended ratio of most landslide risk reduction components and difference between recommended and implemented measures suggest that implementing landslide risk reduction measures remains challenging. As their implementation involves different actors and consequently depends on socioeconomic and political relations (Kjekstad, 2007), most challenges for implementing landslide risk reduction measures are to be sought within a political economy perspective. Nonetheless, the view that science is neutral and only decision-makers are responsible for implementation remains dominant (Cannon, 2008). This is illustrated by the fact that many publications still use outpaced concepts like 'natural' disasters, although it is internationally acknowledged that disasters are socially constructed, i.e. their causes are both bio-physical as well as social, economic and political (Wisner et al., 2004). The different challenges for implementing landslide risk reduction measures that were identified in this literature review are classified in political, scientific, social, economic, related to disaster risk management and geographic bottlenecks (Table 4-5). The main bottlenecks are scientific (30%) and political (29%) in nature, corresponding to the first two priorities of the Sendai Framework, i.e. (1) understanding disaster risk and (2) strengthening disaster governance to manage disaster risk (UNISDR, 2015).

***Adoption of resilience strategies by households***

The socio-economic data that were obtained from the household surveys have been analysed to understand why some households have the intention to plant trees while others do not. We have tested the Protection Motivation Theory (PMT) and investigated the link between intentions to plant trees against landslides and past experience, actual exposure, perceived threat and perceived capacity to prevent landslides. Ordered probit regressions have been used to quantitatively assess these relations. Further information on this research is found in Mertens et al. (2018). An overview of the PMT and the non-protective response trap is given in Fig. 4-16.

Contrary to what is often said, awareness about landslide risk among farmers in the affected regions is generally high. 78 % of the interviewed farmers consider that the impact of landslides is severe, while 65 % of the farmers consider that a landslide could occur on one of their agricultural lands (Table 4-6). Most farmers are able to assess for their plots whether a landslide could occur. The correlation between self-assessed landslide susceptibility and the comparison with actual landslide susceptibility (as calculated with the susceptibility map in WP 1) is relatively high.

However, awareness about possible measures to reduce landslide risk is low. Farmers are aware of the stabilizing role of trees against shallow landslides, but do not know other risk reduction measures. Moreover, farmers have a very low sense of empowerment (self-efficacy) with regard to planting trees against landslides (Table 4-6). They do belief that trees are effective, but do not believe that, as individual farmers, they are themselves capable of reducing landslides on their land. Landslides are too often considered as 'natural' or 'supernatural' process that cannot be influenced by physical human intervention.

As a consequence, we have found that farmers that are more exposed to landslides susceptibility have a lower intention to plant trees because they do not feel sufficiently empowered to do something to reduce the landslide risk. These results are presented in Table 4-7.

*Table 4-5. Number of publications on landslide risk reduction (# pubs landslide risk reduction) in Scopus for the period Jan. 2005 – Jan. 2015 and number of countries (# countries) citing bottlenecks for implementing landslide risk reduction measures (n total = 109) by tropical region and in total (Maes et al., 2017).*

| | | ***# pubs landslide risk reduction*** | | | | ***Total*** | ***#*** |
|---|---|---|---|---|---|---|---|
| *Category* | **Bottlenecks** | *Africa* | *Asia-Pacific* | *Latin America* | ***Total*** | ***(%)*** | ***countries*** |
| ***Scientific*** | | 1 | 15 | 17 | **33** | 30 | 20 |
| | Lack of (reliable) data on hydro-meteorology and landslide inventory | 1 | 8 | 10 | **19** | 17 | 10 |
| | Lack of risk communication | 0 | 4 | 1 | **5** | 5 | 2 |
| | Lack of scientific knowledge and scientific capacities | 0 | 1 | 3 | **4** | 3 | 4 |
| | Lack of proper risk/hazard assessment to suggest DRR measures | 0 | 1 | 2 | **3** | 3 | 3 |
| | Poor translation of landslide hazard mapping into DRR measures | 0 | 1 | 1 | **2** | 2 | 2 |
| ***Political*** | | 1 | 15 | 16 | **32** | 29 | 25 |
| | Lack of stable environment | 0 | 2 | 9 | **11** | 10 | 10 |
| | Lack of institutionalisation of DRR | 0 | 8 | 2 | **10** | 9 | 6 |
| | Focus on post-disaster emergency actions instead of pre-disasters measures | 1 | 2 | 3 | **6** | 6 | 5 |
| | Lack of community participation | 0 | 2 | 0 | **2** | 2 | 2 |
| | Lack of law enforcement | 0 | 1 | 0 | **1** | 1 | 1 |
| | Lack of enabling policies | 0 | 0 | 1 | **1** | 1 | 1 |
| | Lack of institutional capacity | 0 | 0 | 1 | **1** | 1 | 1 |
| ***Social*** | | 1 | 10 | 4 | **15** | 14 | 11 |
| | Underestimation or denial of landslide risk | 0 | 6 | 2 | **8** | 7 | 5 |
| | Lack of community acceptance and ownership | 0 | 3 | 2 | **5** | 5 | 4 |
| | DRR measures in conflict with short-term livelihood | 1 | 0 | 0 | **1** | 1 | 1 |
| | Poor awareness on underlying causes and triggering factors of landslides | 0 | 1 | 0 | **1** | 1 | 1 |
| ***Economic*** | | 1 | 8 | 4 | **13** | 12 | 8 |
| | Lack of financial resources of government and groups at risk | 1 | 8 | 4 | **13** | 12 | 8 |
| ***Disaster Risk Management*** | | 0 | 4 | 7 | **11** | 10 | 10 |
| | Lack of coordination/cooperation between agencies | 0 | 3 | 1 | **4** | 4 | 4 |
| | Scattered and local efforts by NGOs and by governments | 0 | 1 | 2 | **3** | 3 | 3 |
| | Lack of multi-hazard approach instead of single-hazard approach | 0 | 0 | 2 | **2** | 2 | 2 |
| | No standardisation of data compilation and DRM procedures | 0 | 0 | 2 | **2** | 2 | 1 |
| ***Geographic*** | | 2 | 2 | 1 | **5** | 5 | 5 |
| | Inaccessibility of areas at risk of landslides | 2 | 2 | 1 | **5** | 5 | 5 |
| | **Total # pubs** | **6** | **54** | **49** | **109** | **100** | |

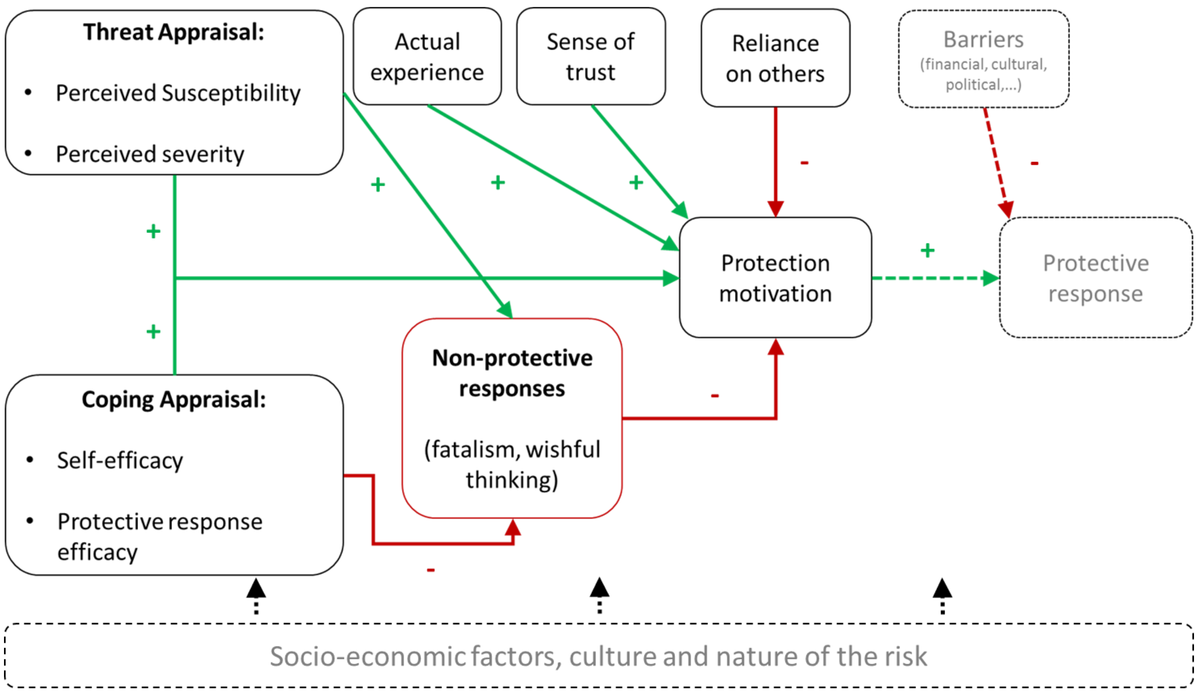


*Figure 4-16. Overview of the Protection Motivation Theory (PMT) as used in our analysis on the intentions to plant trees, adapted from Grothmann and Reusswig (2006).*

*Table 4-6. Descriptive statistics of the variables used for the analysis of intentions to plant trees, adapted from Mertens et al. (2018).*

| | Questions | Acronym | Cronbach Alpha | Before dichotomizing | | | After dichot. |
|---|---|---|---|---|---|---|---|
| | | | | Average (sd) | Min | Max | Average (sd) |
| | **Intention to plant trees** | [WilTree] | N/A | 1.30 (1.26) | -2 | 2 | 0.85 (0.36) |
| **Threat Appraisal** | **Perceived landslide susceptibility** | [PercSusc] | N/A | 0.49 (0.42) | 0 | 1 | 0.65# (0.48) |
| **Threat Appraisal** | **Perceived severity of landslide risk** | [PercSev] | 0.87 | 6.00 (8.37) | -16 | 16 | 0.78 (0.42) |
| **Coping Appraisal** | **Perceived efficacy of planting trees to reduce landslide susceptibility** | [EffTree] | 0.73 | 2.13 (1.85) | -4 | 4 | 0.64 (0.48) |
| **Coping Appraisal** | **Self-Efficacy** | [SelfEff] | 0.80 | -2.23 (2.35) | -4 | 4 | 0.15 (0.36) |
| **Trust** | **Trust in information** | [TrustInfo] | 0.69 | 4.52 (2.33) | -6 | 6 | 0.93 (0.25) |
| **Trust** | **Reliance on others** | [Reliance] | 0.66 | 2.06 (4.30) | -8 | 8 | 0.60 (0.49) |

*Table 4-7. Ordered logit regression with enumerator and sub-county dummies of intention to plant trees on the psychological variables from PMT. Regression 1 considers each of the variables separately, while regressions 2 and 3 include an interaction term between susceptibility appraisal and a continuous and a discrete version of self-efficacy respectively. For clarity reasons, only the most important control variables for our analysis, "experience with landslides" and "the presence of trees", are shown here. Z-statistics are in parentheses (* p < 0.10, ** p < 0.05, *** p < 0.01). Adapted from Mertens et al. (2018).*

| | | (1)<br>Intention to plant trees | (2)<br>Intention to plant trees | (3)<br>Intention to plant trees |
|---|---|---|---|---|
| Threat | Perceived landslide susceptibility | -0.36** | -0.35* | |
| | | (-2.10) | (-1.93) | |
| | Perceived severity of landslide impact | 0.05 | 0.07 | 0.08 |
| | | (0.29) | (0.37) | (0.43) |
| Coping | Self-efficacy | 0.05 | 0.02 | |
| | | (0.33) | (0.11) | |
| | Perceived efficacy of trees | 0.42*** | 0.41*** | 0.41*** |
| | | (2.77) | (2.65) | (2.65) |
| Interaction | (Self-efficacy) * (Perceived landslide susceptibility) | | 0.31** | |
| | | | (2.22) | |
| | Perceived landslide susceptibility if Self-efficacy < 0 | | | -0.67*** |
| | | | | (-3.20) |
| | Perceived landslide susceptibility if Self-efficacy >= 0 | | | 0.01 |
| | | | | (0.04) |
| Trust | Trust in information sources | 0.20 | 0.21 | 0.20 |
| | | (1.49) | (1.51) | (1.43) |
| | Reliance on others | -0.17 | -0.17 | -0.17 |
| | | (-1.07) | (-1.02) | (-1.03) |
| Experience with landslides | | 0.19 | 0.18 | 0.14 |
| | | (0.54) | (0.49) | (0.39) |
| Presence of trees | | 0.42 | 0.42 | 0.45 |
| | | (1.10) | (1.11) | (1.17) |
| Control variables, intercept and dummies | | Yes | Yes | Yes |
| N | | 397 | 397 | 397 |
| r2_p | | 0.15 | 0.15 | 0.16 |
| Chi2 | | 93 | 92 | 89 |
| Prob > Chi2 | | 0.00 | 0.00 | 0.00 |

***Resilience strategies at community level***

Between the resilience strategies at household level and at policy level, also resilience strategies at community level do exist. From the previous sections, it is clear that the impact of landslides is serious for individual farmers and that these farmers resort to work on other farmers' land in order to receive some revenue after the landslides. From qualitative fieldwork it is also clear that affected farmers essentially relie on the extended family for support when a landslide is causing a serious income shock. This implies that landslides do not only pose a serious burden on the affected households, but also on the neighbours and the extended families of those people that have been affected by a landslide (this is illustrated in Fig. 4-17).

Treating norms as the outcome of a repeated game and collective optimization over time, we therefore hypothesized that villages in the Rwenzori region, which have been living with landslides for a long time, might have developed social norms which aim at the ex-ante prevention of landslide related shocks. More specifically, we tested whether social norms might exist which prevent those farmers that would not be able to cope with a serious income shock from acquiring plots which have a high landslide risk. We investigated the presence of such norms at the supply side of the land markets, whereby farmers that want to sell a plot are incited to preferentially sell to non-vulnerable community members whenever these plots have a high landslide susceptibility. The choice experiments, that were presented earlier, have been used for this.

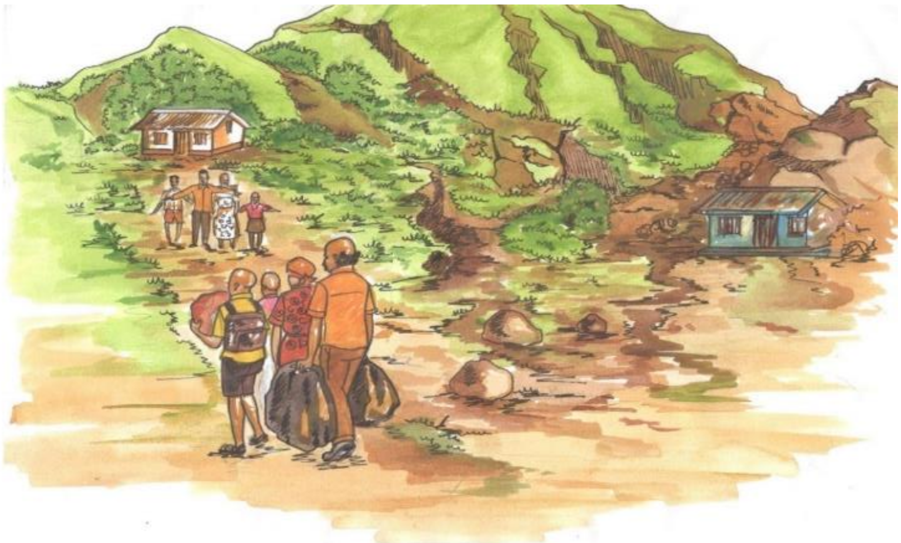

*Figure 4-17."Help each other": Illustration of how a landslide on the house of a neighbour also has consequences for other farmers in the community (Batezereca, 2017). This illustration has been distributed during dissemination of the AfReSlide results.*

From our analysis it is clear that social norms play an important role in determining stated preferences about land transactions in our study area. People prefer to sell their plots to family members (and are therefore ready to forego some revenue from the sale) and target poorer buyers as long as the plots are not susceptible to landslides. When the plots are susceptible to landslides, no preference is shown to sell plots to poorer buyers. This is illustrated in Table 4-8. We calculated the marginal rate of substitution between some buyer characteristics and the price that is being asked during the sale of the plot. We used this to estimate to what extent a buyer with certain characteristics is preferred when selling a plot. Only significant results are reported. It is clear that farmers prefer to sell their land to family members, and they are ready to forego some income for that. They do also prefer people that have only one plot and that are from their own village when there is no landslide on the plot. This preference is not found for plots that have landslides. We refer to Mertens and Vranken (2018) for more detailed explanations.

We think that the preferences that were found in the choice experiment reflect a social norm that prevents people to sell plots with landslides to their family members if these members do not have the capacity to cope with a future shock. This likely reduces the possibility for poor buyers to acquire land in landslide prone area and thus potentially limits the number of vulnerable people to landslides. That does not mean, however, that this social norm is fully beneficial to these poor farmers. Due to the social norm, these poor farmers likely have a more restricted access to land than the rich, since the latter can buy both land in landslide-prone areas and land outside landslide-prone areas. It could partially explain the phenomenon that was observed previously, whereby farmers with a lot of land that is not exposed to landslides acquire land faster than the other farmers. The norm we identified would thus aim at avoiding sudden income losses (due to landslides) among the poor, and thus the needs for support, rather than at limiting poverty or inequality. The long-term consequence of this norm for vulnerability, poverty and inequality is not yet clear.

*Table 4-8. Schematic illustration of Marginal Rate of Substitution between various buyer characteristics and the price (i.e. Willingness to Accept a lower price if a buyer has a certain characteristic) for the full sample (column 1) and for subsamples of plats that have never been affected by landslides (column 2) and plots that have had a landslide according to the respondent (column 3). Symbols indicate to what extent a farmer is willing to receive a lower price for their plot for buyers with specific characteristics (+++ indicate 'very much'; ++ 'much' and + 'some'). Standard errors are in parentheses (* p < 0.10, ** p < 0.05, *** p < 0.01). ns stands for 'not significant'. Significant results are only found regarding sales to family members.*

| | Full sample | No landslides | Landslides |
|---|---|---|---|
| **Preference to sell to family** | +++ ** | +++ ** | ++ ** |
| Additional preference for buyer that has 1 other plot | ns | ++ ** | ns |
| Additional preference for buyer that has no plot | ++ ** | +++ ** | ns |
| Additional preference for buyer that is not from this or neighbouring village | + ** | ns | ns |
| **Preference to sell to clan member (but not family)** | ns | ns | ns |
| Additional preference for buyer that has 1 other plot | ns | ns | ns |
| Additional preference for buyer that has no plot | ns | ns | ns |
| Additional preference for buyer that is not from this or neighbouring village | ns | ns | ns |
| **Preference to sell to person that is family nor clan [baseline]** | | | |
| Additional preference for buyer that has 1 other plot | ns | ns | ns |
| Additional preference for buyer that has no plot | ns | ns | ns |
| Additional preference for buyer that is not from this or neighbouring village | ns | ns | ns |

## TASK 3.2. Assessment of policy level resilience strategy

The second objective of WP3 was to assess specific landslide risk reduction policies and their effects on DRR: i.e. disaster platforms in the Rwenzori Mountains of Uganda and disaster risk zonation in Limbe city of Cameroon.

### *Disaster platforms in the Rwenzori Mountains, Uganda*

Based on the case study research on decentralized platforms for disaster risk management in the Rwenzori Mountains region - and situating this analysis within the debate on network governance-, the dominant discourse of the international disaster community, which portrays network governance as indispensable to achieve effective and efficient disaster risk management, was questioned. Decentralized platforms were observed to act as spatial tactics through which actors from the national scale are responsible for reproducing unequal power relations at their benefit. This is done through three processes of scale structuration: incomplete decentralization, blame dissolution and scale jumping. As a consequence, most decentralized platforms for disaster risk management were observed to be currently non-functioning in the Rwenzori Mountains region. This study argued that implementing network governance for disaster risk management – in an overall centralised, clientelistic governance environment and without conditions to ensure transparency and accountability- has limited chances to improve disaster risk management. Moreover, decentralized platforms might (re)produce unequal risk as they contribute to blame dissolution for the national and local governments, enhance scale jumping, and ultimately legitimise strong centralisation. Hence, this study argued that decentralized platforms can act as just another socio-political strategy allowing semi-authoritarian regimes to disguise undemocratic practices and keep on concentrating power. Full information about this research can be found in Maes et al (2018).

Uganda introduced decentralized network governance for DRM to endorse the Hyogo and Sendai frameworks. Since 2010, the National Policy for Disaster Preparedness and Management (OPMRU, 2010) was established, along with the creation of the national department for Disaster Preparedness within the Office of the Prime Minister (OPM). This 2010 National policy introduced a three-tier structure of network governance at national, district and sub-county level. This policy reflects a paradigm shift from response to DRR. Tall et al. (2013) ranked Uganda among the top nine African countries addressing the HFA goals, yet experience in disaster governance remains limited as compared to global standards. For example, a law to enforce disaster risk management policies is currently lacking (Bamutaze, 2015). This decentralized network governance for disaster risk management is however embedded in the overall governance system of Uganda, which is centralised, militaristic and built on clientelism. Our research reveals that in practice, decentralized platforms for disaster risk management are currently underused and interaction amongst members of these platforms remains very limited. Although the 2010 National Policy dictates that all sub-counties should have a disaster management committee, none of the three studied districts currently has a disaster management committee at sub-county level. According to district and sub-county officials this situation is due to financial and technical limitations. At the district level, we observed that policy and technical committees are combined into one District disaster management committee. Moreover, these committees only meet in case of an emergency and are merely non-functioning. This observation is based on semi-structured interviews with members of these disaster management committees and is consistent with observations in other regions of Uganda (e.g. Bamutaze, 2015). For example, a district official stated: '*We have the district disaster management committee; [but] it is just there in words'* (Personal interview, Interviewee A). Or in the words of a NGO representative of another district disaster management committee: *'The district disaster management committee is by law established; but […] it does not meet regularly, and yet does not have a plan nor a fund'* (Focus group interview, Interviewee B). At the national level, however, interviews and observations suggest that the National Platform for disaster risk management is active and meets about once per month.

As mentioned in the previous paragraph, the inadequate functioning of decentralized platforms for disaster risk management in Uganda can be attributed to three processes of scale structuration which prevent decentralized network governance and *de facto* reinforce centralised hierarchy: (1) incomplete decentralization, (2) blame dissolution and (3) scale jumping.

Incomplete decentralization is the first process of scale structuration which reinforces centralised power in the hands of the national ruling party. Evidence for incomplete decentralization in Uganda can be found in the fact that the devolution of financial and technical resources for DRM from national to local governments lags behind on the devolution of its responsibilities (Bamutaze, 2015). A significant gap between decentralization *de facto* and *de jure* thus persists. This deficit is in line with the general decentralization process in Uganda. Despite the NRM's push for decentralization since the 1990s (Bashaasha et al., 2011), the allocation of funds for local governments remains conditional (Saxena et al., 2010) and service delivery by local governments is still not up to standards (World Bank, 2012). As is often the case in countries of the global South (Banks et al., 2015), the budgets of the Ugandan districts depend on the central government and NGOs (Tumushabe, et al., 2013). According to Tripp (2010), Uganda's decentralization process can be considered as a strategy for the NRM to build a patronage network through setting up local governments that serve the ruling party well during elections (Tripp, 2010). Furthermore, she argues that relations in present-day Uganda are predominantly concerned with producing vertical linkages of patronage and obligation, while minimizing horizontal societal connections to ensure that the ruling party remains in power. Decentralized platforms for DRM are in that sense no different. As a result, these platforms are hardly ever used for the aim they are designed for. Consequently, disaster risk information (e.g. hazard maps made by the Uganda Red Cross) is rarely shared by actors involved in DRM despite being relevant for effective DRM, according to several respondents of the focus groups at the district DMC's. As this 'decentralization' is not further supported by a devolution of resources in terms of finances and skills, this process becomes merely a blame shifting mechanism. This blame shifting strategy of delegating responsibility looks appealing for politicians in Uganda, as the government was blamed for inadequately handling disasters in the previous years (e.g. for the 2010 landslides in Bududa district: Jenkins et al., 2013). Blame for judgemental failure is further delegated to technical experts through the use of technical platforms operating over different politico-administrative levels.

As politicians run the risk that the blame is boomeranged back by experts, the second process of scale structuration is to dissolve blame (Hood, 2002). Several respondents indicated during focus groups that they were lost in the complex hierarchical structure that was set up by the 2010 National Policy. Not one respondent of the studied decentralized platforms could show us a digital or handout copy of this policy despite the claims of OPM members that it was distributed freely to the local governments. In other words, the responsibilities and roles for DRM were considered ambiguous by the participating members, which is a common situation in cases of network governance (Swyngedouw, 2005). While one of the basic responsibilities of the district committees for disaster management is to develop a disaster preparedness plan, two out of the three studied committees did not have such a plan (i.e. Bundibugyo and Kabarole districts). In one case, an attempt for a contingency plan was made but disproved by the OPM as it was a mere copy-past of the national contingency plan.

From the focus groups at district level, we found that household activities were often mentioned as the main cause for landslide loss. Furthermore, most members stated that households should bear the costs of implementing disaster risk reduction measures, not the committees. In addition, decision-making processes in these platforms follow a rather informal haphazard structure which is ultimately lacking transparency, as stated in the following quote of an OPM employee: *'There is no priority on one or the other [hazard]. It is actually cyclic […] when a certain hazard occurs, there is a focus on that hazard'* (Personal interview, Interviewee C). Decisions made by decentralized platforms thus focus on a post-disaster emergency rather than on pre-disaster risk reduction. The responsibilities and roles of the district are considered to be response-focused or in the words of a district environmental officer *'…[the disaster management committee] operates as an emergency…'* (Personal interview, Interviewee D). Claiming the main responsibility is post-disaster emergency, they cannot be blamed for not taking pre-disaster actions.

The third process of scale structuration is scale jumping, i.e. bypassing of administrative levels, which illustrates the persistence of vertical forms of governance within Uganda. During disasters, affected sub-counties or villages often link with, and benefit from, higher administrative scales through the jumping of scales. Evidence of scale jumping can be found in the geographical differences regarding the media coverage on landslides and the amount of relief distributed in the Rwenzori Mountains. At the district level, the media coverage on landslides per district does not reflect the actual spatial distribution of landslide occurrence. Susceptibility analysis shows that the highest landslide densities are found in Bundibugyo district which is underreported in local news articles on landslides (Jacobs et al., 2016a). We argue that, despite the lower density of landslides in Kasese and Kabarole (compared to Bundibugyo) districts, their relative large media coverage on landslides can be attributed to the higher access to national power structures of these districts through scale jumping. On the one hand, sub-counties in Kabarole district have good links with the central government, as many of the war veterans from the Rwenzori region reside in Kabarole district (i.e. linked to the ruling party). The particular attention to war veterans somehow explains why response was relatively rapid and plenty after the 2010 landslide in Kateebwa sub-county, compared to disasters in other sub-counties. For example, Kabonero sub-county was not mentioned as a landslide-prone sub-county in Kabarole district by district officials despite the fact that recent landslide inventories indicate this sub-county as hotspot for landslides (Jacobs et al., 2017). On the other hand, Kasese district is, from an economic perspective, the most prosperous district of the three while Bundibugyo district stands the weakest with a strong dependency on NGOs. Inhabitants of Kasese district have also good political connections because of its relative large number of national parliament members. In addition, Kasese experienced severe flash floods in 2013 (Jacobs et al., 2016c). All these events led to a larger (inter)national attention towards this district and contribute to explain its dynamism in terms of DMC. In a polity of limited resources and clientelism, scale jumping thus provides certain communities and authorities a more direct access to power and resources to reduce disaster risk and for response. Some district officials admitted that attention given to certain villages was not in proportion to the level of impact. Especially the request for, and distribution of relief, is highly politicised as often mentioned during focus groups in the three different districts. Given the fact that decision-making and division of roles and responsibilities are less structured in network governance systems, jumping of scales is more common than in hierarchical forms of governance (Swyngedouw, 2005). For example, a district official states: '*Yes, our people are connected! Information can even reach the minister before it reaches here at the district.'* (Personal interview, Interviewee E). This scale jumping has been observed in several sub-counties of West Uganda.

***Disaster risk zonation in Limbe city of Cameroon***

The case study of landslide and flood risk zonation policy in Limbe city was analysed from an urban political ecology perspective. Drawing upon discourse theory, this study concluded that authorities from national to local level use a post-political discourse to promote and implement disaster risk reduction in Limbe city. This is done by pushing forward a disaster risk zonation policy. A post-political discourse in this context entails that disasters are portrayed as technical and a-political problems. In other words, an approach that deliberately ignores the socio-economic, cultural and political root causes of disasters. This study argued that risk zonation can lead to increased exposure and vulnerability if a post-political discourse for disaster risk reduction is used. In Limbe city, the post-political discourse led to ad-hoc risk assessment and poor enforcement of the current risk zonation policy, resulting in disaster risk accumulation. The main conclusion of this case study research was that risk zonation policy is often recommended as a disaster risk reduction strategy - both globally and locally - for two main reasons. First, risk zonation policy is considered a highly effective strategy in reducing disaster risk, yet when only the bio-physical aspects are taken into consideration and the socio-political aspects of disasters are neglected. Indeed, totally preventing exposure of humans and human infrastructures to natural hazards means no risk of disasters. However, in reality, many hazardous locations are already inhabited, and relocation of these people is a highly contested solution. From this perspective, it is possible to argue that disaster risk zonation is highly political. The emphasis on the efficacy from a bio-physical perspective, justifying the recommendation of policies for risk zonation, are a result from the resurfacing post-political logics promoted by international and national disaster risk reduction communities. Second, risk zonation policy is a beneficial strategy for (semi)-authoritarian regimes in the sense that it provides the opportunity to avoid blame. Risk zonation policy indeed gives the false impression that governments are directing efforts to protection of individuals from 'sufferings'; however, in practice, the post-political discourse to avoid blame leads to disaster risk accumulation instead of reduction at least for the case of Limbe (Fig. 4-18).

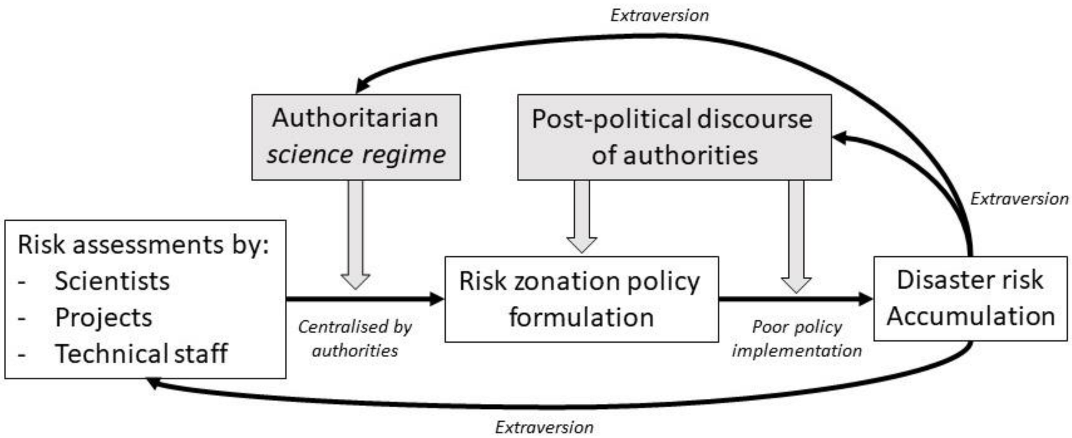


*Figure 4-18. Structural model representing how socio-political drivers shape how risk assessment is produced, circulated and applied through risk zonation policy, including its consequences for disaster risk (Maes et al., accepted in EPC).*

Two processes are at play which influence the malfunctioning of the disaster risk zonation policy in Limbe city: (1) the authoritarian science regime as a driver for conducting risk assessment and (2) the post-political discourse as driver for having risk zonation policy and poor policy implementation (Fig. 4-18).

The first governance process is the authoritarian science regime which influences how risk assessments are conducted and used. The numerous development and research projects in Limbe city, and thus the various 'risk assessments', can partly be explained by Cameroon's shift to a neoliberal agenda after the economic downturn in the 1980s and 90s (Tanga and Fonchingong, 2009). This agenda increased the influx of non-governmental organisations (NGOs) as the drivers for development, especially in the Anglophone regions of Cameroon (Tanga and Fonchingong, 2009). According to various local administrators interviewed for this research, attracting new development projects led by NGOs is crucial given their large contribution to the income for the Limbe City Council. As a consequence, local authorities are hesitant to share the existing risk information in order to keep attracting new projects and money. This strategy of rent-seeking by (semi-) authoritarian regimes of Sub-Saharan African (SSA) countries is often referred to as 'extraversion' by political theorists (e.g. Bayart, 2000; Ferguson, 1990; Mbembe, 2001; Tull et al., 2011). Extraversion refers to turning outwards for foreign money, i.e. seeking for dependency on foreign aid, in order to stay in power. The 'expertise on risk assessment' is thus not a neutral political entity (e.g. Pestre, 2003), but is solely in the hands of the authorities. In sum, the authoritarian science regime in Limbe prevents the circulation of risk assessments in order to continue attracting donors. For example, technicians and politicians did not express interest when we proposed to share the collected risk assessments of previous projects (e.g. GRINP and MIAVITA) during our focus groups. Not communicating risk knowledge is also a feature common for (semi-)authoritarian regimes who typically resist any type of transformative change (Solecki et al., 2017). Calling for more risk assessment enables authorities not to take concrete actions.

The second governance process is the post-political discourse which influences what policy is developed and how it is implemented. The observed post-political discourse of national and local authorities in Cameroon meets the needs of the state-owned industries (i.e. oil refinery and plantation agriculture) instead of striving for safe settlement conditions. The impossibility to contest the power of the state-owned industries for spatial expansion over citizens' need for safe settlement, illustrates Cameroon's post-political character. As much of the remaining land is unsafe for settlement, risk zonation is used by national and local authorities to avert their responsibility for protecting their citizens from hazards in two ways. First, policy documents and interviews show that risk zonation enables the national and local authorities to present the problem of disasters as technical and non-political. As such, the responsibility is diverted to the technical staff of the Limbe City Council (LCC) or even dissolved within the process (e.g. Hood, 2002). This shift of responsibility from politicians to bureaucrats is described by Fiorina (1982) as the shift-of-responsibility model. This shift is explained by the fact that politicians fear to be blamed for not sufficiently planning for disasters but also remain able to take credit in case of a positive outcome. Technical staff however might have limited incentive to enforce the laws or make right decisions in uncertain situations because they are unlikely to be held accountable in case of disaster. According to a LCC representative, this technocratic approach reflects the common disaster discourse in Limbe, as the other main DRR strategies consist of regular dredging of the two main rivers in Limbe and enforcement of building codes by the technical staff of the LCC (Personal interview, Interviewee F).

Building on political theory (Bayart, 2000; Mouffe, 2005; Ferguson, 1990), this study argues that risk zonation policy in Limbe follows a post-political discourse: national and local governments present risk zonation as a pure technical and a-political issue for which finances and enforcement means are limited. By constituting commissions and boards for risk assessment, apparently 'broad-based and neutral decisions' are made, yet these are in reality strongly controlled by the national government and also hard to contest. In the words of a Quarter Head's assistant of a quarter that contains a risk zone: '*We cannot say where it is risky or not, that is the task of the technicians*' (Personal interview, Interviewee G). While the policy – as such – is difficult to contest, citizens found however ways to circumvent its implementation (e.g. through illegal settlement). Second, people are tolerated to construct in risk zones at their own risk. Both officials and residents of risk zones acknowledged the fact that settlement was unofficially allowed if the resident agrees to live in this area on his/her own responsibility. As people have the unofficial approval to settle in risk zones at their own risk, the responsibility to reduce disaster risk is shifted from the government to the people who live in risk zones. People-at-risk are thus blamed in case a disaster occurs. This shift of responsibility is in fact the easiest way for the government to escape from being blamed, as illustrated by the words of a Cameroon Red Cross employee: *'…when something happens and the government did not act, the government will be blamed for not acting. If the government uses force [to relocate people] then the government is wicked'* (Personal interview, Interviewee H). Not enforcing the law and tolerating people to settle at their own risk is thus a conscious choice of not being held responsible. In addition, people in risk zones cannot opt for disaster compensation to which, in theory, every citizen in Cameroon has the right (Bang, 2014). In other words, the responsibility is shifted to the people-at-risk. The explanation on the absence of compensations after the landslides in 2013, provided by a staff member of the Ministry of Housing and Urban Development (MINHDU), is interesting in this respect: *'The houses were demolished by landslides, not by the government'* (Personal interview, Interviewee I). This quote highlights the dominant hazard paradigm (Bassett and Fogelman, 2013) which is essentially post-political.

The reasons for national and local governments not to evict people or demolish houses are plenty. Firstly, authorities do not wish to face political risks (e.g. losing potential votes) and economic loss (e.g. time and money spent) of demolishing houses and providing alternative housing. Secondly, poor enforcement of the law gives the local government opportunities to benefit financially through corruption, which is common in Cameroon (Transparency International, 2013). Corruption is facilitated by face-to-face interactions during the ad-hoc risk assessments, the lack of transparency on risk zonation policy (e.g. not based on transparent but ad-hoc assessments), and the ill-definition of 'risk zones'. Thirdly, it frees the governments from their responsibility to provide public services in these areas or compensate people if they are affected by a disaster. Fourthly, it allows to maintain the availability of cheap labour force within the city, favouring local state-owned industries (e.g. CDC). Paraphrasing Susman et al. (1983) on the explanation of marginalisation, this labour force is kept cheap, vulnerable and dependent through not providing facilities and denying access to land titles, building permits and loans. All these socio-political incentives thus favour poor enforcement of the law of the risk zonation policy.

## WP.4. Cultural representations and motivations for land management

### TASK 4.1. Description of cultural premises related to land and natural hazards

#### ***The intercession of cultural specialists with misfortune***

When asked the qualities of a Mukonzo, people stress the respect for traditions and customs, the ability to speak the language, and the promotion of culture, which includes the belief in cultural beings (spirits). Traditionally, no activity is performed without connections to the spirits (e.g. when eating, something should be thrown down to share with the spirits). According to the kingdom Prime Minister Enoch Muhindo, '*the Bakonzo are a spiritual community, not a scientific one. Anything that comes to them is determined by some spiritual power'*. People consult the seer or spirit medium (*omuraghuli*), dealing with calamities, in order to find out solutions to problems people do not understand, and the sorcerer (*omulhoyi*) for bad fortune. He communicates to the people what the spirits want or not. There are numerous, some of them being on the official list of the government. Some of them have shrines and sacred sites. *Abathahwa* also intercede with the ancestral spirits and predict the future. The elders select the *abathahwa* to perform important rituals. Many people consult them.

Another cultural character involved in disasters is the rain maker (*omuhangyi wembrura*), who has a special power to initiate rain and droughts and who uses a plant arrangement but no stones like the *omuthahwa*. He works together with a blacksmith and inherits its talents from is grand-father and father. During the rainy season, people request him to stop the rain for a burial, a wedding, or construction works. The rain maker reports to the *isemalhambo* in case the community complains about sun or rain, so the *isemalhambo* mediates between the community and him. The community consults the rain maker and has to inform the *omukulhu wawulambo* or the *isemalhambo*. The Church vigorously discourages rain making.

As a whole, the Christian pressure is eager to make people give up cultural institutions. Churches have been struggling to erase such habits from people's way of life by preaching, trying to convert the *abathahwa* and burning culturally significant items.

***Spirits responsible for disasters dwell in plants***

LS are often said to be caused by natural spirits. People have encroached some natural trees in which natural spirits rest in, causing their anger and provoking LS. The trees involved in LS are *eriranga, omuthrubya, omuhahya, omuramura* and *akathi-akubukwa*. When these trees are maintained around a household, no natural disaster is said to ever occur. At the arrival of charismatic and born-again preachers in the 1990s, Christians encouraged the people to chop down traditional trees (Catholic and Protestant missionaries originally came in in 1877), described as satanic. After a massive clearing, disasters became more frequent and one can notice nowadays an increase of interest for maintaining these trees again. As women gain importance within Churches and Christianity, they tend to be the most hostile to the worship of traditional trees.

The traditional trees are connected to the spirits and shrines; the wetland comes with a spirit *Endyoka* (« octopus » in lhukonzo). *Omuramura* should be planted to prevent *Endyoka* to be harsh. The *omuraghuli* gives *eriranga* which has squeezable leaves to drink to recover from the shock of the octopus. *Eriranga* is a tree planted for boundaries, and its leaves are used for wounds and its seeds for oil and perfume. There are many stories about *Endyoka*. It is one of the fears in the river, lakes and water bodies. The *omuthahwa* can kill *Endyoka* using special herbs. Sometimes, *Endyoka* can contribute to the landslides: it produces more water to the land which becomes more wet. *Endyoka* is in River Mobuku.

There are many places where customs prohibit building houses and growing crops. Getting along with these prohibitions may cause issues such as LS. Certain schools are always swept by the wind; teachers go to the *omuthahwa* to stop the sweeping. Some crops may not flourish due to the disrespect of a customary prohibition about land, which will be identified by the *omuthahwa* by calling the ancestral spirits.

Some natural spirits stay within the community and others live alongside traditional trees, especially around Nyamutswa hill. In the past, rituals were not necessary to face disasters, trees were just planted to please the spirits (*emirimumebe*). No particular action was required to have good harvest, which is ensured by the respect of customs. Once the spirits are disappointed, they create a LS, sometimes lethal. Christians pretend that once people do not maintain the trees, spirits get away.

***Change and spirits movements***

Since the population displacements in the 1990s, the spirits are said to have shifted and are no longer seen in some areas. The population pressure has been encroaching some of the sacred places where sacrifices have been carried out. The deaths of elders who knew what to do where is causing a lot of mismanagement of the environment. Certain trees are not supposed to be mishandled but people just cut them because cultural leaders are missing to advise them. After some traditional leaders' death in the 1990s, some younger people claimed to be their legitimate heirs without having been appointed nor elected; they are not always followed, leading to land conflicts.

## TASK 4.2. Definition of the local means customarily requested to face natural disasters

***Traditional plants to prevent landslides***

The Bakonzo have special plants that prevent LS, lightning and other natural calamities (the different cultural groups tend to look differently at natural resources, so results may differ elsewhere). The Bakonzo respect moral codes and specific requirements to handle plants. Plants such as *omuthrubia*, *omuramura*, *hempathama*, *ekibonderia* (comes from *eribonderi* = to cool down), *owuthukuru, omuthroma, omukohwa* calm down any strange disastrous happening. They are meant to keep away spirits so the place remains calm and accommodating to the people. *Omuramura, omuthubya, eriranga, erikubya* are the main LS plants. *Obuthembe* calms down the situation, brings milk back to old women; this plant is responsible for people's life. There are different types of *amaranga* (plural of *eriranga*): some are for LS, some for lightning, some for fighting, some for twins. A special *eriranga* from the mountains is called *erikubia* (= to hinder) and prevents calamities to reach people's home. If it is planted, the place becomes good for humans to live. *Eriranga* should be planted with an explicit purpose so that that situation should not happen again. If LS happen repeatedly or if a situation comes out of hand, it is a sign for *emirimumebe* (spirits) so *eriranga* can be planted by the *omuthahwa* (it is specific to *omuthahwa*) to make them go or cool down. When a landslide occurs, whistles come from *emirimumebe*, drums, noises, a kind of alarm; many informants claim to have heard them.

If something wrong has happened (LS), there is a way to use the plant after the LS and another way to use the same plant to prevent a LS. If the LS has killed somebody, you can make sure the spirit of the dead will not affect the remaining people by using the same plant in a different way. Some farmers are interested in this type of plant but they get confused with the challenge of Christianity. The typical character who uses plants is the *omuthahwa*.

***Using plants as land boundaries***

Land demarcation marks are intricately linked to spiritual boundaries. *Enehoya* (green cordylline) is a land demarcation mark as well as concrete (in town), roads (mostly dirt roads, even very narrow trails), some species of trees, euphorbia, bark trees, barbed wire, passion fruit trees, avocado trees, sugar cane, pine trees. Yam is just a plant, even if it can be planted just on the boundaries. If there is a LS, people come at communal level, clear the mud and search for the boundary. The tree *omubiriti* is used for firewood, logs for permanent construction and boundaries.

The *omukulhu wawulambo* is the only cultural leader working on boundaries. The *omukulhu wawulambo* planted the plant *omuramura* for boundaries as well as bark trees. He makes rituals and people give him chicken or *tonto* (or something else) or money nowadays. In case of a land dispute, people may not cut this plant with anger under the threat of death, serious sickness of a family member, non-understandable disease of a child, death of a livestock animal. After the *omukulhu wawulambo* has planted *omuramura*, the owner may continue himself by planting other plants on his boundaries.

***Cultural rules as conservation measures***

Cultural rules are sometimes interpreted as conservation measures by local people themselves. 'Superstitions kept controlling our discipline'. People would never urinate in a river because of *endyoka* (mythical octopus), who is said to be dwelling in the river at around one o'clock; actually, it would prevent people to fetch dirty water downstream. The bark cloth tree may not be cut because spirits of the family are said to be around; actually, it is a very good windbreaker, and its imposing roots prevent the soil to move. Kalikile and another spirit were said to be in the big wetland of Kyanzuzu (Mahango), actually protecting the clean water that used to be there before people began practicing agroforestry.

During the preliminary mission in January 2014, a driver for LS occurrence mentioned by the stakeholders in the Kasese workshop was a “breakdown in cultural beliefs”. As the first series of interviews showed, the use of traditional plants for land boundaries – hand in hand with the relative decay of traditional rituals in some areas – tends to decrease given the intense pressure of monotheist religions and Churches. However, several meetings with cultural leaders were held to discuss the possibility to re-settle the rituals and organize a massive plantation of the incriminated cultural plants. They also intended to organize a mountain sweeping ritual in July-August of several consecutive years, but the ritual did not take place given political tensions and dozens of casualties in the Rwenzori. If the cleaning ritual is not performed, the spirits are annoyed, and the land may slide. In order to appease the spirits aggressiveness, they may be fed on hens, from which they drink the blood of the hen (not the meat).

As land boundaries are explicitly related to ethnobotany, work has been done with spiritual specialists, hand in hand with Biogardens (https://www.facebook.com/BioGardensMAMI/), a garden growing and distributing plants traditionally used for both health and ritual purposes. Around sixty plants are used to deal with accidents, incidents and life discomforts. The pressure of Christian Churches to encourage people to give up the spiritual use of plants, with the indirect support of the central government, settles a progressive change in the landscape organization and in the Bakonzo use of nature. For instance, *omukwoha* (“lucky bean” in lhukonzo, erythrina, coral tree in the forest) is said to be “where the gods stay”. Nowadays these plants are transformed into charcoal and firewood. People are over-cultivating the land – which is getting scarce given the high birth rate of the Bakonzo compared to other cultural groups and the dedication of large portions of land as National Parks, preventing the Bakonzo to cultivate it anymore – and widely cut trees compared to their grand-fathers who spared the forest and asked the gods for advice as regards to plants and trees use. According to some interviews, old people tend to lose influence. In the middle of these changes however, some people claim that land disputes and recurrent occurrence of disasters are caused because they have abandoned the old way of living.

***Traditions in the heart of Bakonzo identity***

The research also focused on the expressed qualities of the Bakonzo people in order to identify the cultural connections between cultural precepts and the Bakonzo spatial use of their land, willing of settlement in a specific place, agricultural techniques weakening land stability and favouring erosion and LS, characters involved in the acquisition of land, architectural techniques before and after landslides, land boundaries settlement, and land disputes and conflicts. The *isemalhambo* (ridge leader) represents the “culture” of the Bakonzo people and gives recommendations to his people relating to what is considered an appropriate behaviour. Consideration has been given to local initiatives, such as a series of groups taking place in Mahango sub-county and involving volunteers in different actions in case of a disaster (first aid, continuous schooling of the children, resettlement of the family, damaged cultivated land, specific care to groups such as handicapped people, health teams, disaster reduction).

The Bakonzo have the reputation to be more religious than the others; they mostly live uphill. Their sacred and ancestral places are located « in the mountains » (National Parks). A few years ago, it was prohibited to go to National Parks (on top of the mountains) and now the government allows some ceremonies in the mountains. These ceremonies are essentially performed to face disasters and crisis.

***The central role of the healer***

The main character requested by the Bakonzo people to face misfortune is the *omuthahwa* (healer). The *omuthahwa* is supposed to behave in a certain way: he should serve the community, should not look at himself (or herself), should take care of the people, should not steal, and should never be worried for tomorrow (for eating and a place to stay). There is one *omuthahwa* family for the Bakonzo people, which is scattered among the Bakonzo community. Many community leaders consult the *omuthahwa* - even the president of Uganda (who even finances some of them)-, despite they do pretend not to frequent them given the execrable reputation spread by Christian Churches about these characters.

The *omuthahwa* is trusted to go beyond problems whereas the *omurahuli* (forecasting, seer, devin) is supposed to have an action to change the future. Many people consult both cultural figures in secret: there is a gap between the discourse given to foreigners and the actual practice which can be seen in the crowded « waiting room » of some *abathahwa*. A third character also intervenes in case of difficulties: the *omurahuli,* requested to give proper guidance. He is consulted in case of troubles (financial family, sickness, accidents) but not anymore after a landslide or natural disaster.

Despite the impact of Church pressure to make customs and rituals cease, traditional means to face misfortune tend to be preferred in a situation of crisis such as disasters. In parallel, some Bakonzo families are said to host special spirits who push them to continue their spiritual customs.

### TASK 4.3. Assessment of the coping capacity

***A customary hierarchy in charge of disasters management, morals and land rights***

Traditional leaders are led by the king (*omusinga* Wabakonzo Mumbere Charles Wesley) then the chieftain (*isemalhambo*) then the ridge leader (*omukulhu wawulambo*) then the sub-ridge leader (*omusokyi*). The king is responsible for the all Rwenzori. The *isemalhambo* work in different mountains, the *omukulhu wawulambo* works in some villages and the *omusokyi* works at village level.

As the Rwenzori is an area of disasters, the Obusinga Rwenzururu kingdom has a Minister in charge of ethics, integrity, disasters and regional recovery. If the norms of the society are overlooked, it could result into a natural disaster. Wild animals are also part of these disasters; if the spirits keep eating animals or even human beings, it is a punishment by the spirits as a result of the fact that the community has misbehaved and contravened some natural norms.

Traditionally, the *isemalhambo* (ridge leader) works for purposes of administration and for conflict resolution, especially related to land. His powers are inherited. He advises and guides the *omusinga* (king) for traditions and rituals, and he is responsible for peace, especially related to land use and ownership. The *isemalhambo* is also consulted for domestic violence. He has been teaching people to avoid AIDS (no open sex) since recently, sets up land conflicts, cultural values, good discipline, and the African dressing code. The African dressing code is, for women, not to wear trousers: it is reported to the police. They should cover their heads, no breast and shoulders visible, long dress.

Men should wear trousers (not a dress), a shirt and not be naked.

The *isemalhambo* should also teach people to conserve the environment, give food to children and take children to school. The Bakonzo were left behind by other cultural groups because of the conflict with the Batooro: they had to leave the mountains and could not go to school. In 1982, the conflict stopped; the government began to unite them and asked the Bakonzo what they wanted and chased the Batooro to Fort Portal.

In case of a disagreement, the *omukulhu wawulambo* (chieftain) and the elders make a judgment. Sometimes the case goes to court if it cannot be solved by traditional means. Whenever they expect a disaster, the *isemalhambo* and the *omukulhu wawulambo* are responsible to perform rituals and sacrifices to the *emirimumebe* (spirits). The great majority of the informants have paid a tribute to the *omukulhu wawulambo* under the shape of the symbolic equivalent in money for a goat (20000 UGX).

As regards land rights, families, companies, churches, everybody owns land individually. Trading centres and shops are often closed in the morning because the people go to ditch their gardens (or piece of land). The government began offering titles and people claimed it as their land. Originally, people were given free land and they would offer goat to the *omusokyi*, who would bring it to the *omukulhu wawulambo* who would bring it to the *isemalhambo*. In case of a disagreement about land ownership, the *isemalhambo* knows the owner. Land boundaries are taken care by the *omukulhu wawulambo* who plants the specific plants used as boundaries and witnesses land sales. Some people take advantage of other people's ignorance, get a title and lease their land; however, traditional owners do not have land titles. Advertisements warn against such land grabbers.

***A mountain sweeping ritual to prevent LS***

Supposedly every year, the mountain sweeping ritual (*eribiryia malambo*) is performed by the *isemalhambo* in the mountains, from the top to the lakes. Cleansing is done to avoid calamities. Certain signs must be seen before performing it like disasters (rivers went in rampage flooding, more rain, pass the banks causing disasters), supposed to be signs of anger from the spirits. The chieftain will perform the ceremony and allow the ridge leaders to cleanse up to the lowlands. The ritual aims at pushing away bad omen and spirits that prevent people's activities to happen. Spirits have different names depending on the misfortune they make: whereas Kalikya is for animals, Endyoka (LS and floods) is for water, and there is also one for harvest (Muthundi).

The ritual is organized in order to appease cultural beings and prevent or limit further disasters and misfortune to occur. Fought by Christian Churches (mostly Catholic and Presbyterian), who have been struggling since decades against any other representation about “the invisible” but Christian, the mountain sweeping ritual has not been organized anymore in the Rwenzori since 2006. The creation of the Bwamba cultural kingdom in Bundibugyo in July, 2014, caused tensions that have compromised the organization of the ritual planned at that time to reduce the tendency for disasters to rise up. The performance of the ritual is presented by a series of customary leaders as an emergency. The king of the Rwenzururu and an assembly of cultural ministers and cultural leaders have come to the point that given the increasing number of disasters (mostly LS and floods), time has come to organize it. Sponsored by both cultural leaders and ritual specialists, the impact of the ritual on social life – all the communities are mobilized during a whole week for the sweeping and submitted to a series of prohibitions, preventing them to perform other activities and work – presents a window over the whole Bakonzo societal mechanisms.

Many Bakonzo people stress the importance of the mountain sweeping ritual to get rid of calamities. Hill sweeping is challenging and performed after having taken food and offered sacrifices of animals. The ancestral spirits could not be seen but are said to reside on the mountaintops and to make rain. After the harvest, the spirits traditionally get a portion of the harvest, sheep, goats and *matoke* as thankful gift for the work that has been made; this custom however tends to disappear.

When rain is expected in March and is not coming, the people consult the *isemalhambo* (ridge leader), who prepares special leaves to call rain. When he begins sweeping, he would throw a hen alive (not slaughtered) for the spirits whereas other people are drumming. A drink made of local banana, *tonto* (there are two types, the commercial one is called *waragyi*), is used in rituals to talk to the ancestors. Local drums are used; every Mukonzo has one in his home and brings it outside when there is happiness and plays with the children. It is also used in churches, but the sound for church is different than for the chat with the ancestors. Different sounds are produced for different occasions. After the sweeping, people go to the *isemalhambo*'s home to ask for seeds to plant to bless the garden of the individual homes.

***A local initiative to sensitize the farmers to the use of traditional plants***

As the use of spiritual plants is believed to prevent disasters, a local initiative combines cultural representations and daily practical uses of plants: the Biogardens Indigenous Development Centre, founded in 2004. Biogardens sensitizes the people to the uses of traditional plants and sites and helps people to understand their past, related to the present. It looks at people's cultural techniques, skills and knowledge. With the support of *abathahwa* (healers), the team advises farmers on how they should use their traditional skills in farming and traditional plants in health so that they can spare and use their money elsewhere. In their medicinal plants demonstration garden, they collect plants from the mountains and plant them near the people to avoid the destruction of the protected areas. Their farmer training centre is busy with agriculture, handcraft, herbal medicine, and conservation. Their herbal medical clinic is dedicated to people who cannot afford Western medicine and some who failed in modern hospitals. Knowledge collected from spiritual specialists (*omuthahwa*, *isemalhambo*, *omukulhu wawulambo*) in Kamwenge, Bundibugyo, Kasese and Fort Portal is used to evaluate how traditional culture can be improved to suit the current modern changes.

***Coping capacity and governance***

The coping capacity can be examined from the governance side. At the customary level, the *ekyaranda* (board of elders) is set up for every clan to discuss every issue. Its decisions are generally followed by the community. At the government level, some groups of local people are involved in disaster management with the support of the chairmen LOC I, II and III. In Mahango for instance, which is particularly dynamic compared to other sub-counties, one can find 5 Community-Based Disaster Rehabilitation groups (CBDR) with 25 members each, 125 members in total. These groups write reports to the sub-county. They are equipped with skills of rehabilitation issues and give a psychosocial support (they do not rebuild houses). They identify affected households and report them to the sub-county, district and Red Cross with whom they work hand in hand. The role of the committee is to teach disaster management and to report to higher offices, Red Cross and first aid. It has no funding; it is volunteer work. Members are elected by other community members for no specific period. Some other groups are focused on other societal issues such as HIV prevention, adult literacy or the involvement of the disabled in community life.

The community-based disaster reduction groups are set up at the parish level. At the village level, the Village Health Teams (VHT) include 5 volunteer members per village. They are active in health, sanitation, vaccination for young people and mobilize the people to be ready to different problems. At the sub-county level, some structures are chaired by the sub-county chief. All these groups report to the District Disaster Committee at the district level. The district committee supervises other committees' work. Local residents ask the committee for help.

Marednet (Mahango Rural Development Network) is a drama group created in 2012 and led by Semu Ngwirakaghe. There are 15 other comparable groups, all volunteers. The group of Matere village in Mahango parish counts 35 members (10 men) who compose and realize what should be put in sounds such as: "Cover the soil, build trenches". They have the right to tell the leaders about the concerns of the communities with theatre plays, songs and talking. They play to advise the community how to prevent and to avoid AIDS, the good methods of farming, domestic violence, how development can be initiated at grassroots, good governance (fighting corruption that leads to poverty). They have composed two songs and one play (out of 20) about LS and have the intention to complete the show with costumes.

### WP.5. Risk mapping and selection of resilience strategy

#### TASK 5.1. Risk mapping

The potential loss in monetary values due to landslides was calculated for one key sub-county in the Rwenzori Mountains: the Mahango sub-county. Therefore, all risk components were integrated: exposure, vulnerability and hazard. The risk is calculated for the two vulnerability scenarios. The risk, or predicated annual losses, of the entire sub-county ranges between 14.06 and 70.34 million USH per year. The total risk of both vulnerability scenarios is calculated per element at risk (Table 4-9). The two first columns indicate the absolute part of the total risk, while the third column represent the relative part of the total risk expressed in percent. If we look in general, human infrastructures counts for 91.2 % percent of the total risk versus 8,2 % for land cover. If we look in details, the highest risk value is obtained for the houses with 11.9 and 59.6 million USH/year, or 85 % of the total economic risk, for the two scenario's respectively. In term of surface however, houses only represent 2 % of the total area. In comparison, the community roads cover 1.2 percent of the total area and represent only 2.9 % of the total risk (0.4 and 2.0 million USH/year). Compared to the community road and the houses, the land cover types represent 18, 64 and 13% of the total area for trees, cropland and pasture respectively. Nevertheless, they only account for 1.6, 4.6 and 2.0 % of the total risk respectively.

*Table 4-9. Landslide risk scenario 1 and scenario 2 for the different elements at risk (Schoonenbergh, 2017).*

| **Element at risk** | **Risk Scenario 1** (Million USH/year) | **Risk Scenario 2** (Million USH/year) | **Percent** (%) |
|---|---|---|---|
| District Road | 0.132 | 0.662 | 0.9 |
| Community Road | 0.407 | 2.035 | 2.9 |
| School | 0.079 | 0.437 | 0.6 |
| Water Spring | 0.033 | 0.166 | 0.2 |
| Sub-county Headquarters | 0.054 | 0.271 | 0.4 |
| Health Center III | 0.034 | 0.168 | 0.2 |

| | | | |
|---|---|---|---|
| House | 11.937 | 59.684 | 84.9 |
| Church | 0.172 | 0.860 | 1.2 |
| Trading Center | 0.047 | 0.235 | 0.3 |
| Cropland | 0.650 | 3.252 | 4.6 |
| Forest | 0.228 | 1.139 | 1.6 |
| Pasture | 0.287 | 1.435 | 2.0 |
| ***Total*** | *14.061* | *70.345* | *100* |

It was not possible to verify the accuracy of the analysis as it is the first attempt of quantitative analysis of landslide risk made in the region. However, some comparisons can be made with the existing literature that consider similar themes. The final value of risk ranges between 14 and 70 million USH which is equivalent to 3 thousand euros to 16 thousand euros per year. In comparison with the average wages of local people determined by Mertens et al. (2016), locals earn in average 2911 USH/day per adult equivalent which is equal to less than one euro per day according to the actual exchange rate (consulted in June 2017). Most of the inhabitant are really poor with 80% of people living from subsistence agriculture (Gollin et Rogerson, 2010). In consequences, it means that if a landslide occurs on a parcel belonging to the upper fourth quartile of the risk distribution, the impact has a significant chance to overcome the wages of the inhabitants. Hence, the last quartile can be considered as intolerable risk because it will exceed the coping capacity of the population. However, the first, second and third quartile do not represent even one percent of the salary. They can be assumed as tolerable risk. Another comparison can be made with the sub-county budget. The total potential loss value for Mahango sub-county is compared with the annual budget of Kirumya sub-county, because data for Mahango sub-county could not be collected. The population of Kirumya is estimated to range between 12 689 and 15 820 inhabitants (UBOS, 2017a) while the population of Mahango sub-county is estimated around 15 493 inhabitants (Okoboi et al., 2004). So, it approximatively the same population in both sub-counties. Kirumya annual budget for year 2013 amounts for 91 million USH. It means that the total risk in Mahango sub-county counts for respectively 15% and 77% of the total budget. This should stress the importance to implement DRR and reduces the potential impact the risk may cause.

The results can also be compared with the paper of Redshaw et al. (2017). They constructed a risk assessment about the built environment at National level for Ethiopia, Kenya and Uganda. They evaluated the annual loss caused to building stock and roads in Uganda about 8 million and 0.110 million US Dollars (USD) respectively. Converted in Ugandan shillings, it costs 28 913 million USH for the buildings and 397 million USH for roads. In Mahango sub-county, if we only take the risk for buildings, potential annual losses amount to 12 and 62 million USH; for roads it ranges between 0.539 and 2.67 million USH. The result at national level is 400 times higher than the one of Mahango sub-county which is normal as the administrative unit are really different. If we assume that the risk is spread equitably between the 997 districts (following the official delineation of census 2002), the potential risk estimated by Redshaw et al. (2017) becomes 29 million USH for buildings and 0.398 million for roads at district level. It is of course a rough estimation as this calculation should consider the size of each district and their relative landslide susceptibility, nevertheless it fits with the ranges obtained in our results.

These estimations of the potential risk can be considered as an underestimation as only direct impacts are taken into account. The indirect impacts could be a starvation period and health problem due to the destruction of subsistence crops as well as a loss of production for several years on agricultural parcels as mentioned in Mertens et al. (2016). They collected testimony that people often suffer from hunger after a landslide. Losses caused by indirect impacts can even exceed significantly direct damage (Amendola et al., 2000), especially when considering loss of fertility, loss of accessibility and interruption of functioning of public services and economic activities. As a significant part of the livelihoods of locals is based on subsistence agriculture, these indirect impacts might be a key factor in the risk quantification (Mertens et al. 2016). This remark prevents to conclude that the risk for human infrastructures, and especially houses, should be considered as the main economic impact of landslides in the Rwenzori.

The goal of this risk assessment is to provide a basis to implement further DRR methods. By improving the precision of risk assessment, it is improving the knowledge on which locations require more urgently the implementation of disaster risk reduction actions. This risk assessment strengthens the conclusions made by previous studies (Maes et al., 2017; Masaba et al., 2017) that continuous risk assessment is required and that more resources should be injected for risk reduction. Such risk assessment that combines the hazard map derived from the susceptibility model with remote sensing mapping of exposure and economic vulnerability estimates have the advantage to provide a spatial pattern of the risk. These results highlighted the fact that exposure and vulnerability are particularly strong components of landslides. This corroborates the findings made that vulnerability and exposure play a strong role in landslide risk in Sub-Saharan Africa (Redshaw et al., 2017). It also stresses that measures to reduce the vulnerability and exposure are as important to implement as measures reducing the landslides occurrence. The spatial distribution of the risk gives indications about further risk reduction method which should be directed on precise locations. For instance, the houses located in high risk prone area should be targeted to implement DRR.

### TASK 5.2. Toolbox for assessing resilience strategies

#### *Weights of evaluation criteria by stakeholder groups*

The four main evaluation criteria to score the various landslide risk reduction measures are: ‘costs’ and ‘effectiveness’ of the measures, ‘feasibility’ for the DMC’s and ‘acceptability’ for the communities-at-risk. These main criteria were divided into 11 sub-criteria (Fig. 4-19).

The weights assigned by the stakeholder groups at the various scales and geographic locations are presented in Table 4-10. At (inter)national level, the stakeholder groups assigned most weight to ‘effectiveness’ and ‘feasibility’ as evaluation criteria. Weights are however more ‘balanced’ between the different main criteria than for other stakeholder groups. At district and village level, the most important criterion attributed by the respective stakeholder groups is ‘acceptability’. At sub-county level, the most important criteria vary depending on the geographic location: ‘costs’ in Mahango sub-county (Kasese district) and ‘acceptability’ in Kirumya sub-county (Bundibugyo district).

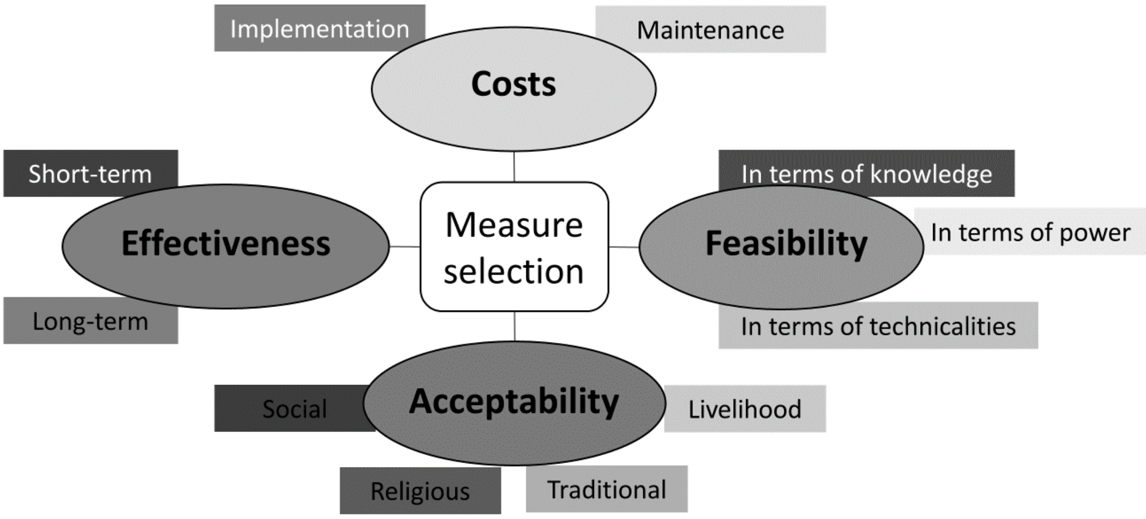


*Figure 4-19. The four main criteria and related sub-criteria used to evaluate landslide risk reduction measures in the Rwenzori Mountains region (Uganda), based on literature review and feedback from the stakeholder groups at district and sub-county level (Maes et al., accepted in Landslides).*

The Spearman Rank correlations between the distinct sub-criteria at any administrative level are insignificant (P > 0.01), except for one at Bundibugyo district (Implementation costs - Acceptability in terms of traditional values), two at Mahango sub-county (Feasibility in terms of knowledge - Acceptability in terms of traditional values; Feasibility in terms of power - Feasibility in terms of knowledge) and two at Kirumya sub-county (Long-term effectiveness - Acceptability in terms of religious values; Feasibility in terms of power - Acceptability in terms of traditional values). This observation indicates a general independency of the criteria.

***Relative scores for landslide risk reduction measures***

A total of 26 landslide risk reduction measures was identified (Annex 2). Scores were attributed to these different measures for each criterion by the district and sub-county stakeholder groups. No significant Pearson rank correlation (r < 0.5; P > 0.01) was found between the order of measures presented to the stakeholders in phase one and the relative scores, nor between the order of measures presented to the stakeholders in phase two and the relative scores. Fig. 4-20 shows the sensitivity analysis of relative scores given by the DMC of Bundibugyo district as an example. Here, the relative scores of each measure for each set of weight (international, district, sub-county and village) are compared with the relative scores for equal weights, i.e. 25% for each of the four main criteria. The main observation is that the relative scores with the weights by international and sub-county stakeholder groups depart the least from the relative scores with equal weights, whereas the weights by district and village stakeholder groups seem to result in quite different (mainly higher) relative scores. Another observation is that vulnerability reduction measures (e.g. ‘give incentives to increase off-farm wage’) are observed to yield higher relative scores with district and village weights than with other weights. Also, knowledge and education measures (e.g. ‘sensitise communities-at-risk') have higher relative scores with village weights and lower relative scores with sub-county weights than with other weights. Further, exposure reduction measures (e.g. ‘forbid any new house construction’) are observed to yield higher relative scores with international weights than with other weights.

The consistent most and least appropriate measures are extracted (Table 4-11). Consistent means that they are among the first quartile, i.e. most appropriate, or last quartile, i.e. least appropriate, ranks for all four sets of weights. As the total number of measures is 26 in our case, 'consistent' means amongst the seven first or last ranks. For all studied areas there are no measures that are consistent most appropriate for the two districts and two sub-counties studied, but two measures that are consistent least appropriate. More specifically, these include the following two policy actions: the prohibition to construct any new house within landslide-prone area and the relocation of communities-at-risk living in landslide-prone area with proper compensation. There are however four measures that are consistent most appropriate for three of the study areas: 'sensitise communities-at-risk', 'include representatives to committees', 'distribute fast-growing trees', and 'encourage saving and credit cooperations'.

***Table 4-10.*** *Weights and standard deviations of the main and sub-criteria according to geographical location and politico-administrative level (Note: I = (Inter)national; D = District; SC = Sub-county; V = Village; Maes et al., accepted in Landslides).*

| **Location** | | Kasese | | | Bundibugyo | | |
|---|---|---|---|---|---|---|---|
| **Level** | I | D | SC | V | D | SC | V |
| **Criteria** | | | | **Weights** | | | |
| Costs | 13% | 7% | 34% | 18% | 14% | 29% | 23% |
| Implementation | 3% | 4% | 13% | 10% | 11% | 17% | 14% |
| Maintenance | 10% | 3% | 20% | 9% | 4% | 12% | 9% |
| Effectiveness | 37% | 26% | 21% | 13% | 16% | 11% | 11% |
| Short-term | 10% | 5% | 7% | 3% | 3% | 4% | 5% |
| Long-term | 27% | 21% | 14% | 10% | 13% | 6% | 6% |
| Feasibility | 28% | 11% | 22% | 22% | 23% | 22% | 25% |
| In terms of knowledge | 6% | 3% | 9% | 12% | 9% | 5% | 9% |
| In terms of power | 10% | 5% | 6% | 5% | 8% | 9% | 8% |
| In terms of equipment | 11% | 3% | 7% | 5% | 7% | 8% | 8% |
| Acceptability | 23% | 55% | 23% | 46% | 47% | 39% | 41% |
| In terms of social values and practices | 7% | 17% | 7% | 12% | 15% | 15% | 9% |
| In terms of religious values and practices | 2% | 10% | 7% | 7% | 5% | 7% | 12% |
| In terms of traditional values and practices | 2% | 4% | 3% | 5% | 11% | 6% | 3% |
| In terms of livelihood | 11% | 25% | 6% | 22% | 16% | 10% | 17% |
| | | | | **Standard deviation** | | | |
| Costs | | | | | | | |
| Implementation | 2% | 5% | 16% | 6% | 7% | 8% | 11% |
| Maintenance | 5% | 0% | 18% | 5% | 3% | 9% | 6% |
| Effectiveness | | | | | | | |
| Short-term | 7% | 7% | 6% | 4% | 4% | 10% | 3% |
| Long-term | 17% | 8% | 8% | 7% | 7% | 6% | 7% |
| Feasibility | | | | | | | |
| In terms of knowledge | 7% | 7% | 8% | 10% | 5% | 3% | 5% |
| In terms of power | 3% | 3% | 5% | 4% | 12% | 9% | 6% |
| In terms of equipment | 9% | 5% | 7% | 2% | 7% | 7% | 7% |
| Acceptability | | | | | | | |
| In terms of social values and practices | 4% | 8% | 10% | 9% | 11% | 10% | 4% |
| In terms of religious values and practices | 1% | 7% | 7% | 4% | 2% | 7% | 4% |
| In terms of traditional values and practices | 2% | 2% | 2% | 5% | 12% | 5% | 3% |
| In terms of livelihood | 9% | 13% | 4% | 9% | 8% | 9% | 6% |

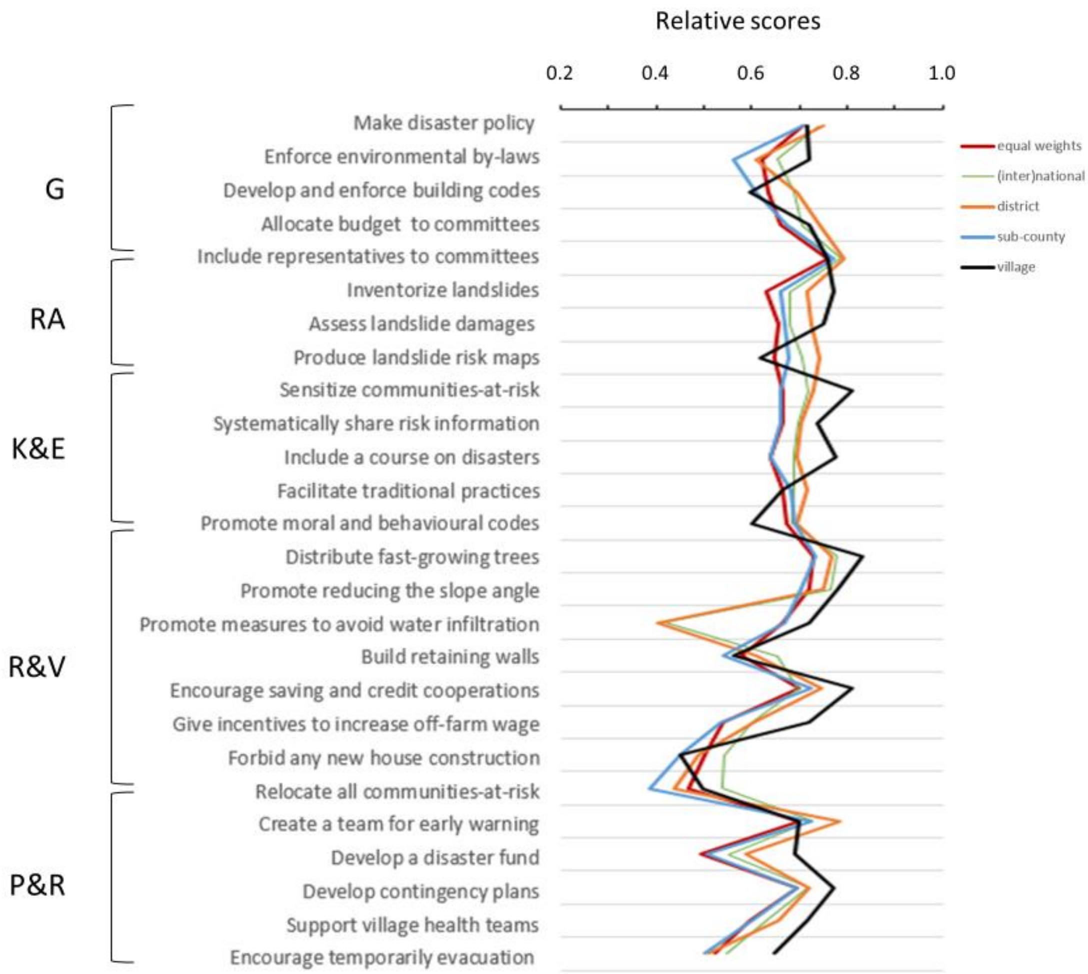


*Figure 4-20. Relative scores of 26 measures for each set of weights (international, district, sub-county and village) in Bundibugyo district (Note: The measures are categorised into five disaster risk reduction components: G = governance; RA = risk assessment; K&E = knowledge and education; R&V = risk management and vulnerability reduction; P&R = preparedness and response; Maes et al., accepted in Landslides).*

*Table 4-11. Consistent most and least appropriate landslide risk reduction measures for all study areas (Note: *Consistent means that they are amongst the seven first, i.e. most appropriate, or last, i.e. least appropriate, ranks for all four sets of weights; Maes et al., accepted in Landslides).*

| | Kasese | | Bundibugyo | |
|---|---|---|---|---|
| | **District** | **Sub-county** | **District** | **Sub-county** |
| **Consistent* most appropriate measures** | | | | |
| Sensitise communities-at-risk | X | X | | X |
| Distribute fast-growing trees | X | | X | X |
| Encourage saving and credit cooperations | X | X | | X |
| Include a course on disasters | X | | | X |
| Include representatives to committees | | X | X | |
| Promote reducing the slope angle | X | | X | |
| Make landslide risk management a government priority | | | X | |
| Promote measures to avoid water infiltration | | | | X |
| Create a team for early warning | | | X | |
| **Consistent* least appropriate measures** | | | | |
| Forbid any new house construction | X | X | X | X |
| Relocate all communities-at-risk | X | X | X | X |
| Build retaining walls | X | X | | |
| Give incentives to increase off-farm wage | | | X | X |
| Develop a disaster fund | | | X | X |

***Disaster discourses***

The weights given to the evaluation criteria by each of the stakeholder groups at the various administrative levels and geographical locations, were linked to a specific disaster discourse. The links between the disaster discourses and the perceived most important evaluation criteria are presented qualitatively in Table 4-12 and Fig. 4-21.

While the disaster discourse per stakeholder group were distilled from the focus group discussions and semi-structured interviews, the average set of weights were calculated based on the individual questionnaires as elaborated on in the previous section. The main observations are that stakeholder groups leaning more towards the vulnerability discourse assigned more weight to the 'acceptability' criterion, the ones leaning towards the hazard discourse assigned more weights to the 'feasibility' and 'effectiveness' criteria, and the ones leaning towards the fatalistic discourse assigned more weights to the 'costs' criterion. In Fig. 4-21, we attempt to visualize these links between disaster discourses and sets of weights.

At international level, the stakeholder group adhere relatively more to the hazard paradigm (Table 4-12; Fig. 4-21). The weighting by the stakeholders at this level shows that the feasibility and effectiveness criteria are considered more important to evaluate landslide risk reduction measures (Table 4-10). These factors are technically oriented, therefore we argue that disasters from landslides are seen more as a technical problem by these stakeholders. This observation is in line with the fact that landslide research is currently dominated by the natural sciences (Maes et al., 2017a), suggesting that most stakeholders at this level treat landslides as an Act of Nature. The preference towards the hazard paradigm at the international level reflects the current dominant discourse in disaster research and practice (Hewitt, 2015). Although in theory, the international DRR community acknowledges disasters as acts of both humans and nature, the hazard paradigm resurfaces at times (e.g. Gaillard and Mercer, 2013) partly because the humanitarian community is reluctant to engage with political and development matters (Pelling and Dill, 2010). Therefore we argue that the international stakeholder group adhere relatively more to the hazard paradigm.

At the district and village levels in both studied areas, the stakeholder groups lean more towards the vulnerability paradigm. We come to this view based on the observation that the most important weights is attributed to the 'acceptability' evaluation criterion (Table 4-10). We argue that this perception reflects their perception that landslides are an Act of Humans. Triggering factors for landslides like farming practices and quarrying are considered as the main causes for landslide disasters according to the perceptions of the participants at district and village levels. As individuals are perceived as the main causes for - and victims of - landslide loss, we suggest that the most important criterion to consider for them is that these same individuals accept the implementation of a certain landslide risk reduction measure. The importance given to acceptability 'criterion' is illustrated in the following statement made by a district official during a focus group interview: *'let us look at the local - the community members – we need not to look at strategies that will be hard for community members to implement'* (Focus group interview, Interviewee J).

*Table 4-12. Summary on the disaster discourses of each stakeholder group according to politico-administrative level and geographical area (Maes et al., accepted in Landslides).*

| **Stakeholder group** | **Predominant evaluation criteria** | **Disasters by landslide are mainly perceived as:** | | **Disaster discourse** |
|---|---|---|---|---|
| | | **An act of:** | **Type of problem** | |
| (Inter)national | Feasibility and effectiveness | Nature | Technical | Hazard paradigm |
| **Kasese** | | | | |
| District | Acceptability | Communities-at-risk and nature | Development | Vulnerability paradigm |
| Sub-county | Costs | God/spirits, communities-at-risk and governments | Cultural | Fatalism |
| Village | Acceptability | Communities-at-risk | Development | Vulnerability paradigm |
| **Bundibugyo** | | | | |
| District | Acceptability | Communities-at-risk | Development | Vulnerability paradigm |
| Sub-county | Acceptability (also costs) | Nature, communities-at-risk and governments | Development and financial | Vulnerability paradigm and fatalism |
| Village | Acceptability | Communities-at-risk | Development | Vulnerability paradigm |

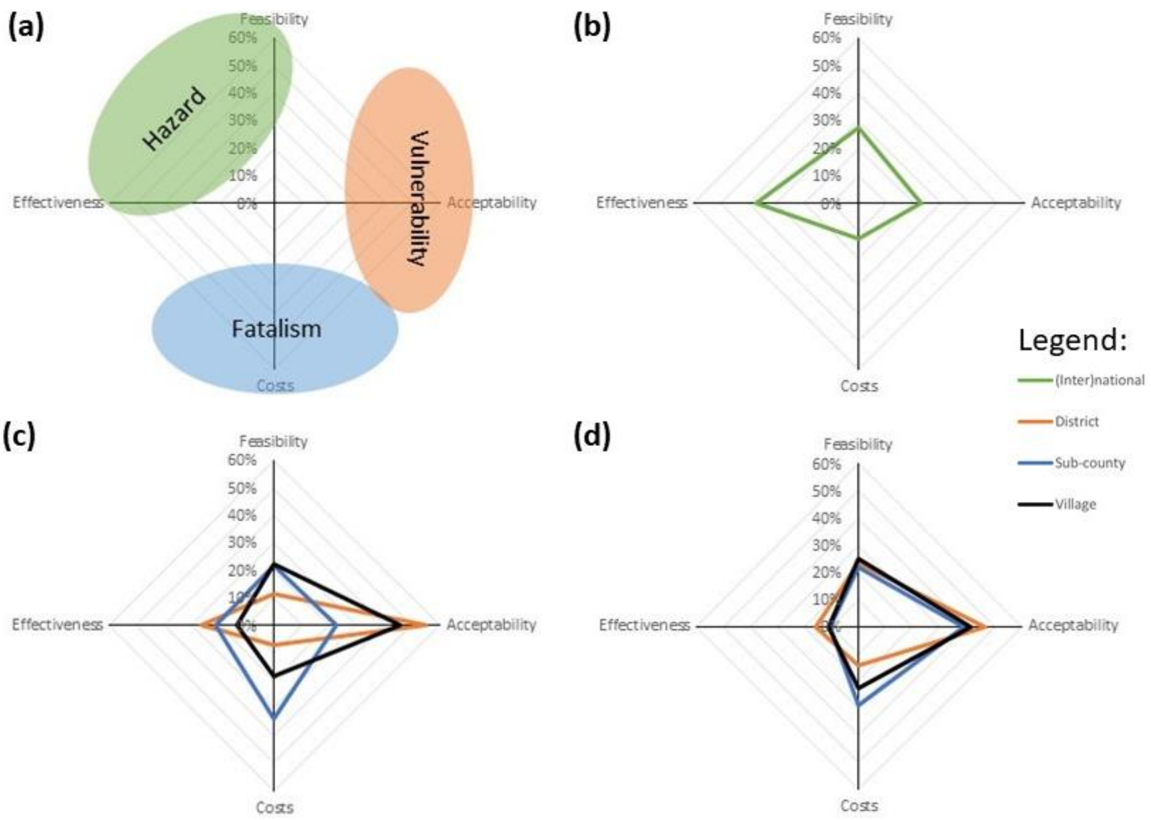


*Figure 4-21. (a) The disaster discourses (hazard, vulnerability or fatalism) and the weights by stakeholder groups for each of the main evaluation criteria (costs, effectiveness, feasibility and acceptability) for (b) international level, (c) Kasese district, and (d) Bundibugyo district (Maes et al., accepted in Landslides).*

At the sub-county level, distilling a specific disaster discourse was less straight forward. At both sub-counties, attracting funding from higher administrative levels and donors is listed second by most respondents as the possible outcome of the social multi-criteria evaluation. This might partly explain why respondents of Mahango sub-county put the criterion 'costs' forward as the limiting factor. The relatively high importance of costs might also be attributed to the fact that following a fatalistic discourse means disasters are viewed as unforeseeable and thus unmanageable. Consequently, the only important criterion to consider becomes the costs of a specific measure. In other words, if they believe a specific measure might not help but does not cost anything, they might as well try. While in both studied sub-counties, landslides are considered as an Act of Humans, causation is also attributed to God or Spirits in Mahango sub-county or Nature in Kirumya sub-county. For example, a sub-county official of Mahango sub-county indicated that it is hard to change people's culture as '*they [people living in Mahango sub-county] believe that landslides are punishments given by the spirits to the people in the community because of not responding to what the spirits require; this means for not appeasing them through offering of sacrifices, known as eri'birya amalhambo'* (Focus group interview, Interviewee K). The stakeholder group in Mahango sub-county thus also perceives disasters through cultural beliefs, which might reflect its slight adherence towards fatalism. The stakeholder group in Kirumya sub-county perceives disasters as a development and financial problem, which might reflect its adherence towards the vulnerability paradigm and to - a lesser extent- fatalism. Noteworthy is that the DMC's at sub-county level are inactive (Maes et al., 2017b). While the sub-county DMC's should include actors from different sectors according to national policy (like at district level), in practice mostly technical staff from the sub-county local government were included in the focus group interviews. Participants of these sub-county focus group interviews often claimed that they felt limited in their actions due to the lack of financial resources. This might partly explain the difference between sub-county weights and discourses, on the one hand, and district and village weights and discourses, on the other hand.

In sum, the results of WP5 offered a social multi-criteria evaluation (SMCE) as a methodology to identify suitable landslide risk reduction measures at several sub-national scales. The field testing allowed to draw case-specific conclusions for landslide risk reduction measures in the Rwenzori Mountains region. According to the tested evaluation, two measures that are proposed by the national policy of Uganda as policy actions to reduce landslide risk (OPMRU, 2010), were observed to be amongst the least appropriate measures for all studied districts and sub-counties. More specifically, these are 'the prohibition to construct any new house within landslide-prone area' and 'the relocation of communities-at-risk living in landslide-prone area with proper compensation'. The case study showed that the appropriateness of measures vary depending on the stakeholder group performing the evaluation and their dominant disaster discourse. In other words, disaster discourse influenced the potential measures to be recommended and therefore selecting a particular stakeholder group for the decision support process implied choosing and leaving out particular discourses. In this case, results from the study showed that international landslide experts were relatively closer to the hazard paradigm, whereas district and village experts to the vulnerability paradigm. Noteworthy is that, according to district and village stakeholder groups, acceptability of a landslide risk reduction measure by the communities-at-risk was considered the most important (main) criterion.

## 5. RECOMMENDATIONS

### Policy recommendations

Based on the obtained scientific results, we can make policy and research recommendations. The policy recommendations have been summarized in a set of policy briefs (annex 3). These were presented and disseminated during a national conference in Kampala, on 6th of February 2018, and during several local workshops in Kasese, Fort Portal and Bundibugyo towns later that week (see chapter 6 – Valorisation). These recommendations are structured according to each Work Packages.

#### WP1 Landslide hazards

In WP1, we have shown that global landslide inventories and susceptibility maps are intended to highlight landslide-prone areas. However, landslides in Central Africa are virtually absent from these inventories, which could falsely create the perception that they do not occur in these regions. The Rwenzori Mountains and the Cameroon Volcanic Line are examples of this. They were not recognized at the international level to be landslide-prone before the start of the AfReSlide project.

Data collection on landslide events and the damage they create is necessary to understand landslide triggers and predict their spatial and temporal occurrence. Detailed archive analysis and field surveys in the Rwenzori and Elgon regions in Uganda and in the Bamboutos in Cameroon provided extensive landslide inventories. These inventories enable to study which rainfall and earthquake events trigger landslides. They allow to understand the topographic, geologic and climatic factors controlling the spatial and temporal distribution of landslides. This leads to the production of susceptibility maps which provide insight on where landslides are likely to occur in these regions.

Recently, a continuous registration network of landslide events was set up in the Rwenzori region. Geo-observers are registering new landslide events in their communities using a smartphone application. This will provide the necessary data to do landslide hazard assessments, i.e. to predict when and where landslides can occur.

Putting landslides on the map is needed, and it is the first step in recognizing, assessing, investigating and tackling the risk they entail for the population. Based on these results from WP1, we can make three recommendations for government representatives:

1. Develop and maintain a database containing the information on new landslides, including their location, timing and impact so that you can assess who, and which area, is affected and how the situation evolves.
2. Identify a service in charge of maintaining such database, which can act as a contact point for the population and bridge the gap between the population, academics, NGOs and other organizations.
3. Record new landslide events and motivate the residents of your district to report new events to your authorities. It increases the awareness locally and abroad (NGO's, national government, international research agencies,…), but it is also needed to better understand what triggers the landslides. This knowledge is crucial to predict future events.

The results of WP1 have also shown that landslides are often referred to as 'secondary hazards' because they occur as a result of intense rainfall or earthquakes. In mountainous areas, floods, landslides, earthquakes and other hazards can co-occur and cause complex interactions. This often results in very damaging multi-hazards impacting the population on a large scale. Understanding and predicting these multi-hazards is very challenging due to their complexity. Being informed about recent events in your area and preparing for cascading events is therefore necessary.

An example is the occurrence of flash floods after large earthquakes or rainfalls. Earthquakes and heavy rain can cause landslides which can block or hamper river flow. This can result in debris rich floods which may occur without warning, for example, when a landslide-dam on the river breaches and water is suddenly released. Other environmental conditions such as forest fires can also interfere with hazards. It is therefore crucial to know which hazards can occur in your area and how they can reinforce each other. The recommendations we can give to government representatives, based on these results of WP1, are the following:

1. After an earthquake, the likelihood that landslides occur in a large region around the earthquake epicentre increases: it is important to remain vigilant for this in the weeks and months after the earthquake. If an earthquake or heavy rainfall has caused landslides in the catchment, be aware that floods could occur days and weeks after these landslides because of the changes these hazards may have made to the river further upstream.
2. Keep regular contacts with local stakeholders and authorities that are aware of the situation within the catchment, including the non-inhabited zones of the catchment, e.g. national parks.
3. Survey the valley for river blockages, either in the field or using satellite data.
4. Keep the alluvial plains and river banks free of construction.
5. Be aware of and take precautionary measures against the increased probability for floods in the years after major fires.

#### WP2 Socio-economic consequences

The research in WP2 resulted in two major outcome. First, all farmers that are affected by landslides see their income decrease for several years following the landslide. Since the severity of the impact is significantly correlated with the percentage of the land that was affected by the landslide, farmers that have a limited amount of plots are likely more vulnerable to landslide impact. Second, we found that households that start their life with small amounts of land that are exposed to landslides do not manage to increase their landholding as much as other farmers that start with land in less landslide-prone areas. Moreover, while over a lifetime these households manage to reduce their exposure to landslides to some extent, they do not manage to end up with an exposure which is fully equal to farmers that started off with plots that were less in landslide-prone areas. This leads to some clear policy recommendations:

1. First, the significant impact of landslides for the livelihood of farmers is often overlooked by media and national reports which are frequently limited to fatalities and destroyed houses and infrastructure. This biases the support provided by governments and NGO's to big events which cause fatalities. It is, however, clear that the small-scale and recurrent shocks caused by landslides have important consequences for the income and livelihoods of smallholder farmers in the Rwenzori mountains. Punctual assistance, immediately after a landslide, should therefore be increased for small and remote events as well as bigger landslides.
2. Second, punctual assistance immediately after a landslide is useful but often not sufficient to reduce suffering due to landslides. Therefore, relief funds should be made available for several years after severe landslides. Landslide impacts are long-lasting.

3. Third, when a landslide happens, those that lost a significant proportion of their income should be helped first with immediate relief and with aid to restore their rural livelihoods. The development of a solidarity scheme or insurance against landslides, as well as off-farm employment opportunities or access to fertile land that is not affected by landslides could therefore be promoted at village or Sub-County level. Identifying most severely affected farmers requires detailed impact assessment, accounting for socio-economic characteristics of impacted households.

When providing relief against landslides it is important to be aware that some farmers voluntarily acquired land with a high landslide risk, while others are pushed towards these lands because of a lack of resources. In the light of limited budgets, it is sensible to target relief and capacity building towards those farmers most in need. This includes farmers who have little land and for whom a large part of their land is affected or could be affected by landslides in the near future. Identifying these households requires detailed impact assessment but also accounting for the socio-economic characteristics of the households. Local networks and community boards could be used to target support to those that are most in need. Yet, this should be done with care, since local power relations might prevent the poorest to access the resources. Poorer and less connected farmers do frequently not have sufficient information about possible assistance. Reaching out to these farmers requires active dissemination of information about the availability of disaster relief funds, as well as field investigations of the impact.

**WP3 Resilience strategies**

In the past, information and sensitization campaigns with regard to natural hazards have been found to be very ineffective in fostering concrete action at individual level (Tierney et al., 2001). During exploratory workshops in the Rwenzori region, representatives of NGO’s and local governments sometimes mentioned that awareness about landslide risk should be increased. Yet, according to the results presented in WP3, there is no need to further increase this awareness, as farmers seem to be well informed about the landslide susceptibility on their plots and its potential consequences.

Rather, there is a need to increase the farmers’ trust in their capacity to do something about landslides. In some sub-counties in Bundibugyo, close to our study area, the Red Cross has been distributing trees among farmers in landslide prone areas in order to reduce landslide occurrence. Yet, self-efficacy with regard to planting trees against landsliding is very small, suggesting that internal constraints might play an important role in preventing exposed households from planting trees against landslides. It could therefore be necessary to increase farmers’ self-efficacy, rather than their access to tree seedlings alone. This can be done by organize trainings or demonstration plots about how the impact of landslides can be reduced. These trainings would aim at increasing farmers’ sense of empowerment against landslides.

Since the occurrence of landslides on a plot partially depends on the presence of trees on neighbouring plots, collective action around tree planting and other soil and water conservation measures should be promoted at village level. Trees can partially be considered a public good.

A government or NGO that decides to promote actions and measures to reduce landslide risk should be very attentive for existing, local risk reduction strategies. It is important to understand these strategies and their long-term consequences for risk, poverty and inequality, as well as the effect an intervention may have on the functioning of this existing strategy. One should avoid implementing policies that disrupt existing structures of solidarity and cohesion.

The costly risk reduction behavior (i.e. acquiring land in less exposed areas) observed among farmers that are initially exposed to landslide susceptibility would not be necessary if functioning mechanisms of ex-post insurance or solidarity would exist in our study area. Such a system would not need to systematically compensate losses due to landslides, as some farmer that are better off seem to be willing to take the risk of acquiring plots with a high landslide susceptibility. Instead it would have to compensate losses among those farmers that are close to a minimum income level. One could think of solidarity mechanisms at Sub-County level tailored towards farmers having only plots with a high susceptibility.

In WP3, we also evaluated several disaster risk reduction policies, including decentralized platforms for disaster risk management in Uganda and disaster risk zonation in Cameroon. Despite the current non-functioning of decentralized platforms in Uganda, these forms of governance can however also have a ‘transformative potential’ for societies to enhance participatory and deliberative democratic practices (Pelling, 2011). Yet, as DRM is so marginal in terms of government priorities (e.g. only 0.4% of the total Ugandan National government’s budget in 2013), this potential to transform the overall hierarchical form of governance nationally is marginal. Hence, two pathways for recommendations exist to ensure this potential. First, decentralized platforms for DRM should either be implemented in association with overall horizontal forms of governance in the entire country. Second, they should be backed up with the necessary financial, technical and juridical resources to avoid being used as spatial tactics for legitimising centralised power. Besides assigning clear and transparent roles and responsibilities for DRM, mechanisms to hold those - who are responsible – accountable, should be established. In order to make decentralized platforms more effective in reducing disaster risk, the following recommendations should be taken into consideration:

1. It is important to recognise the need to adapt DRM to the local livelihood context and natural hazards. For example, the plans on disaster risk management in Kasese district should target shallow landslides, while the plans in Bundibugyo district could target both shallow and deep-seated landslides. This adaptation and fine-tuning should also consider socio-cultural local specificities and their interaction with the different types of risks.
2. There is a need to better integrate DRM into other policies from the different ministries or district services. For example, DRM could be linked to environmental, developmental and education policies.
3. It is advisable to allocate national and district budgets to pre-disaster activities and to emphasise the actual implementation of policies at the different politico-administrative levels. This should be done by considering clear targets and evaluation criteria. For example, each district could develop a state-of-the-environment report every two years.
4. At district level, the efficiency of disaster management committees may improve if risk information (on location, time and damage of disasters) is shared systematically amongst the members and if meetings are held regularly both in post-disaster and quiet periods. For example, each district committee for disaster management could meet every two months.
5. Capacity building in terms of skills and financial support is needed for disaster management committees at district and sub-county levels as well as for disaster management actors at village level, including village health teams and civil society actors. For example, capacity building on skills could include hazard and risk assessment, vulnerability and capacity assessment, as well as the selection and implementation of suitable DRR measures.

6. Bottom-up initiatives for landslide risk reduction should be recognised and evaluated. If proven effective, these initiatives should be systematically promoted. For example, in the case of the Rwenzori Mountains, bottom-up initiatives include awareness raising by drama groups and encouraging back-sloping of earth wall.

Although our assessment of the risk zonation policy is rather pessimistic for the Limbe case, we do acknowledge the usefulness of this policy to reduce disaster risk. Risk zonation has been shown to be a successful policy in reducing the exposure of population in high hazard areas in some countries (e.g. Mannakkara and Wilkinson, 2013; Randolph, 2004). We consider that this could also be possible in our case study of Limbe city if certain conditions are fulfilled, including a transparent definition and applications of these zones and the development of alternative settlement plans and infrastructure that take into consideration the vulnerability and needs of the population currently living in these high risk zones. More specifically, the conditions to improve the current implementation of disaster risk zonation policy in Limbe city are the following:

1. National and local decision-makers should work towards a more just and equitable provision of public services for all citizens (both inside and outside high risk zones), including strategies of compensation in case of disasters.
2. The technical services of the city council should identify high risk zones based on up-to-date scientific assessments, develop and communicate clear regulations per type of risk zone.
3. National and local decision-makers should provide safe and affordable housing, including both urban development strategies for zones with acceptable levels of risk and alternative housing facilities for people currently living in high risk zones.
4. National and local decision-makers should guarantee corruption-free and transparent policy-making, providing mechanisms to hold accountable those that are responsible for defining and implementing the risk zonation policy.
5. Researchers should produce socio-political sensitive risk assessments, which account for the vulnerability of exposed population and properties, instead of hazard assessments only. In addition, researchers should work together with decision-makers in the translation of the risk assessments into risk zonation policies and disseminate this risk information widely to citizens.
6. Decision-makers, researchers and civil society should lobby for the rights of people living in high risk zones and educate them on their rights. These rights include, for example, compensation in case of loss due to disaster and access to electricity.

Additional research is however needed to investigate socio-political drivers and blockages for effective DRR through risk zonation policy in other settings. Another, more radical, approach to make DRR more effective is the development of alternative policies that are based on more democratic, equitable and participatory decision-making, which acknowledges the different perceptions and needs of policy makers and scientists, on the one hand, and people-at-risk, on the other. Cannon (2008) argues that DRR cannot be effective unless it takes people’s concern about their everyday livelihood into account. In other words, disaster risk reduction should reflect the priorities of those exposed to the risks (Nathan, 2008).

### WP4 Cultural representations and motivations for land management

The King of the Bakonzo people is concerned with the development in the Rwenzori area, especially education. Given the influence of His Majesty over the Bakonzo people, it would be wise to involve him in future initiative related to mitigation measures and in the promotion of the outreach material. He would probably be happy to cooperate in advertising our recommendations and mitigation measures. Cultural leaders (mostly *isemalhambo*) could also be invited to participate to the promotion of the policy briefs and educational poster and in disaster management on a daily basis. By involving these characters, we would also indirectly involve the Churches, as some of them are very active in their Church.

'Geologists could deal with the spirits and handle the disasters', said the King of the Bakonzo. Despite the very presence of the invisible in the Bakonzo discourse, people do not easily talk about spirits as this type of beliefs is considered backwards by some other cultural groups and satanic by the Churches. This does not mean that these beliefs are not vivid. A means to take the beliefs in spirits into account could consist in cultivating specific plants culturally associated to the invisible after ensuring of their impact over soil erosion.

#### WP5 Risk mapping and selection of resilience strategies

In WP5, we explained that rigorous scientific evaluations are still unavailable for identifying appropriate disaster risk reduction (DRR) measures against landslides. We propose a social multi-criteria evaluation tool as a valid participatory methodology, i.e. involving all relevant actors, to support decision-making on these measures. This tool allows to identify which measures are effective and economically, culturally and technically adapted to the local context.

Practically, you first need to gather experts with interest in DRR. This includes members of sub-national disaster platforms, such as technical and environmental advisors, construction engineers, NGO and private sector representatives and other professionals involved in disaster risk management. These experts should then be asked to evaluate and rank potential DRR measures, through applying the following steps:

1. Select a set of potential DRR measures (e.g. 'temporary evacuation' and 'tree planting').
2. Select a set of evaluation criteria (e.g. 'short-term effectiveness' and 'implementation costs').
3. Score each DRR measure for the different evaluation criteria (e.g. 'tree planting' might score low on short-term effectiveness while 'temporary evacuation' might score high).
4. Weigh the relative importance of each evaluation criteria (e.g. 'short-term effectiveness' might be more or less important than 'implementation costs').
5. Calculate the relative scores of the DRR measures by multiplying each score with the respective criteria and ranking them (e.g. 'temporary evacuation' might be ranked higher or lower than 'tree planting' as an appropriate DRR measure).

After these steps, decision-makers should be gathered to discuss the evaluation and ranks of the DRR measures. This discussion allows for a dialogue between decision-makers and scientists to support decision-making on appropriate DRR measures.

Based on the results of WP5, we can give two general recommendations to government representatives:

1. Work together with researchers or use the social multi-criteria evaluation to identify appropriate risk reduction measures for landslides or other hazards in your specific region. This information can support debate about current and potential policy actions for future planning and budget allocations related to disaster risk management.

2. The decision-making concerning suitable DRR measures should be transparent and inclusive, meaning all stakeholders should have a saying in the final decision. Otherwise, this support system might give negative results in terms of DRR.

Based on our field testing of the social multi-criteria evaluation as presented in WP5, case-specific conclusions can be drawn for landslide risk reduction measures in the Rwenzori Mountains region and the proposed methodology. Two landslide risk reduction measures are observed to be, on the one hand, consistent 'least appropriate' measures for all studied districts and sub-counties based on the tested social multi-criteria evaluation, and on the other hand, proposed by the national policy on disaster risk management of Uganda as policy actions to reduce landslide risk (OPMRU, 2010). More specifically, these concern 'the prohibition to construct any new house within landslide-prone area' and 'the relocation of communities-at-risk living in landslide-prone area with proper compensation'. The case study showed that the appropriateness of measures vary depending on the stakeholder group performing the evaluation and its dominant disaster discourse. In other words, disaster discourse influences the potential recommended measures and choosing which stakeholder group is used in the decision support process actually implies choosing which disaster discourses is preferred. International landslide experts tend to adhere relatively more towards the hazard paradigm, while district and village experts are observed to adhere relatively more towards the vulnerability paradigm. Noteworthy is that acceptability of a landslide risk reduction measure by the communities-at-risk is the most important criterion according to district and village stakeholder groups. Scholars like Cannon (2015) argue that it is exactly these contrasting disaster discourses (or cultures) that prevent effective implementation of disaster risk reduction measures. By making these disaster discourses more explicit, the proposed social multi-criteria evaluation provides a potential way forward in the participatory decision-making and the context-specific selection of valid landslide risk reduction measures where bottlenecks for its implementation can be anticipated upon. By using these insights as well as to base the selection of appropriate measures on the risk perceptions of the different stakeholders involved, we believe that the generated results of this social multi-criteria evaluation can support long-term development of policy actions and household measures for landslide risk reduction.

## Recommendations for research

### WP1 Landslide hazard

The archive study in the first section of the research shows that by devoting attention and focus to a specific region, in depth analysis of the same type of archive sources used for global landslide inventories can provide insights into whether landslides occur, where they occur, which trigger they have and what damage they cause for the population in regions absent in these global inventories. This method has recently been formalized with clear evaluation criteria and extended to the Kivu rift segment of the East African Rift (Monsieurs et al., 2018).

In densely inhabited regions in the humid tropics characterised by persistent cloud cover, rapid vegetation growth and dynamic land use change of predominantly agricultural land, the mapping of landslides using optical remote sensing techniques can be severely hampered. Although labour intensive, field surveys allow for a detailed understanding of the processes at play. In addition to this, investing in presence in the field also has the more intangible advantage of engaging people to interact on the issue, benefitting from their knowledge of their direct environment, discussing with local inhabitants and raising awareness on the issue with local stakeholders and administrators. Even when remote sensing approaches for characterizing landslides are growing in number and application, the insight gathered through field work and the advantages connected to presence in the field, will remain unique qualities.

In those areas which are inaccessible or too large for field surveys, we rely on remote sensing and aerial photographs for landslide inventory construction and the collection of ancillary information. However, due to the frequent cloud-cover, the acquisition of stereoscopic remote sensing images is seriously hampered. Moreover, in these contexts, obtaining regional datasets of aerial photographs for geomorphologic interpretation is challenging. In case of transboundary regions, the latter problem becomes particularly challenging. With this research we are able to demonstrate the use of synthetic stereo-mate production and subsequent geomorphologic interpretation using the stereoscopic view allow to build unique datasets in these areas. With the current upcoming of TanDEM-X and other high resolution DEMs and very high resolution optical sensors with short revisit times such as the Planet datasets, this methodology can be extrapolated to any data-scarce region where stereoscopic acquisition is not feasible.

In the susceptibility assessment elaborated in WP1, we found that local susceptibility maps outperform the regional assessments. Thus, in parallel to small scale assessments adequate attention should be directed towards local and regional susceptibility studies. The susceptibility assessment is taken one step further by integrating point and polygon data describing landslide occurrences with various accuracy within one regionally validated landslide susceptibility assessment. It is shown that slope units, which provide a more realistic spatial aggregation of the geomorphologic reality, also result in better performing and more stable models in terms of dealing with uncertainties within point datasets. Given that detailed landslide information is still one of the main factors hampering quantitative landslide susceptibility assessments at any scale, the findings from this WP opens doors for the use of heterogeneous or unconventional datasets, such as insurance data or data gathered from crowdsourcing initiatives.

Although still in an initial stage, the results of the crowdsourcing initiative set up in the Rwenzori Mountains are promising. Not only does this initiative allows to valorise the knowledge local inhabitants have on their environment, it also impacts the community by talking about natural hazards and increasing awareness amongst the population and those in power. In an age where mobile Internet is commonly available, also on a remote mountain range in equatorial Africa, similar initiatives could be set up across other landslide-prone regions in order to collect this rare and valuable information on landslide occurrences.

### WP2 Socio-economic consequences

Since exposure to landslides is not random, research on landslide impact should take into account the endogenous processes that are causing some people to be more likely exposed to landslide risk. This could be done by making use of long-term panel data that would measure changes in income before and after a landslide for the same household, rather than comparing different households in cross-sectional surveys.

A lot of research remains to be done in the identification of causal pathways towards vulnerability and exposure to landslides. This project has identified one pathway, being land transactions, but other pathways in rural and urban contexts in different regions of the Global South still need to be identified. Feedback loops, from exposure to risk to new sources of exposure and vulnerability should thereby receive special attention.

The direct impacts of landslides on infrastructure and the physical vulnerability of different elements at risk, such as initiated for the Mahango sub-county, deserve further attention. This would involve collecting more systematic data on the economic value of exposed elements and of their replacement costs after damage, as well as detailed impact assessment after new landslides in order to constrain loss functions. It is also required to understand which characteristics of the landslides (e.g. size, depth, velocity, type of movement) is most influential in controlling the amount of damage caused to infrastructure and agricultural productions.

### WP3 Resilience strategies

Based on the scientific literature review carried out in WP3, several research needs for landslide risk reduction can be distilled. Overall, this review shows that a lot of research has focused on understanding landslide susceptibility and hazards in relation to the bio-physical factors that control them. However, quantitative assessments of the impacts of landslides are much rarer. Also, scientific assessments of the effectiveness of implemented DRR measures are largely lacking in the current scientific literature. Nonetheless, such information is crucial to support cost-benefit analyses and research on how to effectively translate risk assessment into risk reduction measures. This will require multi-criteria analyses identifying the most effective landslide risk reduction measures as a function of the spatial scale, the type of landslides, the (potential) impact, the underlying root causes and bottlenecks, which are currently lacking at national and lower scales.

Moreover, it appears that the responsibility of scientists cannot end at the identification and characterisation of landslide hazard and risk, or the recommendation of generic DRR measures. Effectively reducing landslide risks will not only require better scientific insights, but also efforts to communicate and transfer scientific research results to policy makers and the population at risk. Involving stakeholders at all stages of the scientific research, i.e. from problem identification to delivery of the most practical results, is crucial to promote ownership and to ensure more site-specific and effective efforts. As landslide research currently remains mainly driven by earth scientists, this will require initiatives in developing trans-disciplinary approaches that are able to go beyond the analysis of the physical drivers of landslides, but integrate the social, political, cultural and economic dimensions of DRR in order to identify and characterise the effectiveness of specific DRR measures (Cutter et al., 2015). Hence, earth scientists should actively seek interactions with experts in social sciences and grass-root organisations in order to bridge the gap between the improved understanding of landslide hazard and the effective reduction of landslide risk. The Af*Re*Slide has illustrated how such trans-disciplinary approach can bring innovative insights, but it has to be developed further and lead to the implementation of appropriate DRR measures.

### WP4 Cultural representations and motivations for land management

Future research might continue to document the plants identified to customarily fight misfortune and movements of the soil, and precise their use by local communities for other purposes, in particular land boundaries and health. Work should be done with agronomists to investigate their physical properties of these plants and their impact over soil erosion by surface runoff and the shear strength of the soil at depth.

The data should be confronted to the existing literature, especially regarding plant use in dealing with disasters and calamities in Uganda and other parts of the world. This documentary study would highlight the role of the local culture and social characteristics to provide recommendations for an increased resilience of the communities exposed to LS hazards.

### WP5 Risk mapping and selection of resilience strategies

Concerning the first attempt to produce a landslide risk assessment for Mahango sub-county in the Rwenzori Mountains, it only took into account the potential economic losses related to directs impacts of landslides and economical vulnerability. In order to keep improving the risk management in Mahango sub-county and in general in the Rwenzori Mountains, further research should be dedicated to the assessment of other aspects such as indirect impacts and social vulnerability.

Concerning the identification of potential landslide risk reduction measures in the Rwenzori Mountains and elsewhere, future research might study how to integrate decision support systems, like the proposed social multi-criteria evaluation, into actual policy development. Here, power relations will be the central focus point. The type of agreements in each step are needed to be specified to ensure transparency and democratic decision-making. Improvement of the proposed methodology might also be tested where the stakeholders are provided with extra knowledge on cost, technical requirement and assessed efficacy of measures to make better informed decisions. Finally, the same methodology might be applied at the household level.

# 6. DISSEMINATION AND VALORISATION

## Newsletter and project website

Dissemination of the project results towards policymakers and stakeholders was made through the biannual newsletter and the project website. The first channel we used was the biannual newsletter. In total eight newsletters have been distributed digitally via email and manually during stakeholder involvement activities (see below) to more than 200 contacts in Uganda and Cameroon and the members of the follow-up committee. The newsletter typically consisted of news flashes on recent landslide events in the study areas, recent field work activities, workshops and conferences, research results, and announcements of upcoming field work and conferences. The second channel for dissemination of project results and activities was the project website (http://afreslide.africamuseum.be/home) which was regularly updated with results of field works, conference abstracts and scientific publications.

## Three rounds of stakeholder involvement

The Af*Re*Slide project was designed around three rounds of stakeholder involvement. The first round was at the start of the project to set up local collaborations, identify research needs and organize the future field works (January to August 2014 in Uganda and Cameroon). The second round was halfway the project to check for feedback on the conducted research, adaptations to the future research and fine-tune the research questions (January 2016 in the Rwenzori). The third round was organized in the final months of the project to disseminate and valorise the results, and look for potential ways forward.

### Start of the project: workshops in Uganda and Cameroon

The first round of stakeholder involvement was conducted in 3 of the 4 study areas during the first year of the AfReSlide project (Fig. 6-1). Three workshops were organized in each of the three administrative districts of the Rwenzori region (i.e. Kasese, Kabarole, Bundibugyo) and in main cities of the NW and SW provinces of Cameroon (Bamenda and Limbe, respectively). For each workshop, 20 to 35 stakeholders, representing district and city counsellors, members of risk management committees, environmental officers, local or international NGO's involved in environmental and risk management (Uganda Red Cross Society, Oxfam, WWF...), media and community leaders were invited.

First, a local leader or scientist introduced the natural hazard characteristics of the region with specific attention to landslides and the Af*Re*Slide project. The main part of the workshop was dedicated to focus groups among the stakeholders. Stakeholders were invited to share their opinions and raise questions on separate topics: (1) the identification of zones affected by landslides and the most affected communities, (2) the determination of the types of landslides, (3) the description of the perceived causes of landslides, (4) sharing experiences on the past and potential impacts of landslides, and (5) brainstorming on the implemented and desirable risk reduction measures.

Concerns for sustainability and empowerment in contemporary research literature is increasingly leading to a shift towards more interdisciplinary research which go hand in hand with new methods such as focus groups (Stirling, 2008). Focus groups were here considered as an appropriate approach to interact with community stakeholders in the initial stage of the project to develop and adjust the project's research questions. Focus groups have proven their exploratory capacity to generate further research opportunities (e.g. Powell and Single, 1996; Race et al., 1994). They have often been staged as a platform offering opportunities to empower and give voice to marginalized groups or silent voices (e.g. Leyshon, 2002). In this line, we also use these workshops for their participatory potential.

The discussions took place in groups of seven to 10 people addressing each question separately. The groups were composed in such a way that each of them was heterogeneous, representing as much as possible the diverse opinions of the different groups of stakeholders. Participants used printed maps extracted from Google Earth or Google Maps with simple spatial reference features (e.g. roads, main villages, …) at a scale of about 1:100.000 to highlight specific locations recently affected or prone to landslides (Fig. 6-1c-d). Each group was moderated by one local and one Belgian scientist. One stakeholder participant noted the key points raised by participants on a flip chart (Fig. 6-1e). The findings of each group for the different questions were presented by a stakeholder in a final plenary session during which a final discussion between the groups could take place (Fig. 6-1f). Each workshop lasted from half a day to a full day.

*Figure 6-1. Pictures taken during workshops organized in Uganda and Cameroon. a) presentation of landslide issues in SW Cameroon by V.B. Che (Limbe, May 24, 2014); b) group discussion on the types of landslides in Kasese district, Rwenzori region (January 8, 2014); c-d) identification of zones affected by landslides on printed maps (Kabarole district, Rwenzori; August 8, 2014); e) flipchart summary of landslide impacts (Kasese district, January 8, 2014); f) reporting of group discussions by a stakeholder in a plenary session (Kasese district, January 8, 2014).*

In addition to identifying the concerns and expectations of the local stakeholders relative to the landslide risks, these workshops aimed at establishing constructive connections with local actors to facilitate research actions and to ensure long-term communications between scientists and stakeholders in order to maximize the impacts of the research outcome. These workshops were complemented by preliminary field reconnaissance of the landslide-affected areas in each of the study areas with some of the stakeholders.

### Midterm monitoring: workshops in Uganda

In order to report on the intermediary results of the AfR*e*Slide project, stakeholders' workshops were organized in the relevant districts of the Rwenzori region, as this was the main focus of the AfReSlide project. These workshops were held in the most landslide-prone districts: Kasese and Bundibugyo districts. These workshops were organized in January 2016 and followed-up on, and took a similar form, as the ones organized in January and August 2014.

We invited the same persons as in the 2014 workshops, focusing on the sub-counties most affected by landslides. The stakeholders included representatives of the district and sub-county administrations, relevant NGO's, cultural institutions and others. Due to changing functions, buzzy time schedules and other uncertainties not all participants were the same as during the initial workshops. As no workshop was organized in Kabarole district (Fort Portal), the most relevant persons from that district (including from the Red Cross, UWA and a local research centre) were invited to the Kasese workshop.

Similarly to 2014 the objectives of the workshops were to inform participants about the project preliminary results and to get feedbacks on specific questions. The content of the half-day workshops was therefore split into a 1 hour session of presentations and a 1 hour and a half session of discussions. The presentation covered the aspects of landslide distribution and type per district, landslide impacts on households, and landslide risk reduction strategies. The discussions centred around the following topics which were essential for further research and outreach within the AfR*e*Slide project: (1) land market dynamics as a vulnerability or resilience strategy, (2) reconciling scientific and spiritual interpretations, and (3) what are the expected outcomes of research and how to communicate these.

### End of the project: conference and workshops in Uganda

The third and final round of stakeholder involvement was organized in the first week of February 2018, in the form of a series of outreach activities. The objectives of these activities were to publicize the results of the research conducted since 2014 on natural hazards in the Rwenzori, as well as discuss and generate support from national and local policy-makers, but also local community representatives, for practical disaster risk reduction strategies. These outreach activities included an international conference on disaster risk reduction in Kampala, an academic event and several local workshops in the Rwenzori Mountains. Two major outreach documents were presented and widely disseminated during that week: a booklet with a series of 11 policy briefs (annex 3, 300 copies) and 600 copies of an education posters about landslide disaster risk reduction (annex 4) painted by a local artist and translated in 3 local languages.

***International Disaster Risk Reduction Fair, Kampala, February 6, 2018***

A one-day international conference, entitled *'Disaster risk reduction fair: Examples from landslides and storms in Central Africa'*, was organized on Tuesday, the 6th of February, 2018 at Hotel Royal Suites in Kampala. This event was chaired by Hon. Musa Ecweru, Ugandan Minister of State for Disaster Preparedness and Refugees, Office of Prime Minister, and Mr. Hugo Verbist, Belgium ambassador in Uganda. This conference brought together 120 participants including national policy-makers (OPM, ministry of health, NEMA, …), representatives from international organizations (UNDP, FAO, IITA, WFP), non-governmental organizations (OXFAM, DENIVA, CARE, USAID, World Vision, Red Cross), the media and scientists from several Ugandan (Makerere U, MMU, Busitema U) and international universities (Cameroon, VUB, ULg, KUL).

After opening speeches sketching the importance of disaster risk reduction to ensure the sustainability of development projects (Fig. 6-2 and 6-3), scientists from the different universities presented practical outcomes of their research under the form of booths at which participants could directly interact with them, test out their methodologies, and propose their own contributions and opinions on the proposed methodologies. Among others, these booths included the presentation of (Fig. 6-3):

- A new smartphone-based method to document the occurrence of disasters through the participation of local farmers in the Rwenzori region (VUB – KU Leuven VLIR UOS SI project);
- A satellite-based methodology to forecast intense storms on Lake Victoria (VIEWS project of Prof. W. Thiery – VUB/ETH Zurich);
- Serious games to raise awareness about risk reduction measures among local communities by Mountain of Moon University (VUB – KU Leuven VLIR UOS SI project);
- A participatory methodology to identify suitable DRR measures by consensus within local communities (AfR*e*Slide project);
- A choice experiment using tablets to document social norms in land transactions in landslide-prone areas (AfR*e*Slide project);
- Resilient livelihood strategies in landslide prone Mt Elgon region (SURELIVE TEAM project);
- Landslide susceptibility maps for Uganda, Mt Elgon and Mt Rwenzori (AfR*e*Slide project).

In the afternoon, three round tables were organized around the following topics (Fig. 6-4):

- Building disaster database: What data is required for what purpose? How to homogenize and share data collection?
- Sharing best practices in DRR.
- Forecasting storm on Lake Victoria: technical implementation of the VIEWS method.

Intense discussions and practical recommendations were generated by enthusiastic contributions of all participants. All participants of the conference received Policy briefs (Annex 3) produced as output of the landslide research projects in Uganda.

This event was broadly covered by national media, including interviews on NTVUganda (https://www.youtube.com/watch?v=O8HzVMr1dZo&feature=youtu.be) and West TV of Uganda, several radio interviews. It was also publicized by the Belgian Embassy in Uganda on Facebook (https://www.facebook.com/BelgianEmbassyUganda/) and Twitter.

*Figure 6-2. Opening speeches by Hon. Musa Ecweru, Minister of State for Disaster Preparedness and Refugees, Office of Prime Minister, and Mr. Hugo Verbist, Belgium Ambassador to Uganda.*


*Figure 6-3. Disaster Risk Reduction fair. Scientists present practical outcomes of their research to the Minister and the Ambassador, including maps, smartphone applications, and serious games.*


*Figure 6-4. Roundtable discussions: participants share experiences and provide practical recommendations to improve evidence-based disaster risk reduction in Uganda.*

***Academic event on landslide risk research, Mountains of the Moon University, February 7***

Sixty students and staff members of Mountains of the Moon University, as well as representatives of the Kabarole District authorities and some sub-counties of the Kabarole district participated in an academic event at Mountains of the Moon University, Fort Portal, on February 7. The outcome of the research on landslide hazard, its impacts on farmers' livelihood and the disaster risk reduction strategies were presented and discussed with the audience. A video presenting the new geo-observer network established by the South initiative project was presented (https://www.youtube.com/watch?v=II5yMGgbhCE) and generated a lot of interests and suggestion from the audience. This event was broadcasted live on MMU radio 105.2 FM. The scientific publications of the project were provided digitally on USB sticks to interested participants.

***Multi-stakeholders' Workshops on landslides, Kasese - Bundibugyo districts, February 8-9***

Two workshops gathering district authorities, environmental officers and LOC3 of sub-counties, geo-observers and representatives of the civil societies (farmer organisation, red cross, emergency services) were organized in Kasese and Bundibugyo districts. Each event attracted about 50 participants, including scientists from MMU and its Belgian partners. Participants received policy briefs summarizing the science-based recommendations for landslide disaster risk reduction. A total of 600 educational posters (Annex 4), painted by a local artist, were distributed to be displayed in public spaces and raise awareness about landslide risk reduction in the Rwenzori Mountains. These posters were provided in English and 3 local languages (Rutooro, Lhubwisi, Lhukonzo).

The presentation of the research findings and the new geo-observer network generated great interest from the district and local stakeholders (Fig. 6-5). Suggestions were made to regularly communicate the results of this initiative to the district authorities and to further empower the districts in managing such network of geo-observers and in implementing the recommended landslide risk reduction measures. The interactions between district authorities, scientists and community representatives were considered as essential by all participants, and communities of the Rwenzori expressed their appreciation for having been involved in these risk reduction projects from the starts. They requested further support to continue these interactions and to jointly progress towards the implementation of the suggested DRR measures.

Six members of the AfR*e*Slide team, including the three PhD researchers and three promotors, participated in this activity. In order to pass on the outcome of the project also in Cameroon, three partners from Cameroon joined this restitution mission in Uganda. This included two academics from Dschang University which collaborated in the research in the Bamboutos and Dr George Mafany, member of AfR*e*Slide follow-up committee, and in charge of risk management within the Ministry of Science in Cameroon. Mr Sam Vanuytsel, cooperation attaché of the Belgian embassy in Uganda, and also member of the follow up committee, also participated in the organization of the international conference in Kampala.


*Figure 6-5. Kasese stakeholders' workshop, 8 February 2018. After being introduced to the outcomes of the research on landslide risk reduction by Clovis Kabaseke (MMU), participants interacted with scientists on the selection of these DRR measures, the landslide susceptibility maps, and comments on the policy briefs and the educational poster.*

*Figure 6-6. Group pictures of the participants to the Kasese stakeholder workshop on February 8, 2018. Participants proudly display the policy briefs and educational poster they have received during the workshop. Five members of the AfReSlide team participated in this workshop.*

**Scientific output**

AfR*e*Slide being a scientific project, its outputs were also valorised and disseminated under the form of various types of publications (see section 7). The results of the AfR*e*Slide project were published in 10 scientific publications in peer-reviewed international journals, several other articles being in a final stage of preparation or already in press. These 10 papers were published in nine different scientific journals specialized in different domains from earth sciences to development economics and land use planning, including reputable high impact journals such as *Science of the Total Environment, Progress in Physical Geography, Landslides* and *World Development*. The three PhD researchers active in the AfR*e*Slide project (Jacobs L; Maes J., Mertens K.) defended successfully their thesis in the first half of 2018. AfR*e*Slide led to additional collaborations with other researchers active in the same or nearby regions of Africa on complementary topics (e.g. Monsieurs et al. 2018, Broeckx et al. submitted). The project was also broadcasted in several popularizing articles and at many scientific conferences reaching various scientific communities from the earth and natural hazard sciences, to the development economics and anthropology. Four master theses and one bachelor thesis were also developed by Belgian and Ugandan students in the framework and with the support of AfR*e*Slide.

# 7. PUBLICATIONS

## Scientific publications


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# ANNEXES

## Annex 1

*Inventory details for landslides (LS) and flash floods (FF), with their date of occurrence, material displaced, potential infliction of earthquake -influence by indication with y (yes) or n (no), source used (for codes see Table 1-1), location, damage and fatalities reported. For fatalities and damage reported, the notation 'n.a.' is used when there is no information available in the source. If explicitly stated in the source that there were no fatalities, this is indicated by a zero value. *additional source: GSHAP (2000).*

| | Type | EQ | Date | Source N° | Material | Location | Damage | # fatalities |
|---|---|---|---|---|---|---|---|---|
| 1 | LS | Y: Ms=5.7* | 10-20/02/1929 | 1,5 | Rocks | Tremors in Fort Portal, causing LSs and rock falls south-west of Fort Portal, one rock fall is located on the Kakaka hills. | n.a. | n.a. |
| 2 | LS | Y: M=? | 7-11/03/1929 | 1 | n.a. | Numerous aftershocks around the Rwenzori causing LSs | n.a. | n.a. |
| 3 | LS | Y: M=6.1 | 20/03/1966 | 1 | Rocks | Fort Portal-Bundibugyo road (mile 10.5), Kilembe Mines, Bigu Hut, Nyamileju (Rock fall, located), minor LSs in Bwamba County | n.a. | 0 |
| 4 | FF | ? | 7/04/1966 | 8 | n.a. | Kilembe floods, Kasese district | n.a. | n.a. |
| 5 | LS | Y: M=6.3 | 18/05/1966 | 1 | n.a. | LS on the Ruimi (Rwimi) river, Kabarole district | n.a. | n.a. |
| 6 | LS | Y: M=6.1 | 5/02/1994 | 4,7 | n.a. | Kasese district | 1 person injured | 2 |
| 7 | LS | N | 4/09/2001 | 11 | Rocks/debris | Budinbugyo road towards Fort Portal, 11 km from Budinbugyo town, Bundibugyo district | road block | n.a. |
| 8 | LS | N | 2/11/2001 | 25 | n.a. | Kasitu parish, Kasitu S/C, Bundibugyo district | 12 persons injured, 3356 affected, 2000 relocated | 18 |
| 9 | LS | N | 2/11/2001 | 17,25 | n.a. | Ntandi parish, Kasitu S/C Bundibugyo district | | |
| 10 | LS | N | 3/05/2003 | 12 | n.a. | Katulu village, Kilembe S/C, Kasese district | 30 persons homeless, church destroyed, crops and livestock destroyed | n.a. |
| 11 | LS | N | 23/08/2005 | 25 | n.a. | Bwesumbu parish, Kyabarungira S/C, Kasese district | 28 houses destroyed, 40 houses damaged, 1448 persons affected, Affected crops: coffee, vanilla, cassava and beans | n.a. |
| 12 | LS | N | 23/08/2005 | 25 | n.a. | Buhuhira parish, Kyabarungira S/C, Kasese district | | |
| 13 | LS | N | 23/08/2005 | 25 | n.a. | Kasangari parish, Kyabarungira S/C, Kasese district | | |
| 14 | LS | N | 17/05/2009 | 24 | Rocks at roadblock | Kihondo parish, Kichwamba S/C, Bundibugyo district | 70 families displaced, food crops destroyed, Road block of the Karugutu-Bundibugyo road at Itojo | n.a. |
| 15 | LS | N | 18/05/2009 | 24 | | Kyamaiga parish, Kichwamba S/C, Bundibugyo district | | |
| 16 | LS | N | 15/10/2009 | 24 | Rocks | Fort Portal (Kasisi, six kilometers to Karugutu town), Kabarole district | road block | n.a. |
| 17 | LS | N | feb/10 | 3,25 | n.a. | Bwendero parish, Kyabarungira S/C, Kasese district | 55 houses destroyed, 1 school affected, 300 ha of crops | n.a. |
| 18 | LS | N | 5/03/2010 | 3,25, 26 | n.a. | Mitandi parish, Katebwa S/C, Kabarole district | 13 houses destroyed, 3000 persons affected, 3 education centers affected, 600 ha crops affected, 3 bridges destroyed, 3 schools affected | n.a. |
| 19 | LS | N | 5/03/2010 | 3,25, 26 | n.a. | Mutumba parish, Katebwa S/C, Kabarole district | | |
| 20 | LS | N | 5/03/2010 | 25 | Mud | Buhuhira parish, Kyabarungira S/C, Kasese district | 356 houses destroyed, 249 families affected, 1 school affected , 117ha crops destroyed | n.a. |
| 21 | LS | N | 5/03/2010 | 25 | | Bughendero parish, Kyabarungira S/C, Kasese district | | n.a. |
| 22 | LS+FF | N | 17/05/2010 | 13 | n.a. | Nyabirongo Parish, Kisinga S/C, Kasese district | 300 persons homeless | n.a. |
| 23 | LS | N | 25/05/2010 | 25 | n.a. | Kateebwa parish, Kateebwa S/C, Kabarole district | 28 houses destroyed, 67 persons affected, destroyed crops: Coffeee, bananas; irish potatoes, cassava, bean | n.a. |
| 24 | LS | N | 25/05/2010 | 25 | n.a. | Bunaiga parish, Kateebwa S/C, Kabarole district | | n.a. |
| 25 | LS | N | 25/05/2010 | 25 | n.a. | Kyondo S/C, Kasese district | 91 persons affected | n.a. |
| 26 | LS | N | 25/05/2010 | 25 | n.a. | Rukoki S/C, Kasese district | 30 houses destroyed, 38 persons affected | n.a. |
| 27 | LS | N | early october 2010 | 24 | Rocks | Fort Portal-Bundibugyo Road | road block | n.a. |
| 28 | LS | N | end october 2010 | 24 | Mud | Bundikeki parish, Kikuyu S/C, Bundibugyo district | > 2,000 persons displaced, > 100 acres of cocoa, cassava, rive and vanilla plantations destroyed, numerous houses and food stores destroyed | n.a. |
| 29 | LS | N | end october 2010 | 24 | | Bundimulangya parish, Kikuyu S/C , Bundibugyo district | | |
| 30 | LS | N | end october 2010 | 24 | | Nyankiro parish, Kikuyu S/C , Bundibugyo district | | |
| 31 | LS | N | end october 2010 | 24 | | Busunga parish, Bubandi S/C, Bundibugyo district | n.a. | n.a. |
| 32 | FF | N | 6/05/2011 | 25 | Mud | Kanyangeya, Nyakasanga parish, Kasese TC S/C and Kilembe headquarters Kilembe S/C, Kasese district | 300 households affected | n.a. |
| 33 | LS | N | 2/10/2011 | 25 | n.a. | Busambo, Muhindi, Kighuthu and Busalya village in Nyakiyumbu S/C Kasese district | 1396 persons affected | n.a. |
| 34 | LS | N | 8/10/2011 | 9,22 | n.a. | Mahango village, Mahango S/C, Kasese district | | 5 |
| 35 | LS | N | 14/10/2011 | 25 | n.a. | Kasese district | Crops and houses were destroyed. Many people were left homeless | n.a. |
| 36 | FF+LS | N | 1/05/2012 | 2 | n.a. | Muhokya S/C, Mahango S/C, Kasese district | Crops have been swept away by landslides, 205 households affected by flash flood | 9 |
| 37 | LS | N | 17/05/2012 | 14 | n.a. | Katumba village, Kyalhumba S/C, Kasese district | n.a. | 1 |
| 38 | LS | N | 17/05/2012 | 14,19 | Mud | Butalimuli village, Mahango S/C, Kasese district | 23 houses destroyed | 3 |
| 39 | LS | N | 17/05/2012 | 14,19 | n.a. | Nyakabingo village, Rukoki S/C, Kasese district | n.a. | 1 |
| 40 | LS | N | 17/05/2012 | 14 | n.a. | Bibwe village, Muhokya S/C, Kasese district | n.a. | 1 |
| 41 | FF | N | 1/05/2013 | 6,18, 23,26 | n.a. | Kyalumba, Kyondo, Bulembia, Nyamwamba, Maliba, Karusandara and Bwesumbu S/C, Kasese district | Latrines and water supply affected, 19 bridges destroyed, cut off of Kasese-Fort Portal road, >7000 people displaced | 8 |
| 42 | LS | N | 7/05/2013 | 26 | n.a. | Bwathu and Kalonge village, Maliba S/C, Kasese district | 21 houses destroyed, livestock killed and crops destroyed | n.a. |
| 43 | LS | N | early May 2013 | 21 | n.a. | Kirumya S/C, Budinbugyo district | 2 families homeless | n.a. |
| 44 | LS | N | 25/09/2013 | 2, 16 | Mud | Kabukero village, Kyabwenge parish, Mahango S/C, Kasese district | Kasese-Kilembe road blocked,food and cash crops destroyed, 1 house destroyed | 3 |
| 45 | LS | N | 9/10/2013 | 20 | Rocks | Fort Portal - Bundibugyo road (Kasisi, six kilometers to Karugutu town) | Road block | 0 |
| 46 | FF | N | 1/02/2014 | 2,15 | Mud | Bugoye S/C, Kasese district | 7 households displaced, 57 households lost their land or crops, Ibanda-Nykalengingo road was washed (2.5-3km), 1 Hospital without power | n.a. |
| 47 | FF | N | 8/05/2014 | 18,19 | n.a. | Kasese municipality | 1 school partially destroyed, Katiri-Bulembia road destroyed | 5 |
| 48 | LS | N | / | 10 | n.a. | Around Mubuku river, before reaching Mahoma river, Kasese district | n.a. | n.a. |

## Annex 2

*The 26 landslide risk reduction measures, based on the proposed social multi-criteria evaluation and according to their respective disaster risk reduction (DRR) component, i.e. governance (G), risk assessment (RA), knowledge and education (K&E), risk management and vulnerability reduction (R&V), and preparedness and response (P&R).*

| DRR | Landslide risk reduction measures |
|---|---|
| G | Make landslide risk management a government priority at district or sub-county level |
| | Enforce existing environmental by-laws that concern landslides (e.g. about hill treatment and deforestation) |
| | Develop building codes for construction of public and private infrastructure in landslide-prone areas |
| | Allocate sufficient budget to the district/sub-county disaster management committee for enhancing communication and coordination |
| | Include representatives of communities-at-risk in meetings of the district/sub-county disaster management committee |
| RA | Inventorise the timing and location of past landslides to identify landslide-prone areas |
| | Report damages of all landslide events and socio-economic data of affected households to assess the vulnerability of communities-at-risk |
| | Produce landslide risk maps to define priority areas per district or sub-county |
| K&E | Regularly sensitise communities on causes and consequences of landslides and possible landslide risk reduction measures |
| | Systematically share standardised information on landslide risk, landslide events and damage records between government, NGOs, universities and private sector |
| | Include a course on disaster risk reduction and first aid in primary or high school curriculum |
| | Facilitate traditional practices to mitigate calamities performed by customary leaders (e.g. ‘mountain sweeping’) |
| | Promote moral and behavioural codes by customary leaders to mitigate calamities (e.g. ‘no deforestation in cultural sites’) |
| R&V | Distribute fast-growing trees freely to promote reforestation of landslide-prone areas |
| | Promote reducing the slope angle of the earth wall next to a house on all steep slopes |
| | Promote digging of trenches to drain rain surface water away from landslide-prone zones and fill tension cracks in all landslide-prone areas |
| | Build retaining walls (e.g. gabions) to protect public infrastructures (e.g. bridges, water springs and roads) in landslide-prone areas |
| | Encourage the creation of saving and credit cooperations to improve capacities of people to cope with landslides |
| | Incentivise job creation outside agriculture to improve capacities of people to cope with landslides |
| | Restrict any new house construction in high landslide-prone area to decrease landslide risk |
| | Relocate all communities from high landslide-prone areas to safe areas within the district/sub-county with proper compensation |
| P&R | Create a district/sub-county team to regularly survey the landslide-prone areas for detecting early warning signs (like tension cracks and water ponding) and warn communities-at-risk |
| | Develop a district/sub-county disaster fund for compensation of potential loss by landslides of communities-at-risk |
| | Develop contingency plans at the district/sub-county level |
| | Support long term capacities of all village health teams (VHT) by providing regular training and emergency resources (e.g. stretches and first aid kid) and infrastructures (e.g. health centres, taplings) |
| | Encourage temporarily evacuation |

## Annex 3

*Policy briefs, summarizing the results of the AfReSlide project (Mertens et al., 2018):*
http://afreslide.africamuseum.be/sites/afreslide.africamuseum.be/files/upload/PolicyBriefs_Final_FULL_v2.pdf

LANDSLIDES IN EQUATORIAL AFRICA:

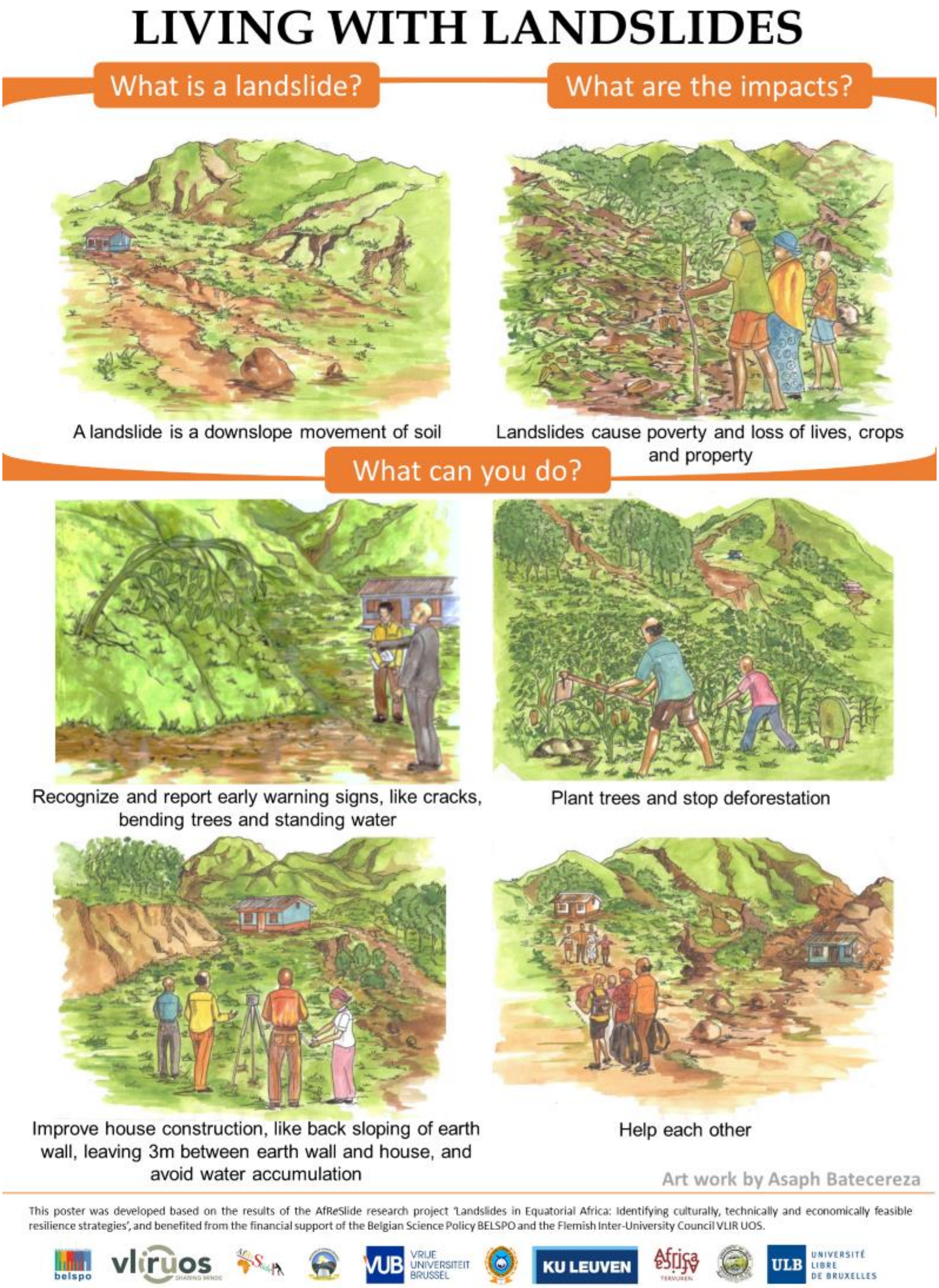
Identifying
culturally, technically and
economically feasible resilience strategies

# LANDSLIDES
# POLICY BRIEFS

**Annex 4**

*Educational poster on 'living with landslides' developed by the AfReSlide project and distributed to village leaders in the Rwenzori Mountains regions in February 2018. These posters were translated in three local languages, including Lhukonzo, Lubwisi and Rutooro.*

*http://afreslide.africamuseum.be/sites/afreslide.africamuseum.be/files/upload/AfReSlidePoster_A2_English_200x.pdf*



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