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The impact of landslides on household income in tropical regions: a case study from the Rwenzori Mountains in Uganda

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The impact of landslides on household income in tropical regions: a case study from the Rwenzori Mountains in Uganda

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Abstract

Landslides affect millions of people worldwide, but theoretical and empirical studies on the impact of landslides on economic development remain scarce, especially in Sub-Saharan Africa. This study estimates the direct impact of landslides on household income and investigates the presence of specific risk sharing and mitigation strategies towards landslides in the Rwenzori mountains in Western Uganda. An original cross-sectional household survey is used in combination with geographical data to acquire detailed information on livelihoods and on hazards at household level. Ordinary least squares regressions and probit estimations with village fixed effects are used to estimate the impact of landslides and the presence of mitigation strategies in the region. Geographical information at household level is used to disentangle the direct impact from the indirect effects of landslides on household income. We show that the income of affected households is significantly and substantially reduced during the first years after a landslide has occurred. We find that members of recently affected households participate more in wage-employment or in self-employed activities, presumably to address income losses following a landslide. Yet, we see that these jobs do not provide sufficient revenue to compensate for the loss of income from agriculture. Given that landslides cause idiosyncratic shocks, finding a significant direct impact in our study indicates that no adequate risk sharing mechanisms are in place or that these mechanisms are not well functioning in the Rwenzori sub-region. These insights are used to derive policy recommendations for alleviating the impact of landslides in tropical mountainous areas. By quantifying the direct impact of landslides on household income in an agricultural context in Africa this study draws the attention towards a problem that has been broadly underestimated so far and provides a sound scientific base for disaster risk reduction in the region.

Key Words: Impact assessment, landslide, household income, quantitative survey, Sub-Saharan Africa, Uganda

JEL classification: Q01, Q12, Q18

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1 Introduction

Disasters have an important impact on development. They disrupt livelihoods, cause loss of human lives and damages to properties and infrastructure are estimated to cost around USD 250 billion worldwide each year (UNISDR 2015; Okuyama & Sahin 2009). This impact is expected to increase due to the increasing occupation of marginal land and changing weather patterns related to climate change (Mendelsohn & Saher 2010). While the absolute monetary damage caused by disasters is larger in high-income countries, the absolute number of fatalities and the relative damage as a share of GDP is largest in low- and middle income countries (UNISDR 2015; Kahn 2005; Toya & Skidmore 2007; Okuyama & Sahin 2009).

Landslides contribute directly or indirectly to about 17% of all disaster-related fatalities worldwide and rank as the 7th most killing natural hazard (Lacasse & Nadim 2009; Petley 2012). They are defined as 'the movement of a mass of rock, debris or earth down a slope' and mostly constitute small, but sometimes frequent events affecting millions of people worldwide (Cruden & Varnes 1996). Landslides occur when triggering factors, like seismic activity or intense or prolonged rainfall, happen in a region that is susceptible to landslides. Landslide susceptibility of a region is determined by the topography and the lithology, as well as soil type and land cover (Jaedicke et al. 2013). Steep slopes, the presence of water accumulation zones, as well as soils with an impermeable layer typically increase the landslide susceptibility (Dai et al. 2002; Corominas et al. 2014).

In the East African highlands, landslides cause large-scale soil degradation and loss of assets, infrastructure and human life (Knapen et al. 2006; Mugagga et al. 2010; Ngecu et al. 2004). Yet the remoteness of the affected areas and the small size of single events lead to serious underreporting of landslides in these regions. This results in limited scientific attention and an underestimation of the impact of landslides on human livelihoods and development (Msilimba 2009; Jacobs et al. 2015).

The small scale and relatively diffuse character of most landslides makes the assessment of their impacts a challenging issue (Petley 2012). In industrialized countries most studies evaluate the impact of landslides by estimating the (potential) costs related to direct damage of infrastructure or by estimating the foregone income for specific industries (e.g. Crovelli & Coe, 2009; Klose et al. 2014; Petrucci & Gullà, 2009; Vranken et al. 2013). In developing countries and especially in Sub-Saharan Africa (SSA), where landslides most frequently affect poor people in remote areas with limited infrastructure, such approaches do not grasp the extent of landslide impacts (Msilimba 2009). Qualitative case studies suggest that landslides in East Africa significantly affect smallholder farmers' income through the loss of houses, crops and soil fertility (Kitutu et al. 2011; Msilimba 2009; Mugagga et al. 2010). To our knowledge, no quantitative assessment of the direct impact of landslides on household income in SSA exists at this time. Such an assessment is, however, necessary to understand how landslides have an impact on the development in the region and how important this impact is. It is also a necessary step for the implementation of cost-effective disaster risk reduction in the region.

The objective of this paper is to estimate the direct impact of landslides on household income in the Rwenzori mountains. We combine geographical data from fieldwork and digital elevation models (DEMs) with detailed information on natural hazards and socio-economic characteristics at household level. This unique combination of data sources illustrates how information on biophysical processes can be combined with detailed socio-economic data to advance the understanding of disaster impact.

This study differs from other recent studies on the impact of natural hazards in several ways. First, it looks at the impact of a single idiosyncratic shock which has received limited attention in environmental and agricultural economics. Secondly, both information on household livelihoods and on disasters is collected at household level, contrary to most studies which only investigated natural hazards at a more aggregate level (e.g. Arouri et al., 2015). Looking at one specific natural hazard which causes idiosyncratic, rather than covariate, shocks at household level allows to disentangle the direct impact from the indirect effects on household income (e.g. Cameron & Shah, 2015). Finally, this research is carried out in a region that is generally under-researched with regard to disasters (Jacobs et al. 2015).

This study is needed to provide relevant input for policy makers and development institutions in the region. By quantifying the impact of landslides on household income this study draws the attention towards a problem that has been broadly underestimated so far and proposes some concrete measures that could help mitigate it. As this paper investigates the impact of landslides on household income in a tropical mountainous regions, its findings and recommendations are relevant to a broad range of similar regions with high landslide-intensity in SSA.

2 Materials and methods

2.1 Conceptual framework

Rural household (HH) income is determined by many factors and these are widely studied in agricultural economics (e.g. Deaton, 1997). It is acknowledged that income in rural developing regions is highly dependent on human, social and physical capital available to the household (Deaton 1997). Human and social capital include education, experience, status and access to social networks. Physical capital include the availability of cultivable land, climate and other productive assets. It has been stressed that many of these factors that determine income are intergenerational, being transferred from one generation to the other (Hulme & Shepherd 2003; Wolfe & Behrman 1984).

The purpose of the current study is to contribute to this research topic by estimating the direct impact of landslides on household income. To do this, it is necessary to control for potential indirect effects. A first type of indirect effects concerns off-site impacts. In contrast to direct impacts, off-site impacts refer to all consequences landslides may have outside the exact spot of their occurrence (Alimohammadlou et al. 2013). Landslides may, for example, decrease the access to markets by cutting off roads or they may cause floods and excessive sediment deposition by temporarily damming rivers, thereby indirectly affecting household income (e.g. Claessens et al. 2007; De Haen & Hemrich 2007; Meyer et al. 2013). While critical infrastructure is limited in our study area, the indirect effects of landslides can still potentially decrease the income of the households at an aggregated geographical level (e.g. at village level) and can be controlled for by including village fixed effects into the analysis.

A second indirect consequence of landslides is related to landslide risk. Regardless of the actual occurrence of a landslide, the mere presence of its risk can affect income by influencing the behaviour of the household (Cameron & Shah 2015; Gloede et al. 2015). When attempting to estimate the direct impact of landslides on household income, it is therefore necessary to control for geographical variables that determine landslide susceptibility, which can be used as a proxy for landslide risk. This is even more relevant if one considers that poor households very often live in the most susceptible areas, thereby possibly exaggerating the measured impact of landslides (Wisner 2001).

When directly affecting a household's house or plots, landslides often destroy crops and productive assets, essentially soil quality and livestock, and thereby cause a shock. We hypothesise that income from agriculture will be reduced and, in case insufficient alternative income sources are found, also total income will be affected. The extent to which income from agriculture is reduced depends on the size and type of the landslide, while the extent to which total income is affected also depends on the capacity of the household to find alternative income sources. This capacity, strongly related to coping capacity, depends on the access to human, social, physical and financial capital, as well as the livelihood strategies and services available in the region (Cutter et al. 2008; Wisner et al. 2003; Rose 2004; Thanapackiam et al. 2012).

Most landslides are relatively small and local, causing idiosyncratic shocks which only affect a few plots at the same time (Glade 2003). The household coping capacity for idiosyncratic shocks can be high if sufficient alternative livelihood strategies and/or adequate risk-sharing mechanisms are present and accessible for all within a community (Dercon 2006; Sen 2001). Finding a significant income shock due to landslides would suggest that improving the access to either income sources outside agriculture or local risk-sharing mechanisms could be a way to improve local resilience against landslide.

2.2 Research area

The research area is located within the Rwenzori mountains in Western Uganda. This tropical mountain range covers an area of approximately 3000 km^2, spread over 31 sub-counties in four districts: Kabarole, Kasese, Bundibugyo and to a lesser extent Ntoroko (Figure 1). Two rainy seasons typically last from September to December and from March to May (Taylor et al. 2009). The subsoil is dominated by gneiss in Kabarole and Kasese and by rift alluvium and gneiss in Bundibugyo (GTK Consortium 2012). The most important cash crop in Kabarole and Kasese is coffee, while Bundibugyo is dominated by cocoa production. Staple crops are manioc, jam, maize, beans, corn and vegetables, though many farmers also grow part of these crops for selling.

The most important ethnic group in the mountains is Bakonzo, but also people from the Babouissi, Bamba and Batoro are present. Bakonzo typically live in the higher regions and consequently on steeper slopes. Among Bakonzo, living on top of a hill is frequently considered as a status symbol.

During the two rainy seasons and following seismic activities, landslides frequently occur both high into the mountains and on the foot-slopes, close to the valleys. Despite a serious underreporting, landslides and flash floods in the Rwenzori are known to have caused at least 55 fatalities and rendered over 14,000 people homeless in the region over the last 50 years (Jacobs, Dewitte, Poesen, Delvaux, et al. 2015).

2.3 Sampling procedure and data collection

Seven sub-counties, typically ca 30 km^2, with frequent landslides were selected for household sampling (Figure 1). To do this, workshops were conducted in three districts with members of the local government, non-government organizations (NGO) and peasant organisations during the first half of 2014 (Kervyn et al. n.d.). During these workshops participants were asked to indicate which sub-counties were most affected by landslides by name or on a map. Participants were also asked to describe the consequences of landslides and to discuss possible resilience strategies. After these workshops, several exploratory field visits were conducted in the whole region and finally seven sub-counties highly affected by landslides were retained for household sampling (Figure 1).

In these sub-counties both affected and unaffected villages have been sampled. A village was identified as 'affected' if at least one household was affected by a landslide in the past 15 years. A household was defined as 'affected' if at least one landslide occurred on one of the plots currently owned or cultivated by the household. No distinction was made between landslides originating on the plots, thus removing soil from the plot, and landslides originating above the plots, therefore likely to deposit debris on the plots. The location of the homestead and the surrounding croplands have also been considered as a plot. Some summary information of the sample structure by district is given in Table 1.

The sample consists of a stratified two-stage random sample of 461 households in 46 villages, of which 80 unaffected households in 14 unaffected villages, and 201 unaffected and 180 affected households in 32 affected villages. Both affected households and affected villages were purposefully oversampled in order to obtain a sample with sufficient affected households for analysis. Due to the low landslide density in Kabarole, fewer villages have been sampled in this district. The high landslide density and heterogeneous topography, as well as the presence of three sub-counties severely affected by landslides, explains why more villages have been sampled in Bundibugyo.

Table 1: Summary information at sub-county level. Data obtained from (*) UBOS (2014) and (**) personal interviews with local chairmen.

	Total	Kabarole	Kasese	Bundibugyo
Total number of villages in sampled sub-counties (*)	254	79	57	118
Number of sampled villages	47	10	15	22
Average number of households (HHs) per village in sampled villages (**)	139 (69)	177 (52)	164 (75)	106 (54)
Average number of affected HHs in affected sampled villages (**)	28 (23)	17 (10)	25 (10)	34 (30)
Total number of affected HHs sampled	180	33	52	95
Total number of unaffected HHs sampled	281	60	97	124

Standard deviations between brackets, if applicable.

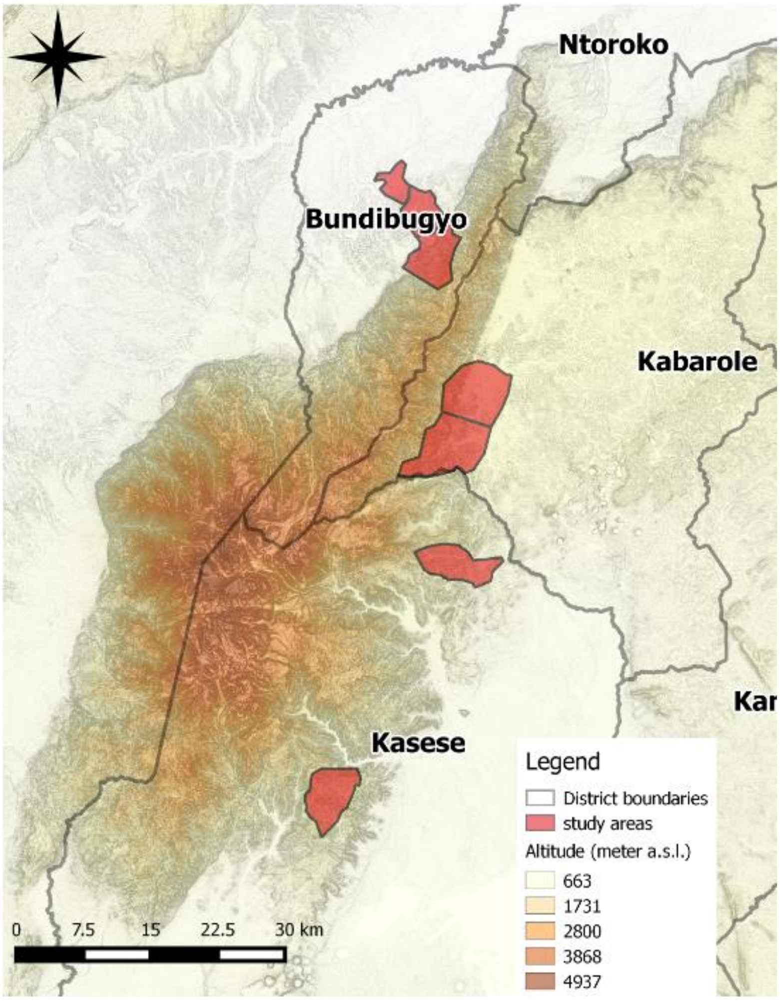

Figure 1: Overview of the study area. Darker areas have a steeper slope

Within every village, households were randomly picked from a list with all household heads in the village. In order to oversample affected households, each time a name was picked, the local chairman was asked to indicate whether that household had been affected by landslides or not. Whenever possible, an equal number of 6 affected and 6 unaffected households was selected in affected villages, while 6 unaffected households were selected in unaffected villages. As local chairmen were not always fully aware of all landslides in their village and sometimes confused landslides with gully erosion, small imbalances exist between affected and unaffected households in some villages.

Interviews with the households were conducted in the beginning of 2015 and 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. Household income data were obtained following the methods recommended by the World Bank (2000). Total income includes income from agricultural production, both for selling and own consumption, income from wage labour and off-farm employment, as well as non-labour income including gifts, transfers and monetary and non-monetary support. GPS coordinates have been taken in front of the house of each household, as well as on the corners of the plots owned or cultivated by the household. This makes it possible to include geographical variables at household level and to calculate the exact amount of land cultivated by each household.

During data cleaning nine households have been dropped because of too much missing information, while two households were dropped because they were severe outliers owning a very large area of land and having a very high income, therefore not considered representative for the study area. While these two households did not affect the results of the econometric analysis, their very high income seriously increased standard deviations in the descriptive statistics.

2.4 Retrieval of geographic information

Geographic information was used to control for landslide susceptibility. Landslide susceptibility is expected to be correlated with both the occurrence of landslides and household income. This has been explained in the conceptual framework and will be further elaborated in the empirical approach. The main landslide-controlling factors in the Rwenzori region are slope steepness and lithology, while slope undercutting by water flows and streams is one of the preparatory factors (Jacobs, et al. 2015). Additionally, soil type, which is only partially determined by lithology, has also been identified as a controlling factor for landslide occurrence. Yet, no data on soil type are available for the Rwenzori region (Jacobs, et al. 2015). Slope steepness and flow accumulation have been calculated with a SRTM 1" Digital Elevation Model (USGS 2014), with a precision of 30 by 30 meters. The flow accumulation tool in ArcGis calculates a scale-dependent value of flow accumulation in each cell of a raster. Therefore it first estimates the flow direction in each cell, based on the direction of the slope in these cells. Subsequently it calculates a relative value for flow accumulation by counting the number of cells 'flowing' into each cell from a higher altitude (ESRI 2015). Data on the lithology in the Rwenzori was retrieved from the geological map of Uganda (GTK Consortium 2012).

A way to obtain a measure for slope steepness, lithology and flow accumulation at household level could be to assess these factors around the house and all the plots of each household. Yet, as plots are generally within walking distance from the house, with a decreasing plot density as the distance from the house increases, the location of the plots is highly correlated with the location of the house. In our sample, average walking time between the house and plots is 28 min and over 85% of the households have an average walking distance to their plots equal to or less than one hour. To obtain single values of slope steepness, flow accumulation and lithology for each household, we calculated the weighted sum of pixel values in a buffer of five km around each house. A weight was attributed to each cell by dividing the value of each pixel by the squared distance from the house.

All calculations have been performed in ArcGIS (ESRI 2015). The weighed focal statistics tool in ArcGis was used to calculate the weighed values for the buffer around the houses (ESRI 2015). An overview of the calculated variables is given in Table 2.

2.5 Empirical approach

An ordinary least squares (OLS) regression model is used to estimate the impact of the occurrence of a landslide on the income of the households in our sample (equation 1).

$$Y_{ij} = \alpha + \beta LS_{ij} + \gamma Susceptibility_{ij} + \delta X_{ij} + \mu Village\ FE_j + \varepsilon_{ij} \qquad \text{[Eq.1]}$$

In this model Y_{ij} is a measure for household welfare, i.e. the logarithm of per capita income. The logarithm of income is taken to normalize the data which are right-tailed. LS_{ij} is a dummy which equals 1 if the household was affected by a landslide in the past 15 years. $Susceptibility_{ij}$ represents the set of variables which control for landslide susceptibility, *i.e.* the calculated values of slope steepness, lithology and flow accumulation. Controlling for these factors likely solves issues related to potential omitted variable bias. X_{ij} represents a vector of covariates, while $Village\ FE_j$ and ε_{ij} are village fixed effects and the error term.

The covariates considered in our model include demographic variables and variables for human, social and productive capital (Table 2). The demographic variables include household size, as well as gender, age and education of the household head, which are proxies for human capital. A dummy for whether the household head is from the main ethnicity in the region, *i.e.* Bakonzo, is included as a proxy for social capital. As living on top of a hill is considered to be a status symbol in the region, the altitude of the house (m.a.s.l.) was also included as a proxy for social capital within the village. To control for intergenerational factors, the number of brothers of the household head and the education level of the parents of the household head are included. These intergenerational factors often determine what land is available to a household head and thus where a household head will construct its house. The variables for productive capital are total land area and number of plots, percentage of land under cash crops (coffee or cocoa) and a dummy for whether at least one household member has an income source from self-employed activities or from wage labour.

Equation 1 does not fully capture what happens when a household is affected, because landslides do not always occur on the totality of a household's land. A landslide can affect one out of several plots, or even only a part of a plot. Therefore in equation 2 the dummy LS_{ij} is replaced by the percentage of the total cultivated land that was affected by a landslide, $LSPerc_{ij}$.

$$Y_{ij} = \alpha + \beta LSPerc_{ij} + \gamma Susceptibility_{ij} + \delta X_{ij} + \mu Village\ FE_j + \varepsilon_{ij} \qquad \text{[Eq. 2]}$$

In this equation the coefficient β estimates how much percentage the income of a household changes for each additional percentage of the total area that was hit by a landslide.

After the initial welfare shock, it is likely that the impact of a landslide fades away over time. It is therefore interesting to estimate the impact of landslides that occurred during different periods. Equation 3 estimates the impact of landslides that happened less than one year ago, between one and two years ago, two or three years ago and landslides that happened longer time ago.

$$Y_{ij} = \alpha + \beta_{t1} LSPerc(t1)_{ij} + \beta_{t2} LSPerc(t2)_{ij} + \beta_{t3} LSPerc(t3)_{ij} + \beta_{t4} LSPerc(t4)_{ij} + \gamma Susceptibility_{ij} + \delta X_{ij} + \mu Village\ FE_j + \varepsilon_{ij} \qquad \text{[Eq. 3]}$$

To explain the findings of these OLS regressions on household income, equation 3 has also been used for a probit estimation on potential coping strategies adopted by affected households after a landslide has occurred. The coping strategies that were considered are: (1) having a household member with a job outside own agriculture, or (2) having received gifts or transfers in the last year.

As a robustness check, a treatment-effects estimation with augmented inverse probability weighting has been displayed in the appendix. In this estimation households are considered as 'treated' if they have been affected by a landslide. After controlling for factors that could determine variations in the likelihood to be treated, the average impact of landslides (Average Treatment Effect) is estimated as the difference between affected and unaffected households. The augmented inverse probability weighting estimation is used because this estimation allows a similar specification as in the OLS estimations, while being robust to misspecifications in either the estimation of the likelihood to be treated or the estimation of the impact of the treatment. For more information on this estimation method, please read Glynn & Quinn (2010) or Stata Press (2013). All analyses have been performed with the Stata 14 software (StataCorp 2015).

3 Results and discussion

3.1 Descriptive statistics

The households in the sample are very poor, with an average income of 2,911 Ugandan Shilling (Ush) per day per adult equivalent (Table 2). This is the equivalent of 2.83 USD per adult per day (purchasing power parity in 2010-2014 from "WorldBank" 2015). Income from agriculture represents 85% of the total income. Incomes in the sample are lower than the average in the districts under study, as average consumption per adult equivalent is around 4,300 Ush per day (converted from UNDP 2014). This is understandable, as our sample targets households in the mountains, far from local towns and exposed to landslides. Approximately 40% of the households in our sample have been affected by a landslide in the past 15 years (Table 2). No significant difference in income exists between households affected by landslides and unaffected households. This is surprising, as 64% of the affected households 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.

According to the multidimensional poverty index (MPI) of Alkire et al. (2011), most households in our sample are multi-dimensionally poor, with 90% below the poverty line. According to this index, households are defined as poor if they obtain a deprivation score of at least 33 out of 100, which implies they have a serious lack of access to education, health and basic living standards (Alkire et al. 2011). Again, no difference exists between affected and unaffected households regarding the MPI (Table 2). Yet, households affected by a landslide seem to have a significantly less educated household head.

On average, 38% of the households has borrowed money in the 12 months before the interview. This can be either through a bank, a microcredit institution or an individual lender. Meanwhile, 49% of the households has a mobile money account, used to transfer money across phones, or has an account at a bank or a microcredit institute. No significant differences exist between affected and unaffected households.

As can be seen in Table 2, the households in our sample own on average 0.8 ha spread over two plots. Households that have been affected by a landslide have significantly more land, spread over significantly more plots than unaffected households. This suggests that there is a selection bias in our sample. The sample was not stratified on the area of land owned by the households. In a village where most of the land is susceptible to landslides, households owning more plots are more likely to be affected by a landslide just because they own a larger area. This selection bias could explain why no lower income is found among affected households in Table 2.

Approximately 50% of the land is planted with coffee or cocoa, whereby coffee is often intercropped with other crops, i.e. banana, beans, cassava and jams. Respectively 22% and 35% of the households have a member involved in wage labour or self-employed activities outside agriculture. In our sample, most wage labour consists of performing part-time work on the fields of other farmers, while self-employed jobs embrace a variety of activities like owning shops, trading cash crops or driving motorbikes for transportation. In total, approximately 50% of the households has at least one member with a job different from agriculture on its own plots. Among these households, the average household income from these jobs is 754 Ush (0.74 USD) per adult equivalent per day. Approximately 49% of the households received gifts or transfers in the previous 12 months, amounting for an average of 184 Ush (0.18 USD) per adult equivalent per day. In the overall sample, no significant differences exist in crop type, activities outside agriculture or transfers between affected and unaffected households.

A significant difference between affected and unaffected households exists for the lithology and for the calculated flow accumulation. This suggests that these variables are indeed correlated with landslide susceptibility and should therefore be controlled for. Due to a high correlation between the village fixed effects and the continuous estimations of lithology in the buffers around the houses, a dummy variable was used for lithology, indicating the dominant lithology in the buffer around each house in the sample. Altitude and calculated value of slope are not significantly different in the overall sample.

Table 2: Summary statistics on main variables for the whole sample and for unaffected and affected households (HHs). Only variables used in the subsequent regressions have received a variable acronym. Variable units are in square brackets (if applicable). Standard deviation in parentheses. ND stands for No Dimensions and N/A stands for Not Applicable. To test for significant differences ttest have been performed between unaffected and affected households * p < 0.10, ** p < 0.05, *** p < 0.01

Variable acronyms		Sample	Unaffected HHs	Affected HHs	Dif (unaff. – aff.)
Welfare indicators					
	Income [Ush/day/adult-equivalent]	2912 (2710)	3012 (2796)	2752 (2566)	
	Income from agriculture [Ush/day/adult-equivalent]	2443 (2434)	2468 (2412)	2403 (2476)	
	Income from agriculture [in % of total income]	86 (23)	84 (24)	88 (21)	
	Multidimensional Poverty Index [ND]	51 (15)	50 (16)	51 (14)	
Experience with landslides					
LS	Farmers affected by landslide [yes = 1]	0.39 (0.49)	N/A	1.00 (0.00)	N/A
	Years since most recent landslide [years]	N/A	N/A	1.60 (1.79)	N/A
	House was damaged by most recent landslide [yes = 1]	0.08 (0.27)	N/A	0.21 (0.41)	N/A
	Human and social capital				
AdEq	Adult equivalents (OECD) [#]	3	3	3	

		(1)	(1)	(1)	
AgeHHH	Age of HH head [years]	45 (16)	44 (16)	46 (16)	*
EducHHH	Years of formal education HH head [years]	6 (4)	6 (4)	5 (3)	**
Female	HH head is female [yes = 1]	0.09 (0.29)	0.09 (0.29)	0.09 (0.29)	
Bakonzo	Ethnicity HH head is Bakonzo [yes = 1]	0.60 (0.49)	0.63 (0.48)	0.56 (0.50)	
EducParents	Years of formal education parents of HH head [years]	2 (3)	2 (3)	2 (3)	
BrothersHHH	Original number of brothers of HH head [#]	4 (2)	4 (2)	3 (2)	
	Productive capital				
TotArea	Land area available to household [hectares]	0.81 (0.71)	0.74 (0.67)	0.92 (0.76)	***
TotPlots	Number of different plots available to the HH [#]	1.95 (1.03)	1.82 (0.94)	2.16 (1.12)	***
PercCash	Land with coffee or cocoa (cashcrops) [% of total area]	47 (32)	49 (33)	46 (31)	
	At least one HH member has a wage [yes = 1]	0.22 (0.42)	0.23 (0.42)	0.22 (0.41)	
	At least one HH is self-employed outside agriculture [yes = 1]	0.35 (0.48)	0.37 (0.48)	0.32 (0.47)	
Job	At least one HH member is self-employed or has a wage [yes = 1]	0.50 (0.50)	0.53 (0.50)	0.45 (0.50)	
	Has a mobile money account, a bank account or an account at a microcredit institute [yes = 1]	0.49 (0.50)	0.49 (0.50)	0.48 (0.50)	
	Household has debts (formal or informal) [yes = 1]	0.45 (0.50)	0.42 (0.49)	0.49 (0.50)	
	Geographical information				
Altitude	Altitude of house [m.a.s.l.]	1369 (404)	1390 (399)	1336 (411)	
Buf_Slope	Slope / squared distance in buffer of 5 km around house [m^{-2}]	4.39 (1.69)	4.35 (1.67)	4.47 (1.72)	
Buf_Water	Variable for water accumulation / squared distance in buffer of 5 km around house [m^{-2}]	90.81 (30.52)	88.59 (29.72)	94.34 (31.51)	*
	Sum of pixels with Gneiss / squared distance in buffer of 5 km around house [m^{-2}]	0.17 (0.13)	0.18 (0.13)	0.16 (0.13)	
	Sum of pixels with Rift alluvium / squared distance in buffer of 5 km around house [m^{-2}]	0.09 (0.12)	0.08 (0.12)	0.11 (0.13)	**
	Sum of pixels with Mica / squared distance in buffer of 5 km around house [m^{-2}]	0.02 (0.04)	0.02 (0.05)	0.02 (0.03)	
Dummy for lithology	Main lithology within weighted buffer of 5 km (gneiss, rift alluvium or mica)	N/A	N/A	N/A	N/A
	Observations	450	276	174	

The summary statistics in Table 2 compare affected and unaffected households and show that the most significant difference lies in the average total area and number of plots owned by the households. Yet, not all affected households own a lot of cropland or more than one plot. In Table 3 differences in income and land area between affected and unaffected households are represented and grouped by the number of plots available to the households. Among households with only one plot, there is no difference in total cultivated area between affected and unaffected households. Meanwhile, a significant difference in income between affected and unaffected households with only one plot is found. Among households with more than one plot, there is a significant difference in total cultivated area between affected and unaffected households, while no difference in income is found. Interestingly, among households with only one plot a significantly larger percentage of the total land area is subjected to landslides than among households with more than one plot.

Table 3: Summary statistics on income and land area among affected and unaffected households (HHs), grouped by number of plots cultivated by the household (one or more plots). Standard deviation in parentheses. To test for significant differences ttest have been performed between unaffected and affected households and between households with one plot and households with more plots * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

# Plots	Income unaffected HHs [Ush/day/adult-equivalent]		Income affected HHs [Ush/day/adult-equivalent]	Total area available to unaffected HHs [hectares]		Total area available to affected HHs [hectares]	% of land subjected to landslide among affected HHs	# HHs
1	2441 (2139)	*	1855 (1612)	0.60 (0.59)		0.74 (0.87)	43 (20)	179
	***		***	***		**	***	
>1	3465 (3158)		3188 (2825)	0.84 (0.71)	*	1.00 (0.69)	22 (15)	271

Table 2 and Table 3 give only a partial picture of the reality due to several reasons. First, not all landslides considered in this research occurred at the same time. Therefore, some households might have been affected a longer time ago than others. Secondly, many households have been affected by a landslide several times, for example during consecutive raining seasons. This can be due to a reactivation of a landslide or due to another landslide affecting the same or a different plot. Finally, the extent to which a landslide has stricken a household's land varies greatly. A landslide can affect 100% of a plot cultivated by a household that has only one plot, or it could damage only 25% of a small plot owned by a household that is cultivating many plots.

In total 273 landslides have directly affected 174 households in our sample (Table 4). One third of the households affected by a landslide state that a landslide occurred only once on their plots, while the majority has been affected two times. More than 40% of the affected households in our sample were affected by a landslide less than 1 year ago, while more than 80% was affected less than 4 years ago. This strong bias towards more recent landslides is attributed to our sample design, whereby the village chairmen were asked whether a household was affected by a landslide or not. As village chairmen are not personally affected by the disaster, they are likely to forget landslides that occurred a longer time ago. On average the landslides in our sample affected 27.4% of the land available to the farmers. More than half of the landslides has stricken 25% or less of the land available to the affected households.

Table 4: Overview of number of landslides and their average extent in column 2 and 4 respectively, grouped by year since the landslide. Column 3 illustrates that most households in our sample have been recently affected by a landslide. Standard deviation in parentheses (if applicable)

	Number of HHs affected by a landslide by year	Number of HHs for whom the landslide in the given year was the most recent one	Average percentage of land affected by the landslides
Up to 1 year ago	61	61	28 (18)
Between 1 and 2 years ago	66	49	24 (19)
Between 2 and 3 years ago	54	27	30 (23)
Between 3 and 4 years ago	15	6	26 (19)
Between 4 and 5 years ago	22	14	29 (17)
Between 5 and 6 years ago	12	6	24 (14)
More than 6 years ago	43	11	28 (17)
Total	273	174	

In order to take into consideration the time since landslides, it is worth looking deeper into the significant differences between affected and unaffected households with only one plot, as suggested by the income differences found in Table 3. Despite the limited number of observations, Table 5 shows that, among households owning one plot, those affected by a landslide less than one year ago, as well as those affected between one and two years ago have a significantly lower income than unaffected households. This trend is not found for households owning more than one plot.

Table 5: Differences among affected and unaffected households with only 1 plot for the most important variables, split by year since landslide. Standard deviation in parentheses. To test for significant differences ttest have been performed between unaffected households and respective columns * p < 0.10, ** p < 0.05, *** p < 0.01

	Unaffected HHs	HHs affected up to 1 year ago	HHs affected between 1 and 2 years ago	HHs affected between 2 and 4 years ago	HHs affected more than 4 years ago
Income [Ush/day/adult-equivalent]	2441 (2139)	1585 (1263)*	1460 (822)*	1549 (1524)	2254 (2238)
Income from agriculture [Ush/day/adult-equivalent]	2034 (1999)	1371 (1233)	1094 (722)*	1263 (1452)	1845 (1864)
Land area available to household [hectares]	0.60 (0.59)	0.78 (0.86)	0.43 (0.21)	0.69 (0.57)	1.11 (1.24) ***
% of land area affected by landslide	0	40 (19)	40 (21)	50 (27)	38 (17)
At least one HH member has a wage [yes = 1]	0.23 (0.42)	0.38 (0.50)	0.28 (0.46)	0.13 (0.34)	0.10 (0.30)
At least one HH is self-employed outside agriculture [yes = 1]	0.29 (0.45)	0.14 (0.36)	0.39 (0.50)	0.19 (0.40)	0.19 (0.40)

# households	122	21	18	16	21

3.2 The impact of landslides on household income

The results of the village fixed effects regressions on the log of household income from agriculture (Ush/adult equivalent/day) are given in equations 1-3 of Table 6, while those on the log of total household income (Ush/adult equivalent/day) are given in equations 4-6. Except for some geographical variables as well as for *EducHHH* and *Job*, which only have a significant impact in regressions 4-6, all the covariates have a significant effect in regression 1 to 6. Reduced-form regressions, without most covariates, give very similar results and are presented in the Appendix (Table A1).

The first equation in Table 6 gives the estimation of landslide impact on income from agriculture with a simple dummy which equals one if the household was affected by a landslide in the past 15 years. This measurement does not take into account the fact that some households might have been affected only to a very little extent or a long time ago. Yet, this equation nevertheless indicates that households that were affected by a landslide have on average 18% less income from agriculture. The same analysis on the total income (equation 4) does not give significant results. Similarly, the treatment effects estimation, displayed in the appendix, finds that landslides reduce income from agriculture by 16%, while no significant impact is found on total income.

The second equation in Table 6 estimates that every additional percentage of land affected by the most recent landslide decreases the income from agriculture by 0.74%, while the fifth equation shows that every additional percentage reduces the total income by 0.56%. An average landslide in our sample has affected 27.4% of the land of the affected households. The estimations in equations two and four therefore suggest that households that have been affected by an average landslide have on average respectively 20% less income from agriculture and 15% less total income than households that have never been affected. These results do not take into account time since the landslide event, although one must keep in mind that most affected households in our sample have been affected less than 2 years ago.

The third and the sixth equation in Table 6 disentangle the effect of a landslide by time since the landslide. We find a negative effect of landslides on income from agriculture for landslides that occurred less than three years ago. A negative and significant effect on total household income is found for landslides that occurred less than one year ago or between two and four years ago. Landslides that happened more than four years ago seem to have no impact on current income. With our data it is hard to tell whether the impact of landslides is indeed not significant when more than four years have passed since the landslide, or whether this is due to incomplete information on landslides that happened several years ago. Time series panel data would therefore be more appropriate to estimate the long-term consequences of landslides.

The results displayed in Table 3 suggest that households which have only one plot are more severely affected by landslides than households that have more plots. We have tested this hypothesis by including an interaction term between *LS* and *TotPlots* but this did not yield any significant result and is therefore not displayed here. It is nevertheless clear from the equations in Table 6 that the impact of landslides is highly dependent on the percentage of the land affected by the landslide. On average, households with more land are therefore likely to be less severely affected by average landslides than households which have less land.

Table 6: Results of Ordinary Least Square (OLS) regressions with village fixed effects on income per adult equivalent per day from agriculture (1-3) or total income per adult equivalent per day (4-6). t statistics in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

Equation number Dependent variable	(1) Log(Income agriculture)	(2) Log(Income agriculture)	(3) Log(Income agriculture)	(4) Log(Income)	(5) Log(Income)	(6) Log(Income)
Experience with landslides						
LS	-0.183** (-2.00)			-0.127 (-1.44)		
% of land affected by most recent landslide		-0.00735*** (-3.09)			-0.00561** (-2.33)	
% of land affected by landslides up to 1 year ago			-0.00588* (-1.71)			-0.00571* (-1.84)
% of land affected by landslides between 1 and 2 years ago			-0.00577* (-1.71)			-0.00344 (-1.01)
% of land affected by landslides between 2 and 4 years ago			-0.00612 (-1.53)			-0.00645* (-1.70)
% of land affected by landslides more than 4 years ago			0.0734 (0.20)			0.104 (0.29)
Control variables on productive capital						
TotArea	0.231*** (2.91)	0.227*** (2.88)	0.215*** (2.67)	0.184*** (2.78)	0.181*** (2.75)	0.171** (2.55)
TotPlots	0.272*** (5.37)	0.236*** (4.68)	0.243*** (4.80)	0.220*** (4.49)	0.193*** (4.01)	0.196*** (4.04)
Job	-0.0813 (-0.90)	-0.0803 (-0.90)	-0.0655 (-0.71)	0.305*** (3.58)	0.306*** (3.61)	0.316*** (3.62)
PercCash	0.597*** (3.61)	0.561*** (3.43)	0.542*** (3.21)	0.355** (2.42)	0.327** (2.24)	0.302** (1.99)
Control for human and social capital						

AdEq	-0.190***	-0.191***	-0.191***	-0.217***	-0.218***	-0.219***
	(-4.67)	(-4.74)	(-4.66)	(-5.80)	(-5.86)	(-5.81)
AgeHHH	0.00600*	0.00603**	0.00572*	0.00739**	0.00742**	0.00712**
	(1.92)	(1.98)	(1.83)	(2.47)	(2.50)	(2.37)
EducHHH	0.0142	0.0137	0.0134	0.0313***	0.0308***	0.0301***
	(1.20)	(1.16)	(1.13)	(2.73)	(2.68)	(2.61)
Bakonzo	0.309**	0.320**	0.312**	0.283**	0.291**	0.280**
	(2.44)	(2.55)	(2.49)	(2.40)	(2.49)	(2.41)
Female	-0.353**	-0.356**	-0.346**	-0.402***	-0.404***	-0.397***
	(-2.18)	(-2.19)	(-2.12)	(-2.75)	(-2.75)	(-2.71)
EducParents	0.0266*	0.0250	0.0247	0.0214	0.0201	0.0199
	(1.70)	(1.60)	(1.58)	(1.40)	(1.32)	(1.30)
BrothersHHH	-0.0305*	-0.0312*	-0.0300*	-0.0345**	-0.0351**	-0.0342**
	(-1.83)	(-1.89)	(-1.80)	(-2.14)	(-2.19)	(-2.14)
Control for landslide susceptibility and location-specific covariates						
Gneiss	0.583	0.470	0.533	0.550	0.459	0.515
	(1.29)	(1.02)	(1.22)	(1.45)	(1.18)	(1.46)
Mica	0.686***	0.658***	0.656***	0.630***	0.609***	0.612***
	(3.01)	(3.08)	(3.02)	(2.96)	(2.97)	(2.93)
ele	0.000259	0.000134	0.000230	-0.000181	-0.000306	-0.000272
	(0.29)	(0.15)	(0.26)	(-0.23)	(-0.39)	(-0.35)
Buf_Slope	-0.0121	0.0134	-0.0201	-0.0198	0.00285	-0.0154
	(-0.10)	(0.11)	(-0.16)	(-0.17)	(0.02)	(-0.13)
Buf_Water	0.00300	0.00296	0.00333	0.00414	0.00415	0.00458
	(1.03)	(1.02)	(1.15)	(1.45)	(1.47)	(1.63)
_cons	4.950***	5.253***	5.198***	6.024***	6.297***	6.301***
	(3.27)	(3.45)	(3.42)	(4.56)	(4.78)	(4.84)
Village FE	Yes	Yes	Yes	Yes	Yes	Yes
N	450	450	450	450	450	450
r2	0.445	0.452	0.452	0.452	0.457	0.461
F	6.897	7.187	7.053	7.575	7.839	7.940

Interestingly, from equations 2 and 5 in Table 6, total household income is 24% less affected by landslides than income from agriculture. This suggests that households affected by a landslide seek external income sources in order to compensate for income losses due to landslides. These alternative income sources can be from gifts, monetary or in kind, and transfers or from household members having a job, either self-employed or in wage employment.

A probit regression that estimates how landslides affect the likelihood of having received gifts and transfers in the previous year is given in equation 1 of Table 7, while a probit estimation on how landslides affect the likelihood of having a household member with a job is given in equation 2. Having faced a landslide does not seem to affect the likelihood to receive gifts or transfers. This suggests no formal or informal insurance mechanisms are present for landslides in the study area.

During interviews farmers frequently mentioned that doing small jobs for other farmers was a way to earn some money in times of need. Our analysis confirms this, as households that were affected by a landslide in the previous year are significantly more likely to have a household member with a job (Table 7). Yet, from Table 6 we see that these jobs are not sufficient to fully compensate for income losses in agriculture. Households affected more than one year ago are not more likely to have household members with a job.

Table 7: Results of probit estimation with village fixed effects on the likelihood to have received gifts and transfers (1) or to have a household member with a job (2). Ten observations could not be included in the estimation of equation 1 because in one village all 10 households were receiving transfers. z statistics in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

Equation number	(1)	(2)
Dependent variable	Having received gifts or transfers in past 12 months [Yes = 1]	Having a HH member with a job [Yes= 1]
Experience with landslides		
% of land affected by landslides up to 1 year ago	0.000507 (0.09)	0.0128* (1.86)
% of land affected by landslides between 1 and 2 years ago	-0.00250 (-0.38)	0.00723 (1.07)
% of land affected by landslides between 2 and 4 years ago	0.00203 (0.35)	-0.00851 (-1.56)
% of land affected by landslides more than4 years ago	-0.656 (-1.13)	-0.987 (-1.63)
Control variables on productive capital		
TotArea	0.248**	0.122
	(2.18)	(1.10)
TotPlots	0.0173	-0.0979
	(0.21)	(-1.19)
PerCash	0.172	-0.314
	(0.71)	(-1.25)
Control for human and social capital		
AdEq	0.0434	0.162**
	(0.70)	(2.57)
AgeHHH	0.00382	-0.0234***
	(0.74)	(-4.28)
EducHHH	0.000471	0.0763***
	(0.02)	(3.90)
Bakonzo	0.466**	0.375**
	(2.55)	(1.98)
Female	-0.217	0.334
	(-0.83)	(1.33)
EducParents	0.0215	0.0314
	(0.87)	(1.28)
BrothersHHH	0.000234	0.00874
	(0.01)	(0.30)
Control for landslide susceptibility and location-specific covariates		
Gneiss	0.0287	-0.0954
	(0.03)	(-0.12)
Mica	-0.0653	-0.199
	(-0.14)	(-0.42)
ele	0.000631	0.00248*
	(0.46)	(1.70)
Buf_Slope	-0.110	-0.268
	(-0.60)	(-1.35)
Buf_Water	-0.000738	-0.00316

	(-0.18)	(-0.70)
_cons	2.418	0.899
	(1.32)	(0.44)
Village fixed effects	Yes	Yes
N	440	450
Pseudo r2	0.1358	0.2107
Wald Chi2	85.07	129.13

4 Conclusions and recommendations

The findings of this paper suggest that households lose a significant percentage of their income from agriculture in the year that they are affected by a landslide. An average loss of 20% is measured for income from agriculture, while an average loss of 15% is measured for total income. These are high numbers implying that landslides have a significant impact on the livelihoods of the affected households. This is particularly relevant because most households in our sample live in a precarious situation, with 90% of the households being multidimensional poor. It should therefore not come as a surprise therefore that 64% of the affected households mention that they faced hunger after the landslide.

The severity of the impact on household income is highly dependent on the percentage of the land affected by a landslide. 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 (Msilimba 2009; Mugagga 2011).

In an attempt to compensate for income losses after a landslide, household members in our sample 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 remains significantly affected by landslides. Moreover, members of households that have been affected by a landslide more than one year ago are not more likely to have a job than members of unaffected households. This suggests that jobs are abandoned once the emergency situation after the landslide has been cleared. Providing more attractive and sustainable jobs outside agriculture could therefore be a way to increase the resilience towards landslides in the region.

We do not find indications of increasing transfers or remittances after a landslide, suggesting that no formal or informal insurance mechanisms are present for landslides in the region. As the burden of landslides is significant and the coping strategies adopted by the households do not seem sufficient to avoid severe income losses, the development of local risk-sharing mechanisms could therefore be promoted. A local disaster relief fund or credit and saving mechanisms at village level could be established with the explicit purpose to provide relief after a landslide.

5 References

Alimohammadlou, Y., Najafi, A. & Yalcin, A., 2013. Landslide process and impacts: A proposed classification method. *Catena*, 104, pp.219–232.

Alkire, S., Roche, J.M., Santos, M.E. & Seth, S., 2011. Multidimensional Poverty Index 2011: Brief Methodological Note. *Oxford Poverty and Human Development Initiative Publication*, pp.1–14.

Arouri, M., Nguyen, C. & Youssef, A. Ben, 2015. Natural Disasters, Household Welfare, and Resilience: Evidence from Rural Vietnam. *World Development*, 70, pp.59–77.

Cameron, L. & Shah, M., 2015. Risk-Taking Behavior in the Wake of Natural Disasters. *Journal of Human Resources*, 50(2), pp.484–515.

Claessens, L., Knapen, A., Kitutu, M.G., Poesen, J. & Deckers, J.A., 2007. Modelling landslide hazard, soil redistribution and sediment yield of landslides on the Ugandan footslopes of Mount Elgon. *Geomorphology*, 90, pp.23–35.

Corominas, J., van Westen, C., Frattini, P., Cascini, L., Malet, J.P., Fotopoulou, S., Catani, F., Van Den Eeckhaut, M., et al., 2014. Recommendations for the quantitative analysis of landslide risk. *Bulletin of Engineering Geology and the Environment*, 73(2), pp.209–263.

Crovelli, R. a. & Coe, J. a., 2009. Probabilistic estimation of numbers and costs of future landslides in the San Francisco Bay region. *Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards*, 3(4), pp.206–223.

Cruden, D.M. & Varnes, D.J., 1996. Landslide types and processes. In A. Turner & R. Schuster, eds. *Landslides: Investigation and Mitigation.* Transportation Research Board, National 631 Research Council, pp. 36–75.

Cutter, S.L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E. & Webb, J., 2008. A place-based model for understanding community resilience to natural disasters. *Global Environmental Change-Human and Policy Dimensions*, 18, pp.598–606.

Dai, F.., Lee, C.. & Ngai, Y.., 2002. Landslide risk assessment and management: an overview.

Engineering Geology, 64(1), pp.65–87.

Deaton, A., 1997. *The analysis of household surveys: a microeconometric approach to development policy*, World Bank Publications. Available at: http://elibrary.worldbank.org/doi/abs/10.1596/0-8018-5254-4.

Dercon, S., 2006. Vulnerability: a micro perspective. *Securing Development in an Unstable World*, 30, pp.117–146.

ESRI, 2015. ArcGIS Desktop: Release 10.2 Redlands, CA: Environmental Systems Research Institute.

Glade, T., 2003. Vulnerability assessment in landslide risk analysis. *Erde*, 134, pp.123–146.

Gloede, O., Menkhoff, L. & Waibel, H., 2015. Shocks, Individual Risk Attitude, and Vulnerability to Poverty among Rural Households in Thailand and Vietnam. *World Development*, 71, pp.54–78.

Glynn, A.N. & Quinn, K.M., 2010. An Introduction to the Augmented Inverse Propensity Weighted Estimator. *Political Analysis*, 18(1), pp.36–56.

GTK Consortium, 2012. Geological map of Uganda 1:100,000 Sheet N° 65 Karambi.

De Haen, H. & Hemrich, G., 2007. The economics of natural disasters: implications and challenges for food security. *Agricultural Economics*, 37(August), pp.31–45.

Hulme, D. & Shepherd, A., 2003. Conceptualizing Chronic Poverty. *World Development*, 31(3), pp.403–423.

Jacobs, L., Dewitte, O., Poesen, J., Delvaux, D., Thiery, W. & Kervyn, M., 2015. The Rwenzori Mountains, a landslide-prone region? *Landslides*. Available at: http://link.springer.com/10.1007/s10346-015-0582-5.

Jacobs, L., Dewitte, O., Poesen, J., Sekajugo, J., Maes, J., Mertens, K., Kervyn, M., Sekajugo, J., et al., 2015. Landslide characteristics and spatial distribution in the Rwenzori Mountains, Uganda. *Submitted to Journal of African Earth Sciences*, pp.1–9.

Jaedicke, C., Van Den Eeckhaut, M., Nadim, F., Hervás, J., Kalsnes, B., Vangelsten, B.V., Smith, J.T., Tofani, V., et al., 2013. Identification of landslide hazard and risk “hotspots” in Europe. *Bulletin of Engineering Geology and the Environment*, 73(2), pp.325–339.

Kahn, M., 2005. The death toll from natural disasters: the role of income, geography, and institutions. *Review of Economics and Statistics*. Available at: http://www.mitpressjournals.org/doi/abs/10.1162/0034653053970339.

Kervyn, M., Bih Che, V., de Hontheim, A., Dewitte, O., Isabirye, M., Jacobs, L., Kabaseke, C., Maes, J., et al., Landslides resilience in Equatorial Africa: Moving beyond the problem identification. *Submitted to BELGEO*.

Kitutu, M.G., Muwanga, A., Poesen, J. & Deckers, J.A., 2011. Farmer's perception on landslide occurrences in Bududa District, Eastern Uganda. *African Journal of Agricultural Research*, 6, pp.7–18.

Klose, M., Highland, L., Damm, B. & Terhorst, B., 2014. Estimation of Direct Landslide Costs in Industrialized Countries: Challenges, Concepts, and Case Study. In *Landslide Science for a Safer Geoenvironment*. Cham: Springer International Publishing, pp. 661–667.

Knapen, A., Kitutu, M.G., Poesen, J., Breugelmans, W., Deckers, J. & Muwanga, A., 2006. Landslides in a densely populated county at the footslopes of Mount Elgon (Uganda): characteristics and causal factors. *Geomorphology*, 73, pp.149–165.

Lacasse, S. & Nadim, F., 2009. Landslide Risk Assessment and Mitigation Strategy. In K. Sassa & P. Canuti, eds. *Landslides - Disaster Risk Reduction*. Springer Berlin Heidelberg, pp. 31–61.

Mendelsohn, R. & Saher, G., 2010. The Global Impact of Climate Change on Extreme Events. *Background paper for the WB/UN report "Natural hazards, unnatural disasters"*, (May), pp.1–42.

Meyer, V., Becker, N., Markantonis, V., Schwarze, R., van den Bergh, J.C.J.M., Bouwer, L.M., Bubeck, P., Ciavola, P., et al., 2013. Review article: Assessing the costs of natural hazards - state of the art and knowledge gaps. *Natural Hazards and Earth System Sciences*, 13(5), pp.1351–1373.

Msilimba, G.G., 2009. The socioeconomic and environmental effects of the 2003 landslides in the Rumphi and Ntcheu Districts (Malawi). *Natural Hazards*, 53(2), pp.347–360.

Mugagga, F., 2011. *Land use change, landslide occurrence and livelihood strategies on mount elgon slopes, eastern uganda*, Nelson Mandela Metropolitan University.

Mugagga, F., Buyinza, M. & Kakembo, V., 2010. Livelihood diversification strategies and soil erosion on Mount Elgon, Eastern Uganda: A socio-economic perspective. *Environmental Research* …. Available at: http://www.medwelljournals.com/fulltext/?doi=erj.2010.272.280.

Ngecu, W.M., Nyamai, C.M. & Erima, G., 2004. The extent and significance of mass-movements in Eastern Africa: case studies of some major landslides in Uganda and Kenya. *Environmental Geology*, 46, pp.1123–1133.

Okuyama, Y. & Sahin, S., 2009. Impact Estimation of Disasters A Global Aggregate for 1960 to 2007. *Policy Research Working Paper, The World Bank*, 4963.

Petley, D., 2012. Global patterns of loss of life from landslides. *Geology*, 40(10), pp.927–930.

Petrucci, O. & Gullà, G., 2009. A simplified method for assessing landslide damage indices. *Natural Hazards*, 52(3), pp.539–560.

Rose, A., 2004. Defining and measuring economic resilience to disasters. *Disaster Prevention and Management*, 13(4), pp.307–314.

Sen, A., 2001. *Development as Freedom* 2nd ed., New York: Oxford University Press.

Stata Press, 2013. *STATA TREATMENT-EFFECTS REFERENCE MANUAL : POTENTIAL OUTCOMES / COUNTERFACTUAL OUTCOMES Release 13*,

StataCorp, 2015. Stata Statistical Software: Release 14.

Taylor, R.G., Mileham, L., Tindimugaya, C. & Mwebembezi, L., 2009. Recent glacial recession and its impact on alpine riverflow in the Rwenzori Mountains of Uganda. *Journal of African Earth Sciences*, 55(3-4), pp.205–213.

Thanapackiam, P., Khairulmaini, O.S. & Fauza, a. G., 2012. Vulnerability and adaptive capacities to slope failure threat: a study of the Klang Valley Region. *Natural Hazards*, 62(3), pp.805–826.

The World Bank, 2000. *Designing household survey: Questionnaires for developing countries*, Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/15195/multi_page.pdf?sequence=1.

The World Bank, 2015. Ugandan Purchasing Power Parity. Available at: http://data.worldbank.org/indicator/PA.NUS.PPP.

Toya, H. & Skidmore, M., 2007. Economic development and the impacts of natural disasters. *Economics Letters*, 94(1), pp.20–25.

UBOS, 2014. *2014 Population and Housing Census: preparatory files for planning*, Kampala, Uganda.

UNDP, 2014. Uganda Poverty Status Report 2014. *Ministry of Finance, Planning and Economic development*, (November).

UNISDR, 2015. *Making Development Sustainable: The Future of Disaster Risk Management. Global Assessment Report on Disaster Risk Reduction*, Geneva, Switzerland.

USGS, 2014. Shuttle Radar Topography Mission, 1 Arc second scenes SRTM1N00E030V3, SRTM1N00E029V3, SRTM1S01E030V3, SRTM1S01E029V3, Unfilled Unfinished, Global Land Cover Facility, University of Maryland, College Park, Maryland, February 2000.

Vranken, L., Van Turnhout, P., Van den Eeckhaut, M., Vandekerckhove, L. & Poesen, J., 2013. Economic valuation of landslide damage in hilly regions: A case study from Flanders, Belgium. *Science of the Total Environment*, 447, pp.323–336.

Wisner, B., 2001. Capitalism and the shifting spatial and social distribution of hazard and vulnerability. *Australian Journal of Emergency Management*, 16(2), pp.44–50.

Wisner, B., Blaikie, P., Cannon, T. & Davis, I., 2003. At risk: natural hazards, people's vulnerability and disasters (Part 1). In *At risk: natural hazards, people's vulnerability and disasters*. p. 134.

Wolfe, B.L. & Behrman, J.R., 1984. Who is schooled in developing countries? The roles of income, parental schooling, sex, residence and family size. *Economics of Education Review*, 3(3), pp.231–245.

6 Appendix

The results of reduced form regressions of the OLS regressions presented in the manuscript are displayed in Table A1. Results are very similar to the results which include all covariates, illustrating the robustness of the analysis.

Table A1: Results of the reduced form Ordinary Least Square (OLS) regressions with village fixed effects on income per adult equivalent per day from agriculture (1-3) or total income per adult equivalent per day (4-6). t statistics in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

Equation number	(1)	(2)	(3)	(4)	(5)	(6)

Dependent variable	Log(Income agriculture)	Log(Income agriculture)	Log(Income agriculture)	Log(Income)	Log(Income)	Log(Income)
Experience with landslides						
LS	-0.178* (-1.84)			-0.158* (-1.70)		
% of land affected by most recent landslide		-0.00978*** (-3.67)			-0.00824*** (-3.18)	
% of land affected by landslides up to 1 year ago			-0.00925** (-2.33)			-0.00675* (-1.80)
% of land affected by landslides between 1 and 2 years ago			-0.00873** (-2.28)			-0.00552* (-1.65)
% of land affected by landslides between 2 and 4 years ago			-0.00739 (-1.54)			-0.00877** (-1.98)
% of land affected by landslides more than 4 years ago			0.127 (0.34)			0.0279 (0.08)
Control variables on productive capital						
TotArea	0.330*** (4.65)	0.307*** (4.57)	0.292*** (4.31)	0.257*** (4.25)	0.237*** (4.11)	0.223*** (3.82)
Control for human and social capital						
_cons	6.699*** (23.34)	6.764*** (22.67)	6.817*** (22.16)	7.145*** (25.34)	7.197*** (24.36)	7.240*** (23.09)
Village FE	Yes	Yes	Yes	Yes	Yes	Yes
N	450	450	450	450	450	450
r2	0.324	0.343	0.346	0.303	0.319	0.322
F	15.020	15.270	14.712	7.503	7.790	7.475

The results of the treatment-effects estimation with augmented inverse probability weighting is displayed in Table A2. This treatment estimation model uses a probit estimation to estimate the likelihood to be treated. The specification of this model is similar to the model presented in Equation 1, except that the variables *Job* and *PerCash* have been omitted. As these variables are modified by the occurrence of a landslide, they cannot be used to estimate the likelihood to be treated. A linear model is subsequently used to estimate the impact of the treatment on households. This linear model makes use of the same variables as Equation 1, including *Job* and *PerCash*. Both estimations use sub-county fixed-effects, rather than village fixed-effects, to allow the common support hypothesis to hold.

Table A2. Result of the treatment-effects estimation with augmented inverse probability weighting on income per adult equivalent per day from agriculture (1) and total income per adult equivalent per day (2). z statistics in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

Equation		(1)	(2)
Dependent variable		Log(Income Agriculture)	Log(Income)
Average Treatment Effect (ATE) of a landslide		-0.16 (-1.91)*	-0.11 (-1.47)
Over-identification test on balanced covariates	Chi2(21)	3.87	3.87
	Prob > chi2	1	1
Observations		450	450