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**Disaster risk reduction among households exposed to landslide hazard: a crucial role for coping appraisal?**

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## Abstract

Natural hazards have a large impact on household livelihoods worldwide, especially in the Global South. Yet, literature on the adoption of risk reduction measures at household level remains scattered and inconclusive. This study combines geographical data with an original cross-sectional household survey to investigate the relation between individual land use plans and both exposure to and experience with a natural hazard. Regressions are used to test the protection motivation theory (PMT) and to investigate the link between intentions to plant trees to reduce landslide risk and past experiences, actual exposure, perceived threat and perceived capacity to prevent the occurrence of landslides. The results show that respondents in our study area in Uganda are well aware of landslide risk and believe trees are effective in landslide susceptibility reduction. Yet, those farmers that would benefit most from reducing landslide susceptibility by planting trees have the lowest intention to do so. A low self-efficacy among exposed farmers is proposed to explain this result. This finding has important implications for disaster risk reduction and land use policies and leads to recommendations on how governments and development agents should communicate about landslide risk.

**Key Words**: Natural hazard, disaster prevention measures, protection motivation theory, sub-Saharan Africa, self-efficacy

**JEL classification:** D1, D8

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# 1 Introduction

Landslides are defined as "the movement of a mass of rock, debris or earth down a slope". As they are causing small, but sometimes frequent events that affect millions of people worldwide, landslides have been called 'an extensive disaster' (Cruden and Varnes, 1996; UNISDR, 2013). The Sendai Framework for Disaster Risk Reduction (DRR) stresses the importance of an "all-of-society engagement", fostering an "inclusive, accessible and non-discriminatory participation" towards disaster risk reduction (UNISDR, 2015a). This aligns with the idea of an integrated risk management, which combines the implementation of risk reduction measures at both household (HH) and aggregated level (Bubeck et al., 2013; De Moel et al., 2011). The dispersed, small-scale character of landslides limits the scope for hazard-preventing measures and land use planning at an aggregate policy level. Therefore, disaggregated land use planning at household level is important in landslide prone areas and this holds particularly for remote and developing regions where protection provided by the state is limited (UNISDR, 2015a, 2015b).

Recent research finds, however, that the adoption of precautionary measures, like *ex ante* land use planning for risk prevention and mitigation, among exposed populations is often limited (Bubeck et al., 2012). Moreover, correlations between risk perception and the intention to adopt mitigation measures is generally weak (Bubeck et al., 2012; Wachinger et al., 2013). The weakness of this correlation has led to the term 'risk perception paradox', which has been explained by various theoretical arguments (Wachinger et al., 2013). A first possible reason is related to a methodological problem of unaddressed reversed causality in cross-sectional studies (Weinstein and Nicolich, 1993). Previously adopted disaster risk reduction measures among populations with a high risk perception might negatively affect the current intention to take measures. Cross-sectional studies that do not take this into account can therefore erroneously find that more exposed individuals have a low intention to take measures (Siegrist, 2012).

Another set of explanations for this 'paradox' relates to individual decision making: the benefits of not taking measures might outweigh costs; individual HHs might not feel responsible for taking precautionary measures (lack of agency); or they could lack access to necessary resources (Wachinger et al., 2013). Finally, the protection motivation theory (PMT) has proposed non-rational psychological explanations for the lack of precautionary measures among exposed HHs (Grothmann and Reusswig, 2006; Rogers, 1983, 1975). In the PMT, developed by Rogers (1975, 1983), decision making in response to threats is determined by both the individuals' threat appraisal and their coping appraisal. The model is related to the theory of reasoned action and the social cognitive theory (Ajzen, 1991; Bandura, 1991). It has been widely used in health psychology and is increasingly being used to explain protective behaviour in the presence of natural hazards (Grothmann and Reusswig, 2006; Milne et al., 2000; Poussin et al., 2014). Frequently, these studies argue that both threat appraisal and coping appraisal should be high in order to foster protective behaviour (e.g. de Boer et al., 2015; Grothmann and Reusswig, 2006).

As climate change and population growth are expected to increase the frequency and severity of disaster impacts, understanding the factors that determine the adoption of mitigation measures at HH level is crucial for developing adequate policies around the world. This is particularly relevant for countries in the Global South, as these are most likely to be severely affected by climate change (UNISDR, 2015a). To our knowledge, land use planning to reduce landslide risk in the Global South has received limited attention as compared to e.g. land use planning for floods in Western countries (Kellens et al., 2013; Tierney et al., 2001)[3]. Yet, it is recognized that differences in culture, institutional context and nature of the risk are all likely to be important factors that shape responses to threats (Tansey and O'riordan 1999; Kellens et al. 2013).

The objective of the current study is to investigate response intentions to landslide hazard in the socio-economic and cultural context of Uganda. In particular, we investigate the relation between exposure to landslide hazard, subjective perceptions on risk, coping capacity and trust, and intentions to plant trees. This study finds a negative correlation between exposure and intentions to plant trees and explores various explanations for this risk perception paradox. Geographical information on landslide susceptibility is combined with subjective perceptions and actual hazard experiences at the HH level, thereby allowing to disentangle the effect of exposure from actual experience and perceptions. Our database is unique since it combines information from a structured HH survey with an estimation of landslide exposure and information on the intentions to implement a specific mitigation measure at plot level.

# 2 Theoretical framework

## 2.1 The protection motivation theory and the risk perception paradox

The protection motivation theory (PMT) relates the intention of an individual to adopt protective measures to its threat appraisal and its coping appraisal (Grothmann and Reusswig,

[3] An important exception is the recent study on drought in Ethiopia (Gebrehiwot and van der Veen, 2015).

2006; Rogers, 1983, 1975)[4]. The threat appraisal factor consists of a perceived susceptibility and a perceived severity component, which respectively measure the perceived likelihood that a devastating event occurs and the perceived impact this event can have upon occurrence. The coping appraisal factor, on the other hand, consists of an individual's self-efficacy, which is the perceived capacity of this individual to take action, and the protective response efficacy, which is the perceived efficacy of a specific protective response (Grothmann and Reusswig, 2006; Zaalberg et al., 2009)[5]. A growing body of literature stresses the importance of coping appraisal for the intention to adopt mitigation measures against natural hazards (Grothmann and Reusswig, 2006; Poussin et al., 2014; Zaalberg et al., 2009).

Some debate still exists regarding the relation between the various components of the PMT. While some researchers argue that the relation between the various components is merely additive, others argue that multiplicative interactions could arise between the aggregate factors of threat and coping appraisal. A detailed overview of this theoretical debate is presented in the Appendix A3. Following the multiplicative interpretation, recent studies that made use of the PMT argue that a high threat appraisal combined with a low coping appraisal could lead to a non-protective response, like fatalism and wishful thinking (e.g. Grothmann and Reusswig, 2006; Zaalberg et al., 2009). A non-protective response thus arises among individuals who know there is a hazard, but do not trust their own capacity to do something about it.

The strength of the PMT is that it does not assume strict rationality of the agents and allows for heuristics and biases (Martin et al. 2007; Tierney et al. 2001). It does not make the frequent assumption that high risk perception will automatically lead to personal protection and thereby offers an explanation for the risk perception paradox (Tierney et al., 2001; Wachinger et al., 2013). While the PMT theory aims at explaining the intention to adopt protective measures, a strong correlation between intention and actual implementation of the protective measure has been observed in previous studies (Ajzen, 1991; Fishbein and Ajzen, 1975).

[4] There are several alternative models to explain protective intentions, like the Protective Action Decision Model (PADM) and the Trans-theoretical model (TTM). Lindell and Perry (2012) compare the PADM and the PMT. They argue that the PMT's emphasis on self-efficacy might be more relevant in case the focus is on one single protective action, while a focus on task demands, like in the PADM, is more relevant when several measures are to be compared (Lindell and Perry, 2012). As we will look at one single protective response, we make use of the PMT. Some researchers have integrated the PMT with the Trans-theoretical model (TTM) to investigate differences between individuals at various stages of preparedness (Martin et al. 2007; Gebrehiwot & van der Veen 2015). As we investigate only one specific hazard reduction measure, instead of a general stage of preparedness, the PMT-TTM combination is not relevant for our research.

[5] The concept of self-efficacy is related to the concept of locus-of-control (LoC), but differs from the latter in that it directly refers to a specific behavioural capability (Smith, 1989). It is also very similar to the concept of 'perceived behavioural control' used in the Theory of Planned Behaviour (Ajzen, 1991) and 'sense of power' in Lin et al. (2007).

Besides threat appraisal and coping appraisal, it has been shown that the actual experience of a disaster influences the protection motivation through a pathway which is not fully mediated by these two elements alone (Wachinger et al., 2013). Decision-making is determined by affect and emotions, which are linked to direct and indirect experiences of a certain disaster and therefore influences willingness to take measures in a way which is not only mediated by cognitive threat appraisal and coping appraisal (Slovic et al. 2004; Zaalberg et al. 2009; Miceli et al. 2008; Peek and Mileti 2002)[6].

Additionally, various studies mention various component of "trust" as important determinants of mitigation intentions (Lin et al., 2007; Paul et al., 2016; Schad et al., 2011). As these studies have not made use of the PMT, it is not clear how this trust is mediated by threat and coping appraisal. On the one hand, trust in public risk reduction measures, and related, a lack of sense of personal responsibility, have been shown to be negatively correlated with mitigation intentions (Kellens et al., 2013; Plümper et al., 2017; Schad et al., 2011). While public risk reduction is limited in developing countries, reliance on social networks and NGO's could have a similar effect for response measures (Maes et al., 2017b). Throughout this manuscript we will call this aspect of trust "reliance on others". On the other hand, trust in media and other potential sources of information about disaster risk have been shown to have a positive effect on mitigation intentions (Lin et al. 2007; Reid and Vogel 2006; Tierney et al. 2001). In our study area, information about landslide risk is mainly provided by persons living nearby, like family, neighbours and potentially extension agents. In the subsequent sections we will call this aspect of trust "trust in information sources".

Previous applications of the PMT have not taken into consideration the possibility of feedback loops between previously adopted risk reduction measures, threat appraisal and intentions to adopt measures. Such feedback loops could explain the low correlations that are generally found between threat appraisal and intention to take measures (Siegrist, 2012; Weinstein and Nicolich, 1993). While time-series data are most suitable to address this concern, a careful formulation of the question and the inclusion of previously adopted measures as control variables in the analysis may partially address this concern (Bubeck et al., 2012; Siegrist, 2012).

## 2.2 Landslide risk reduction

Despite being the fourth most lethal hazard in 2015, landslides have received limited attention in the literature on the individual intentions to adopt measures against risks (CRED, 2016). This

[6] This is related to what has been called 'availability bias', described as "situations in which people assess the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind" (Tversky and Kahneman (1982) cited in Gallagher (2014)).

is surprising, as the spatial distribution of landslide susceptibility is quantifiable and therefore provides an interesting, external source of spatial variability. Moreover, as landslide susceptibility can be modified by various local interventions – including soil drainage, use of stabilizing vegetation and slope engineering – individual HHs can take steps towards hazard prevention (Maes et al., 2017a). This distinguishes small-scale landslides from large-scale natural hazards, like floods, earthquakes and droughts, against which individual HHs cannot easily take hazard-preventing measures. The few studies that investigated HHs' willingness to adopt measures against landslides have neither exploited the spatial factor in landslide susceptibility, nor the preventive potential of HHs with regard to this hazard (e.g. Damm et al. 2013; Lin et al. 2007; Nathan 2008).

There are many structural and non-structural mitigation measures against landslides (Vaciago 2013; Maes et al. 2016a), yet most of these measures are neither technically nor financially feasible for farmers in remote rural areas of the Global South. While not being a silver bullet, planting trees (Fig. 1) stands out as one prevention measure that is within reach of local farmers and that has been proposed for landslide hazard reduction in Uganda and abroad (Mugagga et al., 2012; OPMRU, 2010; Sidle and Ochiai, 2006). Trees stabilize slopes by increasing cohesion with their roots and by increasing evapotranspiration (Reubens et al., 2007; Sidle and Ochiai, 2006). Considering their other benefits, like affordability, provision of food, fibre and fuel, as well as soil erosion control, planting trees is an attractive preventive measure against shallow landslides which remains within technical and financial reach of HHs in rural regions of the Global South.

*Figure 1: Eucalyptus trees stabilising the foot slope of an ancient landslides in Uganda*

## 3 Materials and methods

### 3.1 Study area

This study was conducted in the Rwenzori mountains in Western Uganda. These mountains cover an area of ca. 3000 $km^2$, spread over four districts, *i.e.* Bundibugyo, Kabarole, Kasese and Ntoroko, which together consist of over 31 sub-counties (Fig. 2).

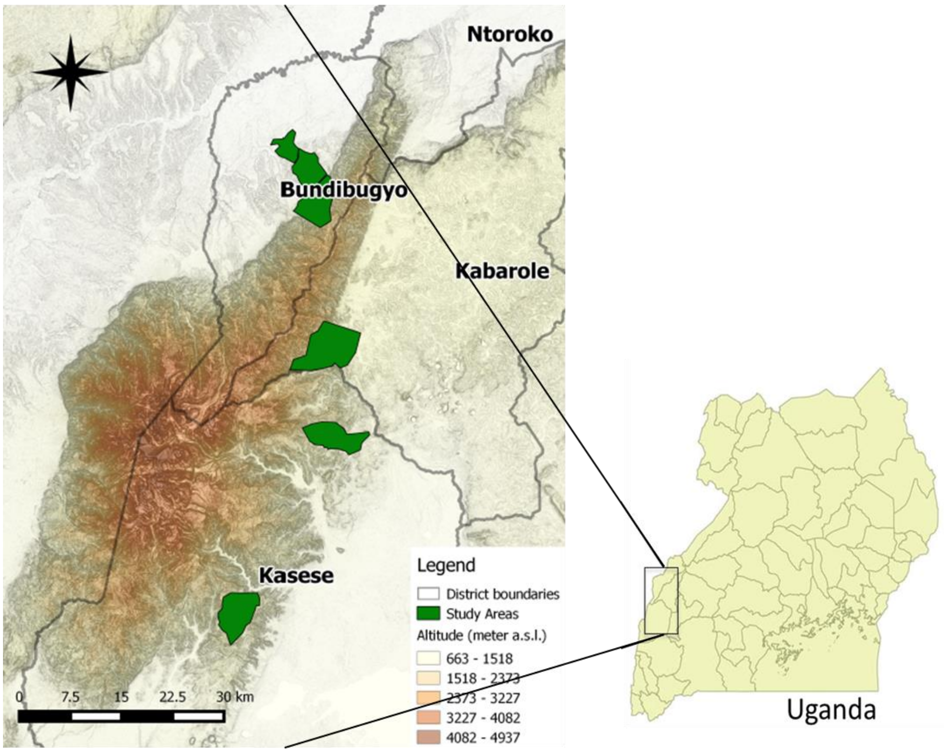


*Figure 2: Overview of the study area. The Rwenzori Mountains are located at the Western border of Uganda (inset). Colours show the elevation range and darker areas have a steeper slope. Green areas indicated the sub-county investigated in the survey (adapted from Mertens et al. (2016)).*

During the two rainy seasons, from September to December and from March to May, and following seismic activities, shallow and deep-seated landslides occur at all elevations in the Rwenzori region, ranging from the glaciated peaks at 5,109 m a.s.l. to the lowlands in Bundibugyo district at altitudes <1,000 m a.s.l. (Jacobs et al., 2017a). A recent study has shown that landslides have a significant impact on farmers' income in the region, therefore seriously affecting people's livelihoods (Mertens et al., 2016). Lack of formal insurance mechanisms or other coping mechanisms, compels farmers to rely on social networks and emergency measures to cope with income shocks following landslides (Mertens et al., 2016). Moreover, 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 et al. 2016a; Jacobs et al. 2016c). This suggests that landslide risk reduction measures are limited or dysfunctional in the area.

One landslide risk reduction measure, *i.e.* planting trees, is nevertheless readily available. Access to tree seedlings is relatively high in the region, as seeds can be obtained for a small price at the botanical garden in Fort Portal and local NGO's like the Red Cross frequently distribute seedlings among farmers in the region. The biggest costs associated to planting trees are the plastic material for breeding the seedlings, as well as opportunity costs for land and labour. Yet, as trees can be planted along the parcels borders, the cost of the latter should be minimal. To our knowledge, no other mitigation measure than planting trees is regularly adopted against landslides in our study area.

### 3.2 The survey

A questionnaire was administered to a stratified two-stage random sample of 401 households (HHs) in 41 villages in the area. The villages were purposefully stratified on the presence of recent landslides, while also the HHs in each village were stratified on whether they had been affected by a landslide in the previous 15 years. Villages and HHs affected by landslides were identified upfront, respectively through workshops at district level and village-level interviews with local chair persons (see Mertens et al., 2016). We visited the HHs a first time in February-March 2015, during which most questions were asked, and a second time in August-September 2016, during which additional plots were mapped and a game was played to elicit risk preferences of the HH head. Only HHs that were interviewed in both rounds are included in the analysis. Attrition in our sample is very low (3%). During data cleaning we dropped four HH for which we have too much missing data because the HH head did not allow us to finish the whole questionnaire. Our final sample thus contains 397 HHs. An overview of the sample characteristics is given in Table 1.

The interviews were conducted in the local languages (Lukonzo, Lutooro or Lubwissi). Careful attention was given to the translation of the questions because of the importance of subjective questions in our analysis. Our 16 enumerators are native speakers for each of the three major languages in the region.

The questions for the current study were part of a questionnaire that collected detailed information at HH level and plot level in 2015. The first two sections of the questionnaire introduced the researcher and inquired about HH demographics. Subjective questions on self-efficacy, perceptions of landslide threat, perceived efficacy of resilience measures against landslides, as well as on the intention to adopt such measures were asked in the third section (Table 2). Care was taken not to reveal our interests in landslides in particular before the end of the third section. Therefore questions about perceptions on landslides were alternated with questions about soil erosion (not shown or analysed here). A question on the perceived landslide susceptibility was asked at plot level in section four. GPS points were taken in front of the houses and on the corners of each plot owned or cultivated by the HHs. Because some plots could not be mapped due to refusal by the owner or excessive distance from the house, a total of 782 plots, or 75 % of the 1038 plots in our sample, was mapped with a GPS. Susceptibility at HH level was estimated from those plots that have been mapped[7].

Risk aversion, or the concavity of the value function, was elicited through a lab in the field experiment with real monetary pay-offs, as described in Tanaka et al. (2016). This method consists of presenting 35 choice sets with binary lotteries that involve gains and losses with different probabilities. After every interview, one of these choice sets is randomly selected to be played for real monetary pay-off.

The actual exposure of the HHs to landslide susceptibility was obtained by first calculating the susceptibility at plot level in a buffer of 30 meters around each plot, and subsequently averaging this value at the HH level[8]. The landslide exposure thus calculated at HH level was then normalized over the whole sample. Landslide susceptibility data were obtained from a regional landslide susceptibility map produced at the 30m resolution through logistic regression modelling using field inventories to calibrate and validate the model (Jacobs et al., 2017b). The main variables taken into account for this susceptibility assessment are topographic variables such as slope gradient, curvature, topographic wetness and aspect, prevailing lithology and average annual precipitation.

## 3.3 Statistical methods

### 3.3.1 Data handling

The respondent's willingness to plant trees was explicitly enquired for with the question "If I had plots in landslide-prone area, I would plant trees to prevent landslides from happening", rated on a five-point bipolar Likert scale (Table 2). This general and hypothetical wording aimed at making the answer independent of the actual perception on landslide susceptibility or the effect of tree planting actions previously taken. The perceived landslide susceptibility was asked with a yes/no question at plot level and then averaged at HH level. The other psychological variables, like perceived severity of landslide impact, perceived efficacy of

[7] While 75% of the plots have been mapped, nearly half of the households in the sample have at least one plot that was not mapped. Dropping all the households for whom at least one plot was not mapped strongly reduces the sample size and the significance of our results.

[8] During robustness checks, also a buffer size of 15 m around the plots was tested, not yielding any different result. We also ran our analysis with the exposure of the most exposed plot only, rather than the exposure averaged over all the plots at household level. This did not change the results.

planting trees, self-efficacy with regard to preventing landslides, trust in information sources and reliance on others were grasped by a combination of several questions (Table 2).[9]

Following Lin et al. (2007) we first used an exploratory factor analysis on all our questions to investigate the correlations between the questions and check if it indeed makes sense to group the questions according to the PMT variables. Subsequently, we did not use the factors but grouped the relevant questions into their respective variable by simple summing up the Likert values. As compared to recent applications of the PMT on the adoption of disaster risk mitigation measures, the Cronbach' alpha coefficients in Table 2 are good, except for "trust in information" and "reliance on others", which yield only moderate alphas (Martin et al. 2007; Gebrehiwot and van der Veen 2015).

*Table 1. Overview of the sample characteristics (standard deviations between brackets). A more detailed overview, split by degree of exposure to landslides, is given in the Appendix A.1.*

| | Acronym | All<br>Mean<br>(sd) |
|---|---|---|
| **Exposure** | | |
| Calculated landslide exposure<br>[Min = -2.25; Median = 0.11; Max = 2.02; after normalization] | Exposure | 0.00<br>(1.00) |
| Past experience with landslides (=1 if experienced a landslide) | Experience with landslides | 0.40<br>(0.49) |
| **Respondent information** | | |
| Education respondent (years) | Education | 4.48<br>(2.61) |
| Age respondent (years) | Age | 41<br>(15) |
| Risk aversion (Higher values = more risk averse)<br>[Min = 0.1; Median = 0.9; Max = 1.5] | Risk aversion | 0.89<br>(0.53) |
| **Human, social and financial capital** | | |
| HH size (adult equivalents, OECD) | HH size | 3.50<br>(1.19) |
| Female-headed HH (=1) | Female head | 0.09<br>(0.28) |
| Total area (Ha) cultivated by the HH | Total Area | 1.12<br>(1.17) |
| Total number of plots cultivated by the HH | Total Plots | 2.86<br>(1.84) |
| The HH head nor his spouse are from this or a neighboring village (=1) | Migrant | 0.17<br>(0.38) |
| **Other factors potentially related with attitude towards trees** | | |
| HH cultivates coffee, cocoa or fruit trees on plots (=1) | Coffee, cocoa, fruit trees | 0.93<br>(0.26) |
| Average distance (km) of plots to 4WD roads | Distance road (km) | 1.86<br>(1.12) |
| Proportion of the plots cultivated by the HH that currently have trees (self-reported) | Presence of trees | 0.80<br>(0.34) |
| Proportion of the plots cultivated by the HH on which HH has once planted trees (self-reported) | % Planted | 0.70<br>(0.37) |
| **N** | | **397** |

[9] For practical and interpretational purposes, we formulated all these questions on a five-point bipolar Likert scale. Consequently, regarding self-efficacy we did not strictly follow the recommendations made by Bandura (2012), who argues that a unipolar Likert scale should be used. Yet, we formulated our questions in such a way that differences between bipolar and unipolar Likert scales were minimal (Sitzmann and Yeo, 2013).

*Table 2: Overview of the questions used to elicit the factors from the PMT. Except the question on perceived landslide susceptibility, all questions were rated in a bipolar 5-point Likert scale ranging from "Strongly disagree/Not at all" to "Strongly agree/A lot". The perceived landslide susceptibility was asked with a yes/no question at plot level and then averaged at HH (HH) level. The last column of the table shows the average and standard deviation after dichotomization (procedure explained in section 3.3.3).*

| | Questions | Acronym | Cronbach Alpha | Before dichotomizing | | | After dichot. |
|---|---|---|---|---|---|---|---|
| | | | | Average (sd) | Min | Max | Average (sd) |
| | **Intention to plant trees**<br>1. If I had plots in landslide prone area, I would plant trees to prevent landslides from happening | [WilTree] | N/A | 1.30 (1.26) | -2 | 2 | 0.85 (0.36) |
| **Threat Appraisal** | **Perceived landslide susceptibility**<br>1. Could a landslide happen on this plot? [yes/no question asked for each plot, then averaged at HH level] | [PercSusc] | N/A | 0.49 (0.42) | 0 | 1 | 0.65# (0.48) |
| **Threat Appraisal** | **Perceived severity of landslide risk**<br>1. To what extent could landslides affect the wellbeing of your HH?<br>2. To what extent could landslides cause financial losses to your HH?<br>3. To what extent would landslides threaten your life?<br>4. In general, how afraid are you of landslides?<br>5. Landslides are an important discussion topic in our family<br>6. During the rainy season my HH members frequently worry about landslides<br>7. In the next 12 months it is likely that my HH members will face hunger due to landslides<br>8. During heavy rains some of the HH members sleep outside our house due to the fear of landslides | [PercSev] | 0.87 | 6.00 (8.37) | -16 | 16 | 0.78 (0.42) |
| **Coping Appraisal** | **Perceived efficacy of planting trees to reduce landslide susceptibility**<br>1. What is the effect of planting traditional trees against landslides?<br>2. What is the effect of planting eucalyptus trees against landslides | [EffTree] | 0.73 | 2.13 (1.85) | -4 | 4 | 0.64 (0.48) |
| **Coping Appraisal** | **Self-Efficacy**<br>1. Landslides can be prevented by individual HHs<br>2. My HH can take concrete measures to prevent landslides (e.g. planting trees) | [SelfEff] | 0.80 | -2.23 (2.35) | -4 | 4 | 0.15 (0.36) |
| **Trust** | **Trust in information**<br>1. In general, I would trust a member of the government if s/he would advise me on landslide risk<br>2. In general, I would trust a member of the local NGO's and organizations if s/he would advise me on landslide risk | [TrustInfo] | 0.69 | 4.52 (2.33) | -6 | 6 | 0.93 (0.25) |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 3. In general, I would trust my neighbour if s/he would advise me on landslide risk | | | | | |
| | **Reliance on others** [Reliance]<br>1. If my HH would be affected by a landslide our family would help us with shelter, food or money<br>2. If my HH would be affected by a landslide our neighbours would help us with shelter, food or money<br>3. If my HH would be affected by a landslide, the government would help us with shelter, food or money<br>4. If my HH would be affected by a landslide, an NGO or other organization would help us with shelter, food or money | 0.66 | 2.06<br>(4.30) | -8 | 8 | 0.60<br>(0.49) |

#Regarding perceived landslide susceptibility, these values imply that 49% of the plots in our sample are perceived as landslide prone by their owners, while 65% of the HHs has at least one plot that is considered landslide prone.

### 3.3.2 Identification strategy

The variables thus obtained have been used to investigate correlations between exposure and intention to plant trees (Equation 1).

$$Y_{ije} = \alpha + \beta Exp_{ije} + \gamma X_{ije} + \mu_j + \pi_e + \varepsilon_{ije} \qquad \text{Eq. 1}$$

In this equation $Y_{ije}$ represents the intention to plant trees (WilTree) of HH i, in subcounty j, interviewed by enumerator e. $Exp_{ije}$ is the calculated exposure to landslide susceptibility at HH level. $X_{ije}$ represents a vector of covariates, as well as HH and respondent characteristics, while $\mu_j$ and $\pi_e$ are sub-county and enumerator fixed effects respectively. The error term is represented by $\varepsilon_{ije}$.

The extent to which a HH is exposed to landslide risk is not exogenous to the HH's socio-economic characteristics and individual choices, which are, in turn, likely correlated with the HH's head willingness to take measures against landslides (Lindell and Hwang, 2008; Mertens et al., 2016). We therefore did not aim at identifying a causal relation between exposure and intention to plant trees. The control variables in our model aim at ruling out some alternative pathways that could explain the correlation we find between exposure and intention to plant trees.

A first set of covariates included into Equation 1 are "experience with landslides" and "the presence of trees". Experience with landslide is measured by a dummy indicating whether the HH experienced a landslide on one of its plots in the past 15 years. Including this dummy alongside our measure of exposure allowed to disentangle the effect of exposure to landslide risk from the effect of actual experience with landslides. Our second control variable, the presence of trees, allowed to partially address the issue of reversed causality which is caused by previously taken measures.

A second set of covariates concerns characteristics of the respondent, including his/her age, education level, risk aversion, as well as proxies for human, social and financial capital at HH level. Besides the respondent's education level, human and social capital are proxied by the HH size, the migration status of the head and spouse, as well as the gender of the HH head. HHs' financial capital is proxied by total land holding (in Ha) and total number of plots owned or cultivated by the HH. We controlled for whether the HH cultivates coffee, cocoa or fruit trees, as this can positively affect the respondent's general attitude towards trees. We also took into account the average distance between plots and a road, as this determines whether trees can be sold as construction poles[10]. We included dummies for the 6 sub-counties in our study area, as well as for the 16 enumerators that conducted the survey, to respectively control for large regional differences in exposure and differences in interpretation of the subjective questions by the enumerators[11].

In a second step we used equation 1 to investigate the relation between exposure to landslide susceptibility and the subjective variables from the PMT. In this step $Y_{ije}$ alternately represents the "perceived landslide susceptibility", "perceived severity of landslides", "perceived efficacy of trees", "perceived self-efficacy", "trust in information sources" and "reliance on others". This step is necessary to understand how the results of the first step relate to the results in step three.

In a third step, the relation between the subjective variables and the intention to plant trees was investigated. We therefore fitted the following model (Equation 2).

$$Y_{ije} = \alpha + \beta_1 PercSusc_{ije} + \beta_2 PercSev_{ije} + \beta_3 EffTree_{ije} + \beta_4 SelfEff_{ije} + \beta_5 TrustInfo_{ije} + \beta_6 Reliance_{ije} + \rho X_{ije} + \mu_j + \pi_e + \varepsilon_{ije} \quad \text{Eq. 2}$$

In this equation $Y_{ije}$ represents the intention to plant trees (WilTree), while our explanatory variables are the different variables from the PMT. We included the same set of covariates as in equation one, as well as enumerator and sub-county fixed effects.

To test whether interaction effects are present between the various components of the PMT model, Equation 3 includes an interaction term between the different components.

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[10] We additionally investigated the effect of including variability in exposure between plots (rather than average exposure) at HH level, as well as the average position of the plots on the slopes. The argument for the second control variable is that HHs that have their plots at the bottom of a slope might indeed have no agency in preventing landslides, because these landslides generally start on neighbouring plots. The argument for the first control variable is that HHs with two plots with average exposure are likely different from HHs with one highly exposed and one lowly exposed plot, even though the average exposure is the same. We investigated both hypotheses, but found no evidence for these mechanisms.

[11] Without these dummies standard deviations strongly increase, reducing the significance of our results.

$$Y_{ije} = \alpha + \beta_1 PercSusc_{ije} + \beta_2 PercSev_{ije} + \beta_3 EffTree_{ije} + \beta_4 SelfEff_{ije} + \beta_5 TrustInfo_{ije} + \beta_6 Reliance_{ije} + \delta Interaction_{ije} + \rho X_{ije} + \mu_j + \pi_e + \varepsilon_{ije}$$

Eq. 3

### 3.3.3 Estimation method

Our dependent variable consists of ordered, discrete values. We therefore estimated abovementioned equations with ordered logit models[12]. Yet, the interpretation of interaction terms in non-linear models is not straightforward as it depends on the entire distribution function (see Ai and Norton (2003), Greene (2010) and (Buis, 2010) for a theoretical debate). Some scholars have therefore argued that linear probability models on dichotomized variables are preferable over non-linear models (Angrist and Pischke, 2008; Hellevik, 2009). Categorical values from a Likert scale are thereby transformed into a dummy which equals one if above zero (respondent agrees) and zero if below zero (respondent disagrees). For the sake of completeness we therefore opted to report the results of a linear probability model in the Appendix A.2. The results are similar. Mean and standard deviation of the dichotomized variables are presented in the last column of Table 2.

## 4 Results

On average, the intention to plant trees among HHs in our sample is relatively high (Table 2). So is the average perceived efficacy of trees against landsliding and the trust people have in their information sources about landslides. Self-efficacy, which is the perceived capacity that one has to do something against landslides, is however low on average. This suggests that, while people might believe that trees can reduce landslide susceptibility, they have a low confidence that they can or will take the necessary steps to plant trees to reduce landslide risk. This is similar to people who believe in the beneficial effects of physical activity for reducing weight, but do not trust their own capacity to start doing a specific sport (Bandura, 2012).

### 4.1 Exposure and intention to plant trees

A first and surprising result of this study is that farmers that are more exposed to landslide risk have a lower intention to plant trees against landslides (Regression 1 in Table 3). Regardless of any causality, this finding suggests that those HHs that would benefit most from the stabilizing effect of trees are the least likely to be actually willing to plant trees against landslides. Two potential explanations for this trend are ruled out in Regression 2 of Table 3. First, the direct

[12] During robustness checks we have estimated several models, including various non-linear models and linear probability models. We estimated ordered probit models on the ordered discrete variables, as well as logit and probit models on the dichotomized variables, all giving similar results. The blow-up and cluster estimator proposed by Mukherjee et al. (2008) also yields similar results (Baetschmann et al., 2015; Mukherjee et al., 2008).

experience with landsliding, which is correlated with the exposure to landslide risk, does not yield a significant reduction in intention to plant trees. Secondly, including a control variable for the presence of trees on the plots does not affect our results either, suggesting that the result is not a consequence of reversed causality caused by previously taken measures among exposed HHs. The inclusion of additional control variables in Regression 3 does not change the trend found in regressions one and two. The strong and negative correlation between our dummy for female-headed HHs and intention to plant trees is currently unexplained and deserves further investigation. Please note that the model fit, as measured by the pseudo $R^2$, is relatively low, but still within an acceptable range, given the subjective and discrete nature of our dependent variable.

*Table 3III: Ordered logit regression with enumerator and sub-county dummies of intention to plant trees on exposure with (columns 2 and 3) and without control variables (column 1). The variables are the same as in Table 2. Z-statistics are in parentheses (* p < 0.10, ** p < 0.05, *** p < 0.01).*

| | (1)<br>Intention to plant trees | (2)<br>Intention to plant trees | (3)<br>Intention to plant trees |
|---|---|---|---|
| Exposure | -0.35** | -0.35** | -0.36** |
| | (-2.57) | (-2.48) | (-2.42) |
| Experience with landslides | | -0.02 | 0.05 |
| | | (-0.09) | (0.19) |
| Presence of trees | | 0.63 | 0.55 |
| | | (1.60) | (1.42) |
| Education Respondent | | | 0.10** |
| | | | (2.12) |
| Age Respondent | | | 0.00 |
| | | | (0.56) |
| Risk aversion | | | -0.14 |
| | | | (-0.54) |
| HH size | | | 0.03 |
| | | | (0.24) |
| Female head | | | -0.77* |
| | | | (-1.78) |
| Total Area | | | -0.06 |
| | | | (-0.47) |
| Total Plots | | | 0.02 |
| | | | (0.33) |
| Coffee, cocoa or fruit trees | | | 1.16** |
| | | | (2.15) |
| Migrant | | | -0.15 |
| | | | (-0.38) |
| Distance to road | | | -0.14 |
| | | | (-0.85) |
| Intercept and dummies | Yes | Yes | Yes |
| N | 397 | 397 | 397 |
| r2_p | 0.10 | 0.11 | 0.13 |
| Chi2 | 62.3 | 64.5 | 77.4 |
| Prob > Chi2 | 0.00 | 0.00 | 0.00 |

## 4.2 Exposure and PMT variables

Perceived landslide susceptibility is positively correlated with previous experience with landslides, while perceived severity of landslides is positively correlated with both previous experience with landslides and exposure (Table 4). These correlations suggest that both direct experience with landslides and indirect experiences, through observing it on neighbouring plots, reasoning or discussions with family and friends, effectively increase the threat appraisal. This trend contrasts with the absence of correlation between exposure and our measures of coping appraisal. The correlation between the perceived efficacy of trees and exposure is even slightly negative, while self-efficacy does not change with exposure or with direct experience with landslides.

Some positive correlation exists between exposure and trust in information about landslides, while there is a negative correlation between experience with landslides and reliance on others. As exposure in itself is not correlated with "reliance on others", the latter suggests that support after a landslide event in the past might be smaller than expected, leading to disappointment and difficulties to cope with the shock among those affected by a landslide.

*Table 4: Ordered logit regression with enumerator and sub-county dummies of psychological variables on exposure. The dependent variables in columns 1-6 respectively are "landslide susceptibility appraisal", "perceived severity of landslides", "perceived efficacy of trees", "perceived self-efficacy", "trust in information sources" and "reliance on others". 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).*

| | Threat | | Coping | | Trust | |
|---|---|---|---|---|---|---|
| | (1) Perceived landslide susceptibility | (2) Perceived severity of landslide impact | (3) Perceived efficacy of trees | (4) Self-efficacy | (5) Trust in information sources | (6) Reliance on others |
| Exposure | 0.22 | 0.61*** | -0.30* | 0.17 | 0.28* | -0.03 |
| | (1.32) | (4.69) | (-1.78) | (1.18) | (1.80) | (-0.18) |
| Experience with landslides | 2.16*** | 1.89*** | -0.13 | -0.21 | 0.05 | -0.65*** |
| | (8.67) | (8.66) | (-0.50) | (-0.94) | (0.22) | (-2.92) |
| Presence of trees | 0.18 | 0.36 | 0.47 | 0.50 | -0.54 | -0.42 |
| | (0.55) | (1.24) | (1.12) | (1.26) | (-1.01) | (-1.15) |
| Control variables, intercept and dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 397 | 397 | 397 | 397 | 397 | 397 |
| r2_p | 0.18 | 0.10 | 0.22 | 0.15 | 0.18 | 0.05 |
| Chi2 | 183.5 | 302.2 | 158.4 | 8295# | 3537# | 94.3 |
| Prob > Chi2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

# In equation 4 and 5, some observations are completely determined by our model, explaining the very high Chi$^2$. These results should therefore be considered with care.

### 4.3 PMT variables and the intention to plant trees

From Table 2 we know that intentions to plant trees and perceived efficacy of trees are high, on average, while self-efficacy is low. Yet, the results in Tables 3 and 4 show that HHs that are more exposed to landslide risk in our sample have a lower intention to plant trees, while being well aware of the risk and having a higher threat appraisal than less exposed HHs. Our analysis thus far does not explain these results.

Table 5 presents the results of regressions of the intention to plant trees on the subjective variables from the PMT, thereby providing a tentative explanation. In a similar way as exposure to landslide risk is negatively correlated with the intention to plant trees, also perceived landslide susceptibility is negatively correlated with this intention (Regression 1 in Table 5). This may seem surprising, as it implies that farmers who are well aware of the landslide susceptibility on their plots have a smaller intention to do something about it. Less surprising is the strong and positive correlation between perceived efficacy of trees and intention to plant trees. Perceived severity of landslides and self-efficacy do not seem to be correlated with intention to plant trees.

According to the PMT, the intention to take measures against landsliding is high when both threat appraisal and coping appraisal are high (see Appendix A.3 for a more detailed discussion of the PMT). Among HHs with a high exposure in our sample, both perceived susceptibility and perceived severity of landslides, i.e. the components of threat appraisal, are high. However, the perceived efficacy of trees slightly decreases with exposure, while self-efficacy is low, regardless of exposure (Table 4). Therefore a potential explanation for the negative correlation between exposure and willingness to plant trees would be that farmers with a threat appraisal above a certain threshold fail to adopt protective responses because they fall into what the PMT calls a non-protective response trap. This would happen because coping appraisal does not increase with increasing exposure and one of its components, self-efficacy, is generally low.

According to this interpretation of the PMT, the intention to plant trees among HHs that have a coping appraisal that is sufficiently large should be positively, or at least not negatively, correlated with threat appraisal. To test this hypothesis, we interacted susceptibility appraisal with self-efficacy in Regression 2 from Table 5. Alternatively, in Regression 3, susceptibility appraisal was interacted with a dummy equalling 1 if self-efficacy is above average and 0 otherwise. The positive interaction term in regression 2, and the negative term in regression 3, suggest that the negative relation that was found between exposure to landslide susceptibility and intention to plant trees only holds when self-efficacy is low. Among HHs with a high self-efficacy, intention to plant trees is not affected by an increase in exposure to landslide susceptibility. This finding points towards a non-protective response trap, but does not confirm it. Our questionnaire did not allow to provide positive evidence for the non-protective response trap, fatalism or wishful thinking. Other interactions between the various psychological variables were also tested, but did not give any significant result.

*Table 5: 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 (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).*

| | (1)<br>Intention to plant trees | (2)<br>Intention to plant trees | (3)<br>Intention to plant trees |
|---|---|---|---|
| Perceived landslide susceptibility | -0.36**<br>(-2.10) | -0.35*<br>(-1.93) | |

| | | | | |
|---|---|---|---|---|
| | Perceived severity of landslide impact | 0.05<br>(0.29) | 0.07<br>(0.37) | 0.08<br>(0.43) |
| **Coping** | Self-efficacy | 0.05<br>(0.33) | 0.02<br>(0.11) | |
| | Perceived efficacy of trees | 0.42***<br>(2.77) | 0.41***<br>(2.65) | 0.41***<br>(2.65) |
| **Interaction** | (Self-efficacy) * (Perceived landslide susceptibility) | | 0.31**<br>(2.22) | |
| | Perceived landslide susceptibility if Self-efficacy < 0 | | | -0.67***<br>(-3.20) |
| | Perceived landslide susceptibility if Self-efficacy >= 0 | | | 0.01<br>(0.04) |
| **Trust** | Trust in information sources | 0.20<br>(1.49) | 0.21<br>(1.51) | 0.20<br>(1.43) |
| | Reliance on others | -0.17<br>(-1.07) | -0.17<br>(-1.02) | -0.17<br>(-1.03) |
| Experience with landslides | | 0.19<br>(0.54) | 0.18<br>(0.49) | 0.14<br>(0.39) |
| Presence of trees | | 0.42<br>(1.10) | 0.42<br>(1.11) | 0.45<br>(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 |

# 5 DISCUSSION

## 5.1 Interpretations of results

The first key result of our analysis is a negative correlation between exposure to landslide susceptibility and intention to plant trees. By investigating the relation between exposure and the subjective variables, we subsequently showed that the respondents are well aware of the threat caused by landslides and, on average, consider planting trees as an efficient measure to reduce the susceptibility. Additionally, we found that exposure to landslide susceptibility was only negatively related to intention to plant trees among HHs with a low self-efficacy. Such a trend was not found among HHs with higher levels of self-efficacy. Our findings were framed by means of the PMT, asserting that individuals who feel highly threatened by landslides and have a low self-efficacy might resort to non-protective responses[13].

Alternative explanations for our findings definitely exist. First, planting trees could be considered as a long-term investment for the production of wood or fruits. Farmers might be less willing to plant trees in more landslide-prone regions because of the higher risk of losing this investment. By explicitly asking for “the willingness to plant trees to prevent landslides from happening” we tried to avoid this problem. Second, the commercial value of trees is highly dependent on the potential for easy transportation and thus the distance from the plot to an accessible road. If remote areas are more susceptible to landslides, the willingness to plant trees

[13] We did not attempt to explain why farmers do not believe they can do something to prevent landslides from happening (i.e. the low self-efficacy). This could be related to technical constraints for planting trees on steep slopes, large (opportunity) costs related to trees, a general discourse about nature which cannot be influenced by human interventions, problems of collective action on slopes with many different owners, or other.

could be lower because of the larger distance to roads. We have tried to address this problem by including a control variable for the distance to roads. Finally, despite our efforts to address this problem, our finding could still be attributed to the presence of other risk reduction measures among exposed HHs. While we have not found any evidence for such measures during fieldwork, only long-term panel data could provide a definite answer on this matter.

It is important to stress that the observed trend does not imply a causal relation between exposure and the intention to plant trees. An obvious risk reduction measure which is not taken into account in our analysis is to get rid of plots in landslide-prone area. This can be done by selling these plots, or migrating out, but also by buying only plots that are outside landslide-prone areas. Many processes and HH characteristics, like attitudes towards risks, could both determine exposure and the intention to plant trees and therefore prevent us from making causal claims. Yet, regardless of any causality, the results shown in this manuscript illustrate that those farmers that would benefit most from reducing landslide susceptibility by planting trees have the smallest intention to do so.

Finally, one should not disregard the importance of differences across socio-economic status for taking protective measures (Tierney et al. 2001; Wachinger et al. 2013). Socio-economic characteristics, culture and the nature of the risk all play important roles in differentiating behaviours between individuals and locations (Tansey and O'riordan 1999). While these factors can be mediated by psychological factors, like self-efficacy, to a great extent, understanding their role is important for the development of tailored policies.

### 5.2 Comparison with literature

Most studies on the intentions to take mitigation measures against disasters find a positive correlation between threat appraisal and mitigation intention (e.g. Gebrehiwot and van der Veen 2015; Zaalberg et al. 2009; Lin et al. 2007). Our study demonstrates an opposite trend among HHs with a low self-efficacy. This negative trend is not observed among HHs with a higher self-efficacy. While we do not have a conclusive explanation, the difference with other studies can be attributed to several reasons.

First, average self-efficacy in other studies could have been larger than in our sample, above the hypothesised threshold which causes threat appraisal to lead to non-protective responses. While most studies have found that coping appraisal is positively correlated with mitigation intentions, they did not include an interaction term between threat appraisal and coping appraisal. Our findings provide some evidence for a multiplicative interaction between the various components of the PMT. Secondly, the cultural, economic and environmental context in our study area is very different from other studies, as we deal with an extensive disaster in a remote rural area in Uganda. Fatalism or beliefs in the ‘act of nature’ or the ‘act of God’ might be stronger in our study than in other studies. Finally, other studies have considered the intention to adopt preparedness measures, rather than preventive measures. Perceptions with regard to preparedness measures might be different from the perceptions on preventive measures.

### 5.3 Implications for landslide risk communication

Besides increasing our understanding of human behaviour in the presence of risks, the PMT is particularly useful to guide policies that aim at increasing the adoption of land use plans for disaster risk reduction at the individual or HH level. 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 this manuscript, 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.

On the other hand, self-efficacy with regard to planting trees against landsliding is very small in our study area. An option for policy maker would be to increase farmers’ self-efficacy with regard to taking specific measures against landslides. This is a challenging task. Self-efficacy is enhanced by “enactive attainments”, “vicarious experiences”, “verbal persuasion” and “psychological state” (Bandura, 1982). Enactive attainments, or *own experience*, and vicarious experiences, or *observing others*, are most influential in determining self-efficacy. A development agent aiming at increasing self-efficacy among farmers in the Rwenzori region could therefore opt for demonstration plots and verbal persuasion of selected farmers to plant trees and act as examples to other farmers. Workshops and agricultural trainings in the region could include a session informing the farmers about their capacity to plant trees for preventing landslides. Yet, further research on effective actions that empower farmers and increase their self-efficacy towards the implementation of proper disaster risk reduction strategies is required (Wauters et al., 2010).

## 6 Conclusions

In this manuscript we combined a theoretical framework, the PMT, with statistical data analysis to derive a tentative explanation for the negative correlation between exposure to landslide susceptibility and intentions to plant trees to reduce this susceptibility. We show that farmers are well aware of the threat caused by landslides and consider planting trees as an efficient measure to reduce the susceptibility. Yet, respondents with a low self-efficacy in our sample have a lower intention to plant trees if they are more exposed to landslide susceptibility.

This finding entails some policy recommendations. While further increasing awareness about landslide risk in the region might be of limited use, campaigns to improve self-efficacy among exposed farmers seem desirable, as well as policies to overcome financial, political, social or cultural barriers towards effective adoption of disaster risk reduction measures. This would comply with the current objectives of the Sendai Framework for Disaster Risk Reduction, which aims at building a culture of resilience (UNISDR, 2015a). We therefore consider the findings of this paper to be a first step towards a better land use policy and the reduction of landslide risks in the area.

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# Appendix

## Appendix A

*Table A.1: Overview of all the variables, after normalization, as they will be used in the regressions. Means and standard deviations (sd) are given for the whole sample and for households (HHs) with a low, medium and high exposure to landslide risk. Ttests on differences between exposure groups are given between the columns. HHs were grouped in three exposure groups by making three more or less equal groups based on Average exposure +- 0.5*Sd.*

| | | Acronym | All | Low Susc. (<= -0.5) | Ttest low-medium | Medium Susc (> -0.5 and < 0.5). | Ttest medium-high | High Susc. ( >= 0.5) |
|---|---|---|---|---|---|---|---|---|
| | | | Mean (sd) | Mean (sd) | | Mean (sd) | | Mean (sd) |
| **Exposure** | | | | | | | | |
| | Calculated landslide exposure [Min = -2.25; Median = 0.11; Max = 2.02; after normalization] | Exposure | -0.00 (1.00) | -1.19 (0.43) | *** | -0.00 (0.28) | *** | 1.00 (0.32) |
| | Past experience with landslides (=1 if had a landslide) | Landslide | 0.40 (0.49) | 0.27 (0.45) | | 0.35 (0.48) | *** | 0.53 (0.50) |
| **Subjective questions** | | | | | | | | |
| | Intention to plant trees | WilTree | 1.30 (1.26) | 1.48 (1.12) | * | 1.20 (1.35) | | 1.21 (1.31) |
| Threat | Perceived landslide susceptibility | SusApr | 0.49 (0.42) | 0.44 (0.43) | | 0.47 (0.42) | | 0.54 (0.40) |
| Threat | Perceived severity of landslide impact | PercSev | 6.00 (8.37) | 3.61 (8.58) | ** | 6.07 (8.19) | * | 7.96 (7.82) |
| Coping | Perceived efficacy of trees | EffTree | 2.13 (1.85) | 2.08 (1.88) | | 2.23 (1.80) | | 2.10 (1.87) |
| Coping | Self-efficacy | SelfEff | -2.23 (2.35) | -2.52 (2.14) | | -2.36 (2.49) | | -1.91 (2.40) |
| Trust | Trust in information sources | TrustInfo | 4.52 (2.33) | 4.79 (2.05) | | 4.50 (2.24) | | 4.30 (2.58) |
| Trust | Reliance on others | Reliance | 2.06 (4.30) | 2.81 (4.19) | | 2.55 (4.22) | *** | 1.10 (4.30) |
| **Respondent information** | | | | | | | | |
| | Education respondent | EducResp | 4.48 (2.61) | 4.67 (2.50) | | 4.20 (2.70) | | 4.52 (2.64) |
| | Age respondent | AgeResp | 41.22 (15.41) | 40.84 (15.22) | | 42.66 (15.32) | | 40.58 (15.66) |
| | Risk aversion (Higher values = more risk averse) [Min = 0.1; Median = 0.9; Max = 1.5] | Risk aversion | 0.89 (0.53) | 0.88 (0.54) | | 0.89 (0.54) | | 0.90 (0.51) |
| **Human, social and financial capital** | | | | | | | | |
| | HH size (adult equivalents) | HH size | 3.50 (1.19) | 3.59 (1.17) | | 3.53 (1.12) | | 3.39 (1.24) |
| | Female-headed HH (=1) | Female head | 0.09 (0.28) | 0.11 (0.31) | | 0.09 (0.28) | | 0.08 (0.26) |
| | Total area (Ha) cultivated by the HH | Total Area | 1.12 (1.17) | 1.06 (1.34) | | 1.18 (1.11) | | 1.14 (1.05) |
| | Total number of plots cultivated by the HH | Total Plots | 2.86 (1.84) | 2.32 (1.52) | *** | 3.09 (2.18) | | 3.16 (1.74) |
| | The HH head nor his spouse are from this or neighboring village (=1) | Migrant | 0.17 (0.38) | 0.12 (0.33) | | 0.18 (0.39) | | 0.21 (0.41) |
| **Other factors potentially related with attitude towards trees** | | | | | | | | |
| | Has coffee, cocoa or fruit trees on plots (=1) | CoCoFr | 0.93 (0.26) | 0.92 (0.28) | | 0.91 (0.28) | | 0.94 (0.23) |
| | Average distance of plots to roads (km) | DistRoad | 1.86 (1.12) | 2.14 (1.29) | | 1.93 (1.24) | *** | 1.58 (0.78) |
| N | | | 397 | 133 | | 105 | | 159 |

Standard deviation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

## Appendix B

*Table A.2: Results of the ordinary least squares estimation with enumerator and sub-county dummies of intention to plant trees on exposure with (columns 2 and 3) and without control variables (column 1). The variables are the same as in Table 2. T-statistics are in parentheses (* p < 0.10, ** p < 0.05, *** p < 0.01).*

| | (1)<br>Intentions to plant trees | (2)<br>Intentions to plant trees | (3)<br>Intentions to plant trees |
|---|---|---|---|
| Exposure | -0.048** | -0.046** | -0.049** |
| | (-2.28) | (-2.06) | (-2.20) |
| Experience with landslides | | -0.011 | -0.004 |
| | | (-0.28) | (-0.09) |
| Presence of trees | | 0.064 | 0.048 |
| | | (1.05) | (0.83) |
| Education Respondent | | | -0.002 |
| | | | (-0.32) |
| Age Respondent | | | 0.001 |
| | | | (0.43) |
| Risk aversion | | | 0.008 |
| | | | (0.24) |
| HH size | | | 0.004 |
| | | | (0.29) |
| Female head | | | -0.181** |
| | | | (-2.37) |
| Total Area | | | -0.017 |
| | | | (-0.97) |
| Total Plots | | | 0.007 |
| | | | (0.69) |
| Coffee, cocoa or fruit trees | | | 0.219** |
| | | | (2.41) |
| Migrant | | | -0.054 |
| | | | (-1.03) |
| Distance road (km) | | | 0.011 |
| | | | (0.51) |
| Intercept | 0.864*** | 0.827*** | 0.621*** |
| | (12.77) | (10.40) | (4.77) |
| Sub-county dummies | Yes | Yes | Yes |
| Enumerator dummies | Yes | Yes | Yes |
| # HHs | 397 | 397 | 397 |
| $R^2$ | 0.11 | 0.11 | 0.16 |
| F | 3.60 | 3.31 | 2.32 |
| p | 0.00 | 0.00 | 0.00 |

*Table A.3. Results of the ordinary least squares estimation with enumerator and sub-county dummies of psychological variables on exposure. The dependent variables in columns 1-6 respectively are "landslide susceptibility appraisal", "perceived severity of landslides", "perceived efficacy of trees", "perceived self-efficacy", "trust in information sources" and "reliance on others". For clarity reasons, only the most important control variables for our analysis, "experience with landslides" and "the presence of trees", are shown here. T-statistics are in parentheses (* p < 0.10, ** p < 0.05, *** p < 0.01).*

| | Threat | | Coping | | Trust | |
|---|---|---|---|---|---|---|
| | (1) Perceived landslide susceptibility | (2) Perceived severity of landslide impact | (3) Perceived efficacy of trees | (4) Self-efficacy | (5) Trust in information sources | (6) Reliance on others |
| Exposure | 0.06* | 0.11*** | -0.03 | 0.03 | 0.02 | -0.03 |
| | (1.89) | (4.19) | (-0.96) | (1.23) | (1.07) | (-0.70) |
| Experience with landslides | 0.47*** | 0.24*** | -0.05 | -0.02 | 0.05** | -0.10* |
| | (12.03) | (7.71) | (-1.05) | (-0.61) | (2.29) | (-1.85) |
| Presence of trees | -0.04 | 0.13** | 0.09 | 0.04 | 0.01 | -0.03 |
| | (-0.71) | (2.48) | (1.27) | (0.81) | (0.18) | (-0.46) |
| Control variables, intercept and dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| # HHs | 397 | 397 | 397 | 397 | 397 | 397 |

| | | | | | | |
|---|---|---|---|---|---|---|
| $R^2$ | 0.45 | 0.40 | 0.38 | 0.25 | 0.21 | 0.17 |
| F | 20.09 | 9.40 | 16.71 | 2.93 | 1.16 | 3.58 |
| p | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 |

*Table A.4 Results of the ordinary least squares estimation 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. T-statistics are in parentheses (* p < 0.10, ** p < 0.05, *** p < 0.01).*

| | | (1) Intention to plant trees | (2) Intention to plant trees | (3) Intention to plant trees |
|---|---|---|---|---|
| Threat appraisal | Perceived landslide susceptibility [PercSusc] | -0.05** | -0.13* | |
| | | (-2.02) | (-1.94) | |
| | Perceived severity of landslide impact | 0.05* | 0.05 | 0.05* |
| | | (1.67) | (0.61) | (1.74) |
| Coping appraisal | Self-efficacy | -0.02 | -0.03 | |
| | | (-0.78) | (-0.49) | |
| | Perceived efficacy of trees | 0.03 | 0.12** | 0.03 |
| | | (1.45) | (1.97) | (1.37) |
| Interaction | (Self-efficacy) * (PercSusc) | | 0.09** | |
| | | | (2.15) | |
| | PercSusc if Self-efficacy < 0 | | | -0.07** |
| | | | | (-2.42) |
| | PercSusc if Self-efficacy >= 0 | | | -0.02 |
| | | | | (-0.51) |
| Trust | Trust in information sources | 0.01 | 0.06 | 0.01 |
| | | (0.41) | (1.00) | (0.29) |
| | Reliance on others | -0.02 | -0.07 | -0.02 |
| | | (-0.98) | (-1.14) | (-0.94) |
| Experience with landslides | | -0.02 | -0.04 | -0.03 |
| | | (-0.49) | (-0.32) | (-0.62) |
| Presence of trees | | 0.03 | 0.14 | 0.03 |
| | | (0.56) | (0.89) | (0.52) |
| Control variables, intercept and dummies | | Yes | Yes | Yes |
| # HHs | | 397 | 397 | 397 |
| Rsq | | 0.18 | 0.22 | 0.18 |
| F | | 2.13 | 2.61 | 2.17 |
| p | | 0.00 | 0.00 | 0.00 |

z statistics in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

## Appendix C

In this section is dedicated to digging deeper into our understanding of the Protection Motivation Theory (PMT). We first give a short overview of various interpretations of the PMT that are found in the literature and then investigate the relation between the various components of the PMT in our data. We believe the latter is necessary to make sure that that the PMT is applicable to the context described in this paper. A graphical representation of the Protection Motivation Theory is given in Figure A1.

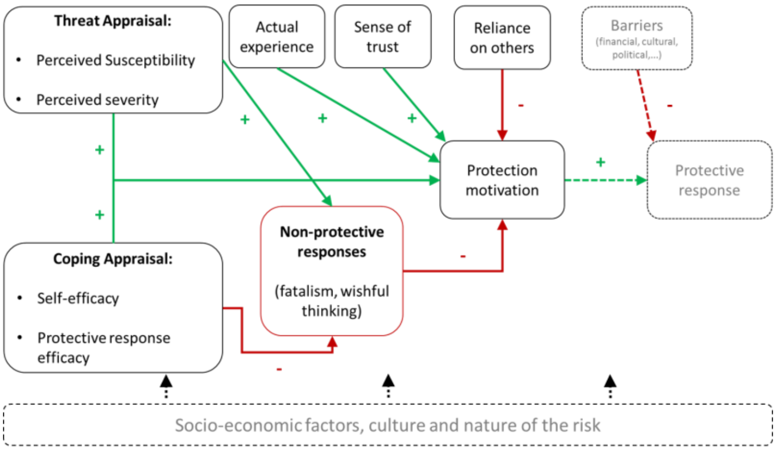


*Figure A1: An overview of the protection motivation framework, as used in current research, modified from Grothmann and Reusswig (2006). Green arrows indicate a positive correlation, while red arrows stand for negative correlations. The grey boxes and stippled arrows indicate that these elements of the PMT are not explicitly investigated in our study.*

Some confusion exists on the presence of interactions between the components of the PMT[14]. In his original model Rogers (1975) proposed a multiplicative relation between the various components of the model. In the revised version of the PMT he nuanced this by arguing that the effect of the components within threat appraisal and within coping appraisal should be additive, while second order interactions could arise between the aggregate factors of threat and coping appraisal (Rogers, 1983). Yet, according to later studies, empirical support for a multiplicative relation between both factors has been lacking and Rogers (1983) has been cited as if no interaction effects were to be expected (e.g. Bubeck et al., 2013; Milne et al., 2000; Norman et al., 2005). Meanwhile, recent studies that make use of the PMT argue that a high threat appraisal combined with a low coping appraisal could lead to a non-protective response, like fatalism and wishful thinking (e.g. Grothmann and Reusswig, 2006; Zaalberg et al., 2009). A non-protective response arises among respondents who know there is a hazard, but do not trust their own capacity to do reduce the risk. Such an interpretation of the PMT assumes some form of interaction between threat appraisal and coping appraisal.

Without aiming at making a statement about the shape of the relation between protection motivation and its components, an visual illustration of the different interpretations of the PMT is proposed in Figures A2 and A3. No non-protective response is possible under high threat appraisal in Figure A2, while in Figure A3 a non-protective response arises when threat appraisal is high and coping appraisal is low.

[14] A similar confusion exists with regard to interaction terms within the theory of reasoned action (see Ajzen and Fishbein (2008) for a discussion on why interaction terms should be included in their model).

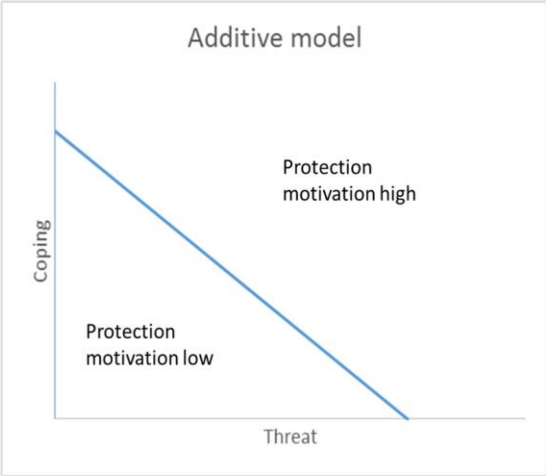


*Figure A2: Protection motivation in the additive model*

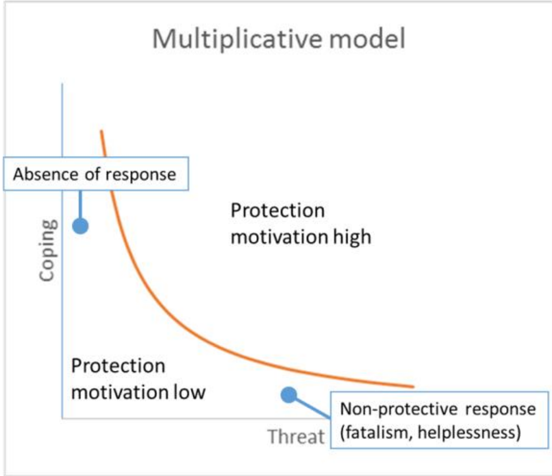


*Figure A3: Protection motivation in the multiplicative model*

To further investigate the validity of the PMT as well as its applicability to our data, Table A1 presents the correlation between the various components of the PMT. The perceived severity of landslides is highly correlated with the perceived landslide susceptibility. This correlation confirms the intuition behind the PMT that perceived severity and susceptibility appraisal are two components of an overall perception of threat. Similarly, perceived efficacy of trees against landslides is correlated with perceived self-efficacy, suggesting that these two variables are components of an overall coping appraisal. The two components of threat appraisal are not correlated with the components of coping appraisal.

The separation between the components of trust is less obvious in our data. Both components are correlated with the various components of threat and coping. Both the susceptibility appraisal and the perceived efficacy of trees are positively correlated with trust in information sources. The negative correlation between reliance on others and perceived severity suggests that farmers that have less confidence in support from their surrounding also consider landslides as a more serious threat. A positive correlation exists between reliance on others and trust in information sources.

Interestingly, there is no correlation between the intention to plant trees and the variables measuring threat appraisal, while a positive relation exists between this intention and the variables measuring coping appraisal. This seems to confirm recent studies stressing the greater importance of coping appraisal over threat appraisal (Grothmann and Reusswig, 2006; Poussin et al., 2014).

*Table A.5. Pairwise correlations between variables of the PMT (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)*

| | | PercSus | PercSev | EffTree | SelfEff | Trust | Reliance | WilTree |
|---|---|---|---|---|---|---|---|---|
| Threat | Perceived landslide susceptibility [PercSus] | 1 | | | | | | |
| | Perceived severity of landslide | 0.444*** | 1 | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | impact [PercSev] | | | | | | | |
| Coping | Perceived efficacy of trees [EffTree] | -0.002 | -0.052 | 1 | | | | |
| | Self-efficacy [SelfEff] | 0.009 | 0.025 | 0.142*** | 1 | | | |
| Trust | Trust in information sources [TrustInfo] | 0.161*** | 0.097* | 0.135*** | 0.043 | 1 | | |
| | Reliance on others [Reliance] | -0.055 | -0.162*** | -0.041 | -0.054 | 0.280*** | 1 | |
| | Intention to plant trees [WilTree] | -0.072 | 0.012 | 0.129** | 0.093* | 0.114** | -0.019 | 1 |