Community based landslide risk mitigation in Thailand

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Rural mountain areas in Thailand have a high hazard potential for landslides. Settlements in hazardous areas are expanding and hill slopes are being deforested. Many former forest areas have been converted into agricultural lands, thereby decreasing slope stabilities. Since the beginning of the 21st century disasters caused by landslides have increased in Thailand. The landslides that lead to disasters in villages are in fact debris flows caused by heavy rains and landslides upstream. Landslides resulting from seismic activities are uncommon in Thailand. The landslide hazard risk in Thailand is defined by the hazard (the debris flow, i.e., landslide prone areas) and the vulnerability (people living in landslide hazard areas). The landslide prone area mapping is based on the geology and the morphology, and the vulnerability upon settlements. The resulting landslide risk map was used to identify all risk areas and consequently the establishment of a community based landslide observation network has been able to reduce the landslide related risks. This network focuses on training local people to understand the risks related to landslides and provides villages with simple tools to detect early signs of threatening landslides and evacuate villagers to safe places. These networks have proven to be very successful, because it was possible to sensibilize and train villagers on the hazard and the risk with the result to effectively protect human lives during several landslide events.

Introduction

Landslides are a common hazard in mountainous areas in Thailand. The predominant natural hazards in Thailand are floods, followed by storms. Even though landslides are considered a rather moderate hazard (Rerngnirunsathit, 2012) because the overall damages and fatalities caused by landslides are comparatively small, the number of affected people by landslides is continuously increasing (Thampanishvong, 2013). The probably most prominent landslide disaster occurred in 1988 in Katoon, Nakhon Si Thammarat Province. 230 people were killed; many houses, agricultural areas and infrastructure were severely damaged. The total cost related to the damage was estimated at around 1,000 million Baht (Tantiwanit, 2005).

The Department of Mineral Resources (DMR) realized in the early 2000’s that landslides are becoming a more important hazard in Thailand and will potentially cause increasing damages in the future. It has been decided to conduct intensive landslide investigations and to establish local landslide watch networks. Supported by a landslide monitoring center, the Geohazards Operation Center (GOC) was installed in Bangkok. The GOC coordinates the landslide risk mitigation interdisciplinarily with relevant agencies including the Thai Meteorological Department (TMD) and the Department of Disaster Prevention and Mitigation (DDPM) as well as local networks (Tatong, 2010).

Landslide Hazards in Thailand

Thailand is located in the tropical monsoon zone between 5°37′–20°27′N and 97°22′–105°37′E. It covers an area of 513,115 km² and has a population of 65 million. Thailand is comprised of 76 provinces and geographically divided into 5 regions, northern, north-eastern, central, east and southern. High mountainous areas can be mainly seen in the northern, southern and eastern regions while the central region is mainly lowland, with some mountains at the Western border. The north-eastern region is a high plateau with mountains at its southern and northern borders.

Thailand is a tropical country, according to the Köppen-Geiger classification it is mainly characterized by an equatorial winter dry (Aw) climate in the central, northern and eastern parts and equatorial monsoonal (Am) climate in the western and southern (peninsula) areas. The main seasons are a relatively dry and mild season from mid-October to mid-February, the pre-monsoon season from mid-February to mid-May and the rainy monsoon season from mid-May to Mid-October, to which the highest landslide hazard is associated to.

The types of mass movement that lead to disasters are mainly debris flow and rock falls. The areas with the highest debris flow hazard in Thailand are in areas with Precambrian and Paleozoic granites, gneisses and schists that are found mainly in the north-west of the country and at some outcrops in central and southern Thailand (see Fig. 1). These rocks are deeply weathered, partly up to 60 m depth. Some debris flows also occur in areas of folded tertiary rocks in northern and central Thailand. Rock falls are common in Upper Paleozoic carbonate areas that are mainly bound to the Peninsula, reaching from Surat Thani to the Satun Province (see Fig. 1).

The debris flows are caused by heavy rainfall that trigger land-
Figure 1. Geological map of Thailand (modified from the Thailand Department of Mineral Resources geological map, 1:2,000,000 scale, 1999).
Landslides among steeper slopes. These landslide carry slope material and plant residues into streams. Due to the rainfall these streams swell and transport the landslide material downstream at a very high speed, leading to debris flows. Rock falls occur due to weathering of tropical karst, mainly among steep, nearly vertical slopes. Since the terms debris flow and rock fall are not commonly used among laymen the overall term landslide is preferred, and also used in this article.

In the 20th and earlier centuries landslides occurred mainly in undeveloped rural areas. The 1988 disaster was attributed to extremely high cloudbursts (according to a 38-year record) and allegedly occurred independently of the vegetation cover (Phien-wej et al., 1993). Other significant events occurred in 2000 in the Phetchabun Province, in 2001 in the Phrae and Phetchabun Provinces (Tantiwanit, 2005) and in 2006 in the Uttaradit and Sukhothai Provinces (ADPC, 2006).

Since the year 2000 the number of landslides per year have been increasing in Thailand. While this might be partially due to changes in rainfall patterns, it is certainly a result of the anthropogenic changes of the living environment and settlement patterns. According to Mairaing (2003) the amount of settlements and the total population has strongly increased in rural, and particularly mountainous areas, converting forests into agricultural land and plantation of unsuitable crops on slopes (e.g., banana) (ADPC, 2006). The importance of the natural forest as a protective measure (Nilaweera, 1999) and Preti (2013) has been continuously neglected and villages are being built in landslide prone areas, see also ADPC (2006).

Landslides triggered by seismic events are uncommon in terrestrial Thailand, e.g., the most recent earthquakes in 2006 and 2014 did not lead to significant landslides. Some landslides occurred and several scars were observed after the 2004 Sumatra earthquake, especially in some small islands in the Indian Ocean.

The landslide hazard in Thailand was mapped and assessed by the Department for Mineral Resources (DMR) utilizing a landslide prediction model that runs under a Geographic Information System (GIS). The factors the model calculates are geology, elevation, slope, flow accumulation, flow direction, vegetation, soil type and saturation (Pantanahiran, 1994). The results of the model were plotted in the form of a landslide hazard zone map in scale of 1:250,000 for the provincial level and in scale of 1:2,500,000 for the whole country. Based on this assessment, there are 6563 villages, in 1084 communities (Tambons), located in landslide hazard zones in 54 provinces, mainly in Northern and southern Thailand (Environmental Geology Division, 2003). The landslide-prone areas zones are categorized based on empirical studies. In 2004 the decades-long observations and field studies in the aftermath of landslides have led to the decision in the DMR to categorize slopes steeper than 30 degrees as landslide prone. The hazard zoning is applied by a combination of the slope steepness, soil type and precipitation.

Zone 1 (red zone): Slope > 30 degrees, loose soil, landslide hazard if precipitation reaches > 100 mm/day; Zone 2 (yellow zone): Slope > 30 degree, loose soil, landslide hazard if precipitation reaches > 200 mm/day; Zone 3 (green zone): Slope > 30 degree, loose soil, landslide hazard if precipitation reaches > 300 mm/day.

The landslide risk is based on the combination of the landslide hazard with the population in the landslide prone areas, i.e., the vulnerability is defined by people potentially affected by landslides.

The landslide season extends from May to December alongside the rainy season that is influenced by the south-west monsoon which follows the inter-tropical convergence zone moving from north to south. Thus landslides usually occur in Northern provinces starting in May moving gradually to the Southern provinces.

It is possible to reduce landslide hazards with technical solutions, which are studied and applied in Thailand (Fowze et al., 2012). Importantly also land-use planning can support the landslide risk mitigation (Galve et al., 2015). The DMR supports villages in installing and maintaining soft and/or simple structures, e.g., bamboo fences and check dams and has installed 25 landslide observation stations all over the country. However, these 25 stations have great challenges in continuously monitoring and maintaining structures in all identified 1084 hazard-prone communities. A further problem is that some slopes are considered as safe, but this is only valid until they are illegally deforested at a later stage. There are first approaches to monitor illegal deforestation in Thailand, e.g., the “Illegal Logging Portal” reports that Thailand has started negotiations with the EU to join the Voluntary Partnership Agreement (VPA) to improve forest governance with the aim to promote trade in verified legal timber products. On the other hand much of the illegally logged wood in Thailand is used nationally and is therefore difficult monitor (Illegal Logging Portal, 2017). There are approaches to use social media to monitor illegal logging, (Siriwat and Nijman, 2018) nevertheless these first initiatives to are not yet included into the landslide monitoring network.

A further challenge is that climate change alters precipitation patterns and heavy cloudbursts might increase in the future, leading to an overall increase of the landslide hazard (IPCC, 2014) and Fischer and Knutti (2015). The current categorization is that cloudbursts exceeding 100–300 mm/day, depending on the underlying geology, soil and slope are categorized as landslide triggering. These might be reviewed once climatic changes prove to affect precipitation patterns.

The landslide prone areas with high risks are usually located in remote mountainous areas and thus far from help. Heavy rain often causes the mobile phone network to collapse and roads might be cut off. It is therefore nearly impossible for government agencies to conduct search and rescue operations during or immediately after a landslide occurred. The best measure to reduce risks is therefore to increase self-protection capabilities, e.g., by raising awareness and increasing the knowledge amongst local people on vulnerabilities and landslide risks in their villages.

In order to reduce landslide related risks the DMR acts on behalf of a, continuously renewed Thai Cabinet resolution to act in all 1084 landslide hazard prone communities. The DMR established the Geo-hazards Observation Center (GOC) and started to develop the so-called Landslide Watch Network in the early 2000’s. The highest priority was given to villages located in the Zone 1 (red zone) and these areas were the first to establish the landslide networks, followed by communities in Zone 2 and 3.

Landslide Monitoring

For landslide monitoring the critical indicator is precipitation. The GOC receives weather data from the Thai Meteorological Department (TMD) via the internet. The weather data includes satellite images,
Figure 2. Landslide hazard map of Thailand. Department of Mineral resources, Thailand. First published in 2004 and updated in 2016.
weather (precipitation) radar and precipitation data (measured and forecasted). When the weather radar detects heavy precipitation lasting longer than 3 hours, the GOC staff inform the respectively affected municipalities (Tambons) and local networks to assess the local precipitation amounts.

When heavy rainfall is locally confirmed and the estimated precipitation reaches over 100 mm/day, the GOC will disseminate a so-called landslide watch bulletin. This bulletin summarizes all important weather information, especially expected precipitation, for a specific area. The bulletin is sent to Tambons and villages at risk; television and radio stations and other relevant agencies. The networks in risk areas are also informed by telephone and Short Message System (SMS). After receiving these early warnings, representatives of the networks are sent to defined observation points and gauges to observe precipitation duration and amounts and runoff data. If they detect signs of potential landslides they issue warnings to the villages. During heavy rain events these local observations continue 24/7 in order to be able to identify landslides at a very early stage, and if necessary, evacuate a village. Also the communication with the GOC is constant until a heavy rainfall event has ceased. This is to avoid time-lags in the communication chain.

The local networks can also directly contact the GOC to get information on weather forecasts or to report landslide and flash flood information. This feedback information is very important for the GOC in order to inform adjacent areas and update the DMR website.

The Landslide Network

The landslide network consists of two major components: The coordination between the GOC, the involved Thai agencies and the villages one on one hand, and between the GOC, the Tambons the local villages and the rescue services (Figs. 4 and 5). Both components are controlled by the Geohazards Centre (GOC – located in the DMR). It closely cooperates with the municipal networks and key agencies including the Thai Meteorological Department (TMD), the Department of Disaster Prevention and Mitigation (DDPM), the Department of Public Relation (DPR), as well as TV and radio stations (see Fig. 2).

Since precipitation is the main triggering factor for landslides the DMR has cooperated with the TMD in weather forecasting since the start of the landslide network project and the establishment of the GOC. The TMD provides precipitation data regularly twice a day (morning and noon). The website updates weather radar data continuously. In the case of extreme events, for example tropical cyclones (typhoons), additionally wind speeds and directions are provided by TMD.

The DDPM has branch offices in every province that act as secretaries in disaster management to the governors. In heavy rain events the GOC disseminates so-called landslide watch bulletins to the local DDPMs which return landslide event data and damage data back to the GOC. The DPR, TV and radio stations broadcast landslide watch information together with weather news (Fig. 4).

The community based landslide network is also headed by the GOC and consists of the Tambons and the villages that were identified by the landslide mapping (see above) as well as relevant agencies, such as Search and Rescue teams, hospitals, etc. When the head of the Tambon and local villages receive early warnings from the GOC they deploy trained villagers to observe the local precipitation and the local stream discharge. In case the precipitation surpasses pre-defined thresholds and the stream discharge reaches critical levels, warnings are issued via speakers and sirens (see Fig. 5).

Building and Maintaining the Landslide Networks

To establish the network, especially trained DMR staff contacts and visits the heads of villages in landslide risk areas. The staff then explains the respective landslide risks of the area to the Tambons and heads of villages to convince them to take part in the landslide network. Usually information on previous landslides is used to demonstrate the risks, such as evidences comprising boulders, deposits and flood levels of streams. Once the hazard and the risks are understood by the heads of the villages and the local people the set-up of the local landslide watch network starts (Tatong, 2010).

The heads of villages choose 6–9 villagers to be volunteers and to participate in special training sessions. Trainings are organized in groups of villages which are located in the same catchment area. The volunteers are trained on landslide types, triggering forces as well as landslide behaviors and impacts. Finally the local volunteers are trained in reading simple rain and runoff gauges in order to learn to read early signs of landslides. These special gauges have been designed for the landslide network. Simple color scales on these instruments do not
require literacy or technical training to detect certain thresholds of precipitation and runoff that potentially cause landslides (Tatong, 2010).

An observation site or check point for the gauges is selected by the local staffs and volunteers. The check point should be located on a high riverbank or elevated spot nearby a stream or river flowing to the villages. The nearness to the stream is important to observe the water level. Color and changes in dispersed sediments are good early indicators of upstream landslides. If observation teams detect rumbling sounds from the mountain and/or observe that the water level is rising rapidly, they must inform the head of village. The head of the village then sends signals to warn the local population and also inform other villages downstream (see also Fig. 3). The volunteers also receive first aid training, as well as basic knowledge in search and rescue operations.

The evacuation routes, and assembly points (or safety areas) are jointly determined by the local villagers. Importantly, the villagers draw the location of their houses, the river and creek valleys, the location of bridges, other important landmarks as well as the most hazardous landslide areas themselves on a map. This map is jointly analyzed to determine safe evacuation routes to the safety areas. The hand drawn map is then edited and printed on large tabloids that are displayed in several spots in the villages, e.g., in schools and restaurants (see Fig. 6). In this way in the case of a landslide and a necessary evacuation of the village, the local population is well informed which evacuation routes to use to reach the safe areas.
After receiving landslide warnings the entire population of a village should gather at these assembly points and after a landslide event the head of the village checks if everybody has made it in time to reach an assembly point. If some people are missing search and rescue teams are deployed. The injured are rescued and brought to the assembly points and hospitals are contacted to transfer the wounded for further treatment.

The first local network was established in 2003. By 2017 691 local networks have been established in 51 provinces. The total amount of trained volunteers amounts to 35259.

In order to ensure the proper function of the networks regular trainings are conducted. The aim is to conduct drills in 8 provinces each year. Trainings are also used to inform about new technologies and tools and to encourage local people to maintain the network. Landslide trainings are often conducted in close cooperation with local search and rescue teams and hospitals.

The trainings are conducted in the following manner: The head of the village issues a landslide warning upon which all villagers move as quickly as possible to an assembly point. Before the training a certain number of people are assigned to specific “injuries”. These “injured” people are hidden in the river catchment. The search and rescue teams have to find them and give first aid according to the designated injuries. After being brought to the assembly point, these “injured” persons are then transported to local hospitals to continue the training with hospital staff. In this way the entire chain of actions and measures are trained in a concerted manner.

Results

Several landslides have occurred since the installation of the network in 2003, many of which have destroyed villages and houses. But most importantly, it was possible to save the lives of many villagers, especially during the large landslides in Krabi, Nakhon Si Thamarat, Sop Muey Nampad and Fang (2011). The high costs caused by the 2011 landslide are borne by the damage to larger tourist facilities (Table 1). Yet, the number of casualties, as compared to the damages are rather small. In fact, tourist sites have been somewhat problematic for the landslide network, because there is some reluctance by the local people to join the network. One reason for the reluctance is the fear to scare tourists in the case of unnecessary evacuations. Another problem in the tourist areas is the different social composition and varying behavior, because many people come from different places and often only for seasonal stays. In the villages people know each other and are keen and willing to help their communities. In tourist areas the identification with the community is often missing and not a priority. It is therefore difficult to find volunteers to be trained and integrated into the landslide networks. The DMR team is working diligently to convince these risky tourist areas to join the network.

Taking the devastating landslide events of 1988 and 2011 as references the community based landslide networks have been very successful because the persons injured in landslides has dropped significantly. The strong climatic effects caused by the El Niño phenomena has led
to a severe drought in North and North East Thailand in 2015 and 2016. The low precipitation has not only led to large losses in agriculture and devastating forest fires, but also to less landslides. Unfortunately casualties were caused by two landslides in 2018. One reason for these casualties is that in the Nan Province the affected area was not identified as landslide prone. Unfortunately it was unknown to the DMR geologists that the forested mountain slopes were in fact once deforested. Obviously the soil had weathered deeply during the deforested phase and the young forest was not able to retain the slope material during the rainstorm that caused the landslide. The village was part of the network, but in the night of the landslide occurred no warning was given for this particular area. In fact people had moved to this place because it was considered as safer than the area where the village was formerly located. Communication with the local citizens yielded their willingness to relocate endangered houses to safer places. This identification of safer places is currently ongoing as part of the post incident investigations. The second landslide that caused casualties in 2018 landslide occurred in Mae Hong Son close to the Myanmar border and affected a refugee camp, which consisted of temporary housing and shelters and was not part of the landslide network.

### Conclusions and Recommendations

The landslide network of Thailand has been very successful as it was able to reach its main priority, to save lives. Furthermore, the trainings of the volunteers have educated and sensitized the population to the landslide hazard and the resulting risks. Meanwhile hazard mitigation structures are propagated by the DMR and installed locally, one of the large factors of the landslide hazard is uncontrolled deforestation. As the installation and maintenance of protective structures continue equally strong emphasize is given to awareness rising and training on the timely evacuation of risky areas in cases of landslides. Unfortunately the DMR and the GOC are understaffed meanwhile the workload and the pressure on the landslide team remains high. There is a constant demand to improve and maintain landslide mitigation measures, maintain existing networks, conduct regular trainings and to integrate more villages into the network. Besides additional staff to maintain and extend the network several further steps should be taken. Foremost is the importance to monitor illegal logging and deforestation. Importantly the illegal loggers should be educated upon the effect of the deforestation on their own communities. But such action will only be successful if other income sources can be identified. The economic necessity of loggers to maintain their livelihood must be addressed. Furthermore the monitoring of logging could be technically improved, e.g., via remote sensing and locally using drones. Another tool to decrease the landslide risk is land-use planning, i.e., taking rural communities the step forward from mapping landslide and flood prone areas locally towards actively shaping local environments, e.g., space for water, etc.

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