More Room for Landslides

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Abstract

Since ancient times, and more intensively from the mid-19th century, land in the mountain region is developing and the space belonging to land and water has been reduced. On the surface that previously belonged to the river have developed agriculture, transport routes and settlements. At the end of the 20th century, development spread over hazardous areas, many torrents flowed in highly confined channels, and ground water recharges drop down, instability of land surface and security for inhabitants decreased. This resulted in the changes reducing water resources of appropriate quality, reducing space for sediment deposit, increasing erosion, affecting natural habitats, causing major flood damage, decreasing groundwater stock, and deteriorating water quality. The water regime integrates all events across space from landslides, debris flow and is manifested in river regime in low lands. This problem is partially covered by many United Nations (UN) and UNESCO documents and reports. Proper actions are also suggested in the Ministerial Declaration from the 7th World Water Forum, where the first mentioned action is the significance of appropriate land management in relation to sustainable water management and planning. More room for landslides control means more space for potential landslide control out man made impacts that cause land slope instability, more space for torrents, more space for water and sediment storages, less impact on the slope stability and higher security for the peoples. We should change paradigm of space planning and development, especially in countries in development under intensive urbanization. The aim of this paper is to present particularly bad examples from Slovenia in order to support this proposal.

Keywords

Landslide • Flood • Spatial planning • Damage • Hazard • Vulnerability • Risk

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Introduction

The campaign *More Room for Landslides* is designed on the basis of successfully implemented campaign *More Room for Water*. The Campaign More Room for Water was started by the Slovenian Committee of UNESCO IHP in the year 2013. The idea of this action is based on an important European project from the Netherlands *Room for the River* (Klijn et al. 2013), of which the main objective is to give back to the river at least some of the space that it once possessed. With the growing population, industrialization and urbanization,

the inundated areas and wetlands have been consumed and, through river engineering, watercourses have been regulated such that the space belonging to water has been reduced (Brilly 2015).

Since ancient times, and more intensively from the mid-19th century, the development of human settlements, infrastructure and economic activities is expanding more and more in the mountain region and the space belonging to land and water has been reduced. On the surface that previously belonged to the river have developed agriculture, transport routes and settlements. At the end of the 20th century, development spread over hazardous areas, many torrent flowed in highly confined channels, and ground water recharges dropped down, instability of land surface and security for inhabitants decreased. This resulted in reduction of water resources of appropriate quality, reduction of space for sediment deposit, increase of erosion, impacts on natural habitats, causing major flood damage, decrease of ground-water stock, and deterioration of water quality. The water regime integrates all events across space from landslides, debris flow and is manifested in river regime in low lands (Brilly 2015).

This problem is partially covered by many United Nations (UN) and UNESCO documents and reports. Proper actions are also suggested in the Ministerial Declaration from the 7th World Water Forum (World Water Council 2015), where the first mentioned action is the significance of appropriate land management in relation to sustainable water management and planning.

More Room for Landslides actually means more space for control of potential landslides caused by human activities that cause slope instability; more space for torrents; more space for water and sediment storages and less impact on the slope stability; consequentially higher security for the people.

The occurrence of landslides in Slovenia can be expected at approx. 1/3 of the total surface area (Ribičič et al. 2005). However, more and more intense and concentrated use of space is increasing risk of landslide occurrence. Furthermore, there are also spatial interventions at unstable areas by which conditionally stable areas change into unstable. Landslides in Slovenia most often occur as consequence of heavy rainfall, which means that landslides are inseparably linked to water.

In our paper we present three cases of landslides that have occurred in the past on the territory of the Republic of Slovenia, and discuss how could measures in the field of spatial planning reduce risk and consequential damage in these cases. We have focused on cases where analysis has shown that due to improperly designed or maintained forest roads and skid trails, the damage was greater: Stože (2000), Laze Dolsko and Slapnica (2009), Upper Savinja Valley (1990).

Network of roads in the forest land have multiple functions: easy access to forest resources for extraction, regeneration, protection, and recreation activities (Akay et al. 2008; Khalipoor et al. 2008). Skid trails, highlighted in this paper are used in ground skidding systems and are recognized as the source of erosion (Jusoff and Majid 1996), in many cases, they also serve as a secondary channel for the transport of the material from the hinterland directly to the settlements.

The construction of forest roads is an economic activity which includes the design, construction and maintenance of engineering structures. The Construction Act (2002) gives legislative framework in this field in the Republic of Slovenia. 5064 km of forest roads were recorded in the social and private forests in Slovenia in the year 1970 (Remic 1971). After this year the length of the network of forest roads started to increase rapidly. The extent of the construction of forest roads per year is shown in Fig. 1 (Robek et al. 2006).

The most intensive period of construction was between years 1982 and 1984, when more than 300 km of paved roads were built per year. In the year 2004 the length of all recorded forest roads (paved roads, unpaved roads, skid trails) in Slovenia was 12,683 km (Slovenia forest service 2004). This means that the density of the forest roads on the entire surface of the Slovenian is approx. 0.63 km/km² (Fig. 2).

On average 1 m of newly built forest road requires an excavation of 3 m³ of soil, 1 m of newly built forest trail requires excavation of 1 m³ and 1 m of reconstruction requires 0.5 m³ excavation of soil. Based on these data, it was estimated that half a million m³ of soil was excavated from hillslopes in the Republic of Slovenia between 2000 and 2005 (Robek et al. 2006). It is true that this is still four times less than in the period of most intensive construction, but for every 3 m³ of harvested timber at least 1 m³ of forest soil is transported. Most of these excavations is on the skid trails, which are more than roads exposed to erosion processes (Robek et al. 2006).

Overview of Landslide Cases in Slovenia

In the next three cases we are highlighting the issue of the impact of inadequate interference into watercourse and scarce maintenance of forest roads on occurrence of landslides and extent of the damage caused by them.

One of the most notable characteristic of the torrential flows is that watercourses have most of the time extremely low flow rates or are even dried up, but the rates increase sharply almost immediately after heavy rains and increase greatly torrent's transport capacity. Since the channels are not able to conduct such large quantities of water often

Fig. 1 Average annual extent of constructions and reconstructions in forestry in Slovenia after 1970 (black square (■) and black circle (●) are missing data)

Fig. 2 Density of the forest roads in the Republic of Slovenia (EGC 2016)

mixed also with substantial quantities of gravel or mud the water finds the way and spills over on the nearby terrain.

Very often there are roads near the watercourses and the water uses the road as a secondary channel that offers the easiest way down to the valley. In Slovenia it has been observed that in many cases especially if they were not planned adequately (without adequate drainage) and in the absence of maintenance, the forest roads form a preferential route and redirect the torrential flow in unfavorable directions and thus can cause disastrous consequences.

Laze, Dolsko and Slapnica, 2009

One of the events of this kind happened on 10th July 2009 in municipality of Dol pri Ljubljani. In the summer of 2009 the area of the Middle Sava River suffered many rain storms and

subsequently large amounts of rainfall. Heavy rain transformed the normally small creeks into powerful torrents, giving them a devastating power and great transport abilities. This, combined with weathering and rot prone flysch basis resulted in enormous quantity of debris that got transported by the torrent from hinterland to the flatter part of the gorges. The debris filled the culverts in the lower part of the stream course, but with the increase of the flow the water started to exit the channel already before it reached the critical part. With no way to go in the original riverbed the torrent flooded the embankments on the transition to the flatter part, where the valleys also slightly expand. The streams took the easier path and started to flow on the nearby forest roads using them as a new water way. Carrying large quantities of debris and mud the water found its way between the houses, depositing the material in flatter parts or near the obstacles (houses and other objects/buildings) and finally on the road and railroad before flowing into the Sava River. The water mixed with mud and debris caused enormous damage on 8 houses and on the outbuildings as well as on main railroad Ljubljana—Zidani most which has been closed for several days (Kambič 2009) (Fig. 3).

Laze pri Dolskem is a settlement located on the right bank of the Sava River, which occupies the greater part of the relatively narrow band between the river and the footstep of the hills of Lipavčev grič and Janče, which steeply rise from Sava River plains. Between village and Sava river runs one of the most important railway connections—the railway line Ljubljana—Zidani most as well as the local road connection between Laze and Jevnica.

The area is composed predominantly by unstable flysch basis, which are extremely sensitive to atmospheric influences (Kambič 2009). The water catchment area is mostly

Fig. 3 Consequences of the storm in the Dol pri Ljubljani, 2009 (Zurnal24 2009)

covered with forest, which is in terms of water retention favorable; however inappropriate interference in such space (inadequate felling, unmaintained forest roads and skid trails) caused devastating damage on a very small area between Gostinica and Jevnica. Due to frequent rainfall during whole summer the soil was relatively soggy and it was not able to absorb large quantities of water anymore. Heavy rain on the night between 9th and 10th July washed large quantities of debris from the steep slopes of Lipavčev grič into watercourses, sediment the material in flatter or less transitional zones of the watercourses and changed the direction of the riverbed. Due to the already very wet ground precipitation has triggered some landslides, which overwhelmed local road, three residential houses and a railway line (Fig. 1).

Less than a month later (on 4th August 2009), abundant rainfall once again covered the area Laze, Dolsko and Jevnica, and additionally soaked hinterland creeks, causing again erosion and triggering slides of material in the headwaters (Kambič 2009). Subsequent analyses of the event showed that, due to large quantities of the debris many torrents in the area burst their banks and the water has paved the way for unmaintained forest roads and skid trails, shifting their way from the regular stream or redirecting water and material into torrent flowing nearby.

The area near houses Laze 32, Laze 33, Laze 34 and Laze 35 was the most affected (Fig. 4). The damage was caused by two parallel streams (one of them almost inactive before) flowing less than 150 m apart. Large damage was caused also by the torrent Slapnica, and the torrent near house Laze 48 and the one near the fire station. Another critical area was the area affected by Gostinica stream.

One of the affected areas was also the area next to the house at Laze 48. The stream with catchment area of 0.06 km² runs normally as a creek, but precipitation before 10th July 2009 filled the creek abundantly and transformed into a powerful torrent. A riverbed was considerably deepened and the water carried a large quantity of debris,

Fig. 4 The most affected areas in Laze pri Dolskem (Atlas okolja 2016)

depositing it on the backyard and garden of the house Laze 48. Since the torrent cuts into two the land plot and divide the house from the garden and the forest and the access to the building is possible only via the channel of the stream the owner lined the fairly under-dimensioned pipes into the torrent to have an access to the house and further on to the forest. During the event the pipes got clogged immediately and the water took its way through the access road.

The worst damage was caused by stream passing the houses Laze 32, Laze 33, and Laze 34 (Fig. 4). The stream catchment area is covered mostly with tame forest and extends on 2.1 km². A forest road runs along the stream, which crosses the watercourse two times and has been used to access forest in the hinterland. In the last period before the storm the road has been used rarely and the lack of maintenance and cleaning of the forest could have been observed.

Less than 1 km to the south-east there is another stream that diverted from the original riverbed and found its way through the forest road causing a devastating damage. The Slapnica stream is overgrown with forest, however the headwater is crossed with forest access roads (Fig. 5). The forest as well as the forest roads are mostly unmaintained and in bad conditions (Fig. 6).

Fig. 5 The devastated area of Slapnica. Red colour marking the devastated area and orange lines the forest roads

Fig. 6 Debris deposited outside the narrow “canyon” near Laze 35. The water used the access forest road (red arrow) as its riverbed (Kambič 2009)

Fig. 7 The consequences of flooding it's clearly visible; the torrent diverted from original channel and took the forest road as its riverbed (Kambič 2009)

Apart from the debris the water brought down to the flatter land branches and pieces of wood. On the watercourse there is a debris retention dam with a fairly big accumulation. However, the transported material exceeded the volume of the storage available and the water mixed with the debris started to flow over the access roads and latter over the meadow and field and flooded the houses and deposited the transported material (Fig. 7).

Upper Savinja Valley, 1990

The case of Savinja valley highlights even better the influence of inadequately planned service roads. The 1990 floods were the most severe in the Savinja valley in the previous

century. They were caused by excessive rainfall; in the period of 26–31 October 100 mm of precipitation fell, causing two small flood waves. The October precipitation was followed by 220 mm of precipitation on 1–2 November, which was catastrophic (Pristav 1991). Three major landslides and many small landslides were triggered. The many landslides surprised the services in charge of emergency procedures during the event. The phenomenon was also affected by the construction of new forest roads, because in the 1970 there were only 16.55 km of roads while in 1990 there were already 79.7 km of roads in the area of Podvolovljek. Most of the forest roads were built on slopes, and as much as 87.7% on slopes with more than a 50% gradient (Kladnik 1991).

A major landslide was triggered at 10 p.m. on the right bank of the Lučnica River, the right tributary of the Savinja in the Upper Savinja valley. The river runs in a narrow valley with steep slopes consisting of andesitic tuffs. The houses in Podvolovljek, Podveža, and Luče at the confluence with the Savinja River are situated along the river channel. The landslide was triggered 2 km from the confluence with the Savinja and dammed the Lučnica River channel. A 20 m high and 200 m wide dam was formed. Behind the dam a lake was formed which quickly filled up and flooded the lower part of the Podvolovljek village, including 4 houses. A 97-year old woman drowned because she was unable to escape from the quickly increasing water (Meze 1991). Civil protection services ordered evacuation of the threatened buildings above and below the dam where there was dam failure risk; flood wave design was also required. In the early morning hours a lake in a length of 1.5 km was formed, with approx. 2 million m³ of water. On the 2nd November at 5:20 a.m. the water overtopped the weir and formed a flood wave of a height of 2 m and in a duration of 3–5 min, which demolished two houses downstream, in Luče. The flood wave caused by dam failure carried away two thirds of the landslide and thus substantially reduced the lake. The wave was then registered at the water station Nazarje on the Savinja at 10 a.m, with a height 80 cm (Natek 1991; Planki 1991). Except for Luče, where all inhabitants of the houses at risk were evacuated in time, the wave in the Savinja did not cause major damage because the water level was lower than the peak of the previous flood wave. A great problem for the functioning of the protection and rescue services was disconnected road connections and demolished bridges at the Lučnica and Savinja Rivers.

Stože 2000

Due to the tragic consequences and scope, the Stože landslide was well studied and documented in papers in professional and research journals. The landslide was caused by

excessive precipitation at the end of the October 2000 and lasted throughout the following month (Mikoš et al. 2002). It rained 2–3 days each week. The event occurred in two parts. The first landslide was triggered on 15th November 2000 in the Stože area, at between 1400 and 1600 m above sea level. The Mangart stream channel was filled with material in a height of 10 m and a length of 1450 m (Majes, 2001). The landslide area is rather steep with a gradient of 30 degrees. The surface of the moraine consisted of clay and scree, while below it there was cracked and permeable dolomite lying on impermeable bedrock. As the Mangart stream was dammed it almost entirely infiltrated the landslide, which filled the stream channel but did not form a special reservoir space for water due to the large gradient of the channel. Because the stream stopped flowing, the Civil Defense Service raised the alarm and moved people out of the houses at risk in the village Log pod Mangartom. The stream started to flow again on 17th November, without causing any special land mass movements or increasing its erosion. This also led to the conclusion that landslide risk no longer existed and that inhabitants could return to their homes, even though the risk level was not called off (Ušeničnik 2001). The inhabitants returned to their homes. The heavy rains from 16th to 17th November triggered another landslide and debris flow a few minutes after midnight reached Log pod Mangartom and caused seven fatalities. The debris flow descended along the steep slope and in the valley filled the channel of the Koritnica with scree. The debris flow reached the village of Log pod Mangartom in 4–5 min and, according to the travel distance of 2200 m, the mass travelled with the speed of 30 km per hour, i.e. 8 m per second, so the population had no chance of a timely withdrawal (Fig. 8). Clay fractions of the moraine were carried away by the river, turbidity on the Soča River at Kobarid was measured at 8112 per m^3 (Komac 2001). The surface of the landslide comprised of 200,000 m^2 , a mass of 1,500,000 m^3 was moved, and of

which debris flow carried away 1,000,000 m^3 so that 1,500,000 m^3 of unstable material was left at the site (Majes 2001). In Log pod Mangartom 700,000 m^3 of material was deposited at a surface area of 150,000 m^2 , and at least 100,000 m^3 was transported downstream as turbidity.

Laboratory investigations revealed very interesting characteristics of the moraine which composed the landslide mass and later the debris flow (Majes et al. 2002). The results of measurement of shear stress and moisture or suspension concentration show that the material with a relatively high shear stress in dry condition (up to a moisture of 20%) loses its moisture relatively quickly by the addition of water and liquefies already at 25% moisture. 5% of moisture will practically completely change material properties.

Discussion and Conclusions

People excessively and especially thoughtless affect riparian areas (e.g. by building homes or other important infrastructure too close to potential hotspots, and in the desire to find life easier violates or does not respect natural laws) and areas where there may be collection of water (ravines, hollows etc.).

In all three presented cases there are forest roads or skid trails that “served” as a secondary riverbed in the hinterland of the affected zones. In all three cases they run next to the stream and crossed it several times. The forest roads and skid trails were unmaintained and were made without proper reflection on its spatial placement and the construction has been carried out regardless on basic principles of drainage and headwaters arrangements. Being on unflattering and irrationally chosen routs and with lack of proper maintenance the diversion from the original channel was just a matter of time.

In the last 20–30 year in Slovenia the number of skid trails and forest roads has increased considerably. Unfortunately, the skid trails are poorly maintained. These skid trails now represent potential paths for water, which, of course, select the easiest way (places with lower potential energy). If the skid trails are not maintained properly, then the drainage does not work (if it was even arranged) because of the buried and blocked channels. Furthermore, if the trails are full of deep ruts, which are result of driving on the muddy road, then the water collects in ruts and direct it on the trails.

In many cases skid trails are located on potentially dangerous or unstable areas. Since the trails are leading from economic or residential buildings into the forest the water can bring material directly to infrastructure or bury transport infrastructure. And if that happens, then the damage is much greater than if it were to happen in an area where there are no human settlements and infrastructure. However, since this can not be completely

Fig. 8 Debris flow Stože has reached the village Log pod Mangartom (Ribičič 2001)

avoided, we want with action *More Room for the Landslides* promote measures to reduce the risk against landslides, more specifically to reduce or even better avoid economic damage and loss of life.

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