# B17 THE IDENTIFICATION OF FORESTED AREAS PRONE TO EROSION IN THE CATCHMENTS OF TORRENTS IN SLOVENIA

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## ABSTRACT

Forestry in Slovenia faces the challenge of restoring degraded forests on a large scale and adapting forest management to increase resilience and reduce the risk of torrential and erosion processes in forested areas. In this study, we present a methodology for identifying forest areas at risk of erosion in the catchment areas of torrents in Slovenia. The methodology is based on the map of small water catchments, the risk map for the occurrence of mass movement processes and the forest land use map, provided by the Ministry of Agriculture, Forestry and Food. The methodology was tested in the pilot area of the Municipality of Železniki and will be further developed at the national level. In addition, the "silent witnesses" of torrential processes were analysed examined in a small catchment of the Zala torrent.

## INTRODUCTION

The increasing frequency and severity of extreme weather events leads to considerable damage to forests in erosion-prone areas. In particular, the increasing occurrence of torrential rainfall in forested areas previously affected by ice storms (Marinšek et al., 2015), windthrow, bark beetle outbreaks (De Groot et al., 2021), forest fires and other large-scale forest disturbances (Vilhar et al., 2022) may lead to increased vulnerability to erosion processes in downstream areas, including outside forested areas in more urbanised valleys. Therefore, forest managers and owners in Slovenia face the challenge of restoring damaged and/or destroyed forests on a large scale in order to increase their vitality and resilience (climate-fit forests). On the other hand, forest managers face the challenge of adapting forest management in order to increase resilience and reduce the risk of torrential and erosive processes in forested areas.

In our study, we were interested in whether the existing forest legislation in Slovenia needs to be adapted for this purpose. We also analysed the existing expert knowledge and tools that are useful both in forest management planning and in the daily work of the Slovenian Forest Service. We hypothesised that the current expert knowledge of the Forest Service is of a high standard, but that there is a lack of a potentially very useful map of erosion-prone forest areas in the catchment areas of torrents in Slovenia. Such a map would inform forest managers and owners about the need for adapted forest management in such areas and alert them for detailed guidelines and recommendations.
In Slovenia, the protective functions of forests are defined by two different forest functions according to the Slovenian Forest Act and the Regulation on Forest Management and Management Plans Game Management Plans. The function of protecting forest areas and stands, the so-called "indirect protection function", is one of the ecological functions (Gucek et al., 2012). It is defined as the protection of the forest site and its surroundings from the effects of erosion processes in the sense of maintaining the resistance of the soil to erosion processes, preventing the development of landslides and avalanches, preventing the deepening of torrent beds, preventing debris flows and maintaining the fertility of forest soils. Forests with a strong "indirect protection function" are mostly defined at the upper timberline, in erosion-prone areas, in floodplains, etc., as defined in the water management regulations, on very steep slopes, in dry areas, shallow rocky or stony soils. For the part of the forests where the "indirect protection function" is exceptionally important, a special legal status, namely the category "protective forest", and thus also a management regime is defined in accordance with the Ordinance on Protective Forests and Forests with a Special Purpose. Another function of the forest that is directly linked to the protective functions (effects) of the forest is referred to as a "direct protection function". It is defined in areas where the forest reduces the threat posed by natural hazards to infrastructure or other facilities. Forests with a strong "direct protection function" protect transport routes, settlements and other facilities from natural phenomena such as rockfall, avalanches, side winds and landslides and ensure the safety of housing and transport. Forests on steep slopes above and below roads or railway lines have a particularly important "direct protection function".

## METHODS

To assess the forested torrential areas in the pilot area (Municipality of Železniki), the map of small water catchments (EHO project, 2023) and the risk map for the occurrence of mass movement processes (MMP) (GeoZS, 2023) were used. The MMP risk map contains 6 risk categories: (0) negligible, (1) very low, (2) low, (3) medium, (4) high and (5) very high. In assessing the torrential areas, we focussed on the presence of the three highest risk categories of the MMP: medium (3), high (4) and very high risk (5) for the occurrence. For each small catchment, we calculated the total proportion of all three higher risk categories in the catchment. If the sum of these three categories accounted for at least 10 % of the catchment area, we defined the entire catchment as a torrential area.

In addition, we applied the forest land use map provided by the Ministry of Agriculture, Forestry and Food (MAFF) to the catchment areas where the proportion of the three highest risk categories was at least 10 % or more (MAFF, 2020). This resulted in a map of forested areas prone to erosion in the catchments hereafter referred to as "forested torrential areas". We decided on the threshold value of 10 % after testing different threshold values, e.g. 10 %, 20 %, 30 %,…100 %. Based on the professional expertise, past torrential processes in the pilot area (Železniki municipality) and their consequences in the past, the 10% threshold proved to be the most suitable for the purpose of this study. Considering the 10% threshold, extremely flat areas were excluded from the assessed forested torrential areas (e.g. wider alluvial plains and extensive valley bottoms) where the risk of MMP occurrence was negligible (0), low (1) or very low (2). In addition, karst plateaus with karstified surfaces and the absence of surface waters were excluded from the assessed forested torrential areas, confirming the 10% threshold as suitable. In addition, the 10% threshold was also tested in 3 other Slovenian municipalities (Kranjska Gora, Koper, Žalec), which differ in terms of geology, geomorphology, climate and vegetation.

The assessed forested torrential areas were compared with forests where the "indirect protection function" and the "direct protection function" were defined by the Slovenian Forestry Service in the Forest Management Plan according to the Slovenian Forest Legislation (ZGS, 2023). We were interested in the proportion of these forest categories that correspond to the assessed forested torrential areas in our study. That latter plays an important role in the forest management guidelines and recommendations in erosion- prone forest areas in the catchment areas of torrents in Slovenia.

To further categorise the assessed forested torrential areas according to the severity of erosion hazard, where hazards such as torrential debris floods may occur frequently, the "silent witnesses" of torrential processes were investigated in-situ by field observations in a small catchment of the Zala torrent in the pilot area (Železniki municipality), applying the methodology of Papež (2011) and Kienholz et al. (2008). We investigated all categorised torrents in the Zala catchment area that were recorded by the Slovenian Water Agency (EHVZ, 2021) in the official hydrography and water area inventories. The Zala catchment has an area of 137 ha in steep terrain between 700 and 1300 m above sea level. The distance between the centre line of the torrent bed and the most prominent part of the silent witness was measured. A map of the recorded "silent witnesses" of torrent processes is presented in our study. The recorded "silent witnesses" in the Zala catchment were also checked using national LiDAR (Lidar, 2016) to test the possibility of remote sensing identification.

## RESULTS AND DISCUSSION

Our results show that the pilot area of Železniki municipality has many catchments, prone to erosion, in which the share of the three highest risk categories of mass movement processes is at least 10% of the catchment area (Figure 1).

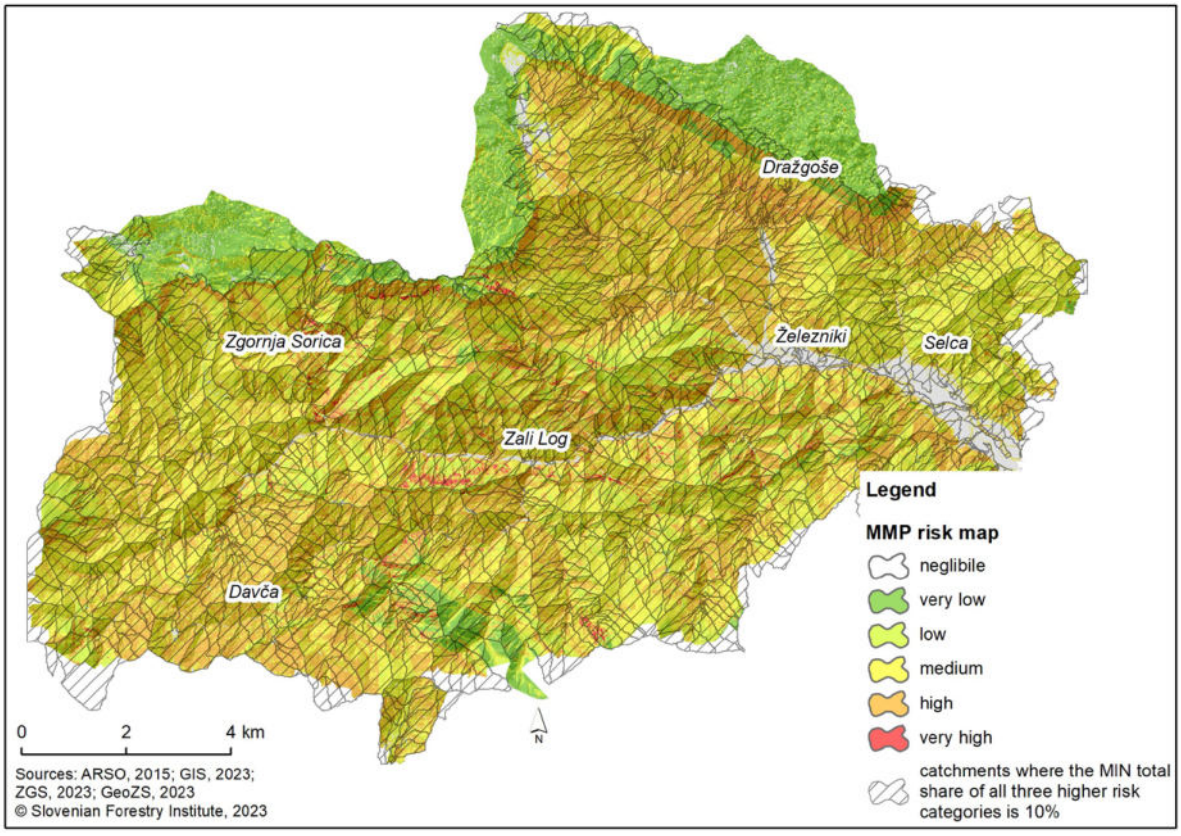


*Figure 1: Risk map for the occurrence of mass movement processes (MMP) with the small water catchments in the pilot area (Municipality of Železniki) where the total share of the three highest risk categories of mass movement processes (medium, high and very high) is at least 10% of the catchment area.*

The entire pilot area covers a total of 16,379 ha, of which 81.2% (13,296.7 ha) is defined as forest land use (MAFF, 2020). 11.963.5 ha or 73.0% of the total area or 90.0% of the forest land use were determined as forested torrential areas according to our method (Figure 2). Within the forested torrential areas, there are 404.1 ha (3.4%) of forests with "indirect protection function" and no forests with "direct protection function" according to the forest management planforest management plan of the Slovenian Forestry Service (ZGS, 2023).

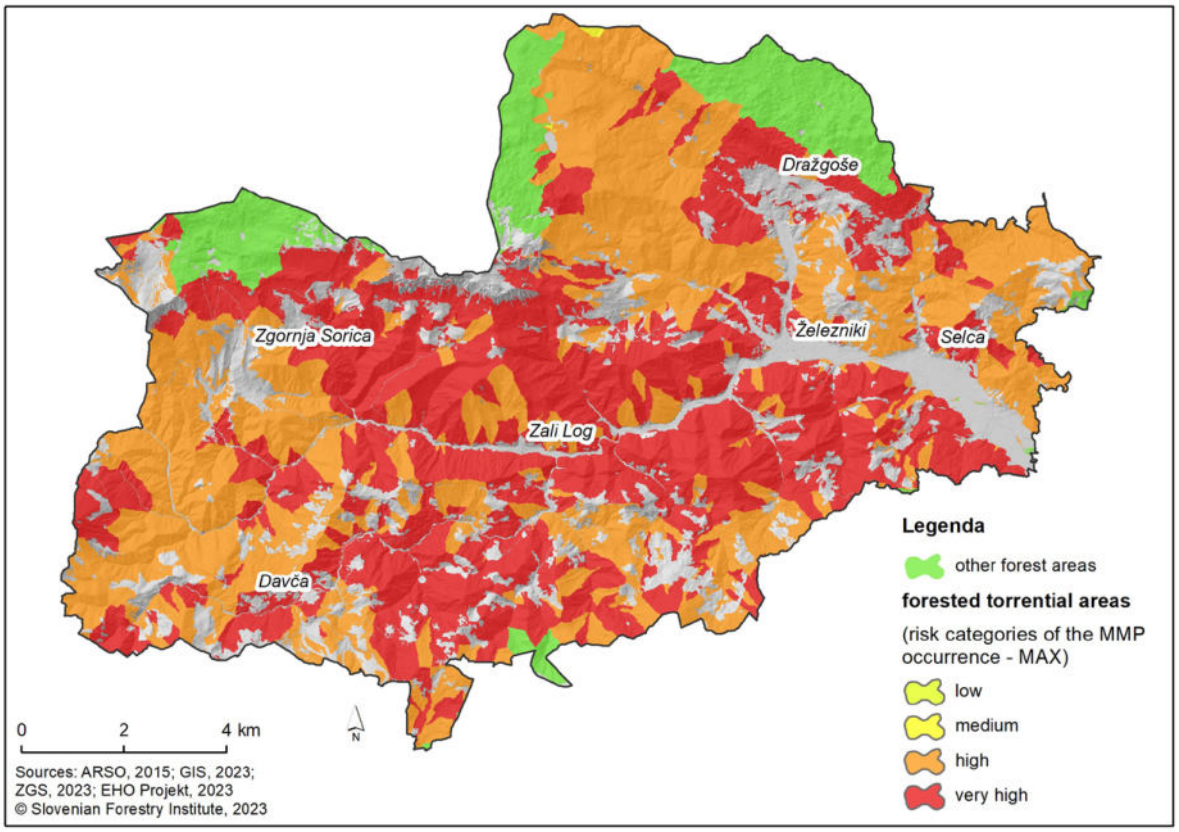


*Figure 2: The map of forested torrential areas - forested areas categorised according to the three highest risk categories of mass movement processes (MMP: medium (3), high (4) and very high risk (5)) in the pilot area (Municipality of Železniki).*

A total of 3692 m of categorised torrents were recorded in the Zala catchment area (EHVZ, 2021) (marked in blue in Figure 3).
The "silent witnesses" recorded in the Zala catchment were divided into two main categories. 53 silent witnesses of the first category can be represented with dots covering small areas close to the torrent bed and directly related to the impact of water in categorised torrents (widening of the streambed, crooked growth of trees, deposition of driftwood, damage to skid trails and forest roads, ...). Figure 3 shows the "silent witnesses" in three groups: (1) closer than 5 m from the centreline of the torrent bed; (2) between 5 and 9 m from the centreline of the torrent bed; and (3) between 10 and 14 m from the centreline of the torrent bed.

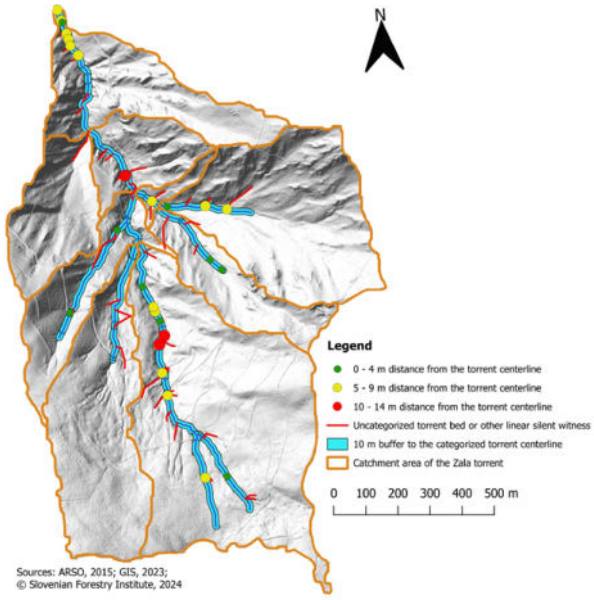


*Figure 3: "Silent witnesses" of torrent processes in the Zala catchment in the pilot area (Železniki municipality).*

Secondly, 40 "silent witnesses" with a total length of 1875 m (red lines in Figure 3), which occurred more than 10 m from the centreline of the torrent bed, could be identified by lines and are mostly related to secondary – uncategorised torrent beds or torrent diversions and smaller landslides. According to our survey, for every metre of categorised torrents in the Zala catchment listed in the official hydrography and water area records of the Slovenian Water Agency (EHVZ, 2021), another 0.5 m of uncategorised torrents were recorded by field observations. Only some of the uncategorised torrents could be mapped with the national LIDAR, but most of the "silent witnesses" require individual in-situ field observations or more sophisticated precise remote sensing techniques.

## CONCLUSIONS

This study presents the methodology for the assessment of forested torrential areas in the pilot area (Municipality Železniki). In the pilot area of the Municipality of Železniki, 73.0% of the total area or 90.0% of the forest land use was identified as forested torrential areas according to our methodology. According to the forest management plan of the Slovenian Forestry Service, only 3.4% of these forested torrential areas were designated as forests with a direct or indirect protection function. This shows that the existing forest legislation and the designation of forests with a protection function in Slovenia need to be adapted.

Other specific methodological difficulties were related to the map of categorised torrents provided by the official hydrography and water land records of the Slovenian Water Agency (EHVZ, 2021). Our field observations on site in a small watershed of the Zala torrent show that most of the "silent witnesses" were located within 10 m of the centreline of the torrent bed. Furthermore, for every metre of categorised torrents, an additional 0.5 m of uncategorised torrents were recorded. To overcome the lack of an official torrent hydrography, the small water catchments map was created (EHO project, 2023) and combined with the mass movement process (MMP) risk map (GeoZS, 2023). The MMP has so far been developed for several municipalities in Slovenia, but will be finalised at national level in the future.

Recognising and recording "silent witnesses" through field observations requires individual fieldwork, which is time-consuming and requires qualified professionals. Another option is sophisticated, precise remote sensing techniques, although national LiDAR data has not proven to be detailed enough.

## ACKNOWLEDGEMENTS

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