

## GOOD PRACTICES OF LANDSLIDE HAZARD MONITORING AS A SUPPORT FOR SUSTAINABLE SPACE DEVELOPMENT – EXAMPLES FROM POLAND

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**Abstract.** *The southern Poland has fragmented structure of land parcels, highly relief area, and the geological structure conducive to landslides. There are numerous examples of landslides. The Landslide Protection System is a project of national importance, which is being implemented in several stages. The basic objective of the SOPO project is to identify and document all landslides and areas potentially threatened by mass movements in Poland and establish a system of in-depth and surface monitoring. This provides a starting point for mapping landslide susceptibility and, at a later stage, for developing a system of forecasting, assessment and mitigation of landslide hazards in Poland, i.e. for limiting to a considerable extent the damage and destruction caused by landslide development.*

**Keywords.** *property boundaries, landslides, risk maps*

### Introduction

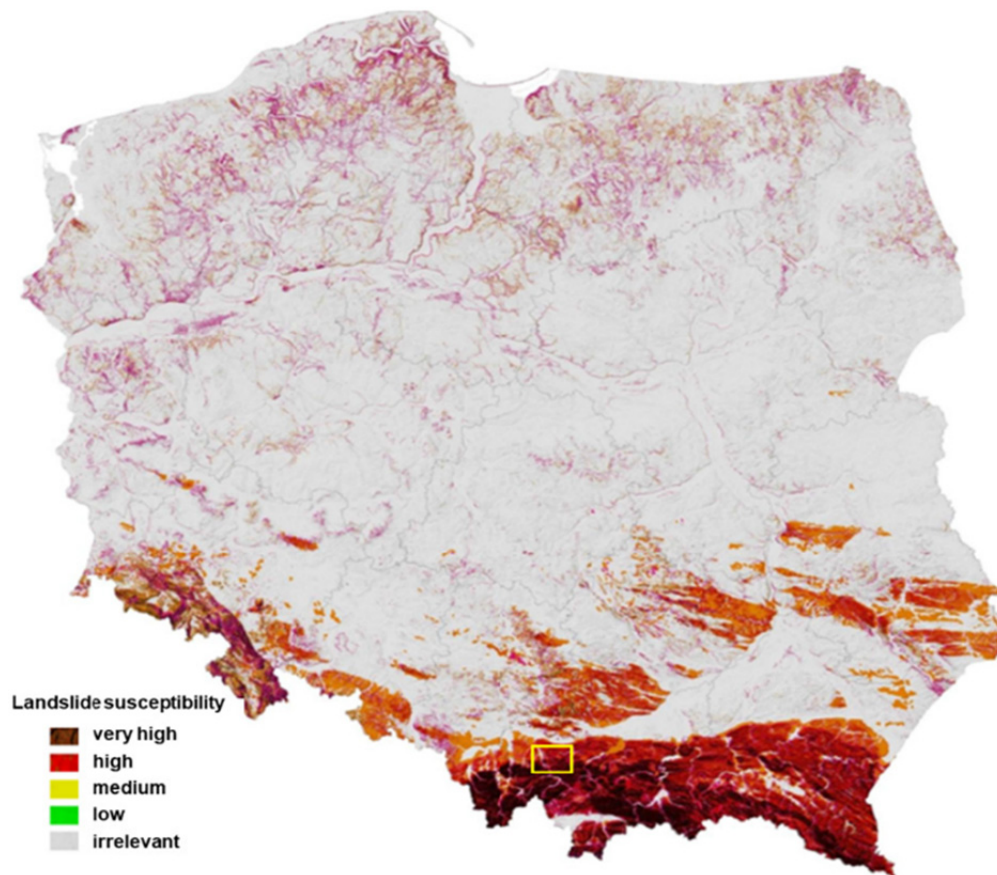
At the global scale Poland is described as a country with low susceptibility to landslides [1]. The European Landslide Susceptibility Map made within the ELSUS1000 project available on the website of the European Soil Data Centre (ESDAC) only in the southern part of Poland, in the Carpathian Mountains and in parts of the Sudety Mountains the landslide susceptibility was described as medium and in some places high [2].

The occurrence of landslides depends on a set of factors that determine the stability of slopes. These are referred to as passive factors and include (1) geological conditions i.e. lithological and tectonic conditions, (2) morphological conditions such as slopes, exposure and slope shape, (3) hydrological and hydrogeological conditions and (4) land cover [3]. On the other hand, the occurrence of a landslide itself is triggered by active factors, i.e. precipitation, fluvial or marine erosion, seismic shaking or human activity [4].

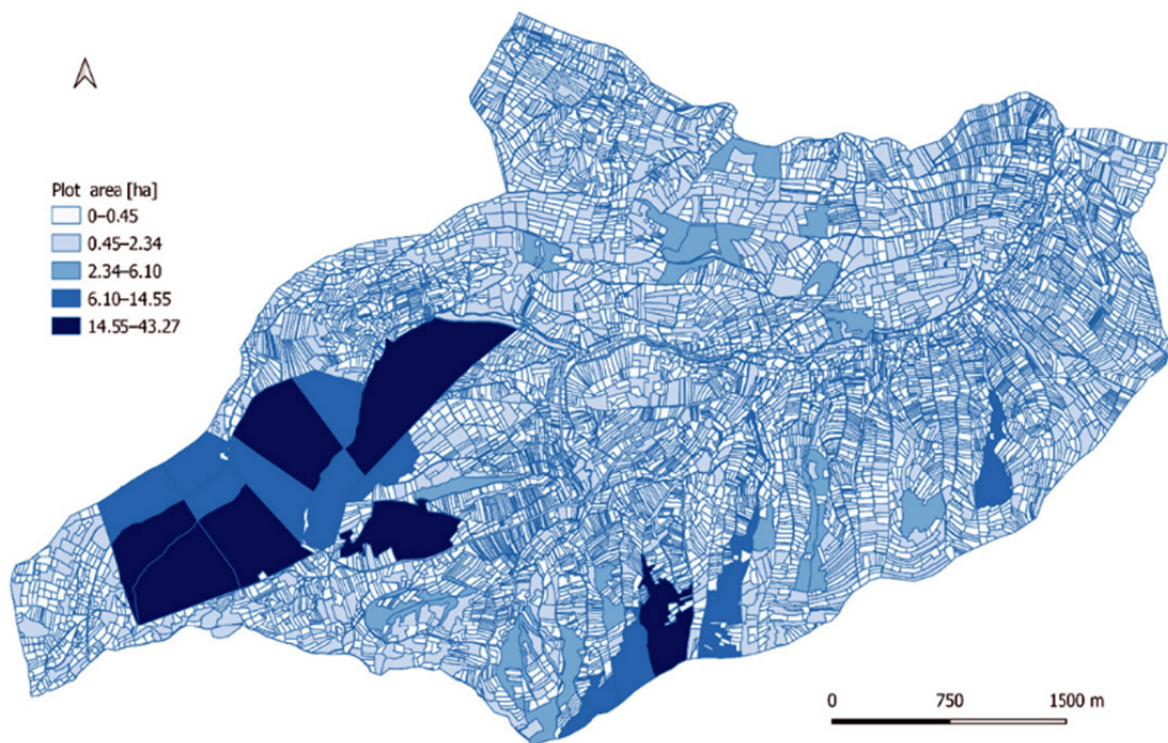
The most susceptible areas to mass movements are those where landslides have already occurred. In practice, a landslide susceptibility map is drawn up on the basis of an analysis of known factors [5]. The map gives a picture of the potential for landslides to occur in a given area due to the environmental conditions there [6]. Until a few years ago, the landslide hazard message in Poland limited the problem of mass movements to the Carpathian Mountains. On the basis of the inventory of landslides in Poland in 1968-1970, a map with the distribution of areas threatened by mass movements was prepared (fig. 1). This was the basis for the development of the Landslide Protection System (SOPO), which covers the whole country. Conducted by means of a uniform and consistent method, the inventory of landslides [7] and provides an increasingly detailed picture of Poland in terms of landslide hazards.

The scale of the landslide problem, with particular attention paid to land tenure relations, can be seen on the example of one of the foothill villages, Grzechynia, located in the county of Sucha Beskidzka, in the

municipality of Maków Podhalański. Due to the high fragmentation of land parcels, there are more than 10,000 land parcels in an area of approximately 18.3 km<sup>2</sup>, with an average plot size of 0.18 hectares (see fig. 2, table 1).



**Fig. 1.** Landslide susceptibility map of Poland with mark on the village Grzechynia in Carpathian Mountains (yellow rectangle). Source: own study based on [3].



**Fig. 2.** Spatial distribution of plot sizes in one of the village in Carpathian Mountains in Poland – the village of Grzechynia. Source: own study.

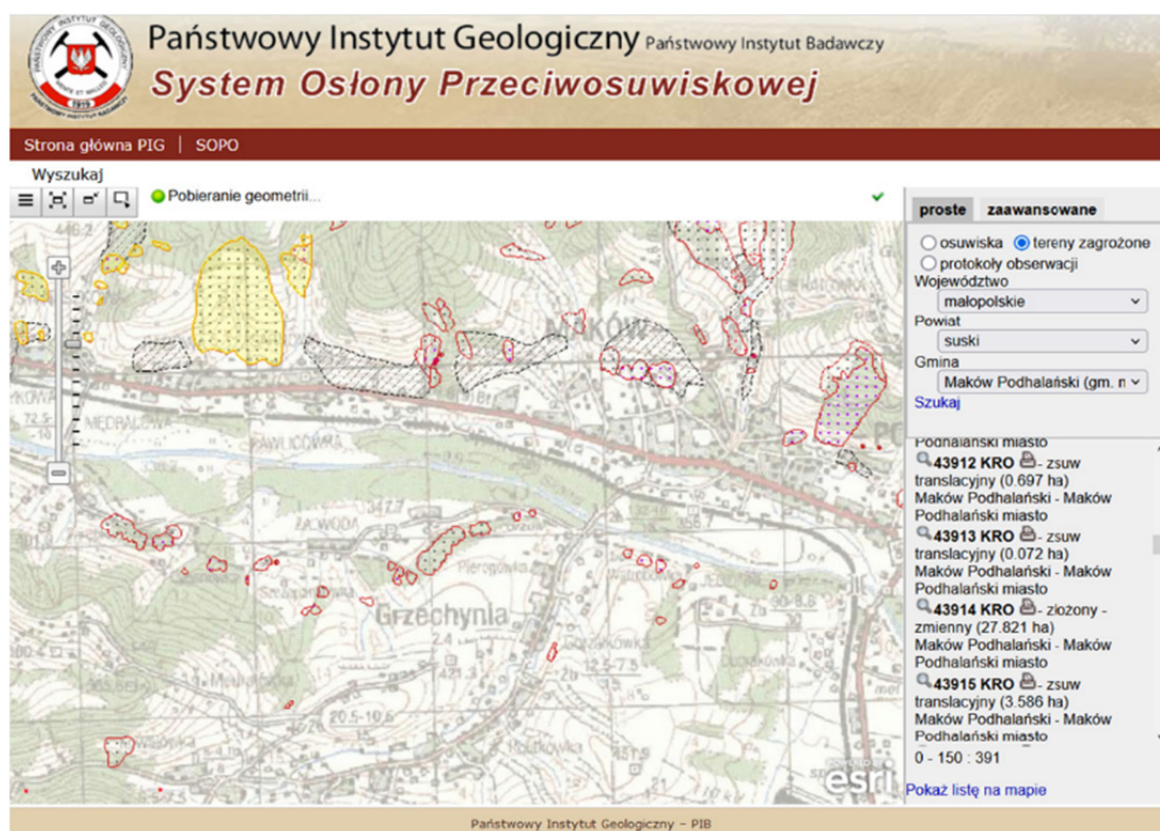
**Table 1. The characteristics of plots in Grzechynia village in Carpathian Mountains.**

No	Size of plots (in hectares)	Number of plots	Percentage proportion to the total number of plots	Total area of plots in size groups (in hectares)	Percentage proportion to the total plots area	Average area (in hectares)
1	0-0.45	9,548	95.1	1139.37	62.3	0.12
2	0.45-2.34	455	4.5	328.93	18.0	0.72
3	2.34-6.10	24	0.2	95.24	5.2	3.97
4	6.10-14.55	11	0.1	117.23	6.4	10.66
5	14.55-43.27	6	0.1	148.06	8.1	24.68
Total		10,044	100%	1828.83	100%	0.18

Source: own study

### Landslide Protection System (SOPO) and landslide data

The specialists from the Geohazards Centre of the Polish Geological Institute and a dozen geological companies in southern part of Poland have already located and inventoried over 70,000 landslides and over 6,500 areas at risk. As we can observe there are some examples of risk areas also in Grzechynia village (fig. 3). In Poland monitoring is being carried out on several dozen particularly hazardous and active landslides using the latest research methods. Approximately 38% of the landslides are classified as active and periodically active. The proportion of active landslides may now be higher, as mass movements are dynamically variable phenomena in time, and some of the work was done before the so-called landslide catastrophe of 2010, which resulted in thousands of landslides becoming active.



**Fig. 3. The front page of Landslide Protection System in Poland for landslide data searching.**

Most mass movements and their associated hazards occur in the Carpathian Mountains contributing to serious material losses. For this reason, the main emphasis of mapping work has so far been on the Silesian,



Lesser Poland and Subcarpathian Voivodeships. The current state of reconnaissance makes it possible to estimate that there may be more than 100,000 landslides in Poland [8].

On the basis of landslide susceptibility data, it can be concluded that the probability of landslides is about 15% of the area of Poland. Very often, mass movements are recorded in anthropogenic embankments, which were not taken into account in the draft SOPO. Very high and high landslide susceptibility together cover just over 6% of the country's area [3].

## Conclusions

The landslide susceptibility map of Poland provides an indicative picture of the hazards that may arise from mass movements. The researchers compared the susceptibility map with the database of topographic objects at a scale of 1:10,000. They calculated that in the landslide-prone area, which accounts for 15% of the country's area, there are 1 051 989 buildings, of which more than 570 000 are residential buildings. More than 25,000 industrial buildings are located in landslide-prone areas, while there are 9,520 public buildings. Approximately 7080 km of roads, and 585 km of railway lines run through these areas. It can therefore be concluded that there is a very large number of vulnerable infrastructure in Poland that may be threatened to some extent by landslides in the future [3].

Due to the small scale of the input data, the landslide map available in the Landslide Protection System cannot be used for spatial planning purposes – however, it is of great illustrative value and has another important application as it is the basis for estimating the costs of planned landslide inventory works and their verification in individual administrative units. There are also examples of more accurate local landslide maps, which can be used for planning purposes [9].

The Landslide Susceptibility Map of Poland is updated annually. As the number of identified landslides increases, so does its quality and accuracy. Further improvement of the quality and detail of this map may enable better and more accurate input data and further development of methods of landslide susceptibility calculations in the future.

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