

## FLOODS AND LANDSLIDES IN THE CITY OF TUZLA AREA CAUSED BY NATURAL DISASTERS IN 2014

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*The paper analyzes the occurrence of floods and landslides in the city of Tuzla area, due to above-average rainfall during 2014. Water levels, flows and floods caused by natural disasters in May and August of 2014 were significantly higher proportions compared to previously registered values. The cause of the extremely high water levels and flooding in May was 3.5 times higher amount of rainfall, compared to the average monthly value, which were extradited to the ground saturated with water of earlier rainfall. Precipitation caused reactivation of the old and the emergence of new landslides, even on slopes where previously were not registered. Extremely high rainfalls are a major cause of destabilization of slopes, but also negative anthropogenic activity in space. Landslides have caused significant material damage, particularly on the residential slope zone of the city and suburbs.*

**Key words:** *precipitation, anomalies, variability of rainfall, floods, landslides, natural disasters, Tuzla*

### INTRODUCTION

The City of Tuzla is located in the Jala basin, in the region of northern Bosnia, specifically in the subregion of Spreča-Majeвица region with Semberija, in the northeast of Bosnia and Herzegovina. The area of Tuzla, Bosnia and Herzegovina, as well as most of South-Eastern Europe in 2014 received above-average annual rainfalls that have caused so far unregistered values of water levels, strong streams, flooding and numerous landslides and huge material damage.

The research topic is the phenomenon of floods and landslides in the Tuzla area, due to above-average rainfall during 2014. Water levels and flooding caused by natural disasters in May and August 2014 were significantly higher proportions compared to earlier periods. Due to heavy rainfall which have caused the floods, there was a sharp rise in water levels and water spillage from the riverbed. This precipitation caused a reactivation of the old and the emergence of new landslides, especially on slopes with increased human activity. The problems of research in this paper are the causes and consequences of natural disasters in 2014 in the city of Tuzla. Studies have been conducted to analyze previously undertaken measures and procedures to reduce consequences of these types of natural disasters. Also, the researches show the negative anthropogenic activity, which has caused significant material damage and threaten the safety of citizens. It was presumed that the anthropogenic

activities, in the area of Tuzla have reduced the safety of the population and increased the risk of damage in terms of natural disasters.

For the study the mentioned geological, geomorphological, hydrographic, even pedographic problem, used a more scientific research methods, and the starting point was the analysis of the available literature, and sources of information on these natural disasters. Carried out the studies and surveys of the population of the mentioned phenomenon, and numerous information obtained by the method of direct observation, which is unavoidable in geographical research of space. In addition to the above, the paper used: cartographic methods to obtain the data on area and create thematic maps, statistical methods for processing data on meteorological elements, the causal method by which to determine the causes and consequences of natural disasters and comparative which was compared with the prior state from 2014.

So far a number of papers on the topic were written and published, whose results were used in the work and discussed in the section literature and sources. The research processes the geographical aspect of problems, causes, processes, effects and consequences of natural disasters in the named area.

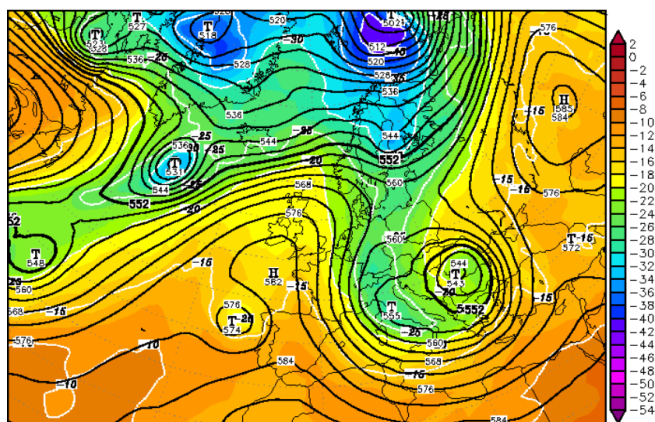
## FLOODS AND LANDSLIDES, CAUSES AND CONSEQUENCES IN THE TUZLA AREA

### Anomalies and variability of rainfalls in 2014 in the Tuzla area

If we compare the average value of annual rainfall, with annual rainfall in each analyzed year, we will notice that in each year does not fall the same amount of rain. The average deviation of annual precipitation from the mean values for many years is called volatility or variability of rainfall (Spahic, M. 2002).

The average deviation for the climatic zone which is located in Tuzla amounts to 15-20%. However, the average deviation of annual precipitation in the area of Tuzla in 2014, was as much as 32% compared to the reference period (1961-1990), and the reason is the formation of a larger number of cyclones and their longer retention of Southeastern Europe, which was particularly pronounced in the second decade of May that year (see Table 1).

The cyclone activity over the area of Bosnia and Herzegovina, particularly in the spring and early summer can bring heavy rains, which can be harmful and treated bad weather. They are especially intense at the time of strengthening the Azores anticyclone.



**Fig. 1: Cyclon over southeastern Europe, 15.05.2014.**

Data source: RHMZRS, preuzeto sa [www.water3.de](http://www.water3.de), 2014.

These weather conditions hit the western Balkans in the spring of 2014, and in the meteorological practices have been incorporated into a maximum rainfall and water levels date (Spahic, M. 2015).

By the analysis of the synoptic situation, it was noted that in Genoa Bay on 13. May a deep cyclone were established, which shifted over the southern Adriatic area and in the period from 14.05. to 17.05.2014. and deployed over large parts of Bosnia and Herzegovina, Serbia and Croatia. At the same time in the northeast of Europe the spacious anticyclone was formed that prevented the mentioned cyclone to move further to the east. The temperature stratification with height was ideal for cyclogenesis and deepening of the cyclone and a constant supply of warm, moist air from the Mediterranean resulted in the formation of a thick layer of clouds and a strong and heavy rainfall (see Figure 1). It should be noted that on April 20, rained almost the whole day, so that the ground was already saturated with water, causing swelling and rapid increase in water levels in rivers. A cyclone activity on May 17 gradually weakened, the rain slowly stopped, and in the last decade of May a period of good weather with temperatures above 30°C occurred. The analysis of pluviometric regime in Tuzla was based on the results of measurements from the Meteorological station " Tuzla " ( $\varphi = 44^{\circ}32'N$  ,  $\lambda = 18^{\circ}41'E$ ), in a way by comparison of mean monthly rainfall in 2014 with the first climate period 1961-1990.

**Table 1: Average monthly precipitation in Tuzla in 2014, and the average monthly and maximum daily precipitation in the period 1961-1990.**

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	$\Sigma$ /Year
R mm (2014)	28.6	39.1	72.4	186.9	339.3	64.1	111.7	183.5	135.3	94.0	22.6	75.6	1,353.1
R mm (1961-1990)	63.0	59.8	64.0	79.7	96.5	107.5	89.8	83.2	69.3	60.5	77.7	76.0	927.0
Rmax (1961-1990)	40.5	43.5	43.5	43	60.5	58.5	80	52	58	44	44.5	46.5	80

*Data source: Meteorološki godišnjaci, FHMZ, Sarajevo, 2015.*

Analysing the data on average monthly rainfall in the first period 1961-1990, it was found that Tuzla belongs to continental pluviometric regime. The average annual rainfall in the area is 927 mm.

The main maximum of precipitation is in June, as a result of frequent barithic depression, occurred at this time of the year. Considerable amount of precipitation falls in the form of thunder showers, the family of cumulus clouds of vertical and frontal development, in a short period of time. Since June rainfall decreases until October, when it reaches the secondary minimum. Since December rainfall decreases until February, when it reaches the main minimum, and then rises up to June.

The total number of days with precipitation averages 159. In June, when the most rain were fallen, an average of 15 precipitation days or 50 % of the possible occurred. The probability of precipitation, which is obtained as the ratio of the average number of days with precipitation and the total number of days in the month is 0,5. This means that in the month of June we can expect that in 10 days will be five days of rain. The relative annual fluctuation amount of precipitation is 47.7 mm.

In 2014, in Tuzla had fallen 1,353.1 mm of precipitation, which is 426 mm more than the climatological average. Also, there were 178 days with precipitation. The maximum amount of rainfall was recorded in May, 339.3 mm, which is about 3.5 times the average of

monthly precipitation. This is the highest amount of rainfall, compared to all the weather stations in Bosnia and Herzegovina, for the month. In May 2014, in Zvornik fell 303 mm, 301.2 mm in Gradačac, Doboj 270 mm, 252.5 mm Bijeljina, Banja Luka 217.8 mm, 212.1 mm Sanski Most, etc.

During May in Tuzla fell about 25% of the rain in 2014, which is about 1,4 times more than the climatological average for spring, 1,2 times more than the average for the summer, 1,6 times more than the average for the fall and 1,7 times more compared to the climatological winter average. In this month the maximum of daily rainfall dropped to 94.6 mm, which was recorded on May 15 and throughout the month of the total of 18 precipitation days. From 14 to 17 May in Tuzla fell in total more than 250 mm of rain, which is 2.5 times more compared to the climatological average for May.

In April 186.9 mm of rainfall was recorded, which is about 2.3 times higher than the climatological average for that month. In this month there were 23 rain days, where on 17 April fell 48.4 mm of rain. Only in April and May fell 526.2 mm of precipitation, or about 57% of the average amount of precipitation for Tuzla.

Increased rainfall in 2014 was recorded in August, when 183.5 mm of rain fell. In this month, more precisely, on August 6, the second highest daily rainfalls in 2014 of 82.8 mm were recorded and 14 precipitation days also. In the period from August 5, 2014 from 18:00 to 6 August 2014 to 10:00 o'clock fell 128 mm of rain, which means that the precipitation in 16 hours was approximately 50% greater than the average amount of monthly rainfall for August which for Tuzla is 83 mm.

Above-average rainfall, particularly in the second decade of May caused the emergence of powerful flood, flood and activation of a large number of landslides in the area of Tuzla. These negative phenomena and processes contributed previously very wet, a period during April and the first week in May, because the ground was already saturated with water.

### **Floods in the City of Tuzla area during 2014**

The town of Tuzla is located in the basin of the river Jala, which rises on the slopes of Majeвица at Ravni Liještak, at an altitude of about 700 m. The total length of the main flow from the source to the mouth of Spreča is 37 km. Tectonic characteristics and petrographic composition have enabled this stream to form asymmetrically with developed right side, river network-angled type. All major tributaries flow into the river Jala from the right. The only major tributary on the left, the river Požarnica with Kovačica flows in at the source area. The largest right tributaries of the river Jala are: Solina, Grabovac, Joševica and Mramor stream. The Jala river and its tributaries regime is pluvial-nival. Despite the large number of tributaries, Jala is a small watercourse, especially in drought years. And it has a very strong torrential character. So on the profile of Tuzla in the period 1961-1990. a minimum flow of 0.06 m<sup>3</sup>/s and a maximum of 268 m<sup>3</sup>/s were measured. Jala has a normal valley and its sides are characterized by small angles, large bottoms and shallow ravines. This aquifer has the most water levels in the period from November to May with a peak in April, the lowest from June and October with a minimum in August and September.

The City of Tuzla is at the time of high rainfall exposed to occasional occurrences of floods and flash floods, and the most vulnerable areas are alluvial plains along the Jala and lower parts of its tributaries. Floods threaten settlements Gornja Tuzla, Simin Han,

Slavinovići, Grabovica, Solina, Lipnica, Bukinje, Mihatovići, Mramor and some parts of the city because of the impossibility of accepting large quantities of rainwater.

The rainfall caused floods which, conditioned by the geology, strongly destroy the riverbeds. The destruction of the lateral riverbed undercutting threatens the population and parts of villages located along the courses. These phenomena and processes are most threatening settlements Sepetari, Mosnik, Moluhe, Batva, Solana and others. The Jala riverbed and the lower course of the stream through the city of Tuzla is arranged, and the bottom and sides of the bed are made of concrete, thus reducing the effects of flood activity. Regulation of riverbeds accelerated flow thus reducing the possibility of flooding of coastal zones of the city.

Floods caused by natural disasters in May and August 2014 were significantly with higher proportions compared to the previous period. The cause of the extremely high water levels and flooding in May was by a 3.5 times higher rainfall compared to the average monthly value. Also, this month is excreted in four days  $250 \text{ l/m}^2$  on the ground and is saturated with water during the rainy months of April above average. Due to heavy rainfall on one day, a sudden increase in water levels and water spillage from the riverbed occurred. On the river Jala a maximal flow of  $350 \text{ m}^3/\text{s}$  was recorded (Suljic, N. et al . 2015). According to our calculations the maximal flow in Tuzla was  $325 \text{ m}^3/\text{s}$  (see Figure 2 and 3).



**Fig. 2: Tuzla, Jala river bed, 15.05.2014.**



**Fig. 3: Flood protection, 15.05.2014.**

The tidal wave of Jala endangered the agricultural land and a small number of mostly illegally built residential buildings. Torrent streams and tributaries caused flooding of a number of residential, office and other buildings and damaged and destroyed a significant number of bridges and local roads. The groundwater increase flooded a number of basement rooms, cellars and garages, especially those that are located near the Jala. Due to rainwater drainage lack, the city roads were flooded, especially in the area of subsidence, where the northern roads, at a distance of about 300m and the complex filter systems of "Pannonica", where flooded and where a great material damage were made. This part of the city is flooded by even much smaller amounts of precipitation than they were in May of 2014. Since the riverbed Jala is regulated, and this and its cleaning was done before the flood, the water spills and flooding the surrounding area and facilities were reduced. After the cessation of rainfall the water quickly receded in its beds, but the catastrophic floods occurred downstream, at the river Spreča, Bosnia and Sava.

Precipitation of 5 and 6 August 2014. caused new flooding, because the soil is saturated with water left from previous months. Water level of the river Jala in the city was about 30cm higher than the water level in the month of May, and the cause is, in addition to rainfall, an enormous amount of sediments in the riverbed created by the floods (see Figure 4).

These flood waves swept some buildings, houses, apartment buildings and industrial facilities that remained out of the reach of high water in May 2014 (see Figure 5 and 6).



**Fig. 4: Tuzla, Jala river bed, 14.11.2015.**



**Fig. 5: Tuzla, Irac settlement, august 2014. (water level in basement rooms – red line)**



**Fig. 6: Damage caused by floods in August 2014.**

## **Landslides in the City of Tuzla area in 2014**

From the architecture and the environment standpoint, the process of sliding in the rocks is one of the most important egzodynamic processes, sometimes with disastrous consequences. Basically, the landslides are occurrence of moving surface, loose parts of the terrain on the slopes, with more or less depth, causing a transformation of relief landscape.

Among the most significant geohazards, which are changing the shape of relief, the tectonic is the most important, such is: volcanism and earthquakes, while the landslides may be caused by egzodynamic processes related to meteorological and hydrological severe weather conditions (Spahić, M. 2014). Landslides are formed in a vertically articulated or sloped relief. They can be formed in a slight slopes, with inclinations less than 5°, but mostly formed on the slopes with a inclination between 5° and 30°. So, beside of the morphostructural characteristics of the space, created as a result of endodynamic processes, landslides and relief reshaping are initiated by egzodynamic processes too.

The most common external modifiers are pluviometric, which in a short daily periods, can overcome the triple monthly maximum of rainfall. Of all egzodynamic processes natural disasters are dominant, which is why the climate fluctuations, which cause frequent temporal variations, attributed a leading role in the transformation of the landscape relief (Spahić, M. 2014).

After the water of the May rainfall, withdrew in riverbeds, in the area of Tuzla it triggered numerous landslides, dispersals and landslide of rock material. The main causes of the formation of new and reactivation of existing landslides, in this area, can be classified into two groups: natural and anthropogenic factors. Of natural factors, beside the sloping terrain and intense, long-termed and heavy rainfall, the undermining slopes by torrential waters, difficult drainage of the surface water and their lake forming can be specified. On this phenomenon the geological built was very significant, because this area is dominated by clastic sediments with the changes of impermeable and permeable rocks. Considering the tectonic structure, litostratigraphic characteristics, geomorphological position and contemporary dynamics of relief and local particularities, the area of Tuzla belongs to foreland steps and slopes of hills of northern Bosnia.

Foreland step slopes and slope hills area of northern Bosnia are designed by slope and fluviouduational processes on the different types of clastic "soft" lake sediments, marine (clay, sand, marl and smaller limestones), fluvial (sands, gravels), sloping and eolian (loess and loess like sediments) origin of Tertiary and Quaternary and Eocene flysch. Landslides usually occur on Neogenic clays, flysch, relict soil horizons, in the case of younger and stronger uplift egzogenously-morphological segmentation of the terrain (Bognar, A. 1996).

The dominant anthropogenic factors of formation and reactivation of landslides in the area of Tuzla are: excessive load of slopes, illegal buildings construction, as well as their foundations in layers of poor physical and mechanical properties, unregulated rainwater runoff and waste water, deforestation of unstable slopes, cutting into the hillside, inadequate construction roads, agricultural production on the slopes, untimely implementation of measures of rehabilitation of landslides during the first traces of the instability of the slope etc.

The wider area of the City of Tuzla, and prior to 2014, characterized by a large number of landslides, resulting from a combination of geological structure, geomorphological characteristics of the terrain and anthropogenic activities. We point out in 2001 and 2010 when, due to the high value of rainfall, the numerous landslides were triggered and when it was declared a state of emergency by floods and landslides. In December 2010, in the local community Mosnik, was a total destruction of a few houses and three people lost their lives during a sudden drop-out.

According to the Cantonal Administration of Civil Protection Tuzla, in the city of Tuzla, during 2014, there was 2,170 registered landslides. Due to excessive saturation of the soil with water, caused by prolonged and heavy precipitation, it reactivated the old and established new landslides and appeared drop-out parts of slopes and collapse of rock mass (see Table 2). Landslides jeopardized the settlements: Badre, Solina, Crno Blato, Kula, Orašje, Čaklovići, Simin Han, but also all other urban, suburban and rural settlements.

In the city of Tuzla area, by 2014, the unstable slopes with landslides occupied 40.75 km<sup>2</sup>, or 13.44%, and conditionally stable terrains included 29,97 km<sup>2</sup> or 9.89% of the total area of the City. Total, landslides and unstable (conditionally stable) slopes occupied the 70.72 km<sup>2</sup>, or 23.33% of the total surface area of the city of Tuzla. Intense rainfalls during 2014, most of conditionally stable slopes, also become unstable and there appeared

landslides and attritions. So, today over 20% of the City territory is characterized by unstable slopes (see Figure 7 and 8).

**Table 2: The number of reported landslides and damage assessment in the City of Tuzla in 2014**

Area	Number of reported (active) landslides			Number of destroyed objects (May-August 2014.)	Assessment of damage (consequences of floods and landslides) in 2014		
	June 2005.	June 2010.	1.12.2014.		May 2014.	August 2014.	Total
City (municipality) Tuzla	346	324	2,170	93	352,760,000	800,000.00	353,560,000.00
Tuzla Canton	1,856	1,573	6,730	351	519,373,500	119,678,256.48	639,051,756.48

*Data source: Prostorni plan za područje Tuzlanskog kantona 2005-2025., str. 57  
 Prostorni plan općine Tuzla za period 2006 – 2026, prednacrt, str.253  
 Zbirni izvještaj o procjeni šteta na materijalnim i drugim dobrima izazvanim djelovanjem prirodnih nepogoda na području Tuzlanskog kantona u 2014. godini, Kantonalna komisija za procjenu šteta od prirodnih i drugih nesreća, Tuzla, januar 2015. godine*

The largest number of landslides appeared in the eastern and central part of the city (until 2014 municipality) areas, where the landslides that threaten material goods appeared, with less risk of endangerment of human life. The landslides were formed on slope inclinations, mostly between 5° and 30°. On these slopes the human activity is expressed, that is, the forest vegetation was removed, a large number of suburban and rural areas which do not have adequate infrastructure was built, and the most of buildings are without permits. The terrain is further destabilized by laboring slopes from soil and inadequate agricultural production.



**Fig. 7: Material damage in slope zones of Tuzla**



**Fig. 8: Tuzla, Badre settlement, may 2014.**

The greatest risks occur in slope areas of the urban area of Tuzla, which are made of sands, where the soil layer is thinner and where was established a strong landslides and drop-outs. This is an area of high risk for material goods and human lives, because there is a large number of housing units built without proper municipal infrastructure, and it's densely populated (see Figure 9 and 10).



Property damages in 2014, emerged as a result of floods and landslides, are estimated at about 350 million, or 50% of total claims incurred in the Tuzla Canton. In the city of Tuzla area, there are 93 residential and other buildings completely destroyed, and more than 600 were damaged or threatened by landslides.

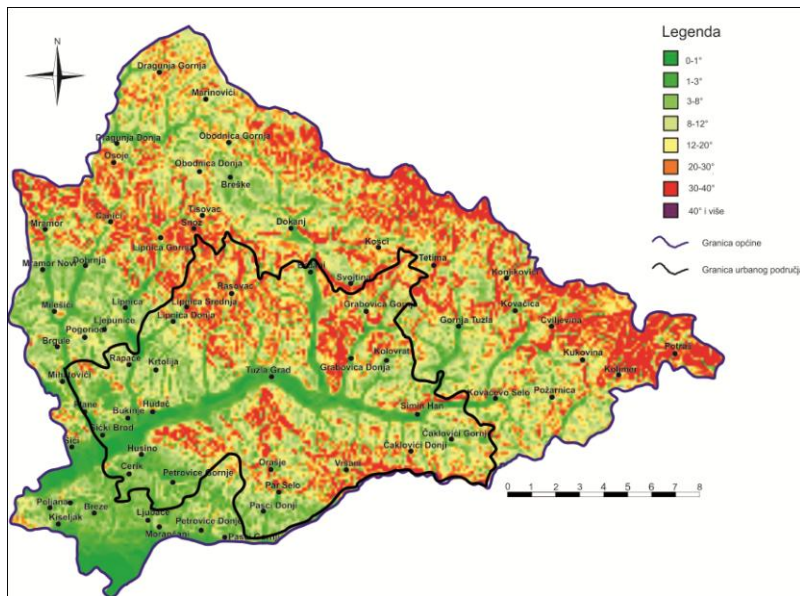


Fig. 9: Slope angle map of the City of Tuzla (municipality) areas

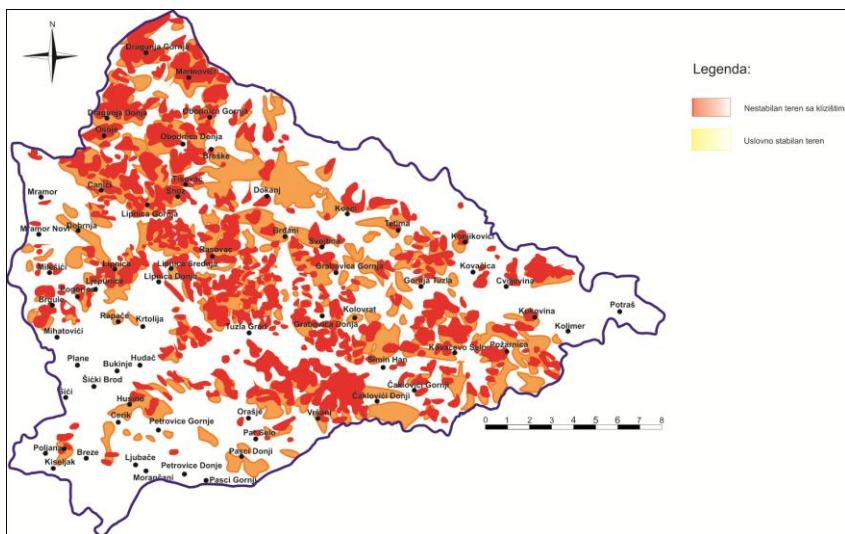


Fig. 10. Stability slope map of the City of Tuzla (municipality) areas  
 Data source: Prostorni plan općine Tuzla za period 2006-2026

## CONCLUSION

In 2014, in the Tuzla area were very pronounced anomalies and variability of precipitation. During the year fell 1,353.1 mm of precipitation, which is 426 mm higher than the climatological average. Also, there were 178 days with precipitation, and maximum rainfall was measured in May, about 3.5 times higher than the average monthly precipitation.

Above-average amounts of rainfall have caused the occurrence of flash floods, floods and activate a large number of landslides in the area of Tuzla. On the Jala river maximal flow was recorded, for about  $39 \text{ m}^3/\text{s}$ , higher than the previously recorded maximum. Since the bed of the river Jala is regulated, and its cleaning was made before the flood, that substantially reduced water spills from its banks and flooding the surrounding area and facilities. After the cessation of rainfall water quickly receded in their beds, and have not caused any damage to property which are usually caused by natural disasters of this scale. Extremely high values of rainfall triggered numerous landslides that have occurred dropout and landslides of rock material. The largest number of landslides were registered in the city slope zones and in areas where human activity is expressed. A very small number of landslides were registered in areas where the human activity lacked of, which means that the negative anthropogenic effects, particularly in urban areas, significantly increased the resulting damage to property and threatened the safety of the population.

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