VULNERABILITY TO SURFACE EROSION DUE TO RAINFALLS AND RELIEF

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Abstract. *The main purpose of this study is to analyze the vulnerability of the Bara territory (located in the low hills, with altitudes between 128 - 278 m.) to the action of erosion processes under the influence of precipitation, slope and slope orientation. To analyze the climate of the study area were used meteorological data recorded at the meteorological station Lugoj in the period 1980 - 2010 and in 2010. Based on this data were calculated de Martonne Aridity Index, Angot Index, Fournier Index. Using Digital Elevation Model was generated, by ArcGIS software, map of the slopes and aspect, used to identify areas vulnerable to the action of surface erosion and to establish correlations between the slope and slope exposure. In 2010, de Mrtonne Index was 34.44 for the type of humid climate. Fourier Index has a value of 31.85, which means that, in 2010, the potential erosion by rainfall falls in the "very low", but the temporal distribution of rainfall is uneven and the Angot Index highlighting rainy periods, favorable production erosion processes, in spring and early summer. The interval from April to June can be considered critical erosion season, in this range falls 38.81% of annual precipitation. In terms of slope gradient, approximately 85% of the Bara teritory is vulnerable across the occurrence of erosion processes. Assuming that surface erosion occurs more intensely on the slopes with predominantly southern exposure, 35% of the total area (land with orientation SE, S, SW) shows greater vulnerability. Category slope from 5.01 - 20% has the largest share in the total area of each orientation class values ranging between 75.14 - 82.70%; the largest areas with slopes in the range mentioned are on the slopes NW and E and the lower slopes oriented N.*

Key words: *risk, erosion, rainfall, slope, orientation*

INTRODUCTION

Vulnerability as a key concept in the analysis of natural hazards, can be defined as an attribute of elements likely to be affected by a particular type of hazard. In terms of physical-geographical, factors that make a particular territory to be vulnerable are numerous and sometimes, through their action having effects difficult to quantify. It is known that the relief and the climatic parameters influence both directly and indirectly, the genesis and evolution of certain natural processes, regardless of the geographical location or existing anthropic systems.

Identification of areas exposed to the risk to surface erosion is a necessity, this offers a differentiated approach and taking measures to prevent and combat according to the specific conditions of each subareas.

MATERIALS AND METHODS

The area analyzed in this paper overlaps administrative-territorial unit (ATU) Bara, located in the eastern part of Timiş County.

The main purpose of this study is to analyze the vulnerability of the territory referred to the action of erosion processes under the influence of climatic aggressiveness (precipitation) and morphometric characteristics of the hydrographic basin (slope and slope orientation).

To analyze the climate of the study area were used meteorological data recorded at the meteorological station Lugoj: multiannual average temperature (1980 - 2010) and annual average (2010), multiannual average precipitation (1980-2010) and annual average (2010).

Based on meteorological data were calculated: de Martonne Aridity Index, Angot Index, Fournier Index. Based on the results obtained were highlighted climate characteristics and rainfall aggressiveness was assessed, with direct influence on erosion processes.

Using Digital Elevation Model (DEM) was generated, by ArcGIS software, map of the slopes and aspect, used to identify areas vulnerable to the action of surface erosion and to establish correlations between the slope and slope exposure.

RESULTS AND DISCUSSION

Territorial unit Bara is located in the hilly area of Timis county (Lipovei Hills), has total area of 7067 ha (70.67 km^2), of which 5694 ha is agricultural land [7] and fall, from the point of view of altitude in a range of 128 - 278 m (Figure 1), relief amplitude of 150 m.

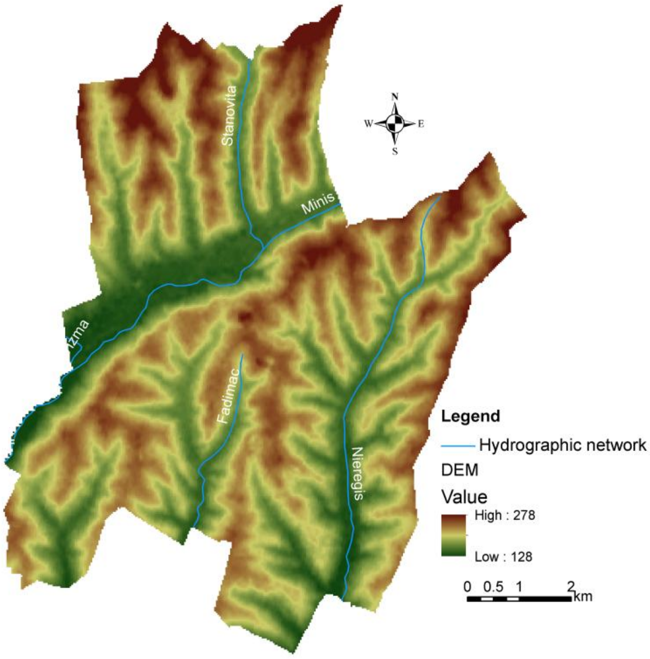


Figure 1 ATU Bara - Digital Elevation Model

The influence of rainfalls on surface erosion

From the climatic point of view, the studied area is located in the province cfbx climate (after Kopenn), temperate climate [8]. In 2010, considered one of the wettest years in the last period (COPACEAN LOREDANA, 2012), de Mrtonne Aridity Index value was 34.44 position according to the humid climate (SATMARI ALINA, 2014).

To investigate the relations between climatic factors and erosion phenomena, were considered average monthly temperatures and monthly average multiannual (Table 1) and precipitation (Table 2) recorded at the meteorological station Lugoj (characteristic for the analyzed area) between 1980 - 2010 and in the year 2010.

Table 1

Average annual temperatures and monthly average (°C) at Lugoj station

Years	Air temperature												Average
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1980 -2010	-0.4	1.1	5.8	11.2	16.4	18.7	21.3	21.0	16.1	11.2	5.7	1.3	**10.8**
2010	0.1	3.2	6.3	11.8	16.5	20.3	22.3	22.0	15.8	9.1	10.1	1.0	**11.5**

Table 2

Average monthly and average annual precipitation (mm)at Lugoj station

Years	Precipitation												Amount
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1980 - 2010	61.7	40.1	43.0	62.8	68.6	87.9	59.3	61.3	55.3	49.2	52.3	61.6	**703.1**
2010	88.7	50.9	30.7	56.9	153.6	77.0	54.7	69.0	25.4	25.9	39.5	68.3	**740.6**

In 2010, average monthly temperatures are higher than the monthly average multiannual until early autumn, when a slight decrease from this and a further increase in November, followed by a slight decrease in December (Table 1). The biggest differences between the average monthly and multianual monthly average in 2010 was registered in February (+2.1 °C) and November (+4.4 °C).

The following will be analyzed rainfall, contributor to the onset and maintenance of erosion processes (ONCIA SILVICA, 2004). Determination of rainfall aggressiveness on the analyzed territory, was based on some indicators such as Fournier Index (index of potential erosion) and Angot Index (monthly rainfall index), the results obtained having direct implications in terms of erosion processes.

Fournier Index (IF), also called climate erosion index (CHIRIAC A, quote SATMARI ALINA, 2014) expresses the ability of erosion by rainfall in a given territory and is calculated by equation (CHIS IRINA, 2013):

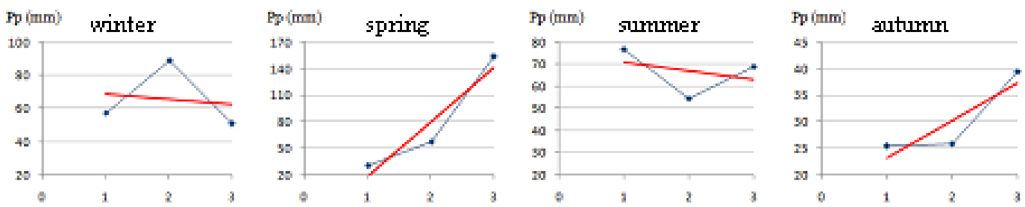
$$IF = \frac{Pi^2}{P}$$

where: Pi - rainfall of the rainiest month of the year; P - the annual amount of precipitation.

For Bara territory, IF has the value 31.85, which means that, in 2010, the potential of erosion by rainfall falls in the *"very weak"* (SATMARI ALINA, 2014).

According to Fournier index, rainfall is very weak "aggressive" but triggering erosion processes can occur when subjected to rainfall over a long period, either due to their high intensity. Thus, accumulate a large amount of water that flows down slopes as run-off, favoring the production processes and torrential runoff (CHIS IRINA, 2013).

Temporal distribution of rainfall is uneven: tendency of reduction in summer and winter, and spring and fall upward trend (Figure 2).



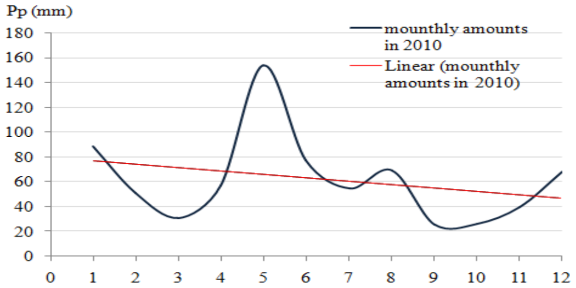


Figure 2 Trends in seasonal and annual precipitation in 2010

The general trend in the evolution of precipitation is reduced from the beginning to the end of 2010 (Figure 2).

To highlight the dry periods, in contrast with rainy periods (favorable production erosion) during 2010 was calculated Angot Index (K) using equation (ALBU ANCA, 2009):

$$K = \frac{q \times 365}{Q \times n}$$

where: q - the average amount of rainfall in a month, n - number of days in that month, Q - average annual rainfall; 365 - the number of days in a year.

Subunit K values indicate drier months and K values supraunitary, rainy months (SATMARI ALINA, 2014). In Figure 3 is the K index for the ATU Bara.

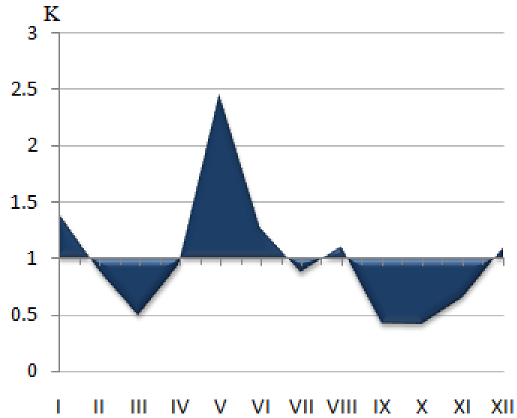


Figure 3 Angot Index (K) for 2010

In 2010 recorded supraunitary value of the index in spring and early summer, when conditions are met for starting slope processes, in this case the surface erosion. Data from the literature show that, in case of the Angot index values are between 1.0 - 1.5, it can show a low and very low susceptibility to the onset of these processes (winter). The values between 1.5 - 2.0, this tendency is medium and when values exceed 2.0 there are conditions for starting erosion processes (CHIS IRINA, 2013), where the analyzed area in the spring (Figure 3), especially in May when recording the maximum rainfall (Figure 2).

From July until the end of 2010, Angot index values are subunitary, these months are considered dry (Figure 3), thus onset rainfall erosion phenomena influence is reduced.

Season April to June can be considered "critical of erosion season" (CHIS IRINA, 2013), during which significant amounts of rain fall, 38.81% of the annual total. Based on average multiannual values obtained a percentage of 31.2% over the same period.

Influence of relief in the onset surface erosion

Installation and maintenance of erosion processes are dependent on a number of morphometric and morphological characteristics of relief, of which we analyze the slope and slope orientation.

Slope, both by inclination and length, is one of the main factors that trigger surface erosion (IANOȘ GH, 1997).

To identify areas of ATU Bara susceptible to surface erosion, with ArcGIS software, we generated slope map (Figure 4), based on DEM.

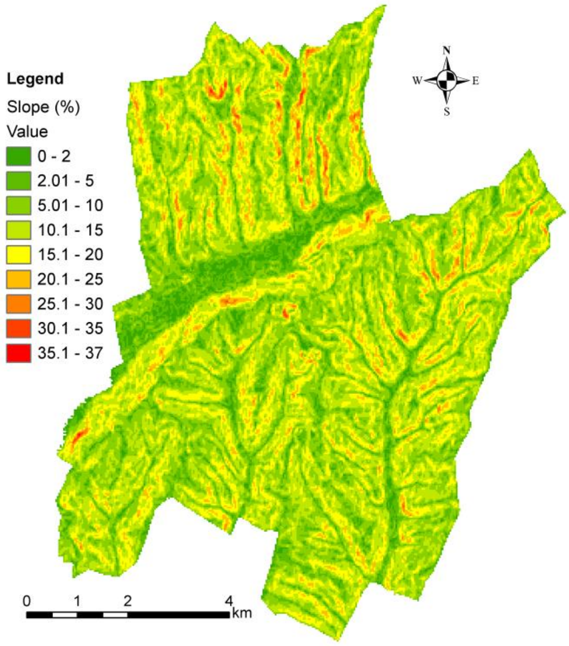


Figure 4 ATU Bara – slope map

Slope map in raster format (Figure 4) was classified (they kept the 9 classes according to specific slope methodology) and converted to vector format (Figure 5), is possible in this way automatic calculation of surfaces assigned to each category of slope.

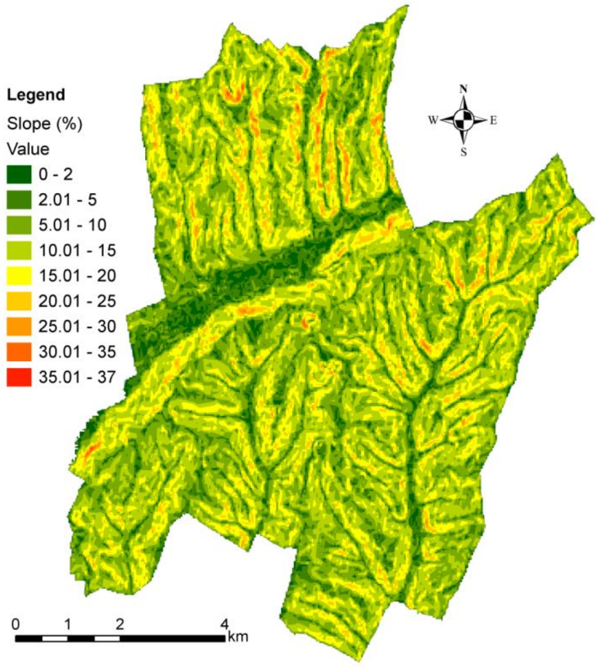


Figure 5 Slope map in vector format

The highest values of slops are found in northern ATU Bara and the lowest values, in the river meadows (Figure 5).

The land and percents of the total area of slope ATU Bara are summarized in Figure 6.

Slope (%)	Surface	
	km^2	%
0 – 2	2.398	3.394
2.01 – 5	8.141	11.520
5.01 – 10	20.291	28.713
10.01 – 15	23.776	33.644
15.01 – 20	12.566	17.781
20.01 – 25	2.880	4.075
25.01 – 30	0.523	0.741
30.01 – 35	0.087	0.123
35.01 - 37	0.003	0.005
Total	**70.67**	**100**

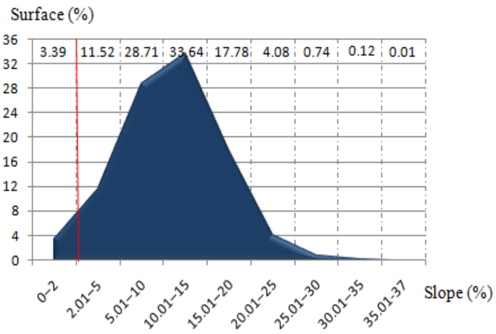


Figure 6 The distribution of land on the slope categories

Land approximately plan (slope below 2%) is found on only 3.39% of the total area and the land slightly inclined (slope between 2.01 - 5%) occupies an area of 11.52%. Of the total of 70.67 km^2, 28.71% is land with a slope between 5.01 - 10.01% and 33.64% land with a slope between 10.01 - 15%. The slopes over 25.01% are in small areas.Data from the literature show that the risk of surface erosion occurs from the slopes of 5%, which means that, in terms of slope, approximately 85% of the ATU Bara is vulnerable across the appearance of slope processes, so erosion in this case. The higher the slope inclination, intensified erosion processes: increase the speed of the water flow and the amount of water in the soil infitrată decreases and thus increase the power of erosion (CHIS IRINA, 2013).

Slope orientation (Figure 7) is another important factor in the analysis of slope processes, according to this being differentiated and the types of processes that occur on them.

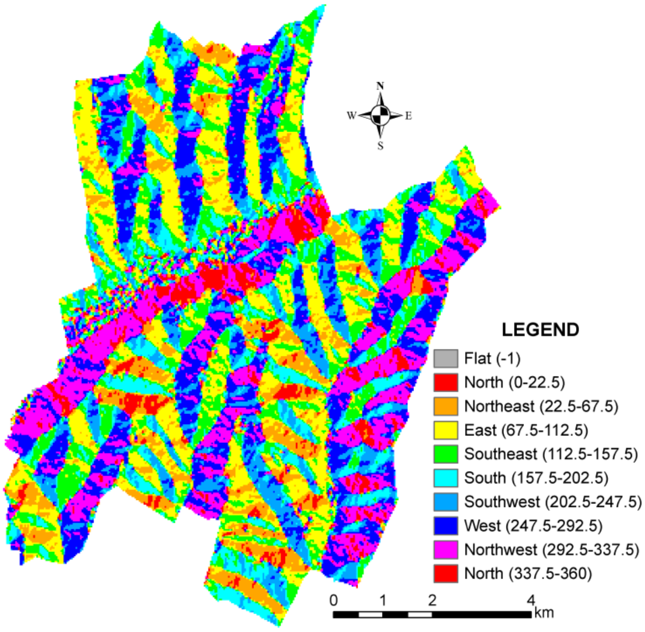


Figure 7 ATU Bara - aspect map (slope orientation)

Aspect map or slope orientation (Figure 7) was generated also from the DEM.

The areas for each type of orientation have been obtained by reclassification of the aspect raster map (Figure 8) and its conversion into a vector format (Figure 8).

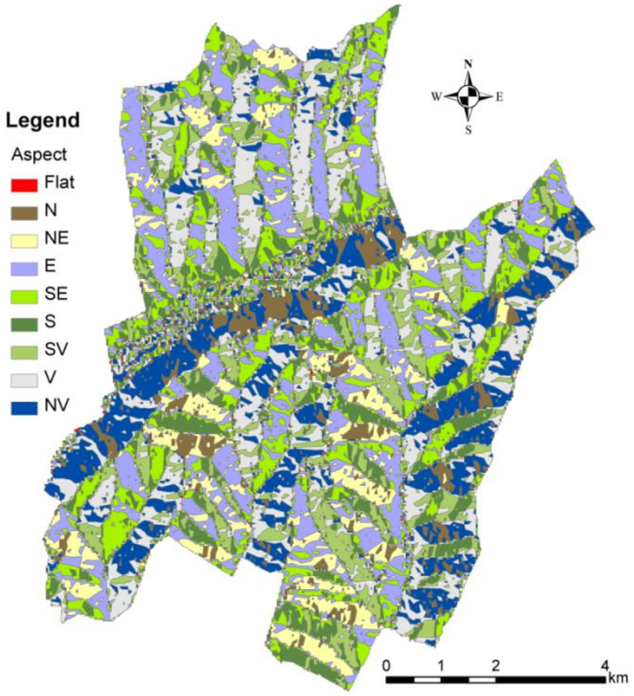


Figure 8 Map of slopes orientation in vector format

As shown map and tabular material, depending on the slope orientation distribution is heterogeneous, with the mosaic appearance. The largest areas are oriented E (18.09%) and V (16.72%) due to the orientation N - S of waterways (Figure 1) and the surfaces were oriented N lowest weight, 6.02 % (Figure 9).

Orientation	Surface	
	km^2	%
Plan	0.104	0.147
N	4.26	6.028
NE	6.869	9.720
E	12.789	18.097
SE	9.759	13.809
S	7.291	10.317
SV	8.104	11.467
V	11.816	16.720
NV	9.664	13.675
Total	**70.67**	**100**

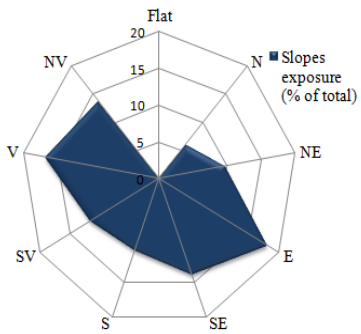


Figure 9 Distribution of areas depending on slope orientation

Previous research (CHIS IRINA, 2013) support the hypothesis that surface erosion occurs more intensely on the slopes with predominantly southern exposure, which means that in the analyzed area approx. 35% of the total area (land with orientation SE, S, SW) shows greater vulnerability.

Analysis slope-aspect (Table 3) highlights the relatively uniform distribution areas.

Table 3

Distribution areas based on categories of slopes and orientations

Slope (%)	Slope orientation (% from total area)									**Total (%)**
	Flat	N	NE	E	SE	S	SW	W	NW	
0–2	0.13	0.37	0.37	0.41	0.46	0.39	0.42	0.42	0.39	**3.394**
2.01–5	0.01	0.87	1.06	1.74	1.75	1.68	1.49	1.62	1.26	**11.520**
5.01–10	0.00	1.54	2.79	**5.04**	**4.69**	**3.58**	**3.33**	**4.42**	**3.24**	**28.713**
10.01-15	0.00	2.02	**3.46**	**6.42**	**4.46**	**3.11**	**3.63**	**5.57**	**4.97**	**33.644**
15.01-20	0.00	0.97	1.66	**3.37**	1.99	1.37	1.99	**3.32**	**3.10**	**17.781**
20.01-25	0.00	0.21	0.35	0.87	0.39	0.15	0.47	1.08	0.57	**4.075**
25.01-30	0.00	0.03	0.02	0.17	0.04	0.02	0.10	0.26	0.09	**0.741**
30.01-35	0.00	0.00	0.00	0.02	0.01	0.00	0.02	0.04	0.02	**0.123**
35.01-37	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	**0.005**
Total (%)	**0.147**	**6.028**	**9.72**	**18.097**	**13.809**	**10.317**	**11.467**	**16.72**	**13.675**	**100**

The data summarized in Table 3 were obtained using ArcGIS, by processing information extracted from the leyers slope and aspect (*Tabulate Area command*). For graphical representation of tabular data (Figure 10) were established 3 categories of slope, depending on the weight and surface fitting requirements. It highlights the following issues:

- category slope 0 - 5% is found on surfaces below 21% of the total orientation each class; in the case the eastern slope, west and northwest were identified lowest slightly inclined surfaces
- category slope 5.01 - 20% has the largest share in the total area of each orientation class (Figure 10) values ranging between 75.14 - 82.70%; the largest areas with slopes in the range mentioned are on the orientation NV and E and the lower, N slopes

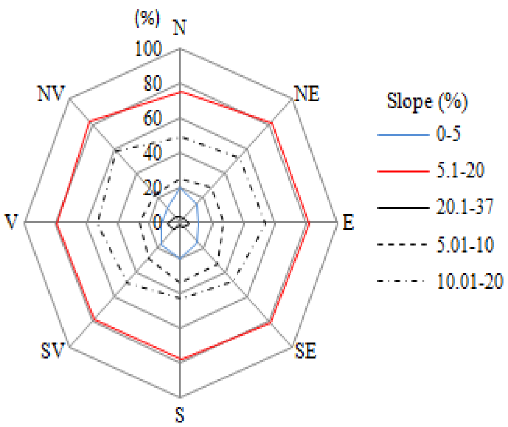


Figure 10 The distribution of land on the slopes orientation and slop categories (% of total of category)

- category slope 20.01 - 37% includes the smallest surface, below 6%, which is well represented on the slopes exhibition E, SW and NW (Figure 10).

CONCLUSIONS

The ATU Bara is located in the low hills, with altitudes between 128 - 278 m. and physical-geographical conditions specific to this altitudinal interval.

From a climate perspective, in 2010 the average monthly temperatures are higher than the monthly average multiannual, de Mrtonne Index was 34.44 for the type of humid climate.

Fourier Index has a value of 31.85, which means that, in 2010, the potential erosion by rainfall falls in the "very low", but the temporal distribution of rainfall is uneven and the Angot Index highlighting dry periods in contrast to the rainy, favorable production erosion processes, is supraunitary in spring and early summer, when all the conditions for triggering surface erosion. The interval from April to June can be considered critical erosion season, in this range falls 38.81% of annual precipitation. Based on average annual values obtained a percentage of 31.2% over the same period.

In terms of slope gradient, approximately 85% of the ATU Bara is vulnerable across the occurrence of erosion processes.

The largest areas are oriented E (18.09%) and W (16.72%) due to the orientation N - S of waterways and surface orientation N have the smallest share, 6.02%.

Assuming that surface erosion occurs more intensely on the slopes with predominantly southern exposure, 35% of the total area (land with orientation SE, S, SW) shows greater vulnerability.

Category slope from 5.01 - 20% has the largest share in the total area of each orientation class values ranging between 75.14 - 82.70%; the largest areas with slopes in the range mentioned are on the slopes NW and E and the lower slopes oriented N.

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