Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ANALYSIS OF THE EFFECT OF DEFORESTATION ON LAND STABILITY BY GEOMATIC METHODS - CASE STUDY ANALYZED IN THE GeoSES PROJECT

Tiberiu Mihai KALMAR[1], Marcel DÎRJA[1], Adrian Traian Gh.M. RĂDULESCU[2], Petru Daniel MĂRAN[2], Virgil Mihai Gh.M. RĂDULESCU[2], Corina M. RĂDULESCU[2], Gheorghe M.T. RĂDULESCU[2]

[1]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, Cluj-Napoca, Romania
[2]Technical University of Cluj-Napoca, 15 Constantin Daicoviciu Street, Cluj-Napoca, Romania

Corresponding author email: mdirja@usamvcluj.ro

Abstract

From 2005 to 2009, in Maramureş, over 1,000 hectares of forest area were cleared, although the entire area is part of the integral protection area of the Maramureş Mountains Natural Park. Although, worldwide, the main cause of deforestation is the development of land for agricultural purposes, in Romania, from the beginning, the main purpose has been to obtain timber. Thus, in Maramureş, and in the year of the 2020 pandemic, more than 104,000 cubic meters of illegally cut wood were reported in a communiqué of the Ministry of Environment, practically 340 hectares of forest being severely affected. The effect of deforestation on land stability can be viewed from at least two points of view: 1. Deforestation causes climate change that in turn causes landslides, 2. Deforestation causes land instability by eliminating stabilizing roots leading directly to landslides.
The analysis of these effects, directly on the case studies made in the field is currently carried out by means of Geomatics. The paper analyses the techniques and tools that can be used, the technological flow and the results, using one of the case studies analysed in the GeoSES Project, located in Sighetu Marmației, the most affected by the more or less legal deforestation practices taking place in Romania.

***Key words**: deforestation, geomatics, landslides, 3D Model, orthophotoplan.*

INTRODUCTION

Regardless of the causes of deforestation, the main effects are climate change and, as a cumulative effect, landslides. The Romanian Parliament, through an Information Sheet entitled Deforestation and forest degradation, a document drafted on September 7, 2009, does not make a correlation between deforestation and landslides. Instead, the parliamentary question of September 27, 2017, addressed to the European Parliament by a Romanian member of Parliament states that the negative consequences of excessive deforestation include an environmental component: increased risk of floods, and slides and other natural disasters.
In a report prepared by the World Bank at the request of the Government of Romania, as a result of the World Bank's Climate Change Advisory Services program, in Chapter 2. Dangers and effects of climate change in Romania, paragraph 2.5 Landslides, confirms the above by stating: "Landslides are caused by gravitational forces, but are triggered by a variety of processes. Deforestation can increase the likelihood of landslides. As a result, the frequency of landslides may increase because of climate change". Globally, from 57% 10,000 years ago, only 38% of the total land area is now covered by forests.
Following a continental distribution of the percentage of forest-covered area of the total mentioned above, Europe represents 25.07%, South America 20.8%, Africa 15.68%, Asia 15.34%, Oceania 4.56%, the rest of the territories not mentioned above representing the difference of 18.55% (https://ourworldindata.org/forest-area).
The view shown in Figure 1 shows the breakdown of the global forest area by world region. In the case of Romania, the forested area decreased from 7.048 million hectares in 2016 to 6.929 million hectares in 2020, according to Eurostat estimates.

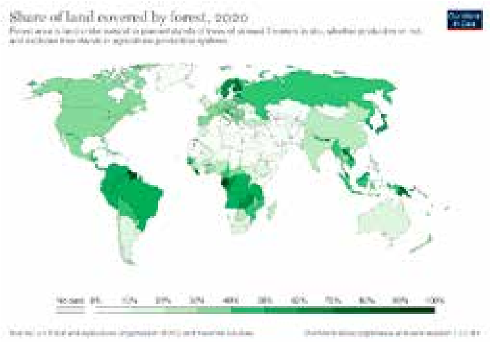

Figure 1. The degree of afforestation of land surfaces worldwide
(Source: https://ourworldindata.org/)

The national forest accounting plan for Romania, for the first commitment period (2021-2025) identifies that among the most important measures that are included in the objective regarding the sustainable management of the National Forest Fund are the following:

- Harmonization of the national system of indicators for sustainable forest management with the European one;
- Continuous adaptation of forests to climate change;
- Development of the integrated information system for forestry; (http://www.mmediu.ro/app/). Rhett Ayers Butler, American author, and founder of the Mongabay platform, considers in his paper Consequences of Deforestation (Butler, 2019) that "the local level is where deforestation has the most immediate effect. The forest acts as a kind of sponge, absorbing the precipitation brought by the storms, while anchoring the soils and releasing water at regular intervals". The same author identifies as the main effects of deforestation: soil erosion and its effects, respectively landslides.

According to Tariq M., deforestation has caused environmental hazards in Pakistan, and he found that as the deforestation rate increases, floods have also increased and deforestation has caused landslides in Dir Kohistan, Pakistan (Tariq et al., 2014). Khan, (Khan, 1994) also mentioned in his papers that deforestation causes landslides and stated that, in the last three decades, the magnitude and severity of the adverse effects of landslides have increased enormously.

Forest cutting, especially deforestation, affects the various hydro geomorphological processes of forest land and has negative effects on improving surface erosion (Roberts and Church, 1986; Edeso et al., 1999). There are also changes in the slope of the hill or the hydrology of the basin (Keim and Skaugset, 2003; Dhakal and Sidle, 2004) and the intensification of landslides (Brardinoni et al., 2002; Jakob et al., 2005; Sidle and Ochiai, 2006).

Immediately after initiation, landslides attributed to deforestation exert significant destructive forces and provide large volumes of sediment to river courses, thereby increasing catchment sediment (Gomi and Sidle, 2003; Constantine et al., 2005), changing the structure of the watercourse and creating ecosystems of water currents (Gomi et al., 2004; Gomi and Sidle, 2003).

Thus, the influence of forest management, including logging and/or forest regeneration, on landslides needs to be assessed to maintain the integrity of river ecosystems, as well as to create better conditions for disaster reduction and prevention.

The presence of vegetation on steep slopes contributes to the mechanical stability of the soil roof primarily by strengthening the roots which improves soil resistance (Schmaltz et al., 2017) and by reducing moisture conditions by evaporation and interception of precipitation. Studies suggest that deforestation favors landslides (Schmaltz et al., 2017). For example, cutting forests in areas with steep slopes has been reported to generate 2 to 10 times more landslides than on sloping lands with vegetation (Brardinoni et al., 2002; Dhakal and Sidle, 2003).

After deforestation, as the young forest slowly recovers, the soil mantle regains strength (Imaizumi et al., 2008), reducing the vulnerability to landslides within 3-15 years after harvesting the wood.

MATERIALS AND METHODS

On June 16, 2009, the Hungarian National Development Agency, in cooperation with the Slovak Ministry of Construction and Regional

Development, the Romanian Ministry of Regional Development and Housing and the Ministry of Economy of Ukraine, opened a call for proposals within the Hungary -Slovakia - Romania - Ukraine Cross-Border Cooperation Program.

All calls organized within the programs 2007-2013, 2014-2020 for the Hungary-Slovakia-Romania-Ukraine Cross-Border Cooperation Program and it seems that also those for the next period, 2021-2027, had themes, objectives, priorities, and measures related to Disaster management. The extension of the operational "Space Emergency System" to the monitoring of dangerous natural and artificial geo-processes in the HU-SK-RO-UA cross-border region was the title of the Project in which TUCN is a partner in the Cooperation Program, 2014-2020, Call 2, HUSKROUA/1702. The project is under Thematic Objectives, TO8 Common Safety and Security Challenges, Priority 1: Support for joint activities to prevent natural and man-made disasters, as well as joint actions in emergencies.

The leader of the project is Uzhhorod National University, Ukraine and the applicants are groups from the Pavol Jozef Šafárik University in Košice, Slovakia, Technical University of Cluj-Napoca, Romania, Budapest University of Technology and Ecomomics, Hungary and Self Government of Szabolcs-Szatmár-Bereg County, Hungary.

Within the GeoSES Project, the role of the Technical University of Cluj-Napoca is to monitor, in terms of vulnerability to disasters, landslides and floods for a delimited area. In this case, the territory of Sighetu Marmației Municipality and the neighboring localities were chosen.

More than 100 landslides were identified, having various causes (Figure 2).

Among the causes were deforestation of areas upstream of the landslides, the case analyzed in this paper Location 6 (Figure 3).

A case was also identified (in Sarasău Township) in which, following landslides on a slope of Solovan Hill, at the foot of which is the territory of the mentioned municipality and Sarasău village, the afforestation of the upstream area was made and thus the land was stabilized (Figure 4.).

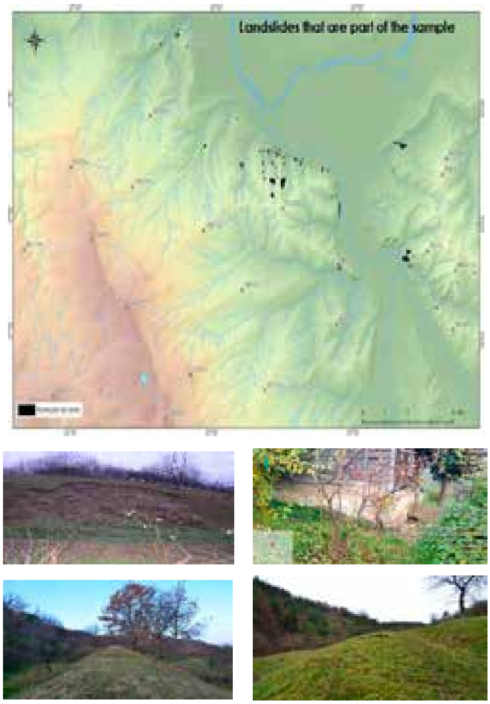

Figure 2. Landslides identified on the territory of Sighetu Marmației Municipality, within the GeoSES Project (Source: GeoSES Project)

Figure 3. Landslides identified on the Location 6. Câmpul Negru - Malec

Within the GeoSES Project, 6 areas affected by landslides were chosen, 5 from the territory of the municipality and one, previously mentioned, from Sarasău Township. These have been monitored so far through four cycles, respectively, Cycle "0" in July 2020, Cycle "1" in March 2021, Cycle "2" June 2021, Cycle "3" October 2021.

Initially, in June 2020, there was a stage of verification of the technologies and tools that we intend to use in the monitoring process and in March 2022 a final cycle of verification of results and introduction of a new tracking technology of land behavior over time based on sensory instruments shall take place. Then, for seven years, there will be a verification cycle using UAV technology to ensure the safety of the area.

The technologies and tools used in the GeoSES Project to monitor landslides were as follows:

1. Geometric precision level, devices used, Foif DS05 Precision Level and Leica LS10 Digital Level;
2. Trigonometric level using Total Stations, Leica TS02plus total station, 3";

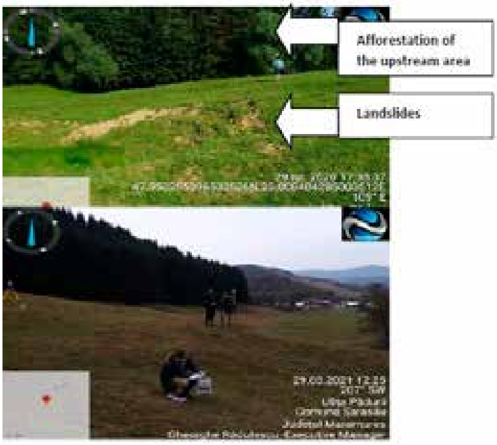

Figure 4. Landslides stabilized by afforestation (Source: GeoSES Project)

3. GNSS technology with Leica GS 08 plus and GNSS RTK L1L2 HI-TARGET V90;
4. UAV aerial photogrammetry, instruments used, DJI Phantom 4 and DJI Matrix 210 TK V2;
5. Laser scanning, instrument used, Z + F 5010x Laser scanner, Zoller + Fröhlich.
6. UAV thermal aerial photogrammetry, instruments used, Drone DJI Matrix 210
7. RTK V2 and FLIR Vue ™ Pro thermal camera;
8. Structural Monitoring Kit BeanScape, Wilow, Wireless Sensor Networks.

Figure 5 shows the operating flow in the project for four-cycle monitoring of the six selected locations.

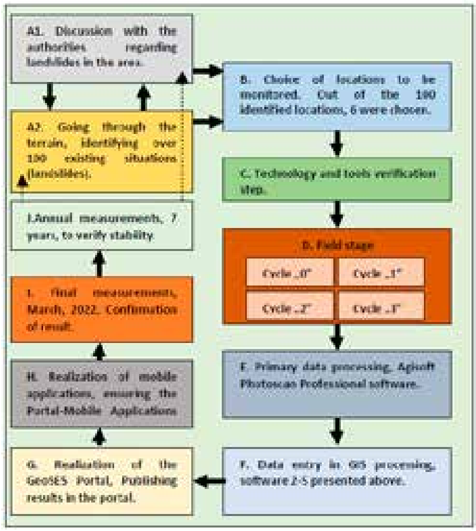

Figure 5. Technological flow in the GeoSES Project (Source: GeoSES Project, Authors)

RESULTS AND DISCUSSIONS

The deforestation that caused the landslides can be easily seen studying the evolution of the land following the deforestation produced, on orthophoto plans made in 2008, 2012 and 2020 (Figure 6).

The location affected by deforestation is located at the foot of Solovan Hill, Câmpul Negru-Malec Street (Figure 7). It is the only active landslide, of the six monitored over two years, i.e. 2020-2021.

From the GeoSES Portal we presented in Figure 8 some images, during cycle “3”, taken with the DJI Matrix 210 RTK drone, purchased within the GeoSES project.

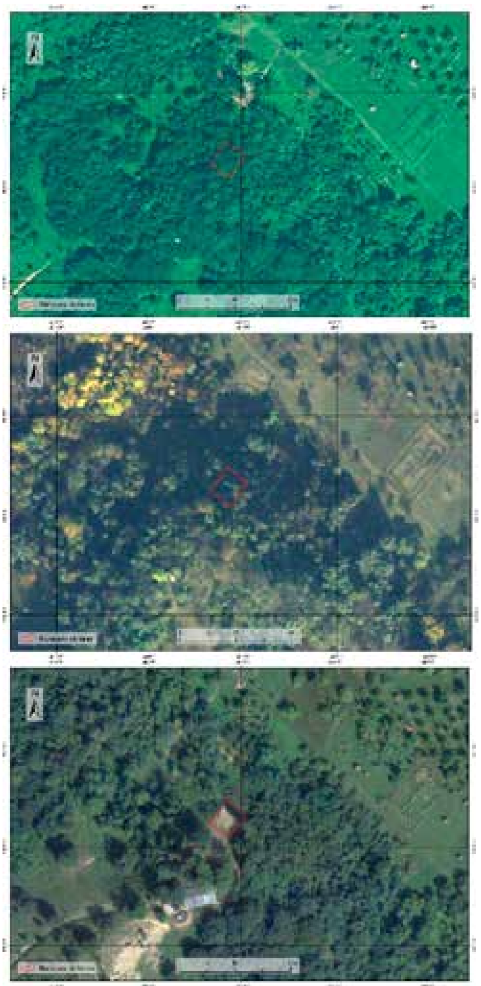

Figure 6. Location monitored 6. Câmpul Negru - Malec, Orthophotoplans made in 2008, 2012 and 2020 (Source: GeoSES Project)

Following the introduction, orthophotoplan orthomosaics, DEM Models, were obtained for each cycle of drone images. After each processing the software generates reports, being presented in Figure 10. Agisoft Photoscan Professional Software Report for Monitored Location, Cycle 4.

Orthophotoplanes and DEMs used below, using Maxent software, to obtain mathematical models, predictions, simulations, and Risk Maps for the monitored areas are presented, for the location analysed in this paper are shown in Figures 10, 11 and 12. (Images taken from the GeoSES Portal (http://geoses.cunbm.utcluj.ro/gis/).

Figure 7. Câmpul Negru-Malec Street, Sighetu Marmației, landslides due to deforestation, identified on Google Earth (Image 2022 CNES/Airbus)

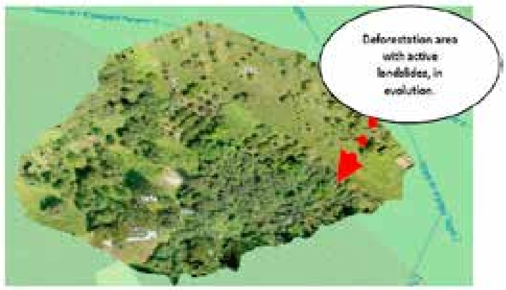

Figure 8. Câmpul Negru-Malec Street, Sighetu Marmației, landslides due to deforestation, image taken from the GeoSES Portal

Figure 9. Câmpul Negru-Malec Street, Sighetu Marmației, landslides due to deforestation, Orthophotoplans, cycles “0”, “1”, “2”, “3”

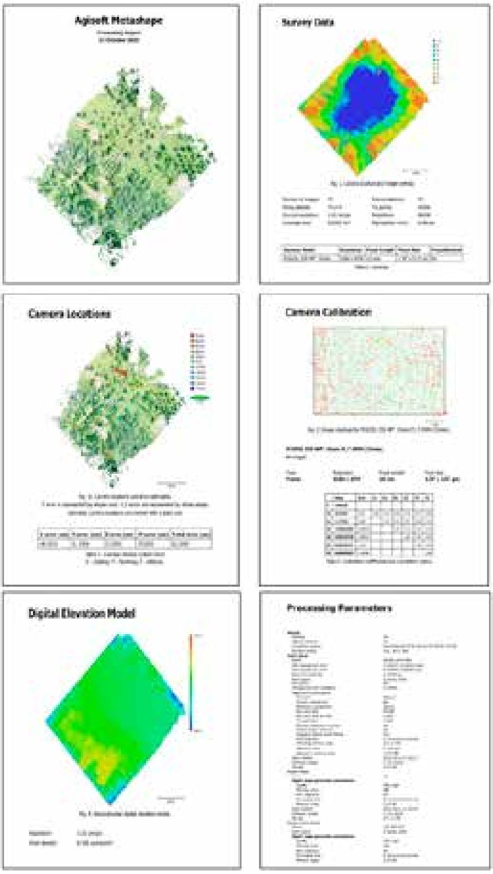

Figure 10. Agisoft Photoscan Professional Software Report, Location 6, Câmpul Negru - Malec, Sighetu Marmației, Cycle "3"

Figure 13 below shows the operating flow with Maxent software, which will finally obtain the landslide risk maps for the monitored locations, generally for the area of Sighetu Marmației Municipality and the surrounding areas. Figure 14 shows Relief Energy, Landslides and Landslides in the Area and Figure 15 shows Câmpul Negru - Malec, Landslide susceptibility.

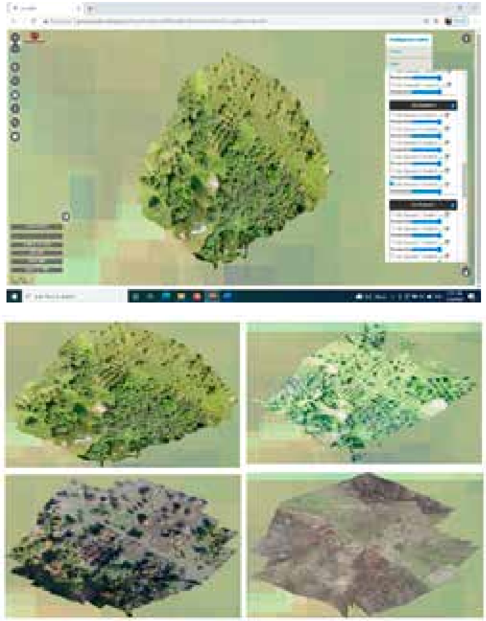

Figure 11. Câmpul Negru-Malec Street, Sighetu Marmației, landslides due to deforestation, Orthophotoplans, cycles "0"

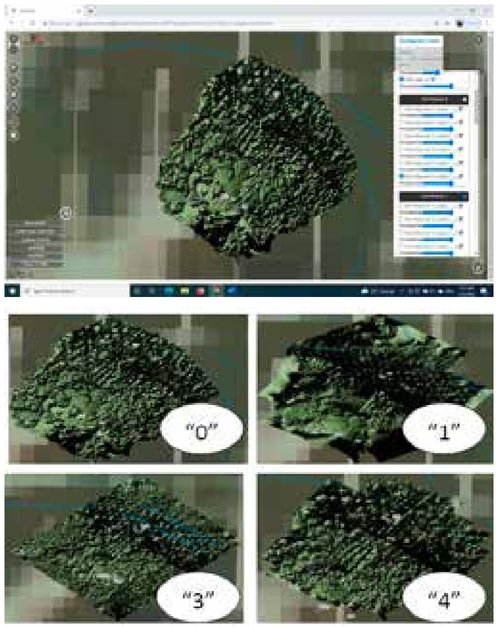

Figure 12. Câmpul Negru-Malec Street, DEMs, cycles "0", "1", "2", "3"

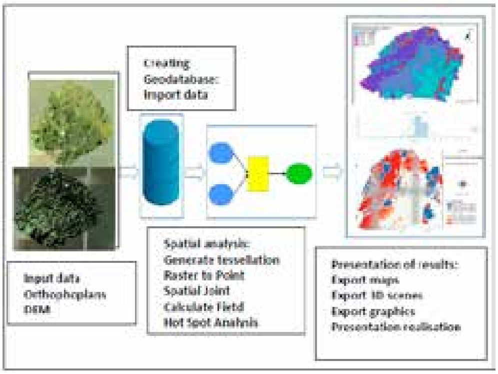

Figure 13. Landslide Deformation Analysis of Spatial Deformation in the GeoSES Project

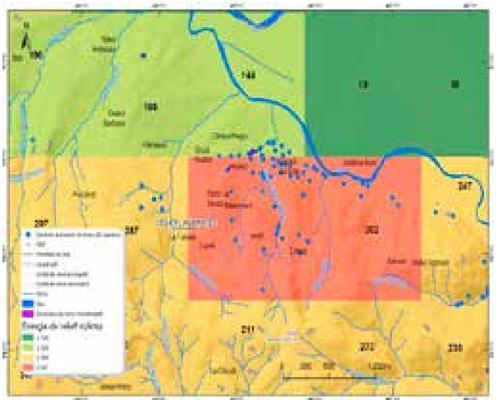

Figure 14. Câmpul Negru - Malec Relief Energy, Landslides in the Area

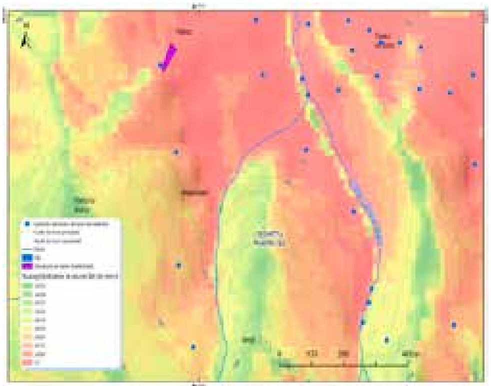

Figure 15. Câmpul Negru - Malec, Landslide susceptibility

Figure 16. Landslide risk map for the analyzed area, Câmpul Negru - Malec Street, Sighetu Marmației Municipality

As can be seen from the landslide risk map generated (Figure 16), after processing the data with the help of Maxent software, for the Municipality of Sighetu Marmatiei and the surrounding areas, the entire area at the foot of Solovan Hill, including the one studied in Câmpul Negru - Malec, are strongly exposed.
However, for the four-cycle monitoring interval (2020-2021) only the Câmpul Negru - Malec area was found to be unstable, with values of spatial displacements of maximum 120 mm.

CONCLUSIONS

"Natural hazards are extreme manifestations of natural phenomena, such as earthquakes, storms, floods, landslides, droughts, which have a direct influence on the life of each person, on society and the environment as a whole" (Cozac and Boian, 2005).
The exposure of the Romanian banks of the Tisza River to various destructive events has been known for hundreds of years.
From this summary it can be seen that the monitoring of the study area considered in the GeoSES Project must continue to take into account disastrous events in the category of landslides and floods. Our team will continue for seven years after the completion of the GeoSES Project on May 31, the results being communicated to the authorities to make the best decisions to manage the situations created.

ACKNOWLEDGMENTS

The entire activity presented in this paper was carried out within the project GeoSES - Extension of the operational "Space Emergency System" towards monitoring of dangerous natural and man-made geo-processes in the HU-SK-RO-UA cross-border region, HUSKROUA 1702/8.1./0065.
The team of authors of this paper, which is also the project team, would like to thank their colleagues from Uzhhorod National University for inviting the Technical University of Cluj Napoca as a partner in the project.

REFERENCES

Brardinoni, F., Hassan, M.A., Slaymaker, H.O., (2002), Complex mass wasting response of drainage basins to forest management in coastal British Colombia. Geomorphology 49: 109–124. DOI: 10.1016/S0169-555X(02)00166-6
Brardinoni, F., Hassan, M.A., Slaymaker, H.O., (2002), Complex mass wasting response of drainage basins to forest management in coastal British Colombia. Geomorphology 49: 109–124. DOI: 10.1016/S0169-555X(02)00166-6
Butler, R.A., (2019), Consequences of Deforestation, https://rainforests.mongabay.com/09-consequences-of-deforestation.html.
Constantine, J.A., Pasternack, G.B., Johnson, M.L., (2005), Logging effects on sediment flux observed in a pollen-based record of overbank deposition in a northern California catchment, Earth Surface Processes and Landforms 30: 813–821. DOI: 10.1002/esp.1190
Cozac, V., Boian, I., (2005). Principalele tipuri de hazarduri naturale şi impactul lor asupra mediului şi societăţii, Mediul ambiant, Natural and anthropogenic hazards, NR. 5 (23) octombrie 2005, pg. 18-25.
https://www.europarl.europa.eu/factsheets/ro/sheet/105/the-european-union-and-forests
Dhakal, A.S., Sidle, R.C., (2003), Long-term modeling of landslides for different forest management practices. Earth Surface Processes and Landforms 28: 853–868. DOI: 10.1002/esp.499
Dhakal, A.S., Sidle, R.C., (2003), Long-term modeling of landslides for different forest management practices. Earth Surface Processes and Landforms 28: 853–868. DOI: 10.1002/esp.499
Edeso, J.M.., Merino, A., González, M.J., Marauri, P., (1999), Soil erosion under different harvesting managements in steep forest lands from north- ern Spain, Land Degradation & Development 10: 79– 88.
Gomi, T., Sidle, R.C., (2003), Bedload transport in managed steep-gradient headwater streams of southeastern Alaska. Water Resources Research 39: 1336. DOI: 10.1029/2003WR002440
Gomi, T., Sidle, R.C., Swanson, D.N., (2004), Hydrogeomorphic linkages of sediment transport in headwater streams, Maybeso Experimental Forest, southwest Alaska. Hydrological Processes 18: 667–683. DOI: 10.1002/hyp.1366
http://www.mmediu.ro/app/webroot/uploads/files/National%20forestry%20accounting%20plan%20of%20Romania_RO.pdf
https://ourworldindata.org/forest-area
Jakob, M., (2000), The impact of logging on landslide activity at Clayoquot Sound, British Columbia, Catena 38: 279–300. DOI: 10.1016/ S0341-8162(99)00078-8
Keim, R.F., Skaugset, A.E., (2003), Modeling effects of forest canopies on slope stability, Hydrological Processes 17: 1457–1467. DOI: 10.1002/hyp.5121
Khan, A. N., (1994), Extent and Evaluation of the Adverse Effects of Landslides on Housing in Murree, Pakistan. Journal of Rural Development and Administration, Vol: 26 (1), P. 119-40.
Roberts, G.R., Church, M., (1986), The sediment budget in severely disturbed watershed, Queen Charlotte Ranges, British Columbia, Canadian Journal of Forest Research 16: 1092–1106.
Schmaltz, E. M., Steger, S., & Glade, T., (2017), The influence of forest cover on landslide occurrence explored with spatio-temporal information. Geomorphology, 290(Complete), 250-264. doi:10.1016/j.geomorph.2017.04.024
Sidle, R.C., Ochiai, H., (2006), Landslides: Processes, Prediction, and Land Use. Water Resources Monograph 18, American Geophysical Union: Washington, DC.
Tariq, M., Rashid, M., Wajid, R., (2014), Causes of deforestation and climatic changes in Dir Kohistan, May 2014, Journal of Pharmacy and Alternative Medicine www.iiste.org, ISSN 2222-5668 (Paper) ISSN 2222-4807 (Online), Vol. 3, No. 2, 2014, https://www.researchgate.net/publication/322522483