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Evaluation of the Landscape Stability in Terms of the Soil Erosion Processes †

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Abstract: Stability of the landscape and soil degradation are the main driving elements associated with climate change in terms of their strong impact on reducing or increasing the acceleration of climate change. Many studies have been devoted to examining the development of the landscape stability of a selected locality as well as assessing the intensity of erosion processes, but studies dealing with the relationship and connections between the development of landscape stability and the intensity of erosion are insufficient. The aim of the article is to determine the relationship and connections between the landscape stability of the selected area and the intensity of its soil water erosion. The study also points to assessing changes in the development of stability during the period selected together with changes in the intensity of the soil water erosion. The results of the article show how the soil degradation processes affects stability of landscape and viceversa.

Keywords: landscape stability; climate change; soil erosion; degradation processes; physically-based model; climate model

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1. Introduction

The relationship between landscape stability and the degradation processes is very close, and these two elements mutually influence each other. Areas in which there is a lower degree of landscape stability due to the action of various elements, i.e., inappropriate anthropogenic activity, natural threats, natural disasters, and the construction of buildings opposed to the environment's natural elements are susceptible to various types of degradation processes. Generally landscape stability is the ability of ecological systems (ecosystems) to resist negative external elements (natural and anthropogenic) by self-regulatory processes and the ability to return to their original state when the negative effects are finished [1].

In order to describe the connection between the changes in landscape stability with the changes in the intensity of soil water erosion, calculations of soil erosion processes were performed during the years, i.e., 1990 and 2018. The purpose of the study was to find out if changes in landscape stability are directly connected with soil water erosion processes and how the intensity of soil erosion processes will change with the stability of landscapes. Both terms used (landscape stability and water erosion) represent one of the most frequently discussed topics in the scientific field and are directly connected to climate change. Deforestation, overgrazing, and poor land use are also major contributors to flood, water and wind erosion [2]. At approximately the same time, the underlying agricultural processes are major drivers of soil and environmental destruction, as well as a significant source of biogenic greenhouse gas emissions [3].

2. Materials and Methods

2.1. Study Area

The research area is located in the western part of Slovakia near its border with the Czech Republic (Figure 1) and extends into three protected landscape areas, i.e., the White Carpathians, the Little Carpathians, and Záhorie [4]. The average annual precipitation is around 660 mm with a runoff coefficient of 22%, which means that more than a fifth of the precipitation will flow out of the final profile. The areas associated with this climate are the White Carpathians, the higher parts of the Myjava Uplands, and the Little Carpathians. The rest of the basin belongs to a warm climate area with more than 50 summer days a year. The lowest amount of precipitation is found in the vicinity of Kúty, i.e., less than 550 milometers. In the middle part of the catchment, the precipitation is around 550–700 mm on average.

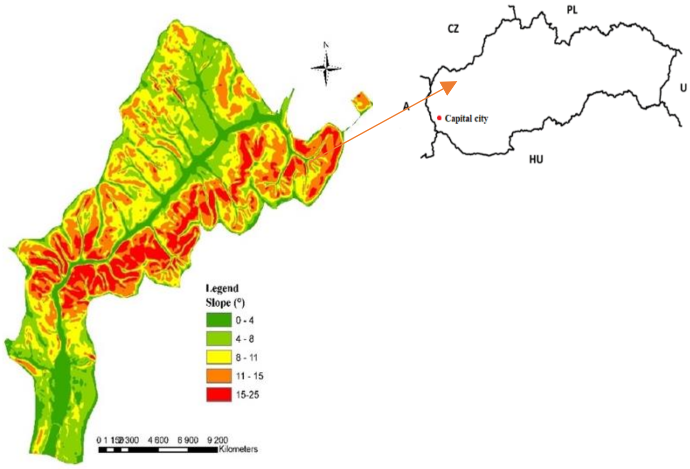

Figure 1. Location of the Teplica River basin with slope representation.

2.2. Characteristics of the Input Data

The analyses of the landscape stability and soil water erosion were conducted for the period covering the years 1990–2018 using landscape stability coefficients according to four methodical principles developed by various authors, i.e., coefficient of landscape stability according to [5–8]. A graphic interpretation of the rainfall amounts received are displayed in Figure 2. This input data was applied for the calculation of the water erosion performed by the physically-based EROSION-3D model.

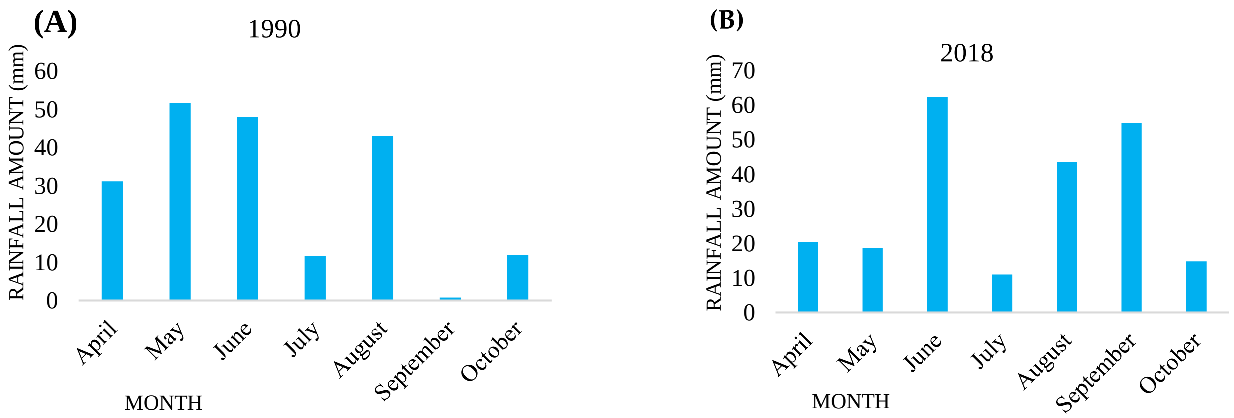

Figure 2. Monthly amounts of rainfall events derived by Community Land Model (CLM model); (**A**)1990, (**B**) 2018.

2.3. CLM Model

The Community Land Model (CLM) represents an element of Community Earth System Model (CESM) and the model determines and shapes ideas of ecological climatology. The basic idea of the model is to examine how natural and human changes in vegetation influence climate. The model was developed with the idea of research the physical, chemical, and biological processes by which terrestrial ecosystems affect and are affected by climate through a variableness of spatial and temporal scales [9].

2.4. EROSION-3D Model

The physically-based EROSION-3D model represents an event-based method that can be applied for calculating the amount of surface runoff generation, the amount of soil loss and sediments, the volume and concentration of eroded sediments, and the deposition processes on agricultural land produced by intensive rainstorms. The model has been developed since 1995 by Michael von Werner at the Department of Geography at the Free University of Berlin and consists of two main submodels, i.e., the infiltration and the erosion model.

3. Results

The study is focused on an assessment of landscape stability together with an evaluation of soil erosion intensity in selected years. The purpose of the study was to determine the relationship between the intensity of soil water erosion processes and the landscape stability of the area analyzed.

The landscape evaluation of the Teplica river catchment took place where the gradual development of the territory and changing areas of the landscape elements were monitored.

Since 1990, the positive landscape elements have increased by 7% in comparison with the negative landscape elements. The positive (stable) elements include deciduous and mixed forests, meadows and tall grass, orchards and plantations, pastures and low grasses, transitional forest cover, vineyards, and water areas in the area analysed. The forests make up more than 29% of the landscape. The negative (unstable) landscape units comprise agricultural land and urbanized areas. Nowadays, the largest area within the territory represents agricultural land, which covers more than half of the total area.

Figure 3A,B describe the results modeled by the EROSION-3D model for the selected years, i.e., 1990 and 2018. The most significant erosion processess were found in the year 1990 where the arable land covers almost 60% of the area together with the lowest coeficient of landscape stability and the least favourable condition of the area. Based on an assessment of the landscape stability coefficients (all the methods used), the territory is rated as an intensively used landscape with a poor quality, a low ecological coefficient, and a predominance of anthropogenic landscape elements. The connection between the coefficient of landscape stability and intensity of the erosion can be found in most cases. The lower the stability coefficient, the higher the intensity of the resulting erosion processes. It is important to mention that among other important factors that have been considered (land-use structure, management practices, soil properties and relief parameters) the precipitation data plays a significant role.

In addition, the results also underline the importance of land use composition, which represents an essential role in terms of quantifying the amounts of land loss, sediment load, and the overall incidence of degradation processes in the river basin.

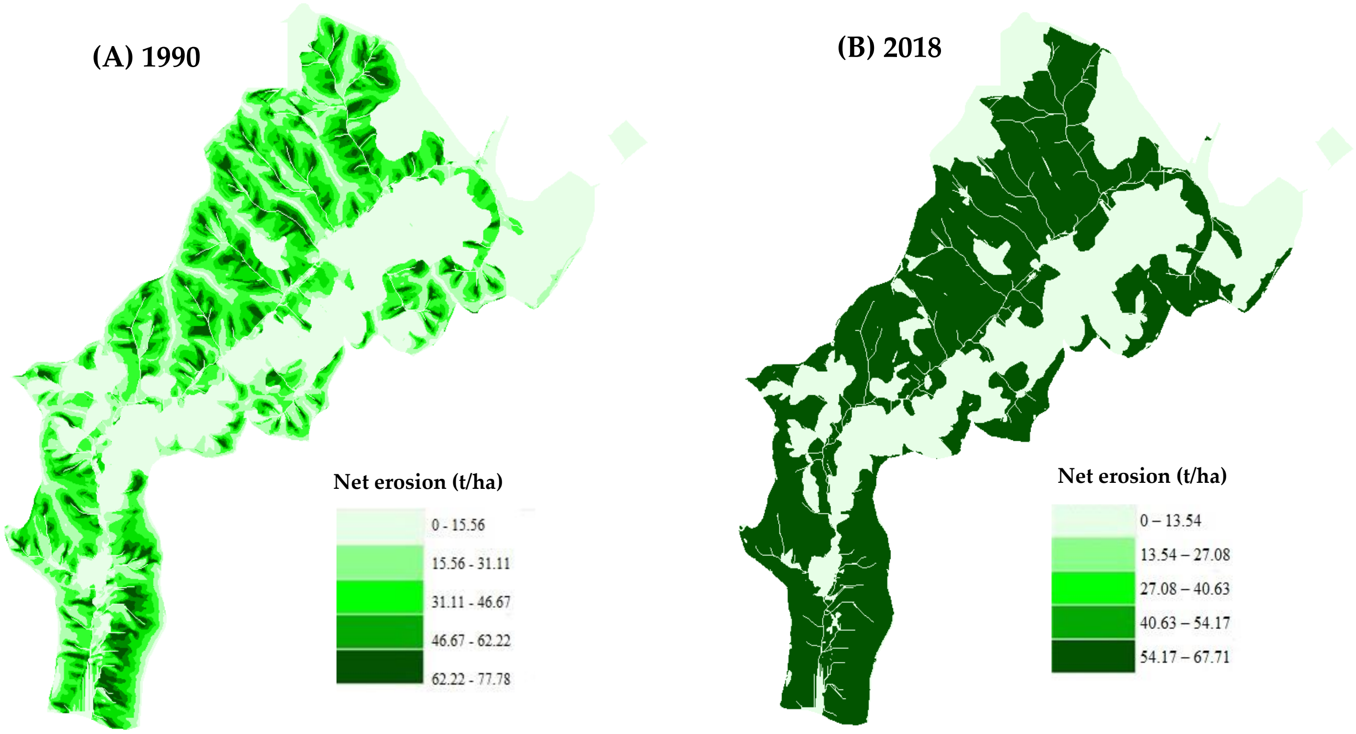

Figure 3. The modelling results (EROSION-3D model) (**A**) 1990, (**B**) 2018.

4. Discussion and Conclusions

One of the most important direct drivers of biodiversity loss and changes in landscape stability are land use transformations that are a part of habitat changes and climate change [10–12]. These two elements are powerful drivers that may influence landscape changes predicted for the future on a global scale (Dale, 1997). The connection between land use and climate is very strong and works in both directions, i.e., land cover is shaped by land use management practices which impact the concentration of greenhouse gases. Finally, changes in land use are a main accelerator of climate change and vice versa: the changing climate can cause changes in land use or land cover. Predictions of the future development of soil water erosion due to climate change, together with land-use transformations, is still under researched as a result of inadequate information [13]. Many studies highlight the importance of climate change without considering landscape transformations [14,15] but works that focus on the effects of both factors, i.e., climate change and land-use transformations, are insufficient.

Nevertheless, in many parts of the world, anthropogenic activities represent the primary driver of land use changes, which are considered to be the most significant transition of the Earth's land surface [16].

This study analyzes the relationship and connections between the landscape stability of an area and the intensity of soil erosion in the same period as well as the land use structure reflected in the current situation in a catchment. This analysis also included changes in the land use structure that occurred within the selected years due to anthropogenic activities. Nowadays, climate change, landscape stability, biodiversity, and soil water erosion are very powerful topics in and of themselves and analyzing their connection and relationship can offer a different level of knowledge and thereby develop new innovative methods for their evaluation.

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