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Original Article

A GIS-based Assessment of Soil Erosion in Wood-pastures of Southern Transylvania

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Abstract

Wood-pastures are landscape elements with high natural, cultural and economic importance. Wood-pastures combines livestock grazing with trees and shrubs. They provide several ecosystem services, including biodiversity, soil protection, carbon storage, water management. However, wood-pastures have been through a sharp decline all over Europe, mainly due to environmentally uncontrolled intensification of agriculture, abandonment and improper management of the land use, which resulted in the loss of the valuable ecosystem services which they provide. In this paper, we investigate the potential of wood-pastures to provide regulating ecosystem services by their ability to prevent or mitigate the soil erosion. The assessment process has been performed by applying the RUSLE model, using GIS. The model has been applied in eight study-polygons, corresponding to four villages situated in the southern Transylvania, Romania. Our results show that wood-pastures have a lower predicted annual soil loss than pastures with accidental presence of trees. We suggest that wood-pastures are more resilient with regard to soil erosion than tree-less pastures.

Keywords: wood-pastures, soil erosion, RUSLE, GIS, ecosystem services

1. Introduction

In the current context of global climate change a key challenge for the sustainability of farming landscapes is to maintain its productivity while being adaptive and resilient [8].

Farming landscapes of Eastern Europe have extraordinary cultural, natural and economical values.

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These values should be simultaneously approached and considered in order to understand the potential trade-offs resulting from the management of the farming landscapes. Fertile soils are key components of the farming landscapes of Eastern Europe. The overall low social and economic capitals of the rural communities from this region of Europe pose a risk for the long-term sustainability of the farming landscapes because the land is prone to intensification [10]. Intensification typically results in the erosion of natural and aesthetic values as well most commonly through land homogenization and compaction.

Pasturing had always been of key importance for the local economies in the European rural landscapes. Traditionally represented by woodland grazing, in the 19th century pasturing and forestry started to be institutionally separated, with grazing being prohibited in forest while the economic value of trees decreased on pastures [22, 11].

Wood-pastures are essentially pastured (grazed) landscapes which retained a substantial number of trees across their surface [20].

Trees were valued for several goods and services they provided for the local communities, including proper microclimate for livestock, fruits, wood products and aesthetic values [9, 18]. Wood-pastures in Europe tend to be increasingly recognized as landscapes with high natural, economic and cultural values [2] in both science and policy.

Historical records for Transylvania (overviewed by Oroszi, 2004) suggest that scattered trees on pastures were also valued for their capacity to decrease soil erosion [19]. In this paper we investigate the potential of wood-pastures to provide regulating ecosystem services by their ability to prevent or mitigate the soil erosion.

The assessment process has been performed in the GIS (Geographic Information System) environment by using the Revised Universal Soil Loss Equation (RUSLE) model.

2. Material and Method

2.1. Study area and villages

The study area is located in the central part of Romania, namely in the Târnavelor Plateau, which is situated in the southern part of the Transylvanian Basin (fig. 1), between Mureș and Olt rivers.

Geologically, the region is predominantly characterized by sedimentary strata, mostly calcareous clays or marls, with some deposits of tufa (volcanic ash), fine sand, and thin-bedded limestone [1].

Thus, the petrographic composition of plastic rocks with a high morpho-dynamic potential, favors the geomorphological processes with permanent and seasonal rhythm of manifestation.

The generated processes are determined by the interaction of certain active factors of stress (precipitation, gravity, temperature) and passive factors, which can modify the progressive dynamics of landforms [4].

The soils vary from luvisols to hidrisols and more acid or lime-poor soils over the sands; the clays generate soils that tend to dry out in summer, and the thin-bedded limestone generate base-shallow soils resembling rendzina and erodosol, especially on steeper slopes [1, 17].The central part of Romania, also known as the Saxon cultural region is one of the richest in traditional landscapes with high natural economic and cultural values. This area went through major cultural and institutional changes, given that the Saxon culture collapsed and the economic poverty dominating in the rural societies. Currently there are several local initiatives which aim to conserve and emphasize the economic potential of the rich cultural and ecological heritage of these landscapes [12].

In the studied region, farmlands are generally extensively managed but prone to both abandonment and intensification. The arable land occupies about 15% of the land, the pastures and meadows reaching 40%, and the forests about 30% [6]. This area is characterized by mixed oak *(Quercus petraea)* and hornbeam *(Carpinus betulus)* forests, found on hills and plains on slopes with southern exposition, and mixed beech *(Fagus sylvatica)* and hornbeam, predominant on slopes with northern exposition [3].

2.2. Polygons selected for erosion assessment

In the region outlined above, we delimited eight polygons belonging to four neighboring villages (Table 1) from the same biocultural region [5]. The eight study-polygons were represented by four typical wood-pastures and four pastures with accidental presence of woody vegetation (hereafter refereed as 'pastures without trees'). Each polygon had approximately 1 km^2 area [5] with one exception when respecting this surface area was not possible (Table 1).

Each polygon was comprehensively surveyed in the field for trees and shrubs. We determined the size (trunk circumference, height, crown diameter) as well as the species of the trees and also located the trees with handheld GPS. Wood-pasture sites in our region showed a typical physiognomy of wood-pastures characteristic for the Central-Eastern part of Europe: a pasture surface dominated by scattered mature oak (*Quercus robur*, *Q. petraea*) and pear (*Pyrus communis* and in a less extent *P. pyraster*) [9] in a variable density between *cca* 3-10 trees ha^{-1}. The oak wood-pasture from Rupea contained over 80 trees (predominantly oak) which were considered 'large old' (sensu Hartel et al., 2018 [13]), while over 20 such trees were found in Viscri and one in Bunesti and Mesendorf respectively.

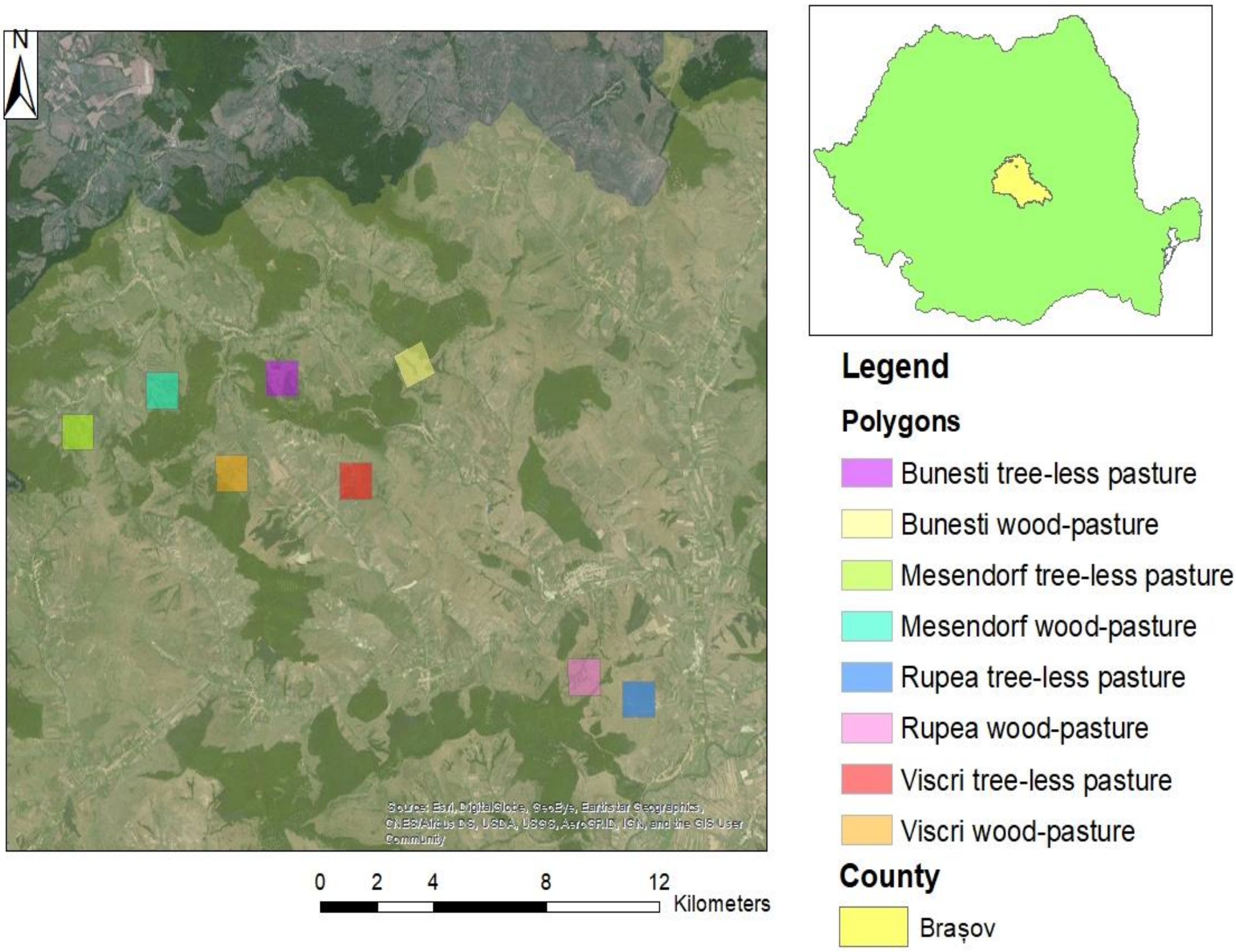


Figure 1. Geographical location of the study area and study-polygons

We were unable to identify pasture surfaces with complete absence of trees within the four villages forming the socio-cultural catchment in our region. Each pasture had sparse woody vegetation mainly because the massive abandonment following the collapse of the communism (1989).

In order to test the relationship between trees and soil erosion, we used the crown diameter for each tree.

Therefore, we were able to calculate the total area covered by the tree crowns, in the investigated pastures (Table 1).

2.3. RUSLE model

The RUSLE (Revised Universal Soil Loss Equation) model represents a set of mathematical equations that estimate the average annual soil loss and accumulation of sediment resulting from surface erosion [23, 7].

One of the great benefits of the RUSLE model used in this study is that it allows the presentation of the results in both graphical and cartographic form. This model is based on the formula developed by Wischmeier and Smith (1965) [24], which is presented as follows:

$$A = R \cdot K \cdot Ls \cdot C \cdot P \qquad (1)$$

where,

- *A = Average annual soil loss (in tons per hectares per year);*
- *R = Rainfall/runoff erodibility*
- *K = Soil erodibility*
- *Ls = Hillslope length and steepness*
- *C = Cover-management*
- *P = Support practice*

- The *R* factor is an expression of the erosivity of rainfall and runoff at a particular location [23]. This coefficient was extracted from the map of Romania's pluvial aggressiveness [16], according to which the study area belongs to the area no. 7, which exhibits a rainfall aggression coefficient (R) of 0.12.
- The *K* factor is an expression of the inherent erodibility of the soil or surface material at a particular site under standard experimental condition [23]. The coefficients of soil erodibility are dependent on soil type and texture. These coefficients have been extracted from Moțoc et al. (1975) [15] and vary in our case between 0.8 and 1.1.
- The *Ls* factor is an expression of the effect of topography, more specifically the hillslope length and steepness [23]. In the present paper, in order to determinate the Ls factor, a digital elevation model with a resolution of 5 m was used, which was interpreted using GIS techniques, the result being then introduced into the formula (GIS function) developed by Mitasova et al. (1996) [14].
- The *C* factor is an expression of the effect of surface covers and roughness, soil biomass, and soil-disturbing activities on rate of soil loss at a particular site [23]. In order to obtain this coefficient, a first step was to develop a detailed map by digitizing every land use polygon from the orthophotomaps, using the ArcGIS software, at a spatial resolution of 5 m. The polygons were also verified in the field and modified accordingly. The next step was to extract the values corresponding to the specific coefficients of each land use type, from the national database developed by Moțoc and Sevastel (2002) [16]. In our case, this coefficient varies between 0.001 and 0.8.
- The P factor is an expression of the effects of supporting conservation practices such as contouring, buffer strips of close-growing vegetation, and terracing, on soil loss at a particular site [23]. For Romania, the values corresponding to different methods and measures of soil erosion mitigation were determined by Moțoc and Sevastel (2002) [16]. Accordingly, the value of 0.1 was assigned for this factor, which corresponds to the absence of soil control and mitigation measures.

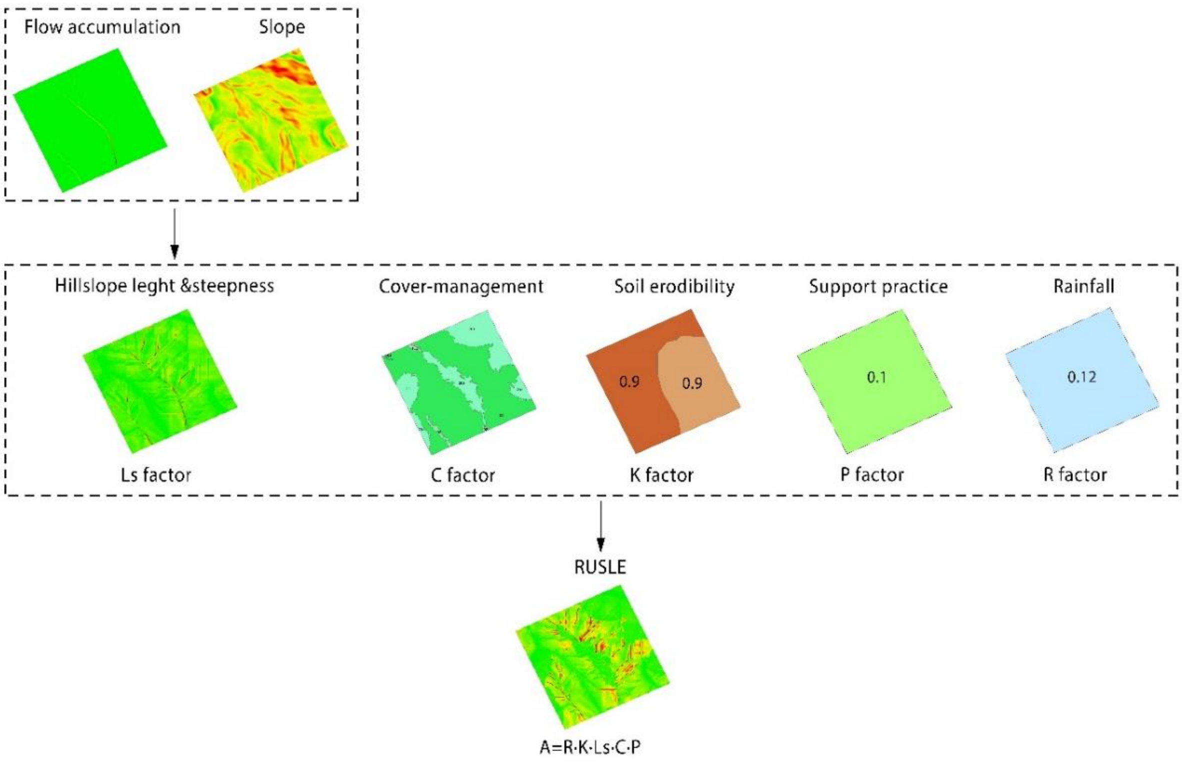


Figure 2. The GIS layers used for each RUSLE factor (coefficient)

From the above it can be seen that the RUSLE model uses five factors which help estimating the rate of soil loss from surface erosion at a particular location, characterized by environmental and anthropogenic conditions, so the specialist can then take decisions regarding the design of the erosion control system and planning activities [21].

These factors have been obtained using ArcGIS software, by applying a specific layer for each factor (Fig. 2) and then applying the RUSLE formula (1).

3. Results and Discussions

The RUSLE model has been applied in all of the eight study-polygons. The results, both numerical and cartographic (e.g. Fig. 3), suggest that the soil loss rate in the polygons corresponding to wood-pastures was generally lower than the rate of soil loss in the polygons corresponding to pastures without trees.

Notably, the maximum value of the average annual soil loss *(A)* for the polygons of wood-pastures was lower than the maximum value of the same parameter for the polygons of pastures without trees, in every case (Fig. 4). However, given that the investigated polygons include not only pastures but also forest areas, or other types of habitats, we wanted to extract all the pastures from the polygons and calculate their mean value for the *A* parameter, in order to further test the potential of wood pastures to prevent or to mitigate the soil erosion. The results show that the mean value of *A* was lower in wood-pastures than in pastures without trees in all but one case.

The exception was the wood-pasture from the Mesendorf village, where the mean soil loss rate had a slightly higher value in the wood-pasture, than in the pasture without trees (Fig. 4). This can be explained by the fact that this wood-pasture is in state of advance degradation due to improper land use.

Thus, in the corresponding polygon we identified a sheepfold, which contributed to land and vegetation degradation by overgrazing

.

Table 1. The difference between the total area of pastures and the area occupied by tree crowns

Village	**Meșendorf**		**Bunești**		**Viscri**		**Rupea**	
Type of pasture	Wood-pasture	Pasture without trees	Wood-pasture	Pasture without trees	Wood-pasture	Pasture without trees	Wood-pasture	Pasture without trees
Total area of pastures (km^2)	0.9606	1.1300	0.8846	0.5971	0.9368	1.1135	0.9234	1.2547
Area occupied by tree crowns (km^2)	0.0098	0.0015	0.0246	0.0103	0.0096	0.0043	0.0177	0.0016
Area of pastures after the removal of the tree crowns (km^2)	0.9508	1.1285	0.8600	0.5868	0.9272	1.1092	0.9057	1.2531
Percent coverage of scattered tree crowns	1.0208	0.1327	2.7809	1.7250	1.0247	0.3861	1.9168	1.0208

Regarding the highest and lowest maximum values of average annual soil loss, figure 4 shows that the highest value (1.1706 t/ha/yr) was found in the pasture without trees from Viscri village, while the lowest value (0.0138 t/ha/yr) was found in Bunești village, corresponding to a wood-pasture well-covered with trees. This result is not surprising, considering that the trees should provide a high protection against soil erosion. This is confirmed by the results from table 1, which show that the tree crowns cover a significant area on the wood-pastures, thus being able to protect the soil from pluvial denudation.

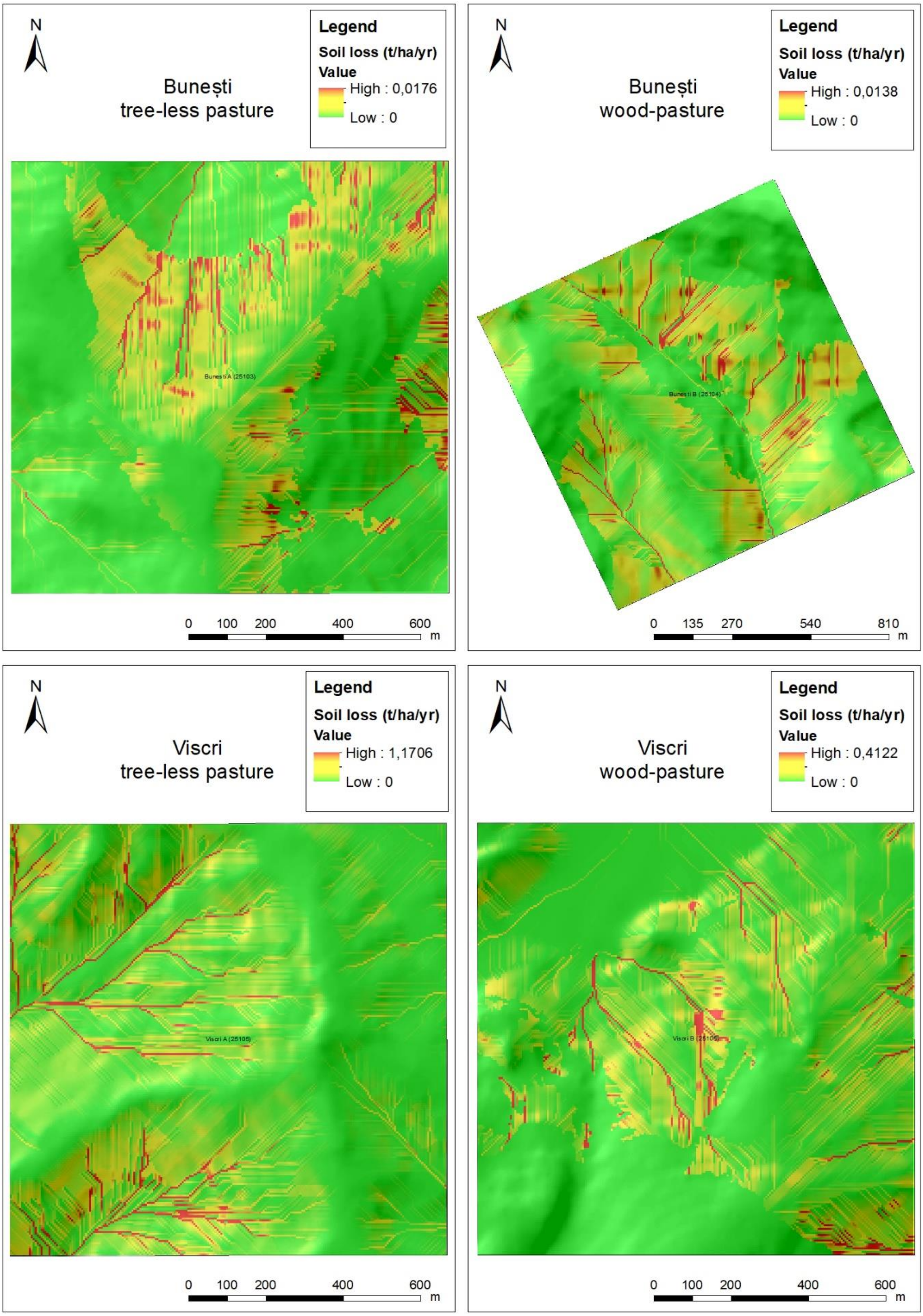
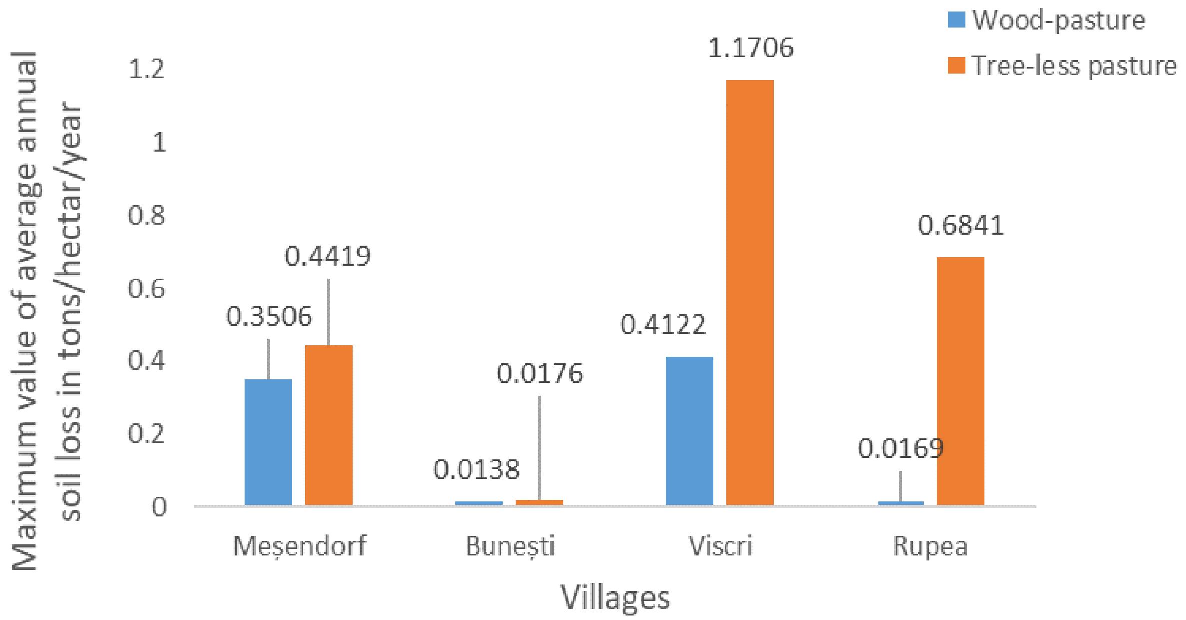


Figure 3. Soil erosion maps of Bunești and Viscri villages



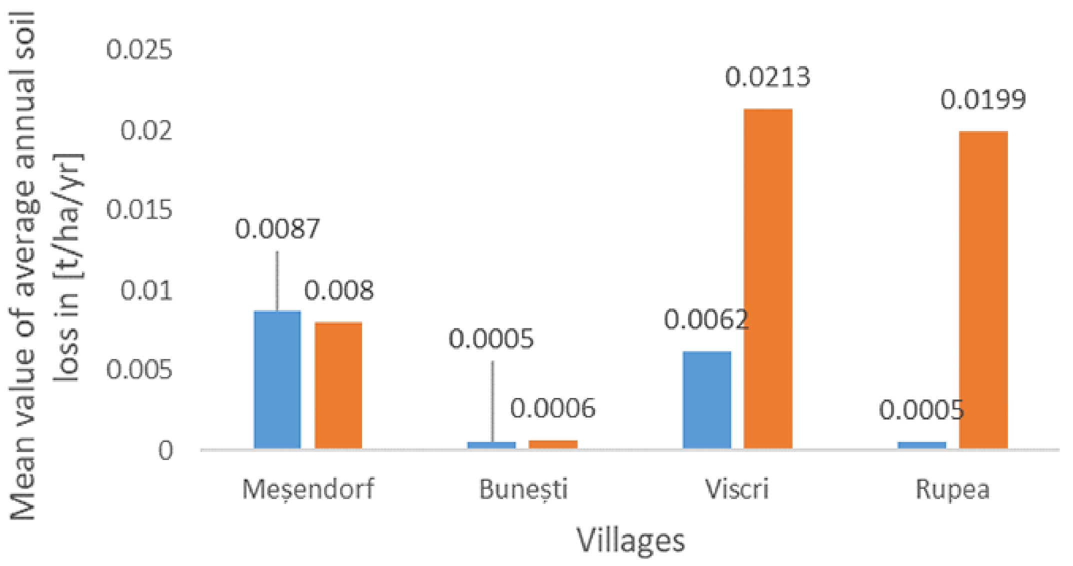


Figure 4. The maximum and mean values of annual soil loss in wood-pastures and pastures without trees

4. Conclusions

This study tried to approach the potential of wood-pastures to mitigate soil erosion. We showed that lower rates of soil erosion coincided with polygons with substantial amount of wood-pasture coverage while the polygons representing pastures without trees had relatively higher soil erosion rates. On the basis of our assessment we conclude that wood-pastures as land uses can better control soil erosion than the pastures without trees. Further research should be carried out in order to better understand the mechanisms through which the management (i.e. type of livestock, livestock density) and scattered trees (i.e. age, species, density) influences the capacity of wood-pastures to provide regulating ecosystem services such as soil erosion control while not compromising production.

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