Opportunities of Identifying and Mapping the Soil Damage by Means of Digital Imagery

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1. Introduction

Nowadays among the efforts for sustainable management and a reasonable usage of the resources, the preoccupations concerning the soil preservation are among the most important ones, at least from the view of the fact that the soil is an important resource of food for human beings and animals.

The soil damage, with its numerous forms (water or wind erosion, drifting processes, sloughing, soil salinization or pollution) and its different intensities, lies among the causes that can diminish the productive qualities of the soil.

Once formed, the degradation forms have to be located and studied qualitative and quantitative in order to apply the most adequate technologies for ecologic reconstruction, in places where a certain limit is exceeded.

Unlike these soil damage assessments done till now on limited areas, sporadic, usually for some isolated damage forms of an increased intensity, using mapping methodologies and means of different accuracy and reliance, the present paper aims at mapping damaged soils on an extended geomorphologic area (the largest part of Suceava Plateau, laying between the Siret and Moldova Rivers, the North border of the country and the South border of Suceava county) using a unitary methodology for a better efficaciousness and reliability, based on digital images of the soil.

The objective is to obtain an estimative map of soil degradation on a large scale, showing the extent of the phenomenon, the grouping of various types of land damage and the areas with the highest intensity of these processes.

2. Materials and methods

The mapping of soil damage is usually done by terrestrial means, inventorying every form of damage present in the area. The inventory takes a lot of time and effort and is practically limited to relatively small area case studies. High resolution digital images (aerial or satellite) give the possibility of extrapolating the terrestrially obtained data on large areas, with little cost regarding the precision of the mapping. The methods are relaying on manual digitizing, on automatic classification or on a combination of the two types of methods. The modern researches are based on **interactive photo interpretation**, a method consisting in the use of complex methods of classification along with the use of ground related patterns of the land surface.

The *study area* is represented by a part of the Suceava Plateau within the borders of the Suceava County. The limits of the area are: the Sireth River, the Moldova River, the North Border of Romania, the Eastern line of the Bucovina's Hills and the Southern border of the county.

The materials used for damaged soils mapping in this case study are represented by ortho-rectified and geometrically corrected aerial photos collected in 2005 within the LPIS Program (***L**and **P**arcel **I**dentification **S**ystem*). The images have a spatial resolution of approximately 0.5m and the spectral characteristics corresponding to visible range.

The aerial photos have been inserted in AutoCAD and georeferenced by using the world file (**.tfw*). Each type of damage to soil has been delineated with closed contour lines, in order to be interpreted as polygons by the program.

The criteria used for degraded soils identification is based on the specific geomorphologic characteristics of each type of degradation; an example for some of the soil damage forms encountered is presented in fig. 1. Each soil damage unit has been drawn in AutoCAD taking into account the entire area affected by the phenomenon; for example, the extension area of gully formations or ravines has been included in the polygon as damaged land due to the high evolution rate of the process (Hadley et al., 1985). On the other hand, all damage forms present in the major riverbeds have not been included in the study, considering the fact that these areas are subject to intense processes of alluviums transport, normal for these kinds of lands (fig. 1.i).

The degradation forms taken into account are:

- **Erosion forms**, including gully erosion and wide area erosion (fig. 1.a and b.);
- **Landslides**, a phenomenon that can be accompanied by the collapsing of terrain (fig. 1.c and d);
- **Pollution affected lands**; in this case, there have been taken into account garbage disposing areas (fig. 1.e), gravel deposits (fig. 1.f), artificial slopes (fig.1.g) and overgrazed lands (fig. 1.h).

After delineating every degradation form encountered on the digital images, the polygons have been grouped according to the administrative units. The area of each shape was computed in ArcGIS using *Calculate Areas* tool and the results synthesized for the entire study area.

The obtained polygons and their attributes have been used for computing statistics regarding the area of the degradation lands, their spatial grouping and the repartition of these perimeters on each administrative unit (ATU – **A**dministrative **T**erritorial **U**nit) by means of database interrogation.

Fig. 1. Soil damage forms taken into account: a. wide area soil erosion; b. gully erosion; c. landslide; d. landslide with terrain collapsing processes; e. garbage deposits; f. gravel deposits; g. artificial land slopes; h. overgrazed zones; i. major waterbed of the Suceava River, with land movement phenomena present.

3. Results and discussions

The soil degradation process has a variable intensity within the limits of the Suceava Plateau. The variability of land degrading forms and their intensity is related specially to the geological and geomorphologic characteristics of the land. The most common types of degradation consist in gully erosion, ravines and landslides; is worth mentioning the fact that these forms don't occur separately, often observing a complex mixtures of different types, combined in different spatial patterns due to variable land vulnerability to degradation. The human activity in the area in time has increased the intensity and the rapidity of soil loss. The current human activities in the area are related to irrational use of soil and ground resources: extensive agriculture, extraction of construction materials (clay, gravel, lamellar stone etc.), deposits of home wastes in inappropriate areas and especially overgrazing. The problems have increased in intensity during the last two decades due to land fragmentation as a result of property restitution laws (18/1991, 1/2000 etc.). The small size of the agricultural parcels makes it impossible to apply protection methods in agriculture: plowing on a perpendicular direction to the highest slope line, building terraces on high slope lands, crop rotation on an yearly basis etc.

The identification of the degradation forms on aerial images of the land is related to the type and the intensity of the process. For example, is easy to delineate large forms of gully erosion or ravines, with a high intensity of soil loss process or a large area landslide with very evident rupture lines in the upper parts. A lower separability is encountered in the case of surface erosion (especially in the incipient cases), due to small contrast with the surrounding areas. Also is difficult to separate gravel pits from the actual riverbed and residue deposits from the neighboring lands.

The most intense soil degradation processes have been encountered in overgrazed pastures, especially related to soil loss and land displacement, related mostly to clay or sandy substrates. Overlaying the degradation forms map on the map of administrative units, a spatial pattern of distribution can be observed: the highest percentage of land damage is located in the south and south east part of the study area, followed by the central area (fig. 2). These areas also present a high intensity of land degradation processes, with rapid evolution towards non usable land.

The intense fragmentation of some perimeters shows the possibility that the entire area surrounding these degradation perimeters could be facing the same degradation problems. The delineation took into account only the forms that can be identified by visual analysis on the aerial photo, without using previous information about the field parameters. The form of each soil damage zone could also indicate the general type of the preponderant degradation process (liniar forms are usually related to gully erosion, compact zones are characteristic for landslides).

Fig. 2. Spatial distribution of soil damage perimeters in the study area.

Analyzing the percentage of UTA area occupied by damaged land areas, one can notice the alarming values of these parameter in the case of UTA Ciprian Porumbescu (16.56%), Tatarusi (10.56%), Dragoiesti (10.3%), Horodniceni (10.21%) (table 1). The lowest percentages are recorded in Balcauti, Siret, Dolhasca, Suceava, Dornesti, Fratautii Vechi, Partestii de Jos, Cacica, Musenita, Fratautii Noi, Milisauti, Zamostea (lower than 1% of the entire area). This low values can be explained either by the geomorphologic unit the UTA belongs to (Milisauti, Zamostea, Musenita are found in plane regions, with low geomorphologic energy), either by high percentage of forested areas (Partestii de jos, Cacica, Fratautii Noi, Fratautii Vechi). The Suceava region has important soil damage areas, but the percentage is low because of the high percent of urban area, with constructions and infrastructure).

There is also the case of administrative units like Preutesti, Bunesti, Vulturesti where the degradation areas appear very fragmented on the aerial images. A field situation analysis shows in these cases that the intermediary zones between the perimeters can also be integrated in the soil degradation areas due to the general process of degradation, involving especially large area landslides.

Table 1. The distribution of degraded perimeters on administrative units

Administrative unit (UTA)	Soil degradation total area (ha)	Area of UTA (ha)	(%)	Administrative unit (UTA)	Soil degradation total area (ha)	Area of UTA (ha)	(%)
Ciprian Porumbescu	508,64	3072	16,56	Granicesti	49,59	1900	2,61
Tatarusi	52,82	500	10,56	Solca	63,29	2500	2,53
Dragoiesti	282,14	2740	10,30	Ipotesti	57,00	2282	2,50
Horodniceni	582,45	5702	10,21	Liteni	158,01	7241	2,18
Volovat	207,10	2229	9,29	Arbore	132,01	6610	2,00
Bunesti	218,24	2651	8,23	Darmanesti	90,46	5051	1,79
Paltinoasa	217,88	2678	8,14	Dolhesti	71,15	4157	1,71
Bosanci	418,83	5200	8,05	Cajvana	39,73	2483	1,60
Falticeni	216,51	2876	7,53	Fantanele	62,26	3981	1,56
Radaseni	286,58	4083	7,02	Siminicea	48,26	3835	1,26
Vulturesti	352,76	5144	6,86	Veresti	48,26	3986	1,21
Preutesti	543,79	7951	6,84	Dumbraveni	48,26	4477	1,08
Botosana	135,81	1994	6,81	Gramesti	37,67	3727	1,01
Salcea	251,57	4000	6,29	Balcauti	30,87	3590	0,86
Marginea	59,36	1000	5,94	Siret	35,56	4340	0,82

Forasti	383,19	6553	5,85	Dolhasca	83,88	11035	0,76
Adancata	223,24	3857	5,79	Suceava	36,76	5210	0,71
Zvoristea	324,17	6594	4,92	Dornesti	18,52	3232	0,57
Todiresti	274,19	5983	4,58	Fratautii Vechi	20,14	3589	0,56
Patrauti	152,15	3773	4,03	Partestii de Jos	21,57	3857	0,56
Vadu Moldovei	156,30	4150	3,77	Cacica	18,71	3400	0,55
Moara	152,00	4186	3,63	Musenita	16,77	4056	0,41
Calafindesti	83,59	2400	3,48	Fratautii Noi	18,48	5457	0,34
Mitocu Dragomirnei	152,15	5285	2,88	Milisauti	11,88	3644	0,33
Udesti	201,50	7621	2,64	Zamostea	0,65	2320	0,03
				Grand Total	**7923,55**	**208182**	**3,81**

The dimensions of the degradation areas are also important in assessing the intensity and the exposure to catastrophic events. Analyzing the distribution of degradation perimeters on area classes (fig. 3), we can notice that most parameters are found in low area classes. The problem is that, on the other end of the distribution, we can find a various number of zones with a very high area with degradation processes (the maximum area of a degradation zone is about 180ha). This fact raises serious problems regarding the designing of the ecological rehabilitation procedures, due to the large area and the variability of soil and hydrological parameters. As wise, the small perimeters represent usually soil degradation initiation zones for major erosion or land displacement phenomena and an early intervention would considerably decrease the costs of damage control and ecological reconstruction.

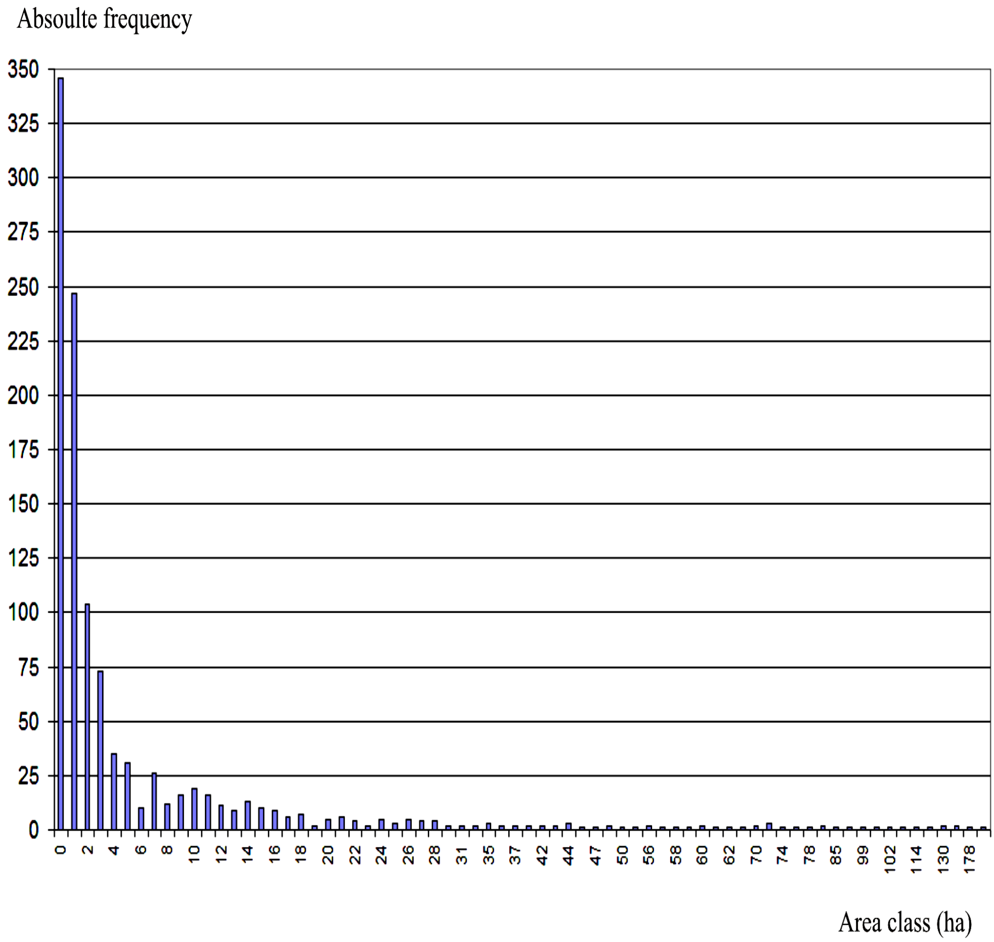

Fig. 3. The distribution of degradation perimeters on area classes

4. Conclusions

The mapping activity and the obtained results show the importance of remote sensing methods in the field of soil degradation analysis. It is important to keep in mind that all assessments that into account only the mapping on aerial images, even if the spatial resolution is high are only estimative and need a thorough validation process that would involve field works and photo-interpretation keys for each analyzed degradation form. The results of the research presented in this paper are only to be used in the subsequent activities for assessing a methodology for land degradation mapping within the project DEGRATER – "THE CREATION OF A GEOREFERENCED DATABASE IN SUCEAVA PLATEAU BY MONITORING THE DAMAGED SOILS ON DIGITAL IMAGES, AS A DECISION BASE IN ECOLOGICAL IMPROVEMENT". The spatial distribution of these areas is important especially in the selecting of the target areas for constituting the mapping model and the validation of the intermediary results. The conclusions are that the most suitable areas for this objectives are located in the next UTA: Ciprian Porumbescu, Preutesti-Bunesti and

Suceava, containing all land degradation phenomena encountered in the mapping procedure in the study area.

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Abstract

Opportunities of Identifying and Mapping the Soil Damage by Means of Digital Imagery

The objective of this paper was to map the degradation form in the Suceava County region of the Suceava Plateau using only digital images. The use of aerial digital images in soil degradation mapping procedures is important in applying unitary and efficient methods on the analysis of wide areas. The available aerial images are characterized by a high spatial resolution (0.5m) and insure the comparability of the results on a national level (they are available for the entire country within the LPIS European program). The mapping only took into consideration data extracted from the digital images by means of visual interpretation. A land degradation areas database has been developed using GIS software (ArcGIS 9.2); the data base contains polygons corresponding to land damage areas on the ground and a spatial distribution within the administrative units. Using data base interrogating facilities of ArcGIS we obtained a synthetic situation of the damage areas characteristics and spatial distribution, situation important in choosing the target areas for constituting the mapping model in soil degradation mapping.

Keywords: land degradation, digital images, Suceava Plateau

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