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MAPPING SOIL EROSION SUSCEPTIBILITY USING GIS TECHNIQUES WITHIN THE DANUBE FLOODPLAIN, THE CALAFAT - TURNU MĂGURELE SECTOR (ROMANIA)

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Abstract: The Danube floodplain, the Calafat – Turnu Măgurele sector, through its main features (topographic and climatic characteristics, land use and soil type) and human activities, constitutes an area exposed to soil erosion. The main objective of the present research is to map soil erosion susceptibility using the GIS techniques for the computation and representation of areas, which are exposed to soil erosion correlated with the field data for the validation. Analyzing the entire model, the relatively simple methodology, the database consistence, the comparability of the results with the existent soil erosion values at national and local scale, we can say that the model was applied with success in the studied area (areas and classes of water erosion susceptibility: very low, low, moderate, high - Ciupercenii Noi, Desa, Măceşu de Jos, Grojdibodu, Orlea, very high - Rast, Negoi, Catane, Bistreț, Goicea; areas and classes of wind erosion susceptibility: very low, low, moderate - Ciupercenii Noi, Dăbuleni, Ianca, high - Calafat, Poiana Mare, Desa, Goicea, Piscu Vechi, very high - Poiana Mare, Rast, Negoi, Bistreț, Gighera, Orlea. The soil erosion susceptibility map can be useful for planning erosion control measures and for selecting suitable sites for runoff plot experiments.

Keywords: the Danube floodplain, soil, water erosion, wind erosion, database, GIS analysis, susceptibility

Introduction

In the context of environmental protection, most concerns about erosion are related to accelerated erosion, where the natural rate has been significantly increased mostly by human activity.

Soil erosion is one of the most critical environmental hazards of modern times. Simple methods such as the universal soil loss equation (USLE) (Wischmeier and Smith 1965, 1978), the modified universal soil loss equation (MUSLE) (Wiliams 1975), or the revised universal soil loss equation (RUSLE) (Renard et

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al. 1997) are frequently used for the estimation of soil erosion from watershed areas.

There are several possible methodologies for creating an erosion map of Europe, some of which are reviewed by Gobin et al. (2002) and Grimm et al. (2001). Some of these are based on the collection of distributed field observations, others on an assessment of factors, and combinations of factors, which influence erosion rates, and others primarily on a modeling approach. All of these methods require calibration and validation, although the type of validation needed is different for each category.

The studied area is located in the south-western part of Romania, on a distance of about 200 fluvial kilometers, between the town of Calafat and the town of Turnu-Măgurele, covering an area of ca. 200,000 hectares (of which 95,000 hectares represent the floodplain proper) (Licurici et al., 2013).

In the context of the general diversion tendency towards the right, imposed by the neotectonics of the region and by the morpho-climatic stability, during the Holocene, the Danube induced the withdrawal of the right slope of the Prebalkan Tableland and within this space there resulted the present river floodplain, significantly more developed on the left side and being dominated by the relatively high slope of the morphological unit across the Danube (Fig. 1). Under the name of the Danube Floodplain there is to be understood all that the Danube built through alleviation and which undergoes the direct action (in natural regime) of the river (***, Geografia Văii Dunării româneşti, 1969). Locally, there appear significant changes because of the increased supply of alluvia and because of the sand dunes or alluvial fans.

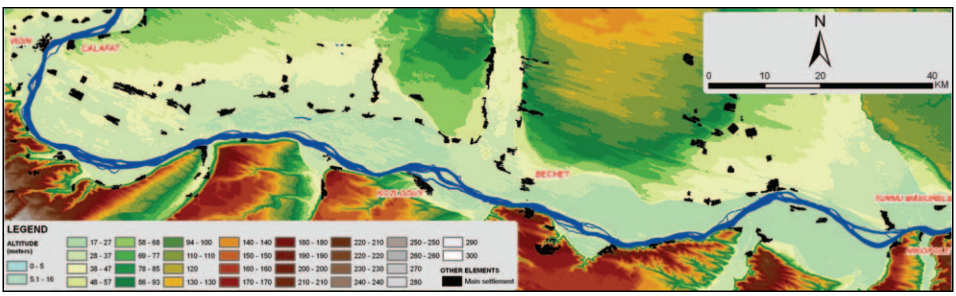


Fig. 1 The Danube Floodplain within the Calafat-Vidin - Turnu Măgurele-Nikopole sector. Hypsometry

The minor landforms of the floodplain proper are rather heterogeneous and their organization sometimes forms genuine geographical individualities. However, in general terms, there is to be noticed a succession of longitudinal stripes: the sandbank located near the riverbed (often the higher area), the middle floodplain (partially swampy), and the low depressions that formerly represented extensive water bodies (lakes, ponds, marshes). Often, the complexity of the relief is augmented by the presence of sand dunes (which sometimes cover the geomorphologic contact) (Calafat – Desa – Pisculeţ, Călăraşi - Dăbuleni etc.) or of the erosion steep. Conclusively, on the sector analyzed in the present paper, the altitudes descend from the Danube towards the interior and up to the central part of the floodplain or even to the neighbouring terrace. The values of the relative altitude are comprised between less than 20 and 40 meters.

With more than half of the population leaving in rural settlements, the area under study greatly depends on agriculture, which is commonly the most vulnerable economic sector to natural hazards (Benson and Clay, 2004). Within the analysed area, arable land prevails, with more than 130,000 hectares (Fig. 2), accounting for 85% of the total agricultural terrains; hayfields and pastures cover almost 18,000 hectares (12%), permanent crops representing just 3% (3823 ha) of the total agricultural terrains. Some of the communes own large surfaces of arable land, as it is the case with Poiana Mare (8259 ha), Bistreț, Gighera, Călărași, Gura Padinii (more than 7000 ha). Poiana Mare and Bistreț also have large heyfields and pastures (1400-1700 ha), while Ghidici, or Măceșu de Jos have less than 200 ha.

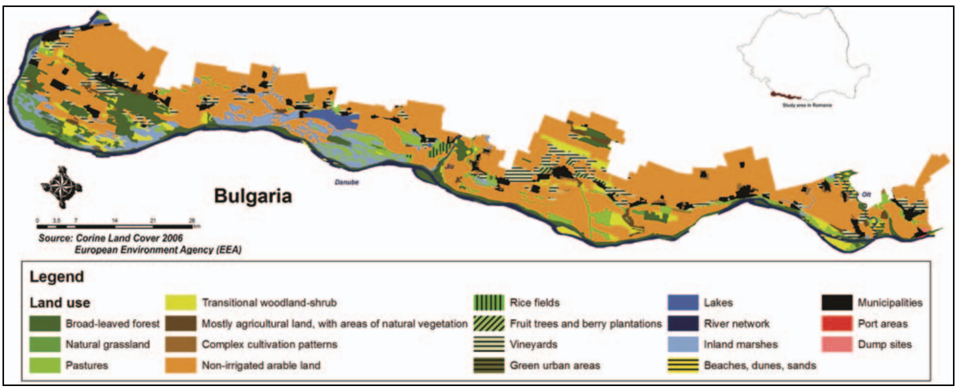


Fig.2 Land cover map within the Danube floodplain. Calafat-Turnu Măgurele sector

(Source: Corine Land Cover, 2006, EEA)

Soils within the Danube floodplain are moderately developed, being influenced directly by the new material deposited during the floods on the low terraces and by the aquifer lying at low depth (alluviosols, glycols, psamosols and loose sands) (Fig. 3):

– in the areas where the aquifer is mineralized and hydric regime favours the salinization process (Gighera, Ostroveni, Bechet and Potelu precincts),salic alluviosols appear (Photo.1).
– in the case of the gleyic alluvisols, the aquifer is found at depths varying on average between 1 and 2 metres, while during the rainy periods, when the water flow on the rivers increases, it can be found near the surface (in patches southwards of Gârcov and Izlaz).
– between Ciupercenii Noi, Desa and Zăval, typically gleyic chernozems cover larger areas (Photo.2). The aquifer is found at a low depth (2-3 m); consequently, there is a moderate gleyzation process.

Photo.1 Soil degradation by hydro-climatic variations, south of Bistreț (Licurici et al., 2013)

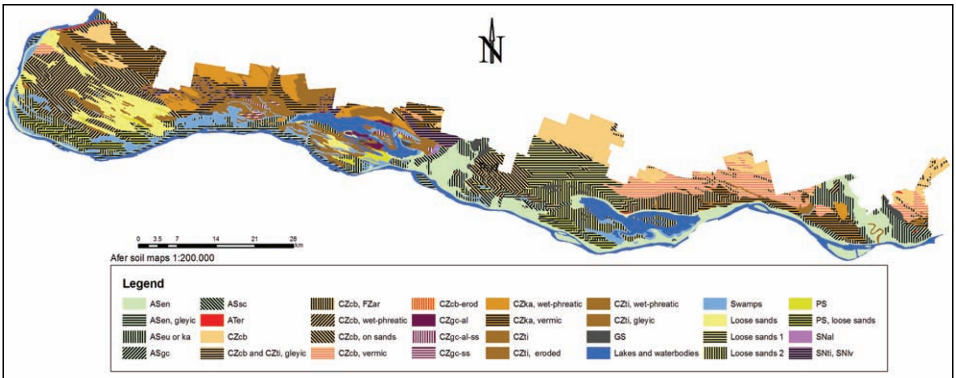
Photo.2 Soil erosion on sands with clay intercalations, south of Zăval) (Licurici et al., 2013)

– at Poiana Mare-Ciupercenii Noi-Desa area and north of Bechet and Giuvărăşti, where the aquifer is at a lower depth, Patches of cambic, wet-phreatic chernozems are found.
– erodic anthrosols are very to excessively eroded or uncovered soils, and the remaining horizons do not allow their classification in a particular type of soil. Within the study are, they cover very small areas, north of Calafat, having a sandy, loamy or loamy-clayish texture.
– for the Ciupercenii Noi-Desa-Ghidici area, as well as southwards of Bistreț, Cârna and Gighera, having a sandy texture, the loose sands are specific. Loose sands in association with psamosoils and gleyic chernozems, on sands, are found on the lower terraces of the Danube,

south of Ciupercenii Noi-Desa_Piscu Vechi, Bistreţ-Cârna-Gighera and within Potelu precincts. There is a strong gleyzation due to the aquifer situated at very low depth.

– psamosoils were formed on parental material made up of sandy aeolian deposits, under a vegetation of xerophytes herbaceous sandy. They are found southwards of Ciupercenii Noi-Desa-Piscu Vechi-Ghidici, Cârna-Măceşu de Jos-Gighera, Ostroveni-Bechet-Călăraşi-Ianca. Locally, they are associated with loose sands.

– in the depression-like areas within the floodplains and plains, Gleysols are found. They are formed on varied deposits from the texture point of view, such as fluvial, fluvial-limnic, limnic, sands etc. and their genesis is conditioned by the presence of the aquifer at low depth.



Legend: ASen = Enthic alluvisols, ASen, gleyic = Enthic gleyic alluvisols, ASeu or ka = Eutric with calcaric alluvisols, ASgc = Gleyic alluvisols, ASsc = Salic alluvisols, ATer = Erodic anthrosols, CZcb = Cambic chernozems, CZcb and Czti, gleyic = Cambic, gleyic chernozems in association with typical, gleyic chernozems, CZcb, Fzar = Cambic chernozems associated with argic phaeozems, CZcb, wet-phreatic = Cambic, wet-phreatic chernozems, CZcb, on sands = Cambic chernozems on sands, CZcb, vermic = Cambic, vermic chernozems, CZcb-erod = Cambic, eroded chernozems, CZgc-al = Alluvic-gleyic chernozems, CZgc-al-ss = Salsodic alluvic gleyic chernozems, CZgc-ss = Gleyic–salsodic chernozems, CZka, wet-phreatic = Calcaric, wet-phreatic chernozems, CZka,vermic = Calcaric, vermic chernozems, CZti = Typical chernozems, CZti, eroded = Typically eroded chernozems, CZti, wet-phreatic = Typical, wet-phreatic chernozems, CZti, gleyic = Typically gleyic chernozems, GS = Gleysols, Lakes and waterbodies, Swamps, Loose sands, Loose sands 1 = Loose sands in association with psamosoils and cambic chernozems, Loose sands 2 = Loose sands in association with psamosoils and gleyic chernozems, on sands, PS = Psamosoils, PS, loose sands = Psamosoils in association with loose sands, SNal = Alluvic solonetzs, SNti, SNlv = Typical solonetzs in association with alluvic solonetzs

Fig.3 Soil map of the Danube Floodplain, Calafat-Turnu Măgurele sector
(Source: Romanian Soil Classification System data updating to the new Romanian Soil Taxonomy System, 2012)

Geomorphic hazards related to soil degradation are also to be put in connection with the inadequate agricultural techniques, deforestation, overgrazing, interruption of the lateral connection between floodplain and the Danube etc. Geomorphic hazards primarily related to (rain) water erosion concern any slope area within the floodplain and the geomorphologic contact of the floodplain with the high terrace (Licurici et al., 2013).

Geomorphic hazards primarily related to wind erosion concern deflation, abrasion and deposition of the sand. Large surfaces of the floodplain (Calafat – Ciupercenii Noi – Desa – Piscu Vechi – Ghidici, Bechet – Dăbuleni etc.) are vulnerable to this type of hazard, which is to be assessed in the context of the land use/land cover changes (cutting down of forest shelter-belts, deforestation, removal of the natural vegetation, usage of pesticides, which leaves the soil naked between crops etc.) and climatic changes (long dry/drought periods, increased occurrence of storms, high-speed winds etc.) (Licurici et al., 2013).

Data and methods

Because the GIS is an efficient tool for managing spatial data and suitable for soil erosion calculations, there have been published various studies of soil erosion using GIS (Mitasova et al. 1996, 1998). The large number of variables taken into consideration in determining the susceptibility as well as the complexity of the model require several characteristic steps to be performed. The outcome of this study, the soil erosion susceptibility map, was achieved through a multiple spatial overlay analysis. This analysis was performed with the ESRI ArcGIS geoinformation software, analysis module “Spatial analyst”, the Raster Calculator function that makes possible the integration of mathematic equations into GIS (Bilaşco et al. 2009).

In the implementation process of the soil erosion susceptibility model, we created a vector and raster GIS database covering the studied area, using specific spatial analysis methods and database interrogations. Considering the necessities of the susceptibility map, a GIS database complexly structured on vector and raster layers was created, starting from the primary database (contours, hydrography, soil and land cover) to the derivate data (digital elevation model) and finishing with the modeled database, raster structures (water and wind erosion grid and soil erosion susceptibility grid) (Tab. 1). The grid format offers many advantages due to the simplicity of operation through matrix algebra, and has been used by many researchers in heuristic or statistical analysis.

Table 1 Database structure used in soil erosion susceptibility map

Name	Type	Structure	Attribute	Origin
Contour	vector	line	altitude	primary
Hydrography	vector	line	name, order, direction	primary
Soil	vector	poligon	type, texture	primary
Land cover	vector	poligon	category of use	primary
DEM	raster	grid	altitude	derivate
water soil erosion	raster	grid	soil erodibility factor	modelled
wind soil erosion	raster	grid	soil erodibility factor	modelled
soil erosion	raster	grid	soil erosion susceptibility	modelled

Results and discussions

A comprehensive assessment of soil erosion and the development of erosion-control plans in any area requires consideration of both wind and water erosion.

Water erosion includes the processes of detachment, entrainment, transport, and deposition of soil particles caused by raindrop impact and surface runoff over the land surface. Soil properties determine its inherent erodibility (susceptibility) to erosion. Wind erosion causes soil-texture changes because fine particles are removed, decreases soil depth and fertility and decreases land productivity.

To the soil database (Romanian Soil Classification System updating to the new Romanian Soil Taxonomy System, 2012), the soil erodibility coefficient dependent to the soil type and texture was introduced as attribute. Their value vary between 1 and 5. The resulted values were grouped into five classes corresponding to a particular susceptibility: very low, low, moderate, high and very high.

Within the Danube Floodplain, Calafat-Turnu Măgurele sector the areas characterized by: water erosion correspond to the following classes of susceptibility (Fig. 4): very low, low, moderate, high (Ciupercenii Noi, Desa, Măceşu de Jos, Grojdibodu, Orlea), very high (Rast, Negoi, Catane, Bistreț, Goicea); wind erosion correspond to the following classes of susceptibility (Fig. 5): very low, low, moderate (Ciupercenii Noi, Dăbuleni, Ianca), high (Calafat, Poiana Mare, Desa, Goicea, Piscu Vechi), very high (Poiana Mare, Rast, Negoi, Bistreț, Gighera, Orlea).

The spatial analysis module "Spatial Analyst", with the Raster Calculator function permits the integration of mathematic equations in GIS environment.

Therefore, regarding the soil erosion susceptibility map we converted the two database – water erosion and soil erosion (grid type) by interrogating the attributes representing the susceptibility.

The evaluation model is based on quantitative classification and five classes of susceptibility (Fig. 6) are derived by comparing tolerated and computed erosion values (water erosion and wind erosion): very low, low, moderate, high and very high. Analyzing the resulting maps of the soil susceptibility we identify the areas with very high and high susceptibility (Rast, Negoi, Bistreţ, Măceşu de Jos and Grojdibodu). Within the Danube Floodplain, Calafat-Turnu Măgurele sector areas affected by soil erosion are generated by the the aquifer situated at very low depth and by the the soils texture (fluvial, fluvial-limnic, limnic, sands etc) mostly extended in the Dolj county.

The model validation was achieved by field trips meant to identify by direct observation or by using a GPS in some areas affected by soil erosion then we compared the results with the modeled database.

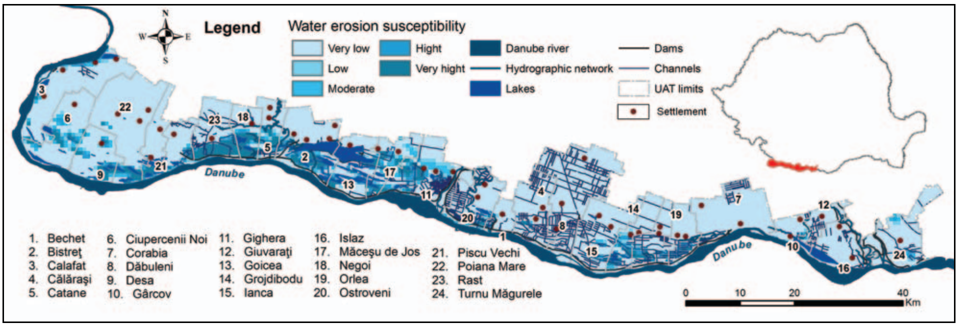


Fig. 4 Water erosion susceptibility of the Danube Floodplain, Calafat-Turnu Măgurele sector

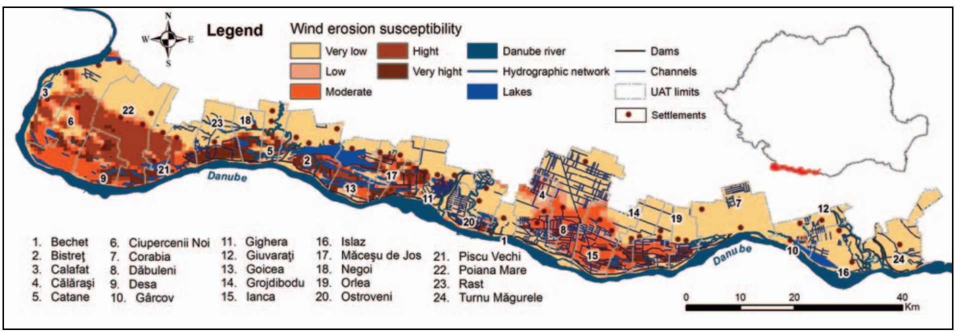


Fig. 5 Wind erosion susceptibility of the Danube Floodplain, Calafat-Turnu Măgurele sector

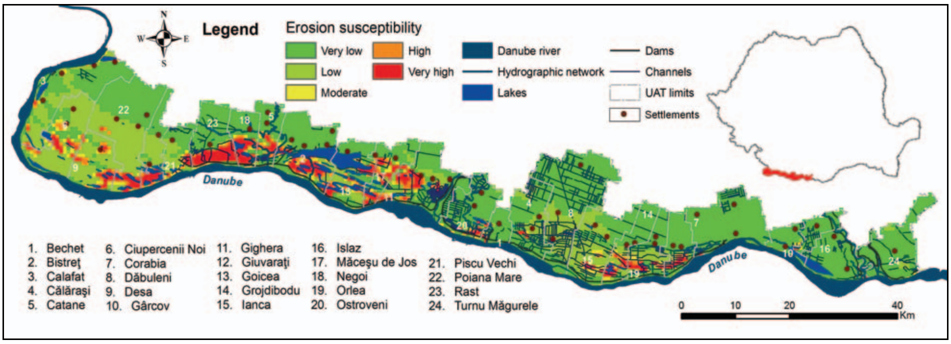


Fig. 6 Soil erosion susceptibility of the Danube Floodplain, Calafat-Turnu Măgurele sector

Conclusions

The complexity of the GIS spatial analysis model presented in this study, the results' accuracy and its good validation prove its significant utility for the practical research in the field and supports its extrapolation to other territories.

The application of a process model for the soil erosion susceptibility map has been preferred here for three main reasons:

1. it applies the same objective criteria to all areas within the Danube floodplain, Calafat-Turnu Măgurele sector, and so can be applied throughout the Bulgarian side, subject to the availability of suitable generic data;

2. it correlates more inputs by using GIS for resulting the susceptibility classes and their distribution in the analyzed area;

3. the methodology can be re-applied with equal consistency with improved current data, and for scenarios of changed climate and land use.

The soil erosion susceptibility classes can be useful for planning erosion control measures given that the environmental legislation, regulations, and certification focus societal attention on short- and long-term impacts of soil erosion and sedimentation.

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