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Hydrogeological modeling in Danube Valley using GIS techniques. Study case

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Abstract

In hydrogeological and pedoclimatic conditions, specific to the Danube River, there is a danger of secondary salinization of soil excluded from the floods. The drought, with an increasing frequency, affects agricultural production in areas where the largest irrigation systems are found. These systems were built during 1960-1990, but they are dysfunctional and unused for 20 years.
The purpose of this study is to insure a model using GIS technologies, in order to reduce the negative effects of the drought and to propose redevelopment of irrigation. Such model is presented in a form of five thematic maps where the main morphometric parameters (hypsometry, slope, slope orientation), in quantitative terms, the types of soils and land use were analyzed for the entire surface of the villages Gostinu-Greaca-Arges, located in the Danube Floodplain. The GIS model provides important information for the investigated area and it is a useful tool for risk assessment and early-warning.
This study is based on observations from the maps interpretation of the studied area, but also from reports and studies published over the years.

Keywords: The Danube River, drought, soil, irrigation.

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1. Introduction

Globally, climate has changed from the last decades due to the amplification of pollution effects, massive deforestation and landscape changes, and caused amplification of dryness phenomenon. These changes also occur in Romania, especially in the Southern Muntenia and Oltenia. Therefore, in areas where drought persists for a long time, dryness occurs, causing lowering of the groundwater and desertification manifested by the disappearance of vegetation and soil degradation.

The combination of both natural phenomena causes adverse effects on soil water reserves and thus on crops, up to the alteration of life. The areas in which these phenomena occur, are classified as vulnerable areas facing economic, social and environmental issues. The phenomenon of dryness has covered the entire country of Romania, in the last years. The causes that lead to these changes are the increase of annual average temperature and the regime and amount of precipitation modification.

Within the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, the Convention to Combat Desertification has developed and adopted in Paris, France on 17 June 1994 and entered into force on 26 December 1994. Also at this conference, it was given the definition of desertification as an ecological complex hazard of lands in arid, semiarid and semi wet due to the reduction of precipitation and human activities (Balteanu & Serban, 2005).

Worldwide, from the data presented by the said Convention to Combat Desertification, a third of the land area is affected by aridity and desertification, also being affected one billion people from over 110 countries in all continents. Five countries from European Union are affected and the annual cost in order to combat this phenomenon is of 42 billion US dollars.

According to FAO, the day of 17 June is dedicated to combat desertification, drought and land degradation, thereby marking a date which seeks to raise public awareness around the world, to fight for mitigating the effects of desertification, drought and land degradation.

In Romania, the drought and its associated phenomena, aridity and desertification, are caused by natural factors (lack of precipitation for a long period of time) and anthropogenic factors. The anthropogenic factors are represented by deforestation and inappropriate agricultural activities that lead to inability to absorb soil water, slopes erosion, silting of riverbeds. Another cause is represented by land reclamation works that are unfinished, lack of maintenance of irrigation systems in drought-risk areas.

The year 2000 was considered one of the driest one in the past half century, as the dryness phenomenon manifested in all 41 counties of Romania. 7642489 hectares, representing 95. 4% of the total plagued area, were affected by meteorological and hydrological phenomena (National Institute of Meteorology).

Climate change, characterized by increasing temperatures, emphasizes meteorological drought, leading to hydrological drought by reducing surface water resources and groundwater. This process leads to decreasing the water supply for cities, industry and agriculture.

2. Study area

The study area Gostinu-Greaca-Arges is located in the Danube Meadow, between subdivision embankment Baneasa-Gostinu in the West, Arges River in the East, Burnas Plateau in the North and the defense embankment of the Danube in the South, which is also the natural border with the state of Bulgaria. The main geographical subdivisions of the area are three relief units: Greaca Floodplain, Arges Floodplain and Burnas Plain, as it can be seen in the hypsometric map. Greaca Floodplain, extended up to Arges River, develops exclusively on the left bank of the Danube and it has relative uniform widths between 6 and 9 km and altitudes ranging from 14 to 15 m. The Arges Floodplain is situated in the eastern part of the study area and it is presented as a lane that surrounds circularly the eastern extremity of the Burnas Plain. Burnas Plain, a fragmented tabular plain, consists of an elongated strip of field on the northern boundary and four terraces of the Danube, with 75-80 m altitude (Botzan, Haret & Stanciu, 1991).

From the administrative point of view, this area is situated in Giurgiu county and Calarasi county.

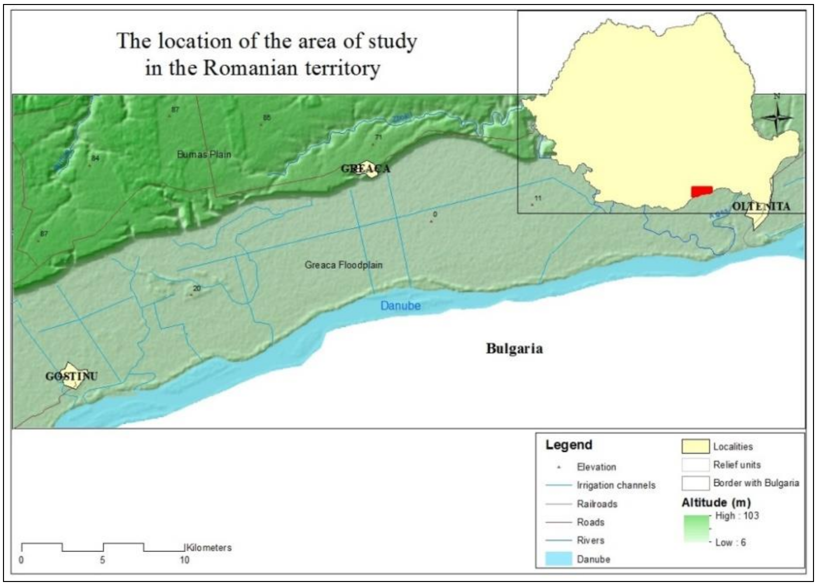

Figure 1. The Location Map of the study area

The area of Gostinu-Greaca-Arges has a temperate-continental plain climate. Some emphasized differences are manifested between cold and warm seasons. Thermal amplitudes range from 22° C to 26° C, the microclimate being influenced by the Danube, which generates late springs and hot summers. The average yearly air temperature is 11 °C. The average air temperature varies from month to month, with a maximum in summer months (July-August) and a minimum in January and February. During vegetation period, there is an average of six intervals of drought (without precipitation), with an average duration of 17 days. Over 50% of the annual precipitations is recorded during the vegetation season in normal years. Potential heat factor is more important than the hydric one.

3. Materials and methods

There were used cartographic materials for database achievement, such as topographic map with contour lines on scale 1:25000 that was processed by scanning and geo-referencing in Stereographic 1970 projection system. The digital elevation model (DEM) on 90 meters spatial resolution, available free of charge on CGIAR-CSI geoportal in WGS84 geographical projection, was initially transformed in Stereographic 1970 projection. This 90 m DEM was re-interpolated and exported to obtain an appropriate resolution of 30 m, required for analyzing the study area. The correction of the SRTM model was done in Arcview, using Spatial Analyst especially. Based on this 30 m DEM, we could define the relief units more accurate and thus to derive morphometric parameters, slope and relief declivity. Also we could create the relief hillshade used for 3D effect view of the relief. This hillshade may overlap other layers with a transparency of 40-50 %.

Vector data are the thematic layers created by vectorization using ArcGis 10.1 software and represented by point (elevation), line (hydrographic network, roads, railways, irrigation channels) and polygon (localities, land use, soils and relief units) that render the land surface elements. Vector data help also to achieve raster data. Following the vectorization of the most important elements, a significant attribute database resulted and could be quantified as tables of attributes. These data characterize both the raster and vector data.

The use of land map was obtained from Corine Land Cover 2000 (CLC 2000) data for mapping of land use, available free of charge by the European Environment Agency. CLC 2000 is the European reference data set which cover the land and it has 44 distinct classes grouped into three hierarchical layers. Satellite database for achieving CLC2000, known as IMAGE2000, was LANDSAT ETM+ images.

Altitudinal distribution of the relief in the studied area can be easily interpreted with hypsometric map. Analyzing the ratio of hypsometric steps, we can notice a uniform distribution of them. The highest altitude at 103 m is located in the northwest area, in Burnas Plain and the lowest, at 6 m, in the estuary of Arges River in Danube River. The largest ratio of the hypsometric steps is represented by the steps of 6-40 m while the most reduced one is represented by 90-103 m altitude. It can be noticed an increase of the altitude steps from the South of the study area in the Danube Floodplain, to the northwest side, in Burnas Plain.

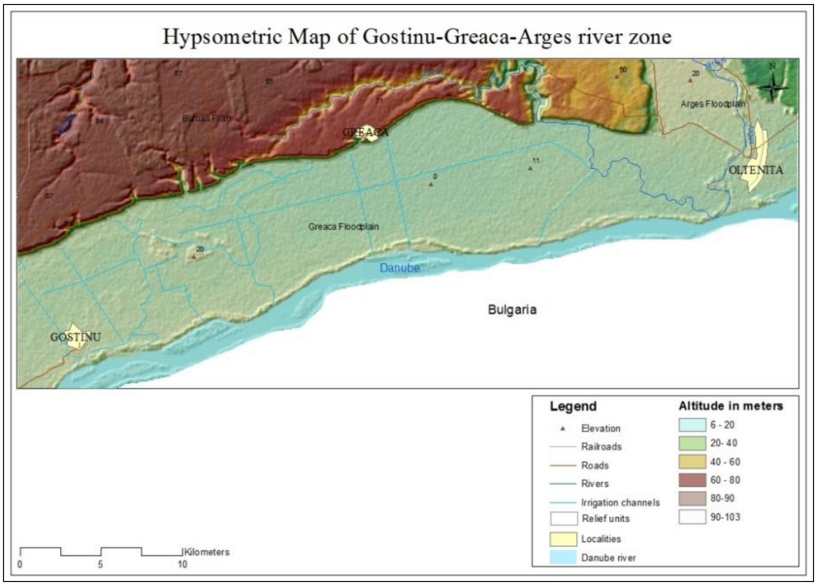

Figure 2. Hypsometric Map of the study area

The relief declivity is one of the most complex features of the landscape and it is in line with hypsometry, thus these two features are directly proportional: the slope relief increases when the values of altitude increase. The largest ratio of slopes is held by quasi-horizontal surfaces where the slope value doesn't exceed 1 degree. These surfaces are represented by the Danube Meadow (Greaca Floodplain and Arges Floodplain) and have a low morphodynamic potential, occupying about 66% of the area. The very gently inclined slopes range from 1 to 4 degrees on 29% of the studied area, while the gently inclined slopes range from 4 to 9 degrees on 5% of the surface. As the elevation ascend to the northwest, in Burnas Plain, the slopes become moderately inclined with values over 9 degrees that occupy only 1% of the total area.

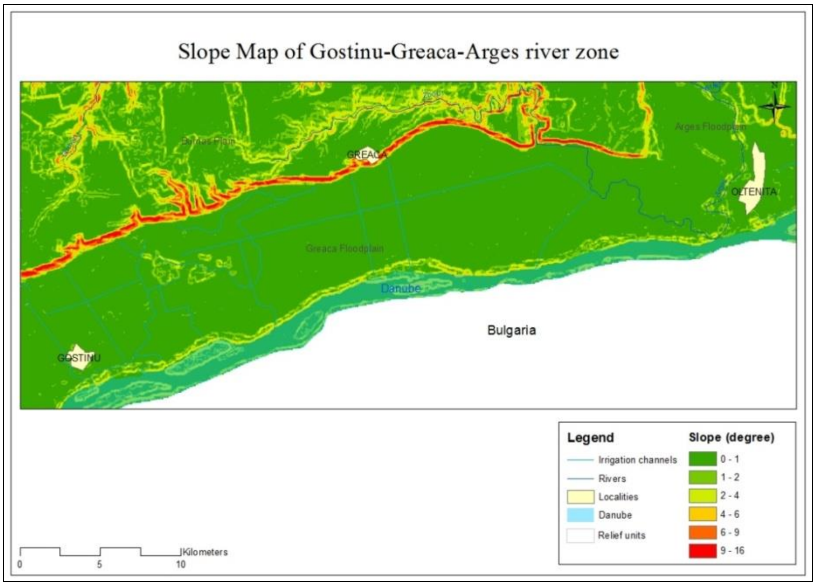

Figure 3. Slope Map of the study area

The aspect of the relief refers to its orientation towards the cardinal directions. The aspect can be determined by simply reference to the North direction, but in a mathematical, geometrical and methodological proper form, the exposition depends on the inclination of the earth's surface. The exposition is a parameter related to geomorphological processes, through its control on solar radiation, temperature and precipitation. The aspect map plays an important role because it influences the use of land and the suitability of crops. The aspect and slope map generate different caloric regimes, which will influence soil moisture, thus inducing quantitative and qualitative nuances of geomorphological processes and vegetation. Analyzing the aspect map, there are uniform surfaces of the exposition with a highest value of the slopes with northern orientation (17%), followed by flat (14%) and eastern (12%) orientation. The minimum value of 8% is given by slopes with a western orientation. These factors will induce discontinuities in diurnal amplitude and substrate.

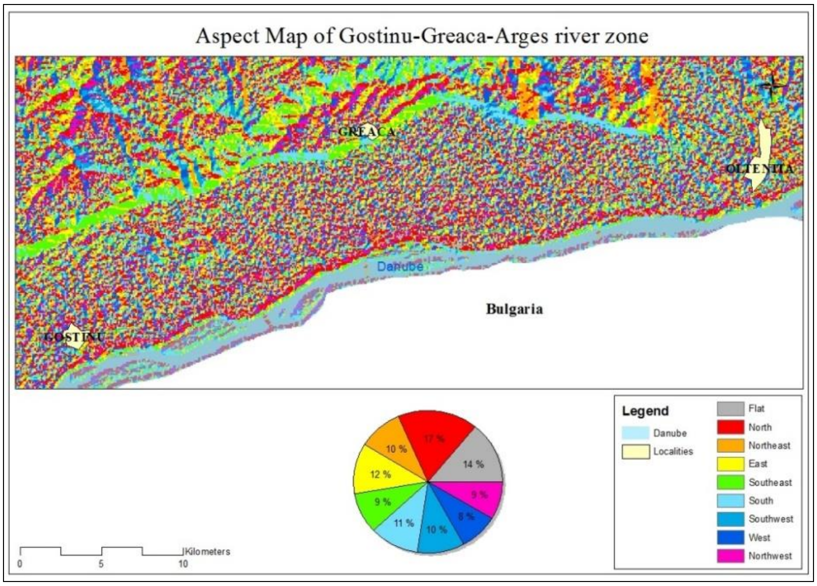

Figure 4. Aspect Map of the study area

Analyzing the Corine Land Cover map, it can be noticed that the largest surface of the Gostinu-Greaca-Arges area is represented by non-irrigated arable land on 71% of the study area, followed by areas with broad-leaved forests, occupying almost 12% of the surface, water courses (3.32%), discontinuous urban fabric (3.25%), vineyards (almost 3%), while the smallest areas are represented by continuous urban fabric (0.06%) and inland marches (approx. 1%). The non-irrigated arable land is located on quasi-horizontal land or terrain with low slopes, such as in the two meadows (Greaca Floodplain, Arges Floodplain) and plain (Burnas Plain).

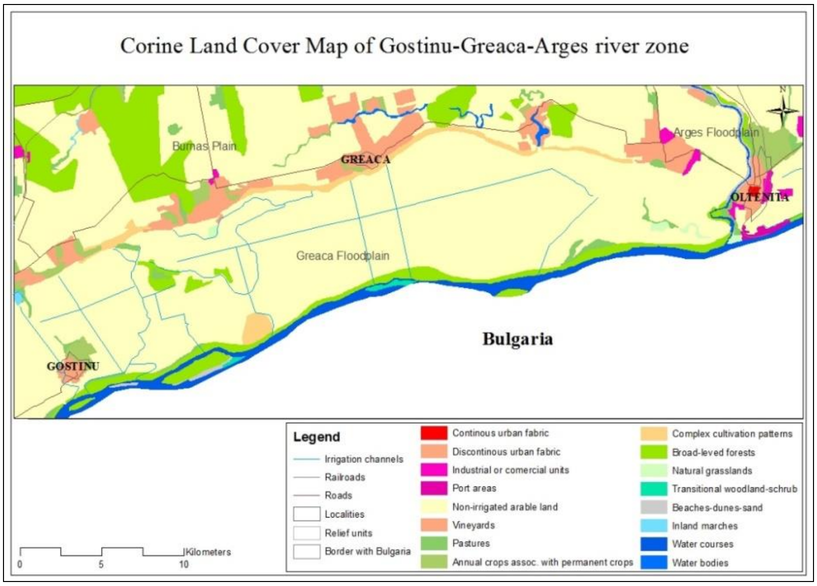

Figure 5. Land Use Map of the study area

Analyzing the soil map, it can be noticed that the predominant soil of the investigated area belongs to the alluvial soils, in various stages of evolution. In terms of pedogenetic, these soils have been formed under the dominant influence of periodic flooding of the Danube, which deposited an amount of sediments into the meadow and depressionary relief. The texture of the actual types of soils was formed depending on the flow velocity of the sediments and their rate of sedimentation. Coarse material was deposited near the Danube River, forming the fluvial grid, while fine colloidal material was lodged in low and depressionary areas and former ponds bottoms. This explains the existence of a wide variety of alluvial soils: from sandy to heavy clay ones, with different stages of gleyzation.

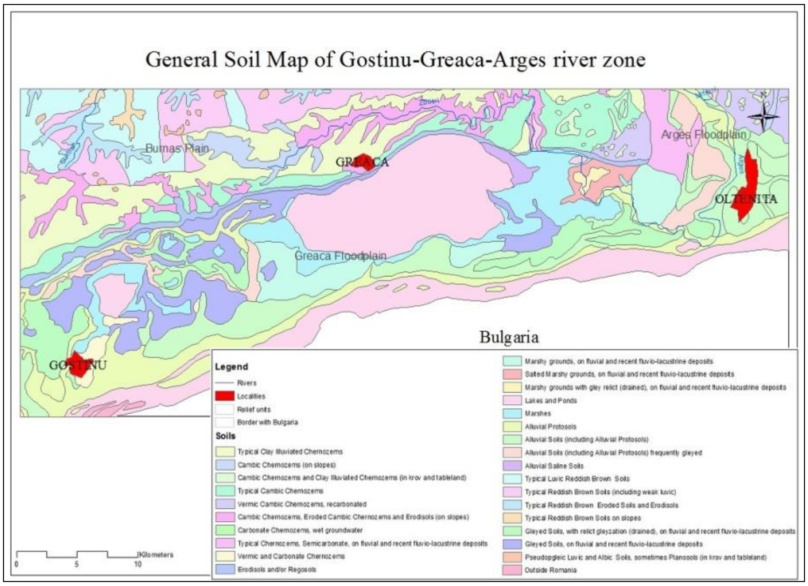

Figure 6. Soil Map of the study area

4. Conclusions

The Gostinu-Greaca-Arges area belongs to the Danube Meadow, with morphometric characteristics that change progressively from the low southern part (minimum altitude being 6 m) to the highest northwest one (maximum altitude being 103 m). An important river which crosses this area in the eastern part and flows into the Danube is the Arges River. Besides this river, other less important rivers belong to the local network. The average altitude of this zone is 54.5 m, specifies to meadow unit.

Analyzing the slope and aspect map, it can be noticed that small values of 1% slopes, specifies to quasi-horizontal surfaces, predominate and the exposition is quite uniform on the studied area. Regarding the land use in the studied area, at present it can be noticed that non-irrigated arable land represents a large surface that require irrigation engineering. It is necessary to eliminate it or include it in other classes, such as annual crops associated with permanent crops or complex cultivation patterns. However, the favorable conditions of Danube Meadow allow the cultivation of various crops: cereals, industrial crops, vegetables and grains. The cereals have the largest share, occupying 60% of arable land. Regarding the types of soils, the calcium, calcium-calcar and chernozems soils, observed in soil map, have an increased risk for drought-aridity-desertification phenomenon. These types of soils are developed on loess deposits, with a medium texture, where the agriculture is practiced, but they require additional supply of water. However, the high fertility of different types of chernozem and alluvial soils that cover over 90% of the surface, explains their wide use in agriculture, as well as the predominant cereals character of agriculture.

According to Ioan Vișinescu and Marcel Bularda (2008) in “Hard changes of Danube Hydrological regime and its impact on agriculture in dammed territories”, the irregular orography, with low cumulative areas, flood patches and lake bottoms on 25-30% of the meadow surface, the frequency of alluvial soils with fine texture covering more than 60-70% of the surface, phreatic level at 3-4 m depths, influenced by hydrological regime of the river, are conditions that may cause the manifestation of secondary processes of soil degradation (swamp, salinization, compaction, dismantling), for the reason that it was not applied the appropriate agriculture, irrigation and drainage. In these areas, preventing the spreading of degradation soil processes and soil amelioration can be achieved by applying an appropriate ameliorative agricultural system. Therefore, it is necessary to improve the aridity tendencies and ecological area for specific biodiversity restoration of floodplain landform.

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