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HAZARD OF HEAVY METAL POLLUTION OF SOIL BY FLOODING FROM DANUBE IN THE ARCHARO-ORSOYSKA LOWLAND (NORTHWESTERN BULGARIA)

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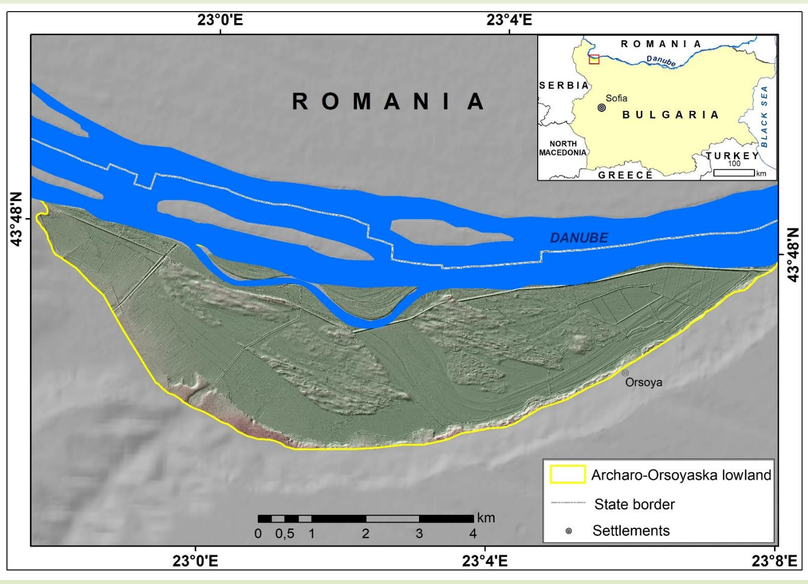
Introduction

Many regions in the world are exposed to natural (geological, meteorological, oceanographic, hydrological, biological) and technological hazards (explosion, release of toxic materials, industrial pollution, structural collapse, transportation, construction or manufacturing accident, toxic wastes, dam failures, fires and oil spills). River floodplains are particularly vulnerable to floods and pollution with hazardous substances originating from the upper parts of the watershed. Danube River has received contaminant loads from numerous sources in its drainage basin for a long period dating back to the industrial revolution in Europe in the 19th century. Ore extraction and processing, as well as industrial and municipal activities, are considered to be the main sources of trace metal and metalloid (TMM) pollution of the Danube river system. At a larger basin scale, deposition of river sediment via inundation seems to be the main path for heavy metals to enter and accumulate in the floodplain of the Danube where may reach toxic levels for the living organisms. Once contaminated, floodplains act as diffuse sources of trace metal pollution delivering additional contaminant load to the river system downstream. Contaminant transport from mining-affected sub-basins to the Danube can be intensified during torrential rainfalls and flood waves due to increased erosion of mine wastes at the mining sites and activated river bank erosion of contaminated floodplains.

Study area

The study area is located in the NW Bulgaria between 22˚257’40.309’’ - 23˚7’49.695’’E and 43˚48’9,836’’- 43˚47’55.024’’N, and envelops an area of 31.97 km^2 .



Methods

To generate a hazard map of heavy metal pollution of soil in the Archaro-Orsoyaska Lowland by flooding from the Danube, a newly developed index method named MeTo (Stoyanova and Kotsev, 2020) has been applied. The acronym of the index is created from the first letters of the included parameters. These are a degree of heavy metal pollution of river sediment (Me) and topography (To). Each parameter is characterized by the following elements: weight (W), ranges, and ratings (R). The relative importance of the three variables is evaluated by comparison between one-another. The highest weight is given to the indicator “degree of heavy metal pollution of river sediment’ followed by the ‘topography’ and ‘distance to the river”. Their weight coefficients are 2 and 1, respectively. The scale of ranges of the parameters characterizes the variety of environmental settings throughout the wetland for the accumulation of heavy metals in soil. A rating (R) from 1 to 4 is assigned to each of the ranges of the individual variables.

Table 1. Rating and weighting values for the parameters of the MeTo index (Stoyanova and Kotsev, 2020)

Parameters	Range	Rating R	Weight W	Total Score
Me - degree of heavy metal pollution of river sediment	0	1	2	2
	0-1	2		4
	1-3	3		6
	>3	4		8
To - topography	high floodplain, sandy ridges	1	1	1
	low floodplain	2		2
	old river channels	3		3
	marshes	4		4

The MeTo index is calculated as the sum of the products of ratings (R) and weights (W) assigned to each of the parameters: $MeTo=Me_W*Me_R+To_W*To_R$. The minimum value of the MeTo index is 3 and the maximum is 12. The whole range is divided into six classes: 3 (negligible hazard), 4-5 (very low hazard), 6-7 (low hazard), 8-9 (moderate hazard), 10-11 (high hazard), and 12 (very high).

Results

Degree of heavy metal pollution of river sediment (Me)

To elaborate on the raster file of the river sediment contamination, we used data on the concentration of As, Cu, Zn, Pb, Cr, and Ni in one representative sample of Danube overbank sediment deposited in the Archaro-Orsoyaska Lowland. The index Cd is calculated to be 2.36 for the Danube overbank sediment in the lowland. This value falls in the range 1-3 of the index and is rated to 3. The limited number of sites with information on the trace elements in overbank sediment in the lowland did not allow us to do interpolation, and the score of 3 is set for the entire study area. The raster file for the degree of heavy metal pollution of river sediment (Me) is created with the tool Spatial Analyst Tools - Conversion Tools - To Raster - Polygon to Raster.

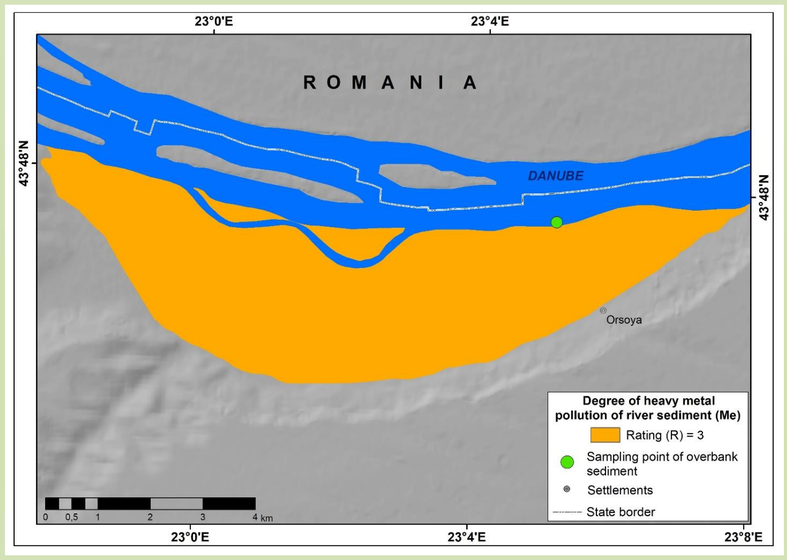
Topography (To)

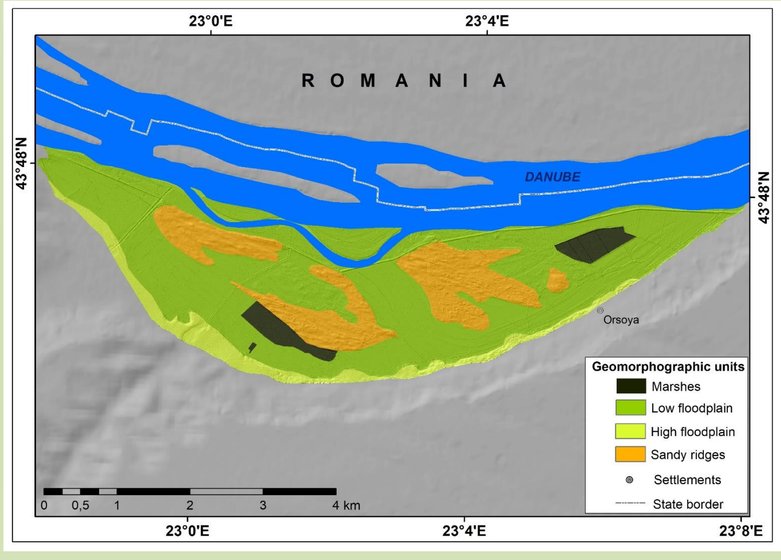
To delineate the limits of the lowland and the geomorphographic landforms, we extracted the slope, aspect, curvature contour, and hillshade from the DTM using the Spatial Analyst Tools - Surface in ArcGIS. The categories of the geomorphographic units are defined according to the classification of Mishev (1959). After classifying and analysing these indicators and comparing them with topographic maps, the following geomorphographic units are defined: marshes, low floodplain, high floodplain, and sandy ridges.

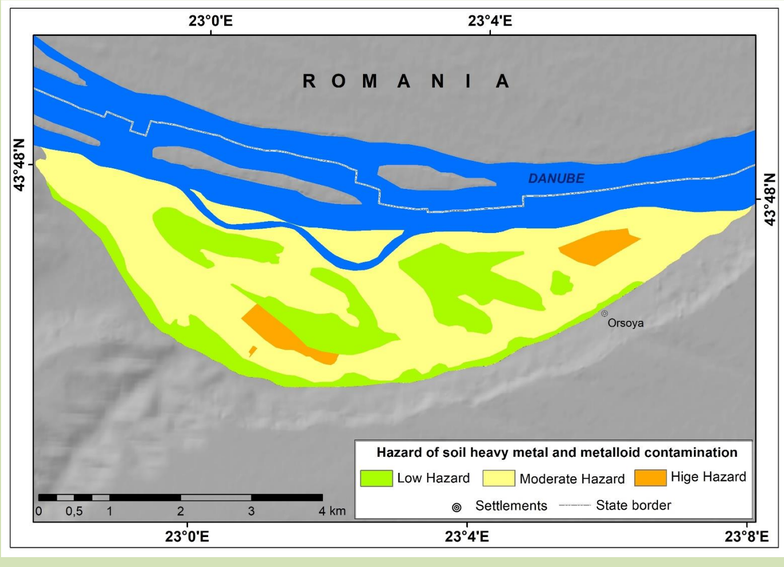
Map of the hazard

The hazard map is created with the Spatial Analyst Tools - Map Algebra - Raster Calculator of ArcMap.

The calculated values of the MeTo index for the Archaro-Orsoyaska Lowland are within the range 7-10 and fall into three classes of a hazard: low hazard (26.27% of total area), moderate hazard (69.90% of total area), and high hazard (3,97% of total area).







Conclusion

The elaborated map shows levels of hazard which are closely associated with the morphology of the lowland. The marshes are highly threatened by metal contamination if flooded, while the hazard of metal contamination of the sandy ridges and high floodplain is determined to be low. The Danube floods represent a moderate threat to the predominant part of the lowland in which the low floodplain is developed. The evaluation elaborated with MeTo can be incorporated as a step in the risk assessment of soil pollution with heavy metals and metalloids in the Danube lowlands. The produced map of the hazard will be provided to local authorities to optimize land use and reduce the health risk to the local population following a flood.

Acknowledgements

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