WATER-RELATED NATURAL HAZARD ASSESSMENT: A GIS-BASED METHODOLOGY FOR THE RHODOPE MOUNTAIN RANGE IN BULGARIA BULGARIA

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Introduction

Water-related natural hazards, so called hydro-meteorological hazards, are a subcategory of natural hazards originating from atmospheric, hydrological or oceanographic processes, which cause severe socio-economic disruptions and damages [1]. Water-related disasters (floods, storms, landslides, and droughts) occurred globally in the past 20 years account for 73.9% of all natural disasters, while nearly 60% of them are caused by floods and drought [2]. In general, mountainous areas are more sensitive to various natural hazards and threats will be more pronounced in them. The Rhodope Mountain Range represent a significant part of the Bulgarian's mountain ecosystems, which play a key role in the national water supply system. On the other hand, the region is vulnerable to water-related natural disasters due to its structural instability, geographical location and topography.

This work is aimed at assessing the hazard component of the risk in The Rhodope Mountain Range (Fig. 1), based on historical data about past events. The main objective is to analyze their temporal and spatial behavior and to identify areas potentially vulnerable to occurrence of water disaster events, in order to facilitate future research and decision-making for water management.

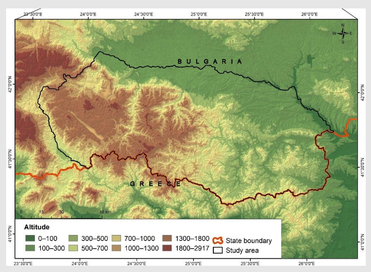

Fig.1. Elevation map of the Rhodope Mountain Range, Bulgaria

Methods

This study is based on long-term hazard inventory data in the Rhodope Mountain Range, provided by official institutions, regarding past hazardous events such as floods, landslides and flow-discharge. A spatial database was created to assess water-related hazards in the Rhodope Mountain Range which also include digital elevation model (DEM) and the shapefiles of streams, gauging stations, roads and settlements, derived from 1:50,000 scaled topographic maps. Flood inventory database comprises information on 622 floods occurred in 207 locations in the investigated area over 10 years of observation, between 2010 and 2020, as well as on their frequency and impact on society, infrastructure, human health, the economy and the environment. Flood frequency was applied in this study to calculate the probability (in percentages) of a future disaster occurrence. Geostatistical kriging and IDW interpolations were then enforced in order to identify flood hazard areas. For the landslide hazard assessment this study adopts the meaning of "landslide hazard" as a synonym of "landslide susceptibility", i.e. probability of landslide occurrence in a given area for a certain time interval. Analytic Hierarchy Process (AHP) was applied to identify landslide hazard areas, which is based on Multi-criteria Decision Analysis (MCDA) and calculating the weights of the landslide causal factors. Low-flow index Q90 (daily flows exceeding 90% of the time), calculated in a previous study [3], was used for defining drought hazard areas. Regarding soil erosion assessment, this paper used Global Soil Erosion Map, provided by the ESDAC of the JRC of the European Commission [4], which had been re-scaled to a regional level. The measurement unit of the map is t/ha/yr.

Results

Flood hazard assessment

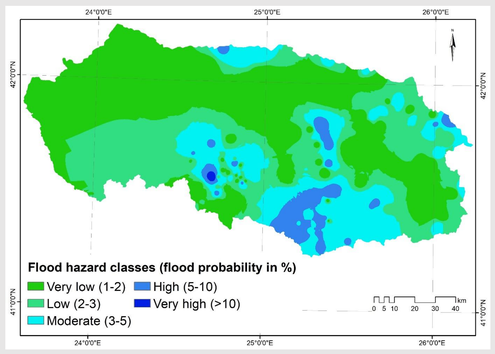

Fig.2. Flood hazard map of the Rhodope Mountain Range, Bulgaria

The flood assessment shows that during the last 10 years a significant part of the Rhodope Mountain region (approximately 20% of the territory) is exposed to a high and very high risk of adverse events in the future, mainly in the eastern and southeastern parts of the region (Fig. 2). In terms of public significance and human health, 3% of events are of medium (2.4%) and high (0.6%) impact. While, in terms of infrastructure and real estate, high and medium impact events exceed 30%. The economic impact of floods in the region, assessed with a medium and high degree of risk, is about 8% of the events. Floods with adverse environmental consequences of medium and high risk are between 7 and 8 percent. The total economic value of the damage amounts to about BGN 2 million.

Landslide hazard assessment

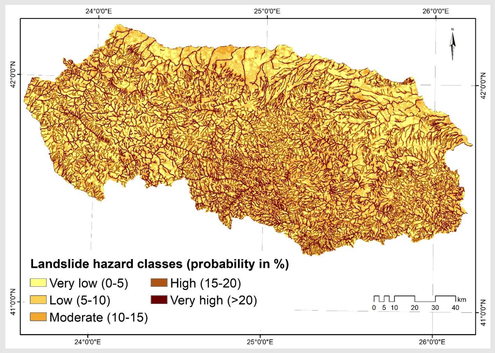

Fig.3. Landslide hazard map of the Rhodope Mountain Range, Bulgaria

Seven factors with the strongest influence on landslide occurrence were selected for landslide susceptibility assessment of the Rhodope Mountain Range. These are average slope gradient, land cover, distance from rivers, distance from roads and two indexes extracted from DEM, which characterize the spatial differentiation of hydrological conditions and the distribution of soil moisture: Topographic Wetness Index (TWI) and Stream Power Index (SPI). Then, they are weighted according to AHP model developed in a previous study [5], so that to develop landslide susceptibility map for the Rhodope Mountain region. Based on this map, the landslide probability in percentages was calculated, which was subsequently used to assess the landslide hazard. The area was divided into 5 hazard zones (Fig. 3). The results show that the areas with high and very high landslide hazard classes are located close (up to 200 km) to riverbeds and roads.

Drought hazard assessment

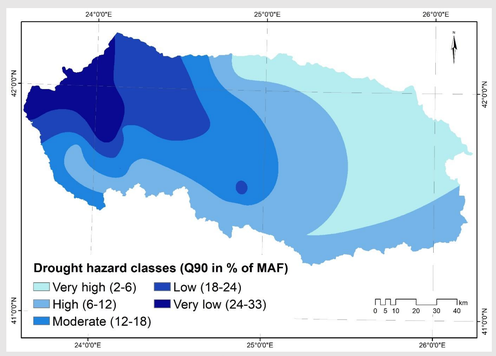

Fig.4. Drought hazard map of the Rhodope Mountain Range, Bulgaria

Since the rivers are now facing increasing pressure to provide water as a result of rapidly growing global human population and global climate change, the assessment of low flow has become an essential for achieving sustainable management of natural resources, especially in drought-prone areas. Considering that water availability is critical for the natural ecosystems and control numerous functions and processes, as well as the ecological balance in the aquatic, riparian and floodplain communities, the Q90 low flow index was selected to assess drought hazard in the Rhodope Mountain Range. The Q90 index was calculated as a percentage of mean annual flow (MAF) and then divided into 5 drought hazard zones, as Q90 values are indicative of habitat quality in these zones (Fig. 4). The results show that the entire south-eastern half of the Rhodope region is subject to water shortages and is characterized by a high and very drought hazard classes.

Water erosion hazard assessment

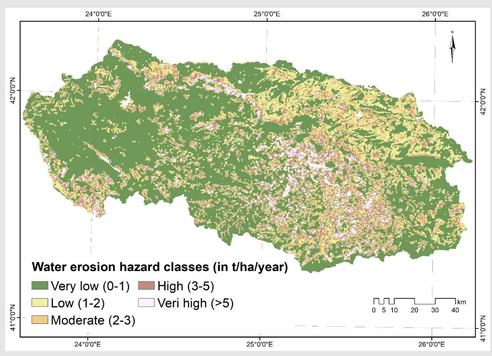

Fig.5. Water erosion hazard map of the Rhodope Mountain Range, Bulgaria

Soil erosion by water is one of the most significant forms of land degradation and leads to desertification, especially in arid areas [6]. Agriculture is the sector most affected by water erosion and leads to loss of cultivable, fertile land and soil structure degradation. Nonetheless the soil erosion can also result in destruction of infrastructures, pollution of surface water, flood risk, etc. In this study, the assessment of soil erosion reveals that large areas of the eastern and southeastern parts of the Rhodope Mountain Range are also affected by soil erosion (Fig. 5). The soil erosion map was divided into 5 water erosion hazard categories. Owing to the large forest areas, in the western part of the region water erosion shows a stable trend, below 1 t/ha/year. While, the majority of the southern and southeastern parts are characterized by a medium, high and very high water erosion hazard categories (over 3 t/ha/year).

Conclusion

The study assessed the water-related hazardous probability in the Rhodope Mountain Range of the territory of Bulgaria based on long-term hazard inventory data for historical events, regarding floods, landslides, drought hazard and soil erosion by water. That work is an attempt to analyze their temporal and spatial behavior and to identify areas potentially vulnerable to occurrence of water-related disaster events. Four hazardous maps were developed using GIS and remote sensing data and the territory was divided into different hazard zones, so that to facilitate future detailed research and analysis. The results find that the Rhodope Mountain region, in particular, its eastern and southeastern parts are exposed to risk from various water-related disaster events in the future. To reduce disaster losses, more efforts must be made to manage disaster risk in the future, given climate change and an increase in vulnerable populations. All these disaster management measures have an important spatial component. In this line, the use of earth observation products and geographic information systems (GIS) has become an important approach in disaster-risk management and hazard and risk assessments.

References:

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