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EVALUATION OF LAND COVER, LAND USE AND WATER QUALITY IN THE REGIONS WITH VARIOUS ANTHROPOGENIC ACTIVITY – A CASY STUDY OF OSAM RIVER BASIN, BULGARIA

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Abstract

Nowadays the world´s demand for natural resources is more pressing than ever before. The good quality of the water and it's enough quantity, the provision of energy sources and food is a very important and difficult issue. This challenge could be done by ensuring a better management of the mentioned resources. Strengthening synergies and reducing trade-offs among the sectors is possible by applying a Nexus approach. This article aims to assets the land cover, land use and water quality in the upper and middle catchment of the Osam River (municipalities of Troyan and Lovech) for the period 2012-2019. Land use and land cover is a key factor in relation to water quality characteristics. The emphasis is on acquiring new knowledge through spatio-temporal analysis of the problem. To assess the river water quality this study considers the following parameters: pH, dissolved oxygen (DO), electric conductivity (EC), ammonia ($N\text{-}NH_4$), nitrates ($N\text{-}NO_3$), nitrites ($N\text{-}NO_2$), phosphates ($P\text{-ortho-}PO_4$), biological oxygen demand (BOD_5). To identify the land use/cover in the region was based on GIS, digital topographic and thematic maps, Corine Land Cover data, high-resolution satellite imagery (Google Earth), digital elevation model, statistics and field studies. The obtained results are a good basis for popularizing the Nexus paradigm at different scales (i.e., local, regional, national, European and beyond) including planning and elaboration of the necessary policies for sustainable management of both land use and river waters in terms of their quality.

Keywords*: Land cover, Land use, Water quality, GIS, the Osam River, Bulgaria.*

Introduction

Today, increasingly large amounts of water are used for various purposes, for example in agriculture, industrial production in the household and for the production of electricity. At the same time in many regions, the water resources are heavily polluted. In this connection the land use planning in a given region is very important due to the land cover and land use effect on the quality of the river water. The quality of waters in the river basins significantly reflects the origin, intensity and degree of anthropogenic impact on the environment. It is known that the quality of river water in a catchment area depends on the land use and the type of the land cover. The study of the spatial and temporal distribution of pollutants in rivers is of particular importance for both the population and ecosystems. European water, energy and food policies can be defined as consistent in their design and implementation. However, the coherence of the common policy faces the challenge between the main objectives, the instruments for their achievement and their implementation. Nowadays, researchers and policy makers increasingly recognize the need to apply an integrated (transdisciplinary) approach to resource planning and management.

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Strengthening synergies and reducing trade-offs among the sectors is possible by applying a Nexus approach. To better understand and realize the Nexus paradigm reflecting land-water-energy-food connection, the international network of researchers works closely with policymakers and the business sector. The focus of the Nexus activities is aimed at creating conditions for improving and protecting the state of the environment in the transition to a circular and low-carbon economy in Europe [1]. In this sense the status of land cover, land use and water quality take a very urgent place. Physio-chemical characteristics of nature water have been strictly defined and this should be the reason that will guarantee the rational use of water resources. It has been found that the values of such parameters for water quality as pH, dissolved oxygen, biochemical oxygen demand (BOD_5), nitrates ($N\text{-}NO_3$), nitrites ($N\text{-}NO_2$) and electrical conductivity (EC) vary widely and very often significantly exceed the permissible norms.

The sources of pollution of nature waters including river waters could be defined as point and diffuse. Usually, the point source have a well-defined place of pollution of water body and it is possible to be identified very easy. A “diffuse” or “non-point” group of source of pollutants does not discharge river waters from an identifiable location. Over the last few decades, a number of studies have been conducted to determine the degree of impact of natural and anthropogenic factors, which affect water quality. According to some of these studies, water quality is closely related to the type of land use [2, 3, 4, 5, 6]. Taking into account the current level of river water pollution, as well as the essence and importance of sustainable water resources management, interactive monitoring of rivers is becoming increasingly important. Sustainable river water management includes review or revision of the current state, protection from pollution and their efficient use. In this regard mapping the water quality will improve monitoring and will contribute to the development and implementation of standards and regulations to achieve better pollution management and control. Geographic Information Systems (GIS), which provide effective tools for land use/cover mapping, also make an important contribution to environmental monitoring [7, 8, 9, 10, 11].

The object of this study is the type of land use and quality of surface waters in the upper and middle catchment of the Osam River in the municipalities of Troyan and Lovech. Fig. 1. presents the study area, which was characterized by a variety of natural conditions that define different types of land cover and land use. This determines the development of various economic activities (industrial, agricultural and communal), which generate different groups of pollutants that vary in their origin and composition.

The main aim of this article is to define the land cover, land use and water quality in the upper and middle catchment of the Osam River in the municipalities of Troyan and Lovech for the period 2012-2019. The emphasis is on acquiring new knowledge through spatio-temporal analysis of the problem. The results of this study will improve the knowledge of the impact of land cover and land use on river water quality and this could be used to manage the pollution in river waters. The analysis and assessment made in this study also are a good basis for better knowledge of the Nexus approach and for effective management including control of the land cover, land use and the quality of the river water in the studied region. In this connection, it is necessary in Bulgaria good practices for sustainable development of the environment to be applied.

Materials and Methodology

Study area

The Osam River flows through the Middle Stara Planina and the Middle Danube Plain. The coordinates of the catchment area are 42° 35 '00 "and 43°13' 00" N and 24° 30 '00 "and 25° 20' 00" E and the area of the river basin is 2824 km^2. The length of the river is 314 km and it flows into the Danube, near the village of Cherkovitsa. The conducive combination of different relief, climate and soils in the Osam River basin is a precondition for the development of various

economic activities that are potential sources of pollutants in the river waters. From this point of view, the subject of research in this article is the upper and middle catchment of the Osam River, which are in the municipalities of Troyan and Lovech and is shown on Fig. 1. The two municipalities are characterized by different hydrological, climatic and soil conditions and by different types of land use and land cover respectively, which define a specific impact on river water quality.

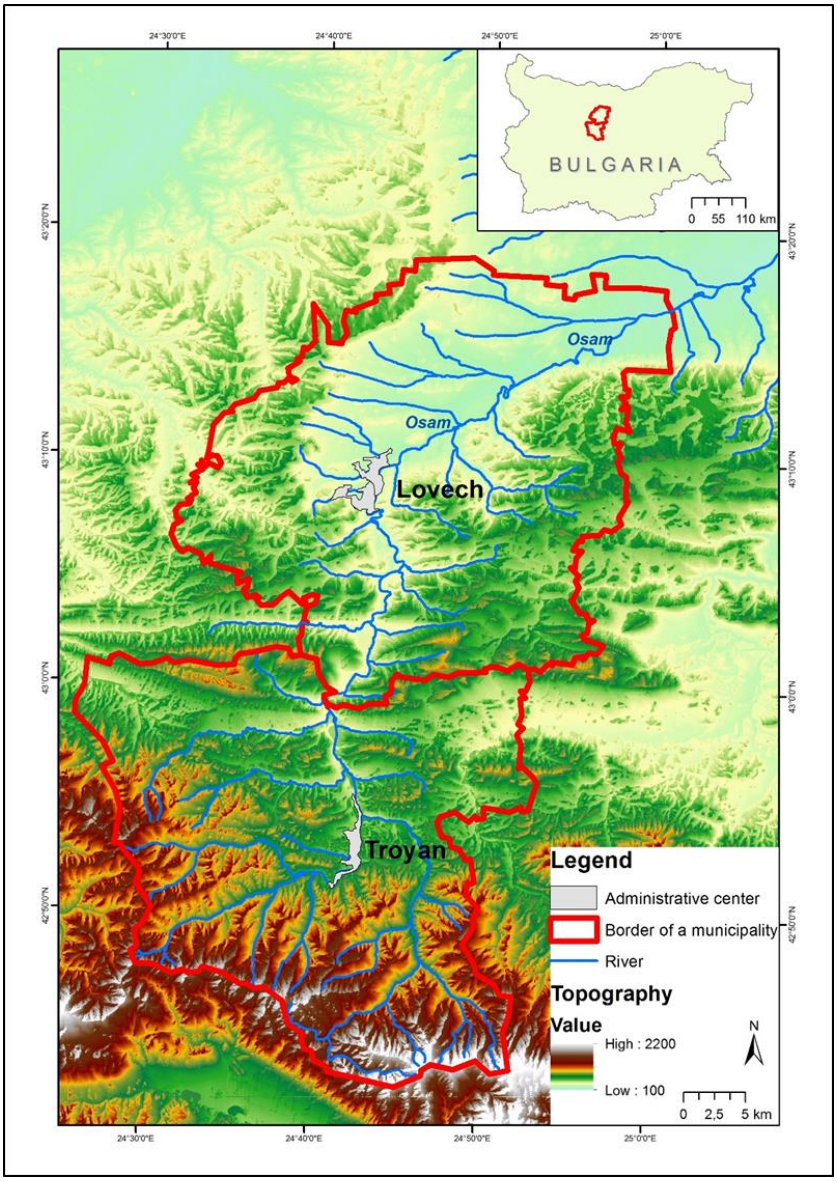

Fig. 1. Map of the study area.

Regulations

After the joining of Bulgaria with the European Union (EU) in 2007 Bulgarian water legislation on the environment have been harmonized with European standards. With this

connection in 2000, a new Water Act was adopted based on the General European Water Directive (60/2000) [12], which requires the achievement of "good" ecological and chemical status for all European surface waters, including rivers. With relation the anthropogenic effects, natural state and future uses of the water the analysis and evaluation of the quality of the river water is of fundamental importance. This study was based on Ordinance N-4 on surface water characterization of 2012 [13].

Samples

Due to the specifics of sampling and the completeness of the initial data officially published by the Executive Environment Agency, Bulgaria for a period of 8 years the study analyzes the values of pH, dissolved oxygen, electrical conductivity, ammonium nitrogen (N-NH_4), nitrate nitrogen (N-NO3), nitrite nitrogen (N-NO_2), orthophosphates (P-ortho-PO_4) and biochemical oxygen demand (BOD_5). The assessment of the hydro chemical status of the upper and middle course of the Osam River was defined according to Water Framework Directive 2000/60/ EC and its requirements for achieving "good" physicochemical status, regulated in Bulgarian legislation through Ordinance № H-4/2012 on surface water characterization and in line with Table 1.

Table 1. The tested parameters and their reference values (Regulation N-4/2012 for surface water characterization).

Status „Fair“	DO mg/l	pH	EC µS/cm	N-NH_4 mg/l	N-NO_3 mg/l	N-NO_2 mg/l	P-ortho-PO_4 mg/l	BOD_5
Mountain types of rivers	8.0÷6.0	6.5÷8.5	750	0.04÷0.4	0.2÷0.5	0.01÷0.025	0.01÷0.02	1÷2.5
Semimountain types of rivers	8.0÷6.0	6.5÷8.5	750	0.04÷0.4	0.5÷1.5	0.01÷0.03	0.02÷0.04	1.2÷3

Methods for determination of Land use and Land cover

For assessment of land use and land cover in the study area, satellite and orthophoto images interpreted in GIS environment (ArcGIS 10.3) have been used to verify CORINE Land Cover (CLC) data for 2018 [14] according to the approved methodology and nomenclature [15]. The developed maps are on a scale of 1:50 000 at the regional level - for the catchment area, and on a scale of 1:10 000 at the local level for the municipalities. In addition, georeferenced topographic maps, high-resolution satellite images (Google Earth), digital elevation model, thematic maps (including hydrological, soil, administrative, etc.), statistics and field check have been used.

Methods for assessment of the water quality

The application of various complex indices to represent the quality of water have been constructed of a set of physicochemical parameters indicating one or another type of anthropogenic impact on water. In this study the "Water Quality Index" - WQI (Canada, recommended by UNEP) was applied [16]. The WQI is a complex assessment but in the same time the tool provide information for major contamination substances of a water body, the extent, frequency of the pollution and how it is changing in spatial–temporal aspect. In this article for assessment the river water quality only the intermediate results of the applied complex index were taken into account. They are representative of water pollution by certain indicators mentioned above. The contamination of the river waters was presented as a multiplicity or degree of exceeding the registered values of the relevant physicochemical indicators above the permissible norms. The values of the polluting indicators are divided into three groups - exceeding up to 10 times the permissible norms, between 10 and 25 times and over 25 times the regulated values.

After determining the values of individual components, it is possible to calculate an integrated complex assessment, but it is not the subject of the present study.

The results obtained in this study present important scientific information necessary for the optimization of land use and control of water pollution, as well as for the making of relevant policies for management and protection of the waters of the Osam River at the local level.

Results and Discussion

Fig. 2 and Table 2 presents the land use/land cover data for 2018 in the upper and middle catchment of the Osam River. The representative monitoring point for the upper catchment of the Osam River is located north of the town of Troyan. In the municipality of Troyan there are 16 classes of land use/cover, represented by artificial surfaces, agricultural areas, forests and semi-natural areas, and water bodies. Table 2 shows that forests and semi-natural areas occupy the highest relative share of the area of Troyan municipality: 62.2% of the municipality's area (55 591.7 ha), agricultural areas cover 34.1% (30 515.3 ha), and artificial surfaces occupy third place in distribution with a total area of 2978.9 ha (3.3%).

Table 2. Land cover and land use for 2018 in the upper and middle catchment of the Osam River.

Municipality	Land cover									
	Artificial surfaces (CLC 1xx)		Agricultural areas (CLC 2xx)		Forest and seminatural areas (CLC 3xx)		Wetlands (CLC 4xx)		Water bodies (CLC 5xx)	
	ha*	%**	ha	%*	ha	%*	ha	%*	ha	%*
Lovech	5152.0	5.4	55 945.7	59.1	33 066.6	35.0	175.9	0.19	274.1	0.29
Troyan	2978.9	3.3	30 515.3	34.1	55 591.7	62.2	-	-	365.2	0.4

The monitoring point in the middle catchment of the Osam River is located north of the town of Lovech. In the municipality of Lovech 19 classes of land use/cover have been identified, represented by artificial surfaces, agricultural areas, forests and semi-natural areas, wetlands and water bodies. Table 2 presents those agricultural areas occupy 55 945.7 ha (59.1% of the area of the municipality) and take the first place in the area. Forests and semi-natural areas rank second with a total area of 33 066.6 ha (35%), and artificial surfaces occupy third place on an area of 5152 ha (5.4%).

Forests and semi-natural areas occupy the largest teritories in the upper part of the catchment (in the municipality of Troyan), but there is a deterioration in the quality of the waters of the Osam River north of Troyan, which is determined mostly by high values of the indicators of orthophosphates ($P\text{-}PO_4$) and BOD_5, which are between 10 and 25 times and over 25 times above the norms. The main sources of pollution are wastewater from settlements and functioning hotel complexes and holiday homes, although most of them have local treatment facilities, which, however, very often do not function properly or work at incomplete capacity. The analysis shows that the water quality in the municipality of Troyan is significantly affected by agricultural areas. The values of the indicators ammonium ($N\text{-}NH_4$), nitrate ($N\text{-}NO_3$) and nitrite nitrogen ($N\text{-}NO_3$) and orthophosphates ($P\text{-ortho-}PO_4$) throughout the period exceed the regulated values significantly up to 10 times. Taking into account of the spatio-temporal changes in the essence of the pollutants, it could be concluded that the main pollutant in the upper part of the valley is the urban sewage of Troyan. The well-developed industry in the city (woodworking, food industry and meat processing) is another possible source of anthropogenic pollution. Despite the fact that Troyan has one of the most efficient urban wastewater treatment plants, this section of the river, judging by its current state, can be defined as a "hot spot" in terms of surface water quality.

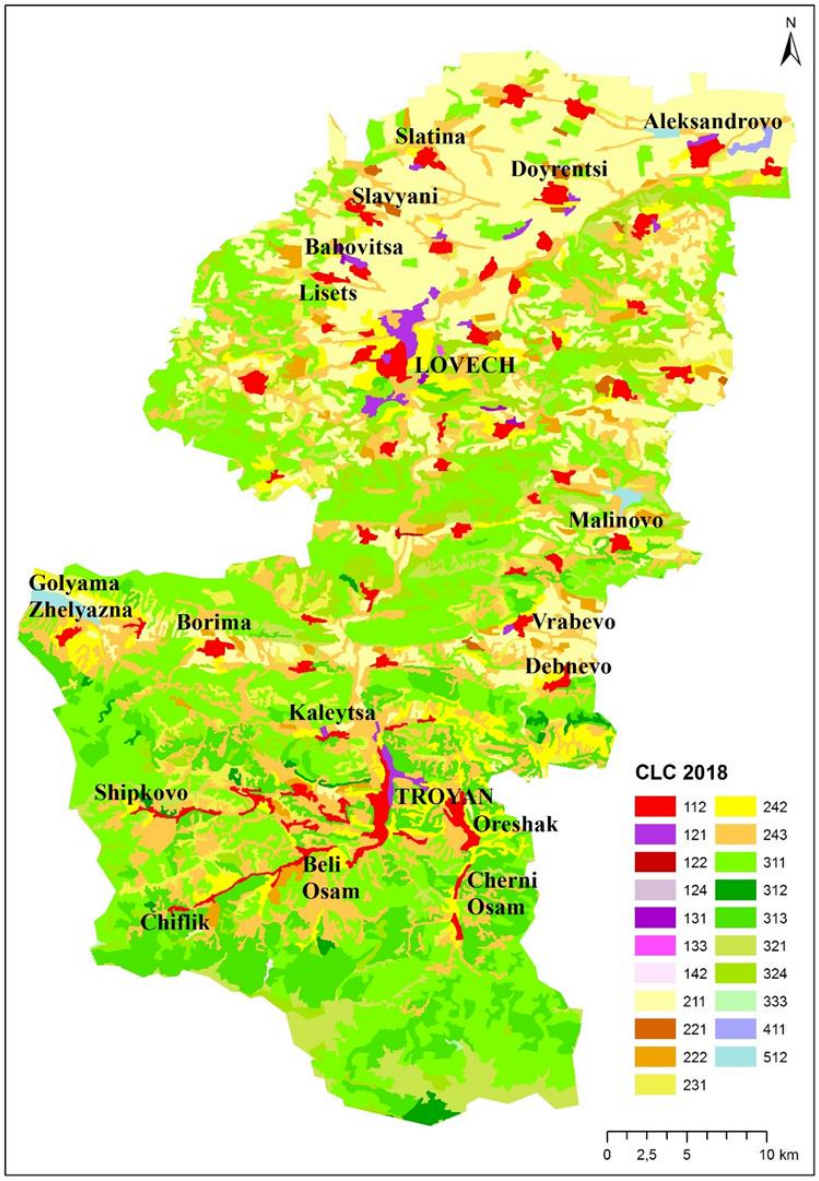

Fig. 2. Land use/land cover map of the upper and middle catchment of the Osam River based on verified CORINE Land Cover (CLC) for 2018.

In connection with the type of land use and the anthropogenic activity in the middle catchment of the Osam River (the monitoring point north of Lovech), throughout the study period deteriorated water quality was found for all studied indicators - ammonium ($N\text{-}NH_4$), nitrate $N\text{-}NO_3$) and nitrite nitrogen ($N\text{-}NO_2$), orthophosphates ($P\text{-ortho-}PO_4$) and BOD_5. The registered values of the indicators exceed the norms for "good" water status most often up to 10 times, and deviations from the normative criteria between 10 and 25 times are not uncommon. The values, which most often exceed the norms between 10 and 25 times, are for the orthophosphates ($P\text{-}PO_4$) and BOD_5 indicators. The high concentration of nitrates ($N\text{-}NO_3$) and orthophosphates (P-

PO_4) in the waters of the Osam River could be explained by their higher content in agricultural lands, which occupy the largest area in the municipality due to the use of mineral fertilizers. Arable land is a significant source of pollution with nitrates and phosphates, mainly due to improper transportation, disposal and dosing. These results have been analytically confirmed in some other studies in which the authors found that river sections flowing through agricultural areas are characterized by higher concentrations of nitrates and phosphates than those receiving water from forests and semi-natural areas [17, 18, 19]. The high content of nitrite ions ($N\text{-}NO_2$) is mainly the result of the city sewage system and the livestock complexes operating in the region. In the middle catchment of the Osam River the anthropogenic impact has a complex - communal, industrial and agricultural character. An important diffuse source of pollution is agriculture, and potential point sources of pollution of surface water are the food indusrty factories, metalworking, pulp and paper and wood processing, chemical and textile, leather industry, poultry and pig farms, slaughterhouses and urban sewerage.

Conclusions

The study provides useful information for identifying sources of pollution and the types of land cover, land use and river water quality. The results obtained show that the different types of land use and land cover in the study area have an impact on the changes in the quality of surface waters, as well as in the type of incoming pollutants. This, in turn, is a good basis for planning and developing the necessary policies for sustainable management of both land use and river water in terms of their quality.

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