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Assessment of Flood Regulation Capacity of Different Land Cover Types in Krumovitsa River Basin (Eastern Rhodopes)

Petko N. Bozhkov*, Borislav G. Grigorov, Assen I. Assenov

Sofia University "St. Kliment Ohridski", Faculty of Geology and Geography, Department of Landscape Ecology and Environmental Protection, 1504 Sofia, 15 Tsar Osvoboditel Blvd., BULGARIA

*Corresponding author: pbozhkov@gea.uni-sofia.bg

Abstract. The area of interest is located in the Eastern Rhodopes, where the winter precipitation maximum often causes floods and material damages. The aim of the presented research is to perform an assessment of flood regulation capacity of different land cover types in the basin of Krumovitsa River, one of the main tributaries of Arda River. Therefore, a drainage network and different land cover types are analyzed and discussed. Due to the size of the area of interest (673 km^2) and its variety the entire study is based on analysis of drainage network and available CORINE land cover classes from different years. High resolution imagery and digital elevation model is used for the visual interpretation of the derived maps. The changes in land cover and its spatial pattern in different years are evaluated. The area of each land cover type is calculated both in absolute in relative units (% of the whole study area). An attempt is made to relate the drainage density with different land cover types. Presented results show relevant information for land cover and flood regulation management. Land cover maps could be used in further evaluation of regulating ecosystem services.

Key words: ecosystem services, floods, Eastern Rhodopes, land cover change.

Introduction

Floods are common phenomena that are restricted by climate, landforms, geological settings, vegetation and land use. Different land cover types have various capacity for flood regulation and flow retention as generally areas with dense vegetation canopy prevent the transformation of overland flow into a channelized flow, which is related to inundations and floods. The area of interest is located in the Eastern Rhodopes, where the winter precipitation is often intensive and torrential, which leads to the rapid melting of snow cover and increase of water levels in rivers. According to Panayotov (1981), the average percentage distribution of precipitation and runoff by hydrological seasons for the Krumovitsa River near the town of Krumovgrad (fig. 1) is as following: precipitation – winter 40.1%, spring 28.9%, summer-autumn 31.0% and runoff - winter 61.5%, spring 32.7%, summer-autumn - only 5.8%. Therefore, the risk of flooding is mainly in the winter months, whereas in the summer and early autumn the discharge is minimal.

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The aim of the presented paper is to perform an assessment of flood regulation capacity of different land cover types in the basin of Krumovitsa River (fig. 1) one of the main tributaries of Arda River. The area of interest covers about 673 km^2 which includes different land cover types and landscapes with various degree of anthropogenic influence. The length of Krumovitsa River is 58.5 km as of from source area near Makaza Pass between Gyumyurdzhinski Snezhnik and Maglenik Ridges to the confluence in Arda River. The mean annual discharge of the Krumovitsa River is 7.32 m^3/s, while the discharge of Arda River near the village of Vehtino is 16.2 m^3/s (Hristova, 2012).

Material and Methods

Land cover and landscapes change over time as land use pattern shifts in both rural and urbanized areas. Thus, detecting land cover changes in a given period is important for understanding the current pattern of the land cover. Land cover data is actively used in mapping and assessment of ecosystems and their services in the European Union (Maes et al., 2014).

The following spatial data sets were used to achieve the purpose of the study: CORINE Land Cover Classes for years 1990, 2000, 2006, 2012 and 2018 available by Copernicus Programme in shapefile format; a digital elevation model (DEM) from Shuttle Radar Topography Mission (SRTM1N42E025V3) with cell size 30 m in GeoTiff format (http://earthexplorer.usgs.gov/) and scanned topographic maps in scale 1:50 000. All datasets are analyzed with the GIS software product of ESRI ArcMap 10.1 (ESRI, 2012).

Secondly, drainage network is extracted from DEM using several different tools, provided by the selected software. The workflow is presented in different papers (Band, 1986; Morris, Heerdegen, 1988; Tarboton et al., 1991; Gurnell, Montgomery, 2000) and can be summarized as a series of successive actions: Fill → Flow Direction → Flow Accumulation. The output from the Flow Accumulation tool is reclassified (Reclassify tool) and converted into a vector layer (Stream to Feature Tool). The derived layer, representing drainage channels is used to calculate drainage density. A polygon grid with a cell size of 1 km^2 was created (Grid Index Feature tool) to calculate the drainage density per each cell (Identify, Summary Statistics). The acquired data was converted to centroids (Feature to Point) and interpolated using Natural Neighbor method to produce a map of drainage density per square kilometer. An attempt is made to relate the channel density with different land cover types by exacting the values of drainage density within each land cover class (Zonal Statistics). The higher the density in a given land cover, the higher the potential of channelizing overland flow and flooding.

Obtained results were used to assess flood regulation capacity of the different land cover types (up to 2018) based on mean drainage density. Thus, all land cover classes were grouped into three categories – areas with low, moderate, and high flood regulation capacity. Furthermore, this approach allows mapping of flood regulation capacity and estimation of risk areas.

Results and Discussion

The basin of Krumovitsa River consists of 17 CORINE Land Cover Classes at level 3 (Table 1). Their nomenclature is based on unique code identification and individual name of each class. Due to changes in land use and landscape pattern the territorial extent of each class changes over time (Table 1). However, the most common land cover types during the studied period (1990 – 2018) are broad-leaved forest (CLC code 311) followed by transitional woodland-shrub (CLC 324) both covering between 252.12 (in 2006) and 277.57 km^2 (in 1990) of the total basin area. Mixed forests (CLC 313) cover less than 10% of the study area and remain relatively sustainable during the last 30 years

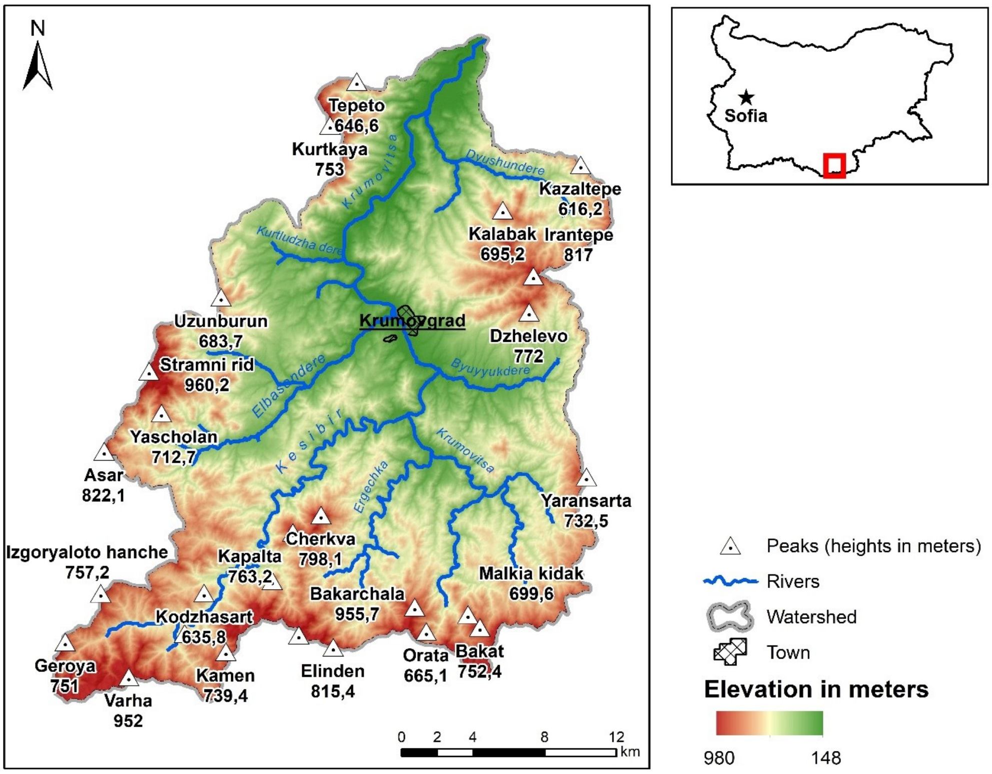

Fig. 1. Map of Krumovitsa River Basin.

Table 1. Territorial distribution (%) of CORINE Land Cover (CLC) classes in Krumovitsa Basin.

CLC/ Year	1990	2000	2006	2012	2018
112 Discontinuous urban fabric	1.38	1.45	1.21	1.21	1.21
121 Industrial or commercial units	-	-	0.0655	0.0653	0.0653
131 Mineral extraction sites	0.24	0.24	0.08	0.08	0.17
211 Non-irrigated arable land	13.29	12.88	11.55	11.53	11.18
221 Vineyards	0.04	0.04	0.04	0.04	-
231 Pastures	7.39	7.75	2.23	2.23	2.34
242 Complex cultivation patterns	4.72	4.74	5.63	5.63	5.69
243 Land principally…	14.61	14.75	18.29	18.26	18.47
311 Broad-leaved forest	20.82	20.37	20.44	20.56	20.59
312 Coniferous forest	6.9	6.99	7.01	7	6.83
313 Mixed forest	9	9.63	9.69	9.67	9.38
321 Natural grasslands	0.78	0.82	5.82	5.81	5.83
323 Sclerophyllous vegetation	-	-	-	0.0003	0.0019
324 Transitional woodland-shrub	20.4	19.88	17.07	17.04	17.37
331 Beaches. dunes. sands	0.05	0.06	0.06	0.06	0.07
333 Sparsely vegetated areas	0.31	0.31	0.72	0.72	0.72
511 Water courses	0.08	0.08	0.08	0.08	0.08
Total %	100	100	100	100	100

mainly as a result of their locations in the low populated upstream areas. Forrest canopy plays a significant role in flood management as trees intercept water from precipitation, therefore decreasing the surface flow. Moreover, Non-irrigated arable land (CLC 211) and Land principally occupied by agriculture, with significant areas of natural vegetation (CLC 243) are also predominant landscapes, which controls the overland flow and the development of erosional processes.

During the study period is observer an increase of CLC 234 as the areas with such land cover increments by 3,86 %, although significant differences in territorial distribution occurs between year 2000 and 2006 (table 1). At the same time natural grasslands (CLC 321) also expanding with about 5%, while other types of land cover types remain practically unchanged in terms of absolute or relative area. They are as follows: water courses (CLC 511), vineyards (CLC 221), coniferous forests (CLC 312) and beaches, dunes, sands (CLC 331) (Table 1).

Sclerophyllous vegetation (ClC 323), previously unobserved before 2012, tends to increase its areas in 2018 (Table 1). It covers small patches of land near the south border of the basin, east of Orata peak (Fig.1). This could be explained by climate change or simply by the insignificant size of these patches as the minimum cartographic unit of CORINE is considered to be 25 ha (Kosztra et al., 2019). Thus, this vegetation might be present in the study area even before 2012. Nevertheless, the exact reason of the expansion of sclerophyllous vegetation is out of the scope of the presented paper.

Simultaneously, between year 2000 and 2006 the areas of pastures (CLC 231) decline with 5,52% as well as territory covered with transitional woodland-shrub, which reduce their areas by 2.81%. These changes in landscape could be related with the processes of depopulation in these parts of the country, which lead to rapid changes in land use and associated adjustment of natural landscapes and environmental processes.

Different types of land cover have various flood regulation capacity since they act as a factor for transformation of precipitation and overland flow. The presence of fluvial landforms such as rills, gullies and valleys is the main indication of predominant channelized flow which often is associated with floods. High drainage density indicates high flood risk (Pallard et al., 2009), especially in areas with sparse vegetation cover. The drainage density of Krumovitsa Basin is 2.24 km/km^2, which is an expected value considering the mountainous territory. However, this parameter has great spatial variability on a local level. The drainage density per square kilometer varies between 0.112 and 5.43 km/km^2 as it tends to be higher along Krumovitsa River and its main tributaries (Ergechka, Kesibir, Elbasandere, Byuyyukdere, Dyushundere) and lower than average near the watersheds (Fig. 2). The areas nearby river beds ant terraces are highly prone to flooding during heavy rainfall events.

Each land cover class has a specific values of drainage density per square kilometer, hence a distinctive flood regulation capacity (Table 2). As it can be expected, stream density varies within each type of land cover, represented of different number of areals (table 2). In this regard, the mean drainage density values can be used as a quantitative measurement of flood regulating services of each land cover class. The lowest mean densities are observed in areas with predominant vegetation canopy while the industrial areas and riparian features (CLC 331) have highest drainage densities (Table 2).

Using the mean drainage density within each type of land cover a simple classification of flood regulation capacity is proposed. The areas with high flood regulation capacity encompass all land cover classes with mean drainage density bellow 2 km/km^2. They are as follows: Sclerophyllous vegetation (CLC 323), broad-lived forests (CLC 311) and natural grasslands (CLC 321), covering about 26.28% of the total basin area located in the peripheral regions near the watershed. Land cover pattern can be easily compared with the map of flood regulation capacity (Fig. 3). The majority of the basin is distinguished by moderate flood regulation capacity (Fig. 3) with is prerequisite for a sustainable landscape development. This group is defined by having drainage density values between 2,1 and 3 km/km^2, and it is comprised of 11 CORINE land cover classes. Less than 1% of the area of interest is considered to be of great risk to flooding. Those sites are represented by industrial and commercial units (CLC 121) near the town of Krumovgrad and river terraces, and sandbanks (CLC 331) along Krumovitsa River in its downstream (Fig. 3). Although areas with low regulation capacity are very small in size, they are located in or nearby settlements or arable land, which is predisposed to damage in case of a flood event.

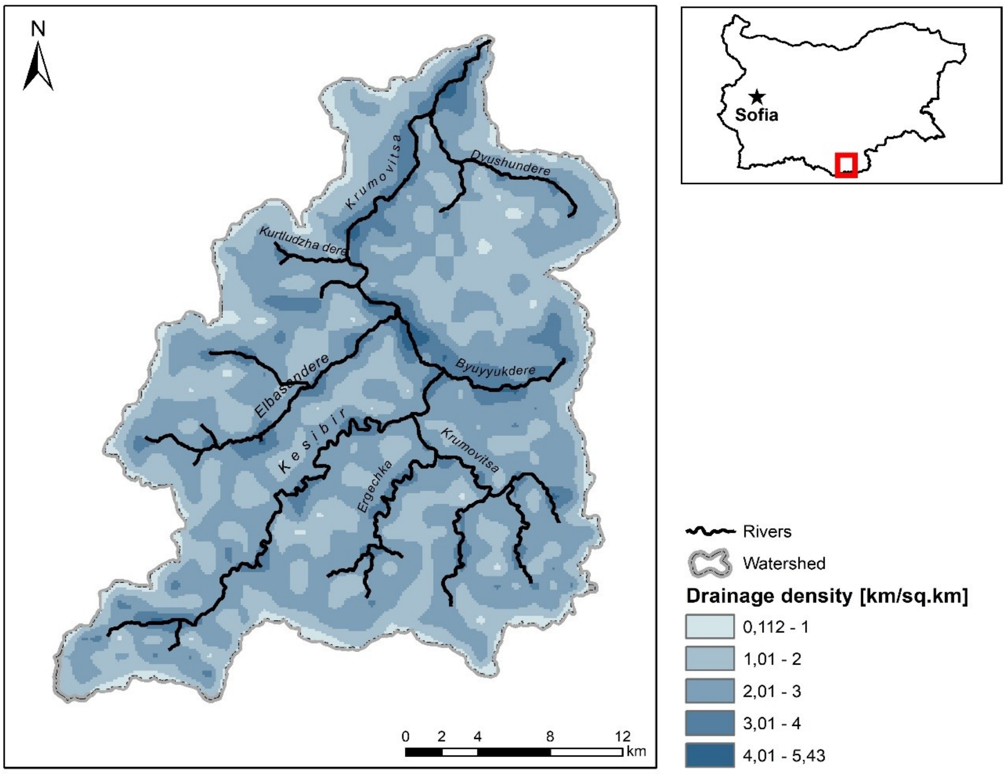

Fig. 2. Drainage density per square kilometer in the Krumovitsa Basin.

Table 2. Drainage network density within different CORINE Land Cover (CLC) classes in Krumovitsa Basin.

CLC code	Level 3 nomenclature	Drainage Network [km/km^2]				
		min	max	range	mean	st. dev.
112	Discontinuous urban fabric	0.380	5.200	4.820	2.415	1.017
121	Industrial or commercial units	3.182	4.360	1.178	3.912	0.246

131	Mineral extraction sites	0.993	2.912	1.920	2.276	0.510
211	Non-irrigated arable land	0.304	5.433	5.129	2.581	0.827
231	Pastures	0.233	3.579	3.346	2.090	0.606
242	Complex cultivation patterns	0.335	4.008	3.673	2.368	0.628
243	Land principally occupied by agriculture, with significant areas of natural vegetation	0.313	4.540	4.228	2.233	0.608
311	Broad-leaved forest	0.112	3.840	3.728	1.897	0.599
312	Coniferous forest	0.339	4.017	3.678	2.243	0.584
313	Mixed forest	0.192	4.303	4.111	2.171	0.592
321	Natural grasslands	0.522	3.988	3.466	1.994	0.523
323	Sclerophyllous vegetation	0.608	0.670	0.062	0.639	0.031
324	Transitional woodland-shrub	0.130	4.350	4.220	2.173	0.646
331	Beaches, dunes, sands	3.079	4.546	1.467	3.889	0.384
333	Sparsely vegetated areas	0.886	3.651	2.765	2.300	0.541
511	Water courses	0.559	3.477	2.918	2.506	0.828

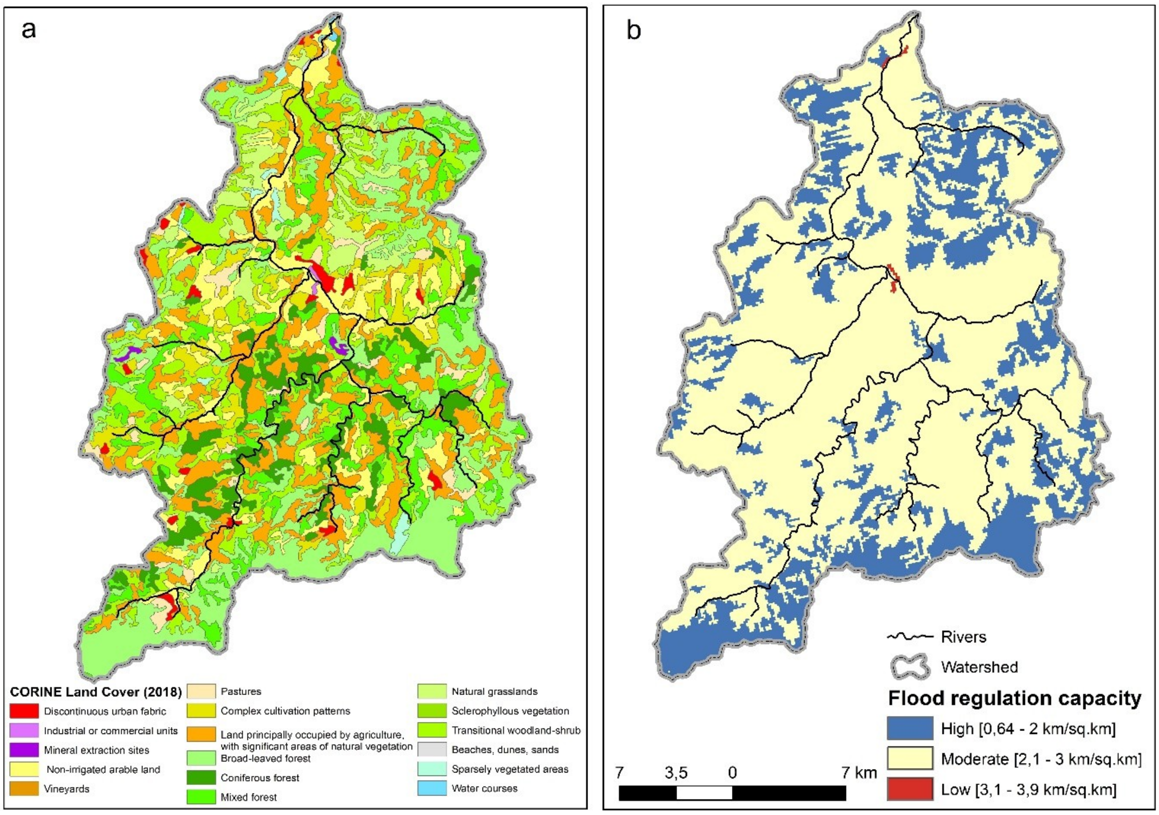

Fig. 3. Land cover pattern in 2018 (a) and flood regulation capacity (b) in the Krumovitsa River Basin.

Conclusions

The land cover in the studied area remains relatively persistent during the last 28 years (1990 - 2018). No significant changes are observed, except the expansion of Sclerophyllous vegetation (CLC code 323) since 2012. The lands principally occupied by agriculture with significant areas of natural vegetation (CLC code 234) increase their area in the study period, which is an important factor for retrieval of primary landscapes and their structure. Simultaneously, the areas of pastures (CLC 231) decreases while natural grasslands (CLC 321) expand their territories with similar rate. Thus, the changes in land use are related with changes in land cover.

The majority of the Krumovitsa Basin (about 37%) is covered with forests (deciduous, coniferous and mixed) which are acting as an erosion and flood limiting factor. The presence of both forest and shrub/grass vegetation reduces the transformation of overland flow into channel flow.

Drainage density is a reliable indicator of landscape susceptibility to flooding. Therefore, the mean drainage density of different land cover types can be used for the assessment of their flood regulation capacity. Using this indicator, the studied river basin is divided into three parts. However, the areas with low flood regulation capacity, e.g. prone to flooding, are urbanized territories and riparian features (floodplains and river terraces). About 73.6% of the Krumovitsa Basin is assessed as an area with moderate flood regulation capacity. Broad-leaved forests and natural grasslands are the most common land cover types with high flood regulation capacity. Therefore, their areas should be preserved for the conservation of their ecosystem functions and services.

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