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ESTIMATION OF SPATIOTEMPORAL CHANGES OF LAND COVER IN LLAPI RIVER CATCHMENT (NORTHEASTERN PART OF KOSOVO)

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ABSTRACT

Aim of the study

In recent decades, Kosovo in general and the Llapi River catchment in particular have experienced landscape transformation, which resulted in Land Use and Land Cover (LULC) changes, mainly in the flat terrains where most of country's population is concentrated. Other landscapes have experienced changes too, but on a smaller scale. The aim of the present study was to identify landscape transformation and driving forces behind it.

Materials and methods

Spatiotemporal changes of Land Use and Land Cover (LULC) were recorded using GIS techniques. Land Cover data from Copernicus Land Monitoring Service (CLMS) with spatial resolution 100 m for three different years: 2000, 2006 and 2018 were analysed. DEM with 10 m spatial resolution was used to estimate slope steepness and catchment altitude. Population data for settlements inside the Llapi River catchment, represented in features, were imported from the Statistical Agency of Kosovo, and those data include population numbers for official censuses between 1948 until 2011, whereas ArcMap 10.8 environment was used for analysis.

Results and conclusions

With GIS technique in analysing Land Use and Land Cover data (LULC) and other open source data, we found that agricultural land have decreased in area, by as much as 9.53%, while the increase of artificial surface was 160.87%. Expressed in absolute values, total size of agricultural areas in 2000 amounted to 37,827 ha, while in 2018, this amounted to 34,334 ha, which is 0.3 ha per capita less than European average. In order to protect agricultural land, zoning and land use plans should be implemented.

Keywords: Llapi River catchment, Land Use / Land Cover, agricultural land, soil resources, Kosovo

INTRODUCTION

Land cover of a region, along with its individual elements, indicate the relationships between humans and nature (Gaitanis et al., 2015), while spatial distribution and pattern index of land cover reveal the impact of human activities. Kosovo, as a small country in the Western Balkans, has been the epicenter of Land Use and Land Cover (LULC) Changes in recent decades, which transformed the flat and gentle terrains into artificial surfaces with the domination of both discontinuous and continuous urban fabric.

Population growth and increased urbanization are changing the environment, with an impact on land-

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scape structures and their functions (Sinha et al., 2016). Thus, human activities are working as a driving force and pressing issue on the landscape (Wolf et al., 2023), affecting environmental sustainability. Transformation of the Earth's terrestrial surface driven by human activities refers to changes in land use and land cover. Some of the activities causing this transformation include urbanization, reducing the expansion of farmland, deforestation, and other changes related to urban heat islands or imbalance of water resources (Xu et al., 2023). The increasing population numbers and rapid urbanization cause alterations in land use and land cover (Lobell and Field, 2007), in water cycles (Schlesinger and Jasechko, 2014), biodiversity loss (Newbold et al., 2015), and soil degradation (Smith et al., 2015). Even though these are global issues, they have local and regional implications and effects.

Initially, human impact on the landscape was minimal, yet after the development of industrialization, the process of urbanization picked up the pace and is now progressing rapidly (Nuissl and Siedentop, 2021). According to some authors, the amount of changes paved the way to Anthropocene (Ellis, 2021). These changes also included Kosovo, which had been relying mostly on agriculture, where the majority of workforce was employed. Industrialization of Kosovo started already in the 1970s, but the most significant changes were introduced over the last decades, and it is those latest changes that impacted more agricultural land by reducing it. Changes in the environment in terms of LULC have become a globally critical issue (Fan et al., 2017), followed by a growing academic attention thereto. The rapid rate of urbanization shows a degradation of the environment, where fragmentation of the landscape is the main observed element (Masný et al., 2023). An estimation shows that 17% of the Earth's land surface has changed at least once from 1960 to 2019 (Winkler et al., 2021), while numerous studies have noted a rapid rate of land cover changes resulting from population growth (Lambin et al., 2003). The last decades are marked by intensive land use (Matson et al., 1997; Lambin et al., 2003) and loss of natural areas (Falcucci et al., 2009). Since the agricultural revolution, land use has been the oldest anthropogenic environmental activity (Cegielska et al., 2018).

In Europe, humans have been changing the landscape for millennia to suit their needs and requirements (Holman et al., 2017), and the same process concerns Kosovo as well. Most transformations impact agricultural land, which after all constitutes the essential soil resource of every country.

During the migration of people, and for the very process of migration, soil quality was a driving force, while it serves as a medium for terrestrial activity (Dror et al., 2021). Soil creation is attributed to natural factors, which determine "soil's capacity to function" (Larson and Pierce, 1991). The observer's interest determines soil function. Viewers see soil, the Earth's outer skin, differently. For a land manager, it is crucial to sustain its quality, while for a conservationist, the importance lies in its protection. A consumer sees food production, while an environmentalist sees the land's capacity to maintain biodiversity, water quality, etc. (Barlow et al., 2012). Scientists observe land use changes differently. A geographer and others dealing with human societies interpret land use as spatiotemporal changes within the ecosystem (Bliege and Nimmo, 2018), whereas an ecologist and conservation scientist observe land use as a disturbance affecting ecosystems in general, especially terrestrial ones.

Agricultural landscapes in Europe have changed dramatically since the 1950s when farming intensified, and as a result, the flows and values of ecosystem services have changed. At the same time, in post-socialist countries in Europe, land transformations have led to the fragmentation of agricultural land (van Zanten et al., 2014). Soil, which is a non-renewable natural resource, sustains life and supports 95% of global food production (Ferreira et al., 2022), whereas changes in land resources have consequences in terms of soil degradation. LULC changes have resulted in the interaction of many factors.

According to physical features, the territory of Kosovo (10,905 km²) is dominated by hilly and mountainous areas. In contrast, in the European Union, more than 35% of the total area is agricultural land (Ustaoglu et al., 2016). While the European Union has 0.52 ha per inhabitant, in Kosovo, agricultural land per capita is 0.25 ha, while the critical threshold for providing enough agricultural products for a country is 0.17 ha per inhabitant. (Institute for Spatial Planning, 2020). Soil provides goods and services that contribute to human well-being. Changes in soils have accelerated soil degradation in Europe, where erosion, declining organic matter, compaction, and salinization are identified as the main factors of that degradation (EEA, 2006).

In some regions of the world, expansion in agricultural land reflects the intensified pressure over the land, causing uncertainties in food production at all levels, while in Kosovo, the agricultural land is reducing due to rapid extension of settlements. Land taken for urban development, infrastructure, and industrial purposes in EEA-39 is 1,000 km² per year (EEA Report, 2017). Land use changes have extensively modified Earth's ecosystems. In Europe, they triggered a widespread loss of agricultural landscapes (Fischer et al., 2012). It should be emphasized that different land use change processes occur in a specific spatial pattern in every region or country (Kuemmerle et al., 2016).

Built-up areas (artificial surfaces) are increasing rapidly. According to Angel et al. (2005), the annual increase of built-up areas in developing countries is 3.6%, which generally results in land consumption. In Europe, the growth of urban land between 2015–2030 is forecast at a 3% level in industrialized areas, while nearly zero in remote rural regions (EEA, 2020). In the Llapi River catchment, the annual built-up area extension rate is 8.93% or 123 hectares per year. Globally, according to the latest studies, land use changes are four times greater than previously estimated (Winkler et al., 2021). As projected, globally, at the end of 2050, the urban population will increase to 70% (Leeson, 2018), which will affect Kosovo too. Based on Kosovo's population urbanization trend, artificial surfaces will increase, where pressure will be placed on agricultural lands.

This study's primary aim is to examine land cover changes within the Llapi River catchment comprehensively. This study explains the complex interactions, and spatial distribution of artificial surfaces concerning soil resources. The inquiry is significant for a nation like Kosovo, which is confronted with the widely recognized phenomenon of growing urbanization, primarily affecting farmland. It is crucial to comprehensively examine these relationships, and formulate strategic land use regulations at the national level to protect and maintain soil resources.

The phenomenon of urbanization, characterized by its rapid pace and effects on agricultural environments, calls for an academic investigation into the dynamic relationship between artificial surfaces and soil resources. Hence, the primary objective is to analyse the intricate dynamics of these interactions, enabling the development of specific land-use strategies that are crucial for the conservation of soil quality on a national scale.

The present research goes beyond a surface-level examination of land cover changes and focuses on the fundamental mechanisms contributing to modifications within the Llapi River catchment area. The analysis uses well-established methodology and theoretical frameworks to elucidate the intricate interdependencies between artificial surfaces and soil resources. Through this endeavour, the research aims to enhance the current reservoir of information and offer unique perspectives that might guide prudent land use planning policies for Kosovo and potentially have positive implications for other regions worldwide facing comparable predicaments.

MATERIALS AND METHODS

Spatiotemporal changes in Land Use and Land Cover (LULC) were traced by using the GIS techniques, which made possible the analysis, interpretation, and development of results. Different datasets were used, including land cover data from Copernicus Land Monitoring Service (CLMS) with a spatial resolution of 100 m. This dataset includes land cover information for three different years (2000, 2006 and 2018), when later spatial and temporal changes were estimated. First land cover data for 24 countries in Europe were published in the year 1990 (Feranec and Kedron, 2017), and in that data, Kosovo was not included. However, data for the year 2012 reveal small changes compared to data for year 2018, when, according to our observation, substantial landscape transformations were already visible in the study area. A Digital Elevation Model with 10 m spatial resolution from Kosovo Cadastral Agency was used to estimate slope steepness and catchment altitude. Population data for settlements inside the Llapi River catchment represented in the point feature were downloaded from the Statistical Agency of Kosovo, and those data include population numbers for official censuses between 1948 and 2011 (Table 1). Firstly, shapefiles containing land cover data were clipped for the catchment. Later data for the respective years were collated and compared, and spatiotemporal changes were found for selected years. A 100 m spatial resolution dataset of land cover data has its limitation in representing large-scale data; nevertheless, the results it produces are highly reliable. All these data were added to the ArcMap 10.8 environment, and their relationship with agricultural land was analysed and interpreted, with results shown below.

GEOGRAPHICAL FEATURES OF THE LLAPI RIVER CATCHMENT

The Llapi River catchment lies in the northeastern part of Kosovo (Figure 1), and is limited to the territory of Kosovo alone (i.e. it lies within state boundaries). Llapi River is a right tributary of the Sitnica River, and the surface waters flow towards the Black Sea. Regarding physical-geographical features, the catchment is located on two plains, namely Llapi Plain and Kosovo Plain, which are surrounded by medium-high altitude mountains. Flat terrains, which represent the bottom of the Llapi Plain, constitute 38% of the catchment areas, while the other 62% are hilly-mountainous areas. Over the last 25 years, environmental transformation has occurred in the region, where hilly-mountainous settlements were mostly abandoned, and the concentration of the population moved towards the plain. The consequence of these developments is the loss of soil resources, even if they are already limited in the context of the overall physical parameters of the catchment. The river catchment lies in the altitudes ranging between 517 and 1,782 m. In geological terms, it consists mainly of hard rocks (flysch, volcanic rocks, greenschists etc.). In contrast, the bottom part of the catchment consists of lake and river sediments, which represent the geological basis of high-quality soils. As the highest plain in the country, located in the northeastern part of its territory, and mainly open to the north, it is also the coldest plain in Kosovo, where the annual average air temperature in the lowest part is between 9.5–10°C, and annual rainfall is 661 mm (Pllana, 2015).

The bottom part of the Llapi River catchment is flat, and with high-quality soil, which constitutes one of the main land resources throughout the country. This particular catchment was selected for the study due to the substantial transformation it has undergone, especially of the artificial surfaces towards high-quality agricultural land. Hilly and mountainous areas have experienced settlement abandonment, and the population migrated towards the flat areas below. In 2011, according to the official country data, the Llapi catchment had 113,236 inhabitants, with an overall population density of 120 inhabitants/km². The percentage of farmland in the catchment is only 25.1%, which completes the description: this is the area characterized by high population density living in agricultural land.

The Llapi River catchment lies in the northeastern part of Kosovo, and it is situated in the hilly and mountainous terrains of the Gollak and Kopaonik Mountains, while the lower part is located in Llapi Plain and Kosova Plain. As these plains have tectonic origin, in the later Neogene period they featured lakes, where loose sediments were deposited in the lacustrine environment (Elezaj and Kodra, 2007; Pruthi, 2011). During its young geological times, the Balkan Peninsula experienced a tectonic uplift, and the plains became dry. Furthermore, today, the main processes in the plains and other terrains are fluvial and slope processes, where mainly alluvial soils are created.

Table 1. Datasets used for land cover changes in the Llapi River catchment (source: Authors' own elaboration)

Data/maps	Resolution/scale	Source
Land Use/Land Cover (LULC) 2000, 2006, 2018	100 m	Copernicus Land Monitoring Service
DEM (altitude, slope)	10 m	Kosovo Cadastral Agency
Topographic maps	1 : 50,000	Kosovo Cadastral Agency
Soil map	1 : 50,000	Kosovo soil database
Soil quality map	1 : 200,000	Hydroeconomy Atlas of Kosovo, 1983
Geology	1 : 100,000	KPMM
Land cover 1990	1 : 25,000	Former Yugoslavia topographic maps
Population statistics	–	Statistical Agency of Kosovo

Fig. 1. Location map of the Llapi River catchment (source: Authors' own elaboration)

In general terms, the Llapi River catchment has been the subject of several studies, which include geological settings (Elezaj and Kodra, 2007; Pruthi, 2011), climate and water resources (Pllana, 2011, 2015), and sustainable use of agricultural land (Ramadani and Bytyqi, 2018), which were addressed by specific studies. Several studies have been conducted at the municipality level, including local studies for the needs of the local population. Settlement type, demographics, and their transformation have been a part of a general study of Kosovo's settlements, including the main physical features, labour structure, and other socio-economic features that describe and distinguish each settlement (Lexicon of settlements of Kosovo, 2020). After the first census in Kosovo in 1948, population increase was recorded in all settlements, but later, after the 1970s, migration process began from hilly and mountainous areas, mostly towards flat terrain of the plains. In 1948, the total population in the 109 settlements of the Llapi River catchment was 56,713, and in the last census (2011), as many as 113,236 were registered in that same area, indicating transformation mostly in agricultural land, where ecological stability began to reduce. Compared to the national-wide figures, the catchment has a lower population density (120 inhabitants/km²), but when analysing the population density only for agricultural land, it has a high density with 479 inhabitants per 1 km² of agricultural land. The main river is Llapi, which has its sources in Kopaonik Mountains and flows toward the Sitnica River, representing its main tributary. Both rivers drain their surface waters towards the Black Sea (Pllana, 2011).

RESULTS AND DISCUSSION

Analysis of topographic parameters in Llapi River catchment

As a founder of soil science, Dokuchaev postulated a number of soil forming factors, where he stated that the soil is always and everywhere a function of parent rock, the climate, the vegetation, the age of the terrain, and the terrain topography (Bockheim et al., 2014). In addition to other factors, climate is critical in creating soils and their features. While climate is a function of the geographic location of a region, altitude plays a vital role among climate features. The Llapi River is located in the middle latitudes and has a continental climate. The studied catchments lie between 517 and 1,782 m above sea level, and land elevation has an insightful impact on agriculture, as altitude is a climatic factor. The discussed catchments can be distinguished in terms of their specific climate features, which indicate different soils and soil zonation, where each type of soil has its own properties, morphology, and features, which determine land quality classes. Agriculture has a positive correlation with low to medium altitudes, where plains and gentle slopes are found, while increasing altitude changes the climate and increases slope steepness, making agriculture nearly impossible.

The average altitude in the catchment is 808 m, while most areas lie 700 m above sea level. The altitude below 700 m represents the bottom of the Llapi Plain and Kosovo Plain, and the Llapi River valley, which connects both plains. Above 700 m sea level, 62% of the territory is primarily hilly-mountainous terrain with steep slopes unsuitable for agriculture (Table 2; Figure 2). Altitude analysis shows that only 38% of the territory is suitable for agricultural purposes; having said that, those areas that are suitable, are also densely populated and experiencing an increase in farmland at the same time. Overall, heterogeneous soil forming factors have indicated different types of soil cover. The geological basis, climate, and vegetation have indicated unfavourable soil conditions in most catchments. The lowest part of the plains consists mainly of fluvisols and vertisols, while brown shallow soils are more familiar with increasing altitude. Climate is a critical factor in the development of soil types (Tuhkanen, 1980). Altitude with its microclimate features affects the microbiology of soil, weathering, and accumulation rate (Matus et al., 2014).

Table 2. Altitude classes in Llapi River catchment (source: Authors' own elaboration, generated form 10 m DEM for Kosovo, produced by Cadastral Agency of Kosovo)

Altitude (m)	Area (km^2)	%
< 700	357.9	38.0%
701–900	339.2	36.1%
901–1200	174.6	18.6%
1201–1500	58.7	6.2%
> 1501	10.2	1.1%
	940.6	100%

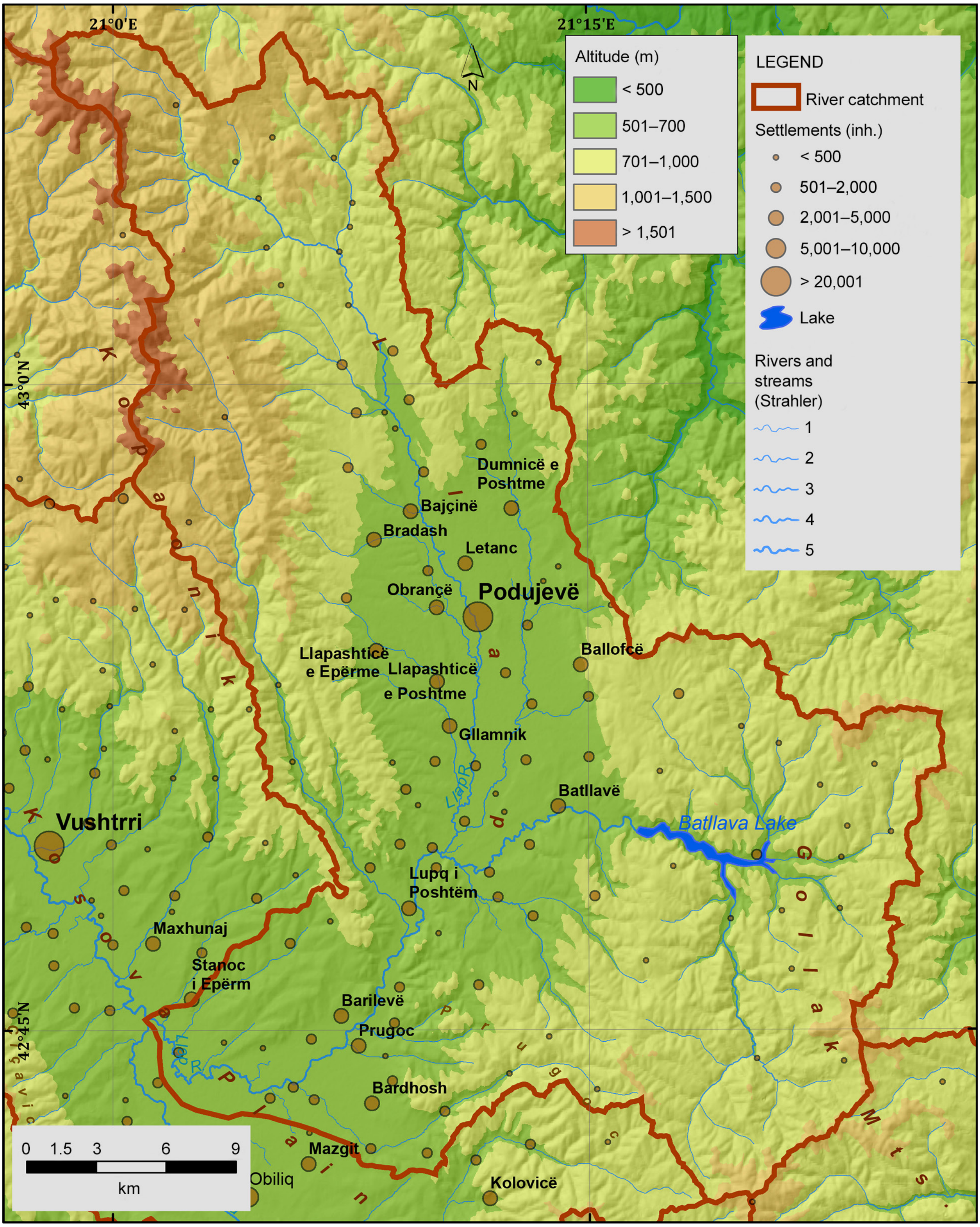

Fig. 2. Altitude classes in the Llapi River catchment (source: Authors' own elaboration)

Located in the northeastern part of the country, with the altitude of the main plain (Llapi Plain) of 600 m, the climate features are of continental climate with an average annual air temperature of 9.5°C, making it both the coldest and the highest plain in Kosovo. Open in the northeastern part, it remains under the influence of cooler continental air masses coming from the inner parts of the Balkan Peninsula. The rainfall in the plain is between 600–700 mm, while the highest part of the catchment receives 1,000 mm (Map of rainfall and air temperature, 1983; Pllana, 2015). Climate as a soil-forming factor informs the general features, but in terms of soil cover, the seasonality of rainfall and temperatures play an important role. As this is continental climate, most of the rainfall happens during summer, and is influenced by the convective movement of air masses. Llapi is the main river system, and with its tributaries, it has modeled the landscape, leading to a more diverse morphography, where high fertile soils are found in the river valley. Both in the past and today, the river has been used for irrigation, while the artificial lake of Batllava (southeast) represents one of the five biggest artificial lakes in Kosovo.

Slope gradient is the main topographic parameter related to the agricultural use of land. The slope's gradient and land use change can influence soil quality and determine sustainable land use and management practices. Conservation practice is crucial for decreasing or increasing the erosion rate in soil erosion estimates. Soil quality is related to slope gradient, whereby increasing slope steepness decreases its quality (Nabiollahi et al., 2018). Different types of slopes are found in the Llapi River catchment, while only 28.7% are slopes under 5 degrees' gradient, meaning flat to gently sloping. Categories of the slopes between < 2° and 2–5° are found mainly at the lowest altitude of the catchment, namely in the Kosovo Plain and in the Llapi Plain. They are related to the bottom of tectonic plains, Pliocene sediments, and fluvial processes, covering 260.7 km². A transition zone between plains and hilly-mountainous areas exists, where slopes with a 5–10° gradient are found. These slopes are created by denudation, whereby fluvial processes intersect with alluvial plains and smooth ridges to make diverse topography, where a number of land use types are distinguished.

According to FAO classification (2006), slope gradients are grouped into six categories. Slope gradient as a leading factor is related to the distribution of potential zones for agricultural production. During its geomorphological evolution, diverse altitudes and the dominance of hilly mountainous areas have created steep slopes unsuitable for agricultural production. Between 5–10° gradients are found in nearly 16% of the catchment's area, while gradients above 10° are categorized as strongly sloping, and these steep slopes constitute 55.3% of the catchments' area (Table 3; Figure 3). As in many countries worldwide, slope gradient and elevation are factors for land cover changes (Birhanu et al., 2019). Nearly the same situation is experienced in the Llapi River catchment.

Based on soil forming factors and geographical features, different soil types are distinguished in the Llapi River catchment, in terms of their physical, chemical,

Table 3. Slope categories in the Llapi River catchment (source: Authors own elaboration, generated form 10 m DEM for Kosovo, produced by Cadastral Agency of Kosovo)

Slope (degree)	Description	Area (km^2)	%
< 2	Flat to very gently sloping	151.3	16.1
2–5	Gently sloping	119.4	12.7
5–10	Sloping	150.1	16.0
10–15	Strongly sloping	138.2	14.7
15–30	Moderately steep	345.3	36.7
> 30	Steep	36.3	3.9
		940.6	100.0

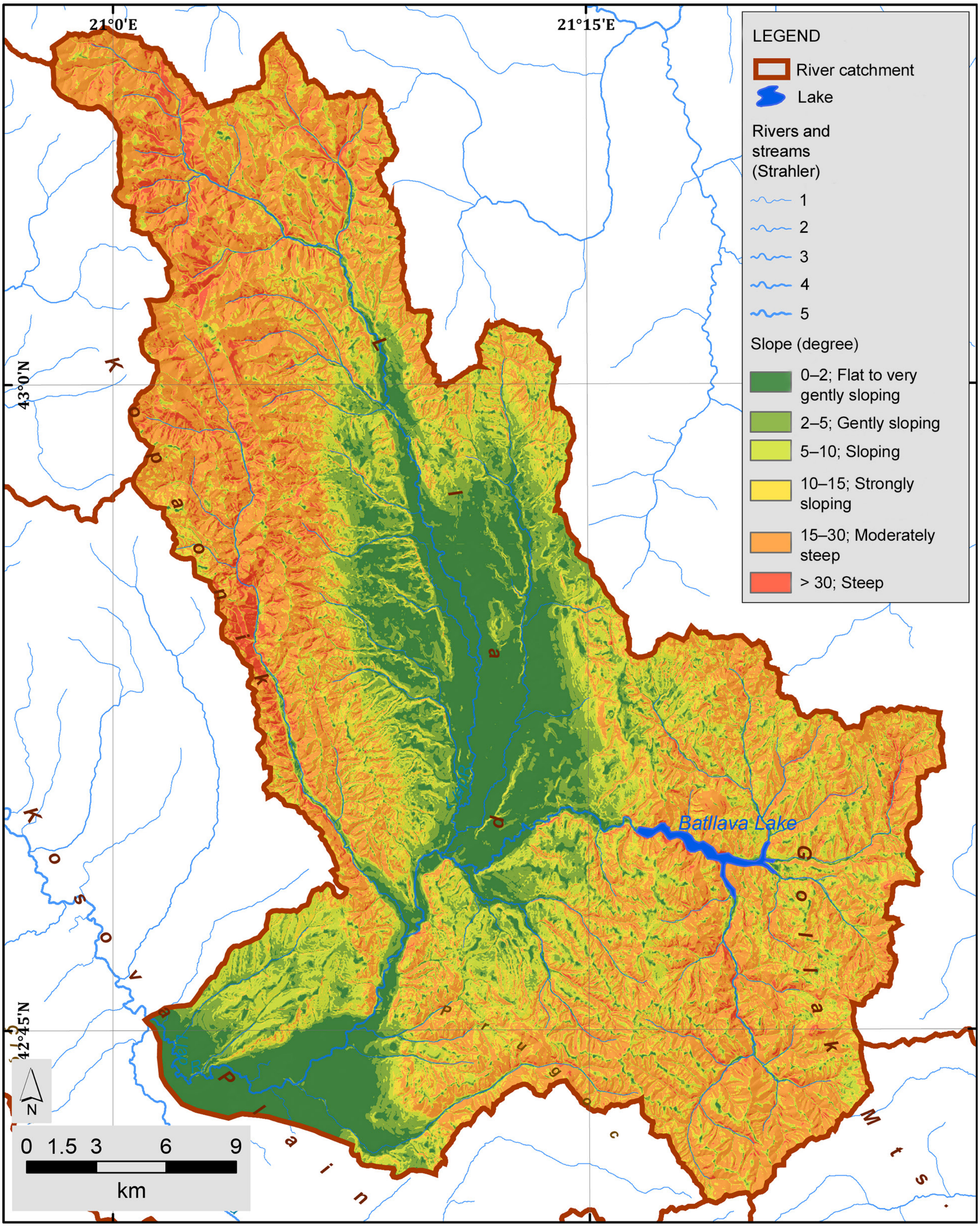

Fig. 3. Slope map of the Llapi River catchment (source: Authors' own elaboration)

and texture qualities. Shallow brown soils are the dominant type of soil, distributed above flysch, sandstone rocks, found above the Kopaonik and Gollak Mountains, and according to their properties, are classified as low fertile soils, while most of them are covered with vegetation (sparse forests). Fluvisols, namely loamy alluvium, are found on both sides of the main river (Llapi River) and its tributaries, mainly flowing in flat terrains where the deposition of loose sediments transported by river processes happens. Smonitsa (vertisol) is found throughout the Kosovo Plain, and also, albeit less frequently, in the Llapi Plain.

Based on soil properties, during the 1980s, a land quality map of Kosovo was created where soils are divided into eight categories, representing their productivity, i.e. quality from the point of view of agricultural production. Dominated by hilly and mountainous areas, elevation, and slopes have indicated the dominance of low fertile soils. The sixth category of soils represents nearly 60% of total soils, while soil quality classified between the first and fourth categories – which, according to regulations in Kosovo, is considered agricultural land – occupies 236.5 km² i.e. one fourth of the total area of the catchment. Statistics indicate a small portion of fertile soils suitable for agricultural production in the Llapi River catchment, while the main driving force (human population) is transforming the landscape towards artificial surfaces and reducing agricultural land (Table 4; Figure 4).

Table 4. Soil quality classes in the Llapi River catchment (source: Land quality map of Kosovo (1983); extracted and calculated by Authors)

Soil quality class	Area (km^2)	Total (km^2)	%	Total %
I	34.3	236.5	3.7	25.1
II	89.6		9.5	
III	59.9		6.4	
IV	52.6		5.6	
V	83.5	704.1	8.9	74.9
VI	560.9		59.6	
VII	59.7		6.3	
	940.6	940.6	100.0	100.0

Humans, as the main driving force of landscape transformation, have impacted the Llapi River catchment. Different physical features, as well as social and economic changes have been observed over the last 20 years, and particularly noteworthy of those are migrations of the population. The bottom part of the catchment has flat terrain, and is very attractive for human activity. Over the years, the expansion of artificial infrastructure has accelerated, significantly impacting the natural environment (Grigoraș and Urițescu, 2019).

In the catchment, there are 109 settlements of varying size, stretching from the altitude of 522 m up to the altitude of 1,250 m. Settlements' demographic size is correlated with the altitude, and with soil resources. Settlements at low altitude, located on suitable agricultural land, are bigger and are experiencing a population increase, while the settlements located in hilly and mountainous areas, on low-quality soils, are experiencing an outflow of inhabitants, and that is a sign of landscape changes in land cover and land use. Overall, the growing population has contributed to the increase of built-up areas, and the decrease in the agricultural land area.

Analysis of land cover change

It is possible to assess how LULC changed over time in the Llapi River catchment by analysing land cover data from Copernicus Land Monitoring Service, where data have a spatial resolution of 100 m. The Llapi River catchment, especially the bottom of the tectonic plains (Llapi Plain and Kosovo Plain), is an attractive environment for living – especially taking into account its soil resources, diverse topography, healthy climate, and other socioeconomic factors. During the analysed period (2000–2018) (Table 5), changes have been observed in nearly all categories of CORINE land cover designation. In some categories, we have observed small changes, and in others, much more significant changes. In general, there was an increase in the size artificial surfaces, which led to shrinking the area of agricultural land. This is the major indicator observed in the catchment in recent decades, and the most obvious change. These uneven shifts threaten agricultural lands and they threaten the resources, which are essential – both on the scale of the catchment, and of the entire country.

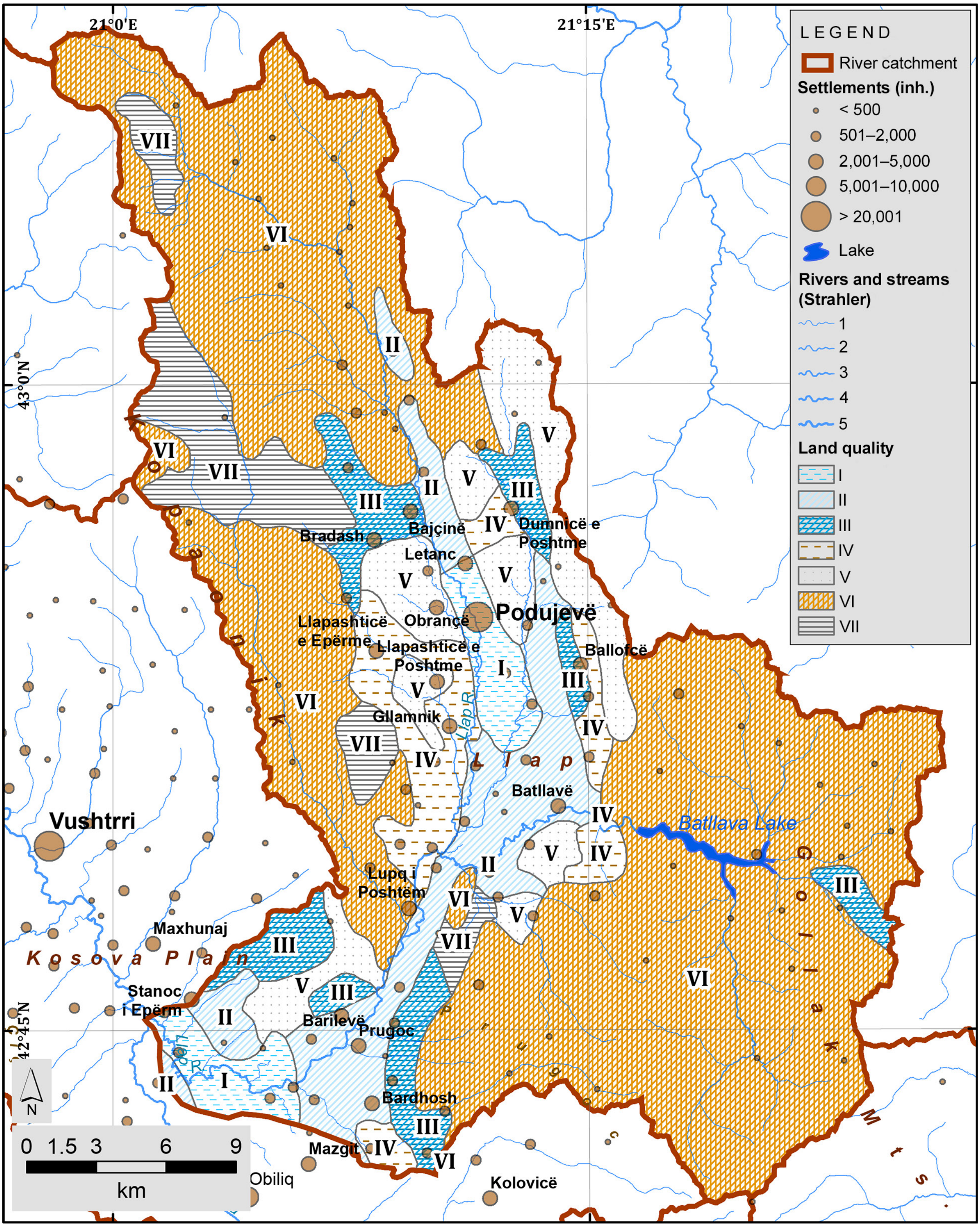

Fig. 4. Land quality map of the Llapi River catchment (source: Land quality map of Kosovo (1983), compiled by Authors)

Table 5. Land cover classes through the years in the Llapi River catchment (source: Copernicus Land Monitoring Service)

CLC code	CLC group	CLC description	2000		2006		2018		Changes 2000–2018
			Area (ha)	%	Area (ha)	%	Area (ha)	%	
112	Artificial surfaces	Discontinuous urban fabric	1,357.2	1.44	1,721.4	1.83	3,501.9	3.72	2,144.7
121		Industrial or commercial units			48.2	0.05	45.0	0.05	45.0
122		Road and rail networks and associated land					64.5	0.07	64.5
131		Mineral extraction sites	27.2	0.03					–27.2
211	Agricultural areas	Non-irrigated arable land	12,497.0	13.29	12,857.1	13.67	16,804.5	17.87	4,307.5
231		Pastures	534.0	0.57	550.6	0.59	692.4	0.74	158.4
242		Complex cultivation patterns	9,404.3	10.00	10,554.7	11.22	6,353.9	6.76	–3,050.4
243		Land principally occupied by agriculture, with significant areas of natural vegetation	15,392.4	16.37	13,369.2	14.21	10,372.1	11.03	–5,020.2
311	Forest and semi natural areas	Broad-leaved forest	43,254.0	45.99	43,626.4	46.38	44,327.7	47.13	1,073.6
312		Coniferous forest	193.4	0.21	187.9	0.20	187.0	0.20	–6.4
313		Mixed forest	378.0	0.40	378.0	0.40	312.1	0.33	–66.0
321		Natural grasslands	3,375.5	3.59	3,508.5	3.73	5,006.7	5.32	1,631.2
324		Transitional woodland-shrub	6,187.3	6.58	5,971.1	6.35	5,188.5	5.52	–998.8
333		Sparsely vegetated areas	1,137.3	1.21	964.5	1.03	834.8	0.89	–302.5
334		Burnt areas					47.3	0.05	47.3
512	Water bodies	Water bodies	318.3	0.34	318.3	0.34	317.5	0.34	–0.9
		Total	**94,055.8**	**100.0**	**94,055.8**	**100.0**	**94,055.8**	**100.0**	

Most changes that have taken place concerned artificial surfaces (an increase by 160.87%), agricultural areas (a decrease of 9.53%), and forests and semi-natural areas (an increase of 2.53%). Significant changes in artificial surfaces are made due to increased built-up areas, classified as discontinuous urban fabric. Urban expansion shifted land cover with increasing impervious surfaces from 1,384 hectares (2000) to 3,611 hectares (2018) (Table 4) and 4,436 hectares in 2020. The rising trend of settlement extension and other artificial surfaces (road networks and commercial units) is associated with population migrating towards plains, and with rapid urbanization. The municipality's centre (Podujeva) and other settlements near regional roads experienced the most significant transformations in population numbers and the largest increase in artificial surfaces. When analysing the specific category of artificial surfaces, discontinuous urban fabric recorded a significant increase – by as much as 158% (from 1,357 ha in 2000 to 3,502 ha in 2018), and it is essential to emphasize that these categories of land cover contain 97% of artificial surfaces. As studies revealed in many countries (Iváncsics and Filepné Kovács, 2021), agricultural land has lost its compactness and has become fragmented. The size of built-up areas could be controlled if zoning maps were created and implemented.

The size of industrial and commercial areas, as specific categories of artificial surfaces, remained stable in terms of areas covered, whereas road and rail networks and associated land exhibited a very high increase, which was due to new infrastructure distribution over time. Throughout the year, this category had a significant increase due to the urbanization of settlements and creation of a new road network.

The annual rate of built-up area extension in the period between 2000 and 2018 was nearly 9% (Table 6), which is a very high rate compared to the Kosovo plain, where the corresponding figure was 4.87%. This is due to the migration of the population towards the plains (40 out of 109 settlements experienced a decrease in population number due to migration). The main driving forces were the extensive urbanization and the absence of construction zoning in urban and rural areas.

Based on data analysis, while artificial surfaces increased in size, agricultural areas simultaneously decreased by –9.53%. In absolute terms, when we compare figures for the years 2000 and 2018, a 3,604 hectares decrease of farmland is recorded. All four categories of agricultural areas have changed throughout the analysis period (Figure 5). While non-irrigated arable land in 2018 increased by 34.47% compared to 2000, complex cultivation patterns and land principally occupied by agriculture decreased by 32.44% and 32.62%, respectively. Non-irrigated arable land is distributed across the bottom of the Llapi Plain and is the leading category in land cover therein, covering 17.87% of the catchment. Complex cultivation patterns are associated with the near-settlement areas (suburbs), used as cultivation land for inhabitants of settlements or export. The decrease of farmland in the area is associated with the extension of built-up areas, where in many settlements, the housing density is very high, and settlements expanded their areas with new houses and infrastructure towards agricultural land. This happens because the force changed its destination from agricultural to other economic sectors or saw new possibilities of international migration. Of the total number of settlements in the catchment (109), 69 experienced an increase in the population, and those settlements were primarily located in the plains.

During the last century, but also today, agricultural production is the major sector in the region; while at the same time, at the national level, the area of agricultural land is declining. The Llapi Plain and the Kosovo Plain are two out of five plains in Kosovo (on a national level), which is essential for agricultural production in the country where the agricultural land per capita is near the threshold for food security (0.25 ha/in.). Based on the analysed statistics, agricultural land per capita in the Llapi River catchment is 0.3 ha/inhabitants, just above the national level but less than European standards. Pastures increased by 29.67% compared to the year 2000. Recently, their area in the region covers 692 hectares, with the growing trend.

Table 6. Changes in land cover classes in Llapi River catchment over the years (source: Copernicus Land Monitoring Service data, analysed by Authors)

	Land cover classes Agricultural areas	2018				
		Artificial surfaces	Forest and semi natural areas	Water bodies	**Total**	
2000	Agricultural areas	33,144.35	185.86	899.35	0.02	34,229.58
	Artificial surfaces	2,419.73	1,181.35	11.00	0.00	3,612.08
	Forest and semi natural areas	2,270.84	17.38	53,625.58	0.91	55,914.71
	Water bodies	0.01	0.01	0.04	317.48	317.54
	Total	37,834.93	1,384.60	54,535.97	318.41	**94,073.91**

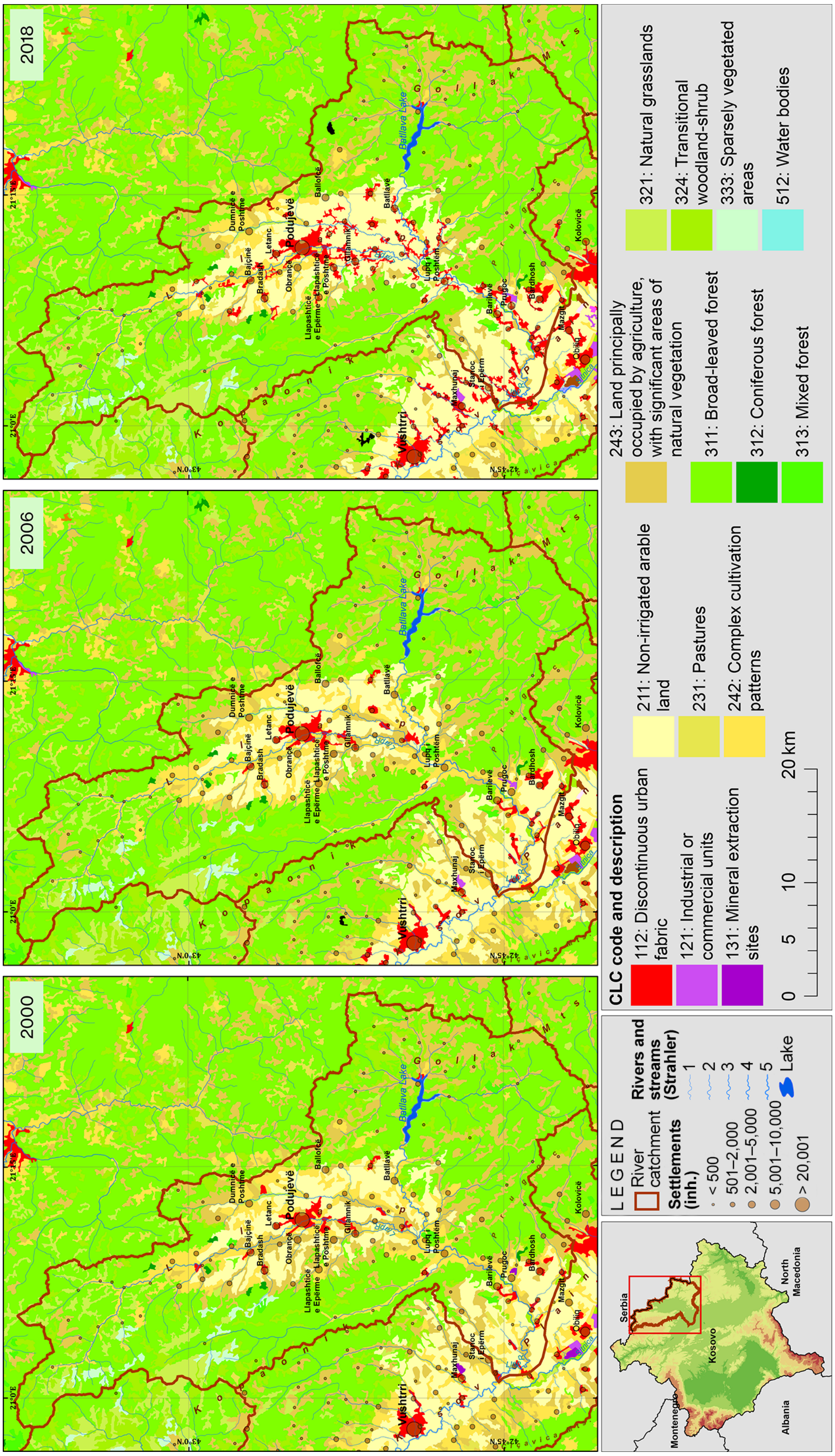

Fig. 5. Land cover maps for years 2000, 2006 and 2018 (source: Copernicus Land Monitoring Service, analysed by Authors)

Forests and semi-natural areas have changed by +2.53% over the last two decades. Broad-leaved, coniferous, and mixed forests occupy 59.54% of the catchment. Their vast distribution is linked with relief and climatic conditions. Being a river catchment with 62% of total areas above 900 m, diverse topography and climatic conditions have influenced the distribution of broad-leaved forests, covering 47% of the catchments' total areas. Expansion of natural grasslands is recorded in hilly and mountainous terrains. In the past, the same areas were used for farming, but since the population abandoned that land, natural grasslands have taken over, replacing the former agricultural areas. This also leads to a decrease in transitional woodland shrubs in the foothills of the mountains, in morphographic contact between the plains and steep slope terrain, due to an increase in the artificial surface. Compared to the year 2000, in 2018, burnt areas have shown a slight increase due to forest fires in specific years (Figure 6). At the European level, it was broad-leaved forests that were the most affected (San-Miguel-Ayanz et al., 2023), and the same is true for the analysed catchment.

During the analysed period, changes occurred not only in the total area of land cover classes but also in the number of patches of land cover classes. In 2000, there were 24 patches of discontinuous urban fabric with an average size of 56.55 hectares, while in 2018, the number of patches increased to 45 with an average patch size of 77.82 ha, which was due to the extension of artificial surfaces with rapid and unplanned urbanization. On the other hand, most changes happened in classes of land principally occupied by agriculture, with significant areas of natural vegetation, where in 2000, there were 103 patches with an average size of 149.44 hectares, while in 2018, the number of patches was reduced to 33 with an average size 123.48 ha (Figure 7).

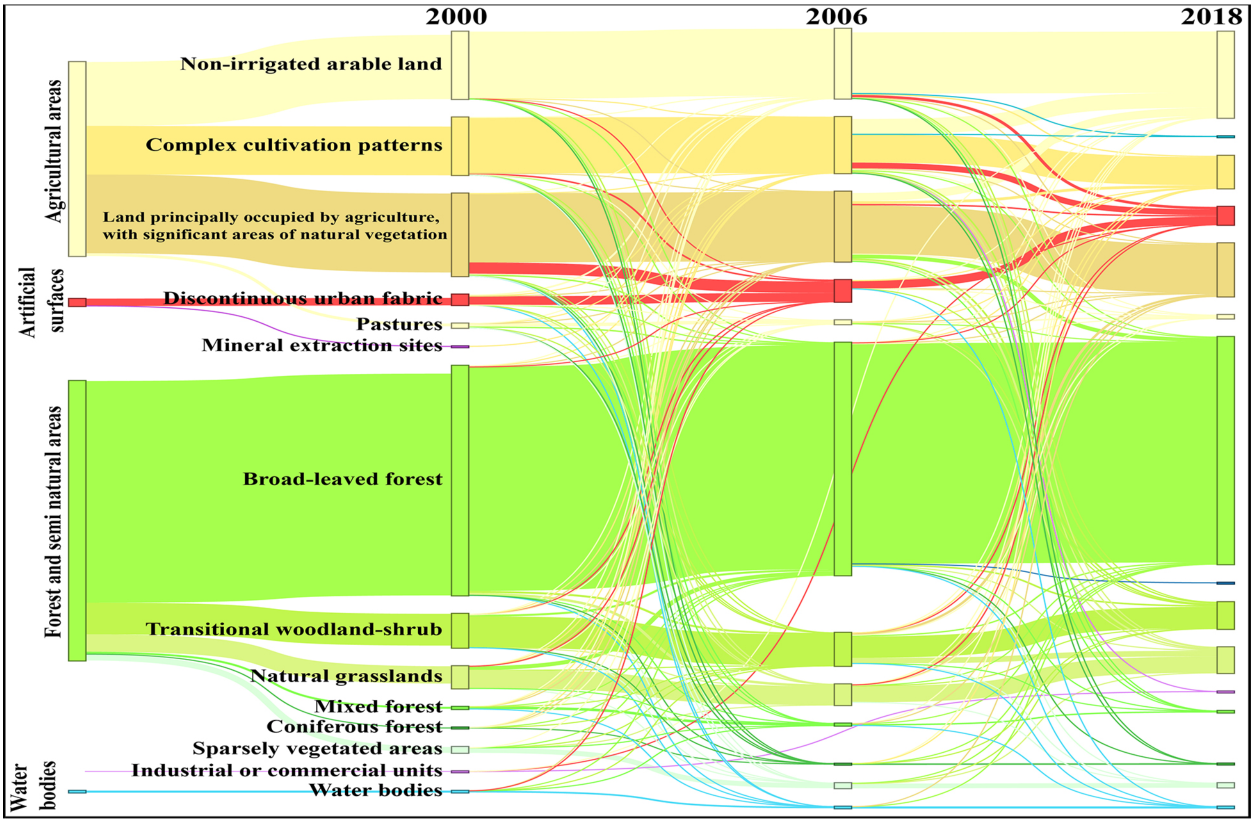

Fig. 6. Visualization of land cover changes over the years (source: Authors' own elaboration)

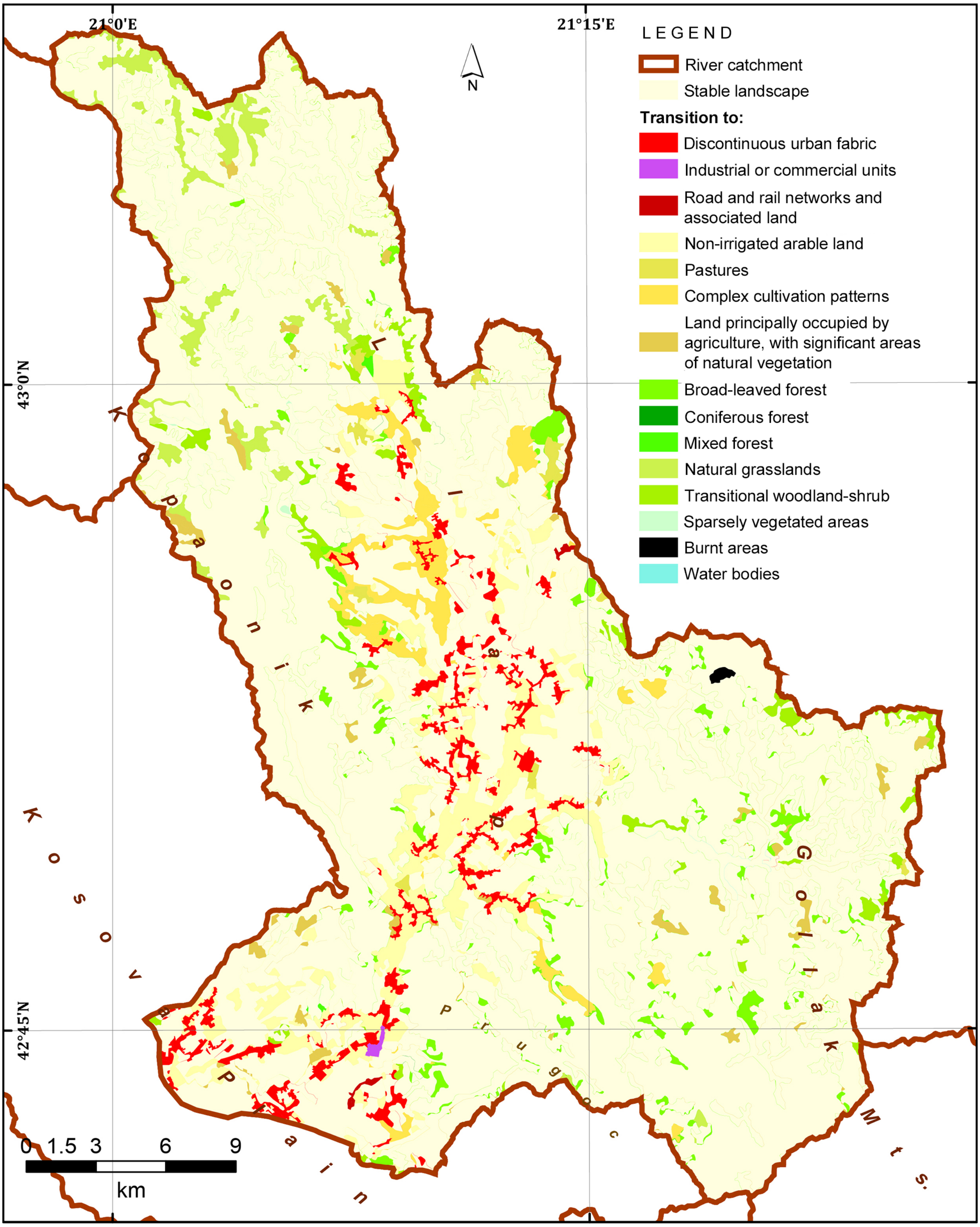

Fig. 7. Transition map of land cover changes from 2000 to 2018 (source: Authors' own elaboration)

The Llapi River catchment includes one of the biggest artificial lakes in the country. This is the Batllava Lake, with a water capacity of 30 million m³ (Pllana, 1996), serving as the source of consumption, irrigation, and industrial water for the region. Even though the lake is situated on a hilly terrain, on the Batllava River, it has experienced an increase in artificial surfaces in recent years, which is due to its scenic values as a major tourist attraction.

The twenty-first century marks an era of intensifying urbanization processes that have altered natural habitats and changed landscape layouts, mainly through increasing artificial surfaces towards the areas previously occupied by agricultural land and forest. This shift has altered the natural landscape, which is becoming less natural day by day. Landscape changes have accelerated soil erosion (Borrelli et al., 2017), and the consequences in terms of soil loss and food security are challenging. At the country level, urban growth and settlement extension is jeopardizing the environment and decreasing agricultural land per capita. Statistical analysis of the changes in landscape during the last 20 years shows that the trend of increasing artificial surfaces will continue, and the most vulnerable decrease concerns the areas of agricultural land. Statistical analysis (R-squared) demonstrates that artificial areas will increase with 87.5% reliability. In comparison, agricultural land will decrease with 85% reliability, further exacerbating the negative scenarios for the future of a region known for its agricultural production.

CONCLUSIONS

The growing population has influenced environmental transformation, where agricultural lands are affected the most. Land cover changes in Kosovo and the Llapi River catchment are occurring rapidly, where, in the last decades, rapid urbanization and increasing infrastructure encroaching on agricultural land have transformed the landscape, coupled with a reduction of agricultural land per capita. Spatiotemporal changes are analysed based on CORINE land cover data for 2000, 2006, and 2018. In the Llapi River catchment, four types of CORINE land cover categories are found, where, with the influence of other physiographic features, forest and semi-natural areas are the dominant group, constituting 59.44% of the total area. In hilly and mountainous areas, over 18 years, their size changed by only 2.53% due to migrations of the populace towards flat and gentle terrain at the bottom of tectonic plains. Population's migration towards the plains implicated the extension of artificial surfaces, particularly the discontinuous urban fabric and road infrastructure, where an increase of 160.87% was observed over a period of 18 years, with an annual rate of 8.93% (123.7 hectares per year); therefore, the landscape transformed rapidly. Kosovo, as a small country in Europe, has 0.25 ha of agricultural land per capita, which is only half of the European average, and in the Llapi River catchment that figure is at 0.3 ha per capita, nearly at the national average. However, with the current trend towards further reduction, the implementation of agricultural policies would be necessary – both to save agricultural land, and to maintain sustainable ecological status. In a river catchment, where only 38% of its area is under 700 m, with 25% of I–IV land quality areas (agricultural land), it is necessary to develop and implement conservation plans to save highly fertile soils. Land use policy with zoning of settlements extension will reduce rapid, unregulated and inappropriate urbanization. In recent years, an inconvenient extension of construction sites has occurred on the shores of the artificial Lake of Batllava, which would endanger water resources in a country that is not so rich in freshwater. Changing the land cover by human impact not only means the transformation of the landscape, but it also means that decreasing the size of farmland in the area of the river catchment could endanger sustainable development and threaten the society with unstable food security. By assessing land cover changes, we can estimate past and future changes, with the primary goal of sustainable use of agricultural land and other natural resources.

According to the existing law, agricultural land is soil of high suitability for farming (classes I–IV). Unfortunately, in Llapi River catchment, land designation of the relevant areas was changed, mostly towards built-up areas. Changes in the functional designation of high-quality arable land are associated with low construction costs, and easy access to the road network. Appropriate policies to protect high quality arable land should be implemented, along with the determination of suitable construction zones in rural settlements, and increasing construction density in order to ensure long-term local and national food security.

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OSZACOWANIE PRZESTRZENNO-CZASOWYCH ZMIAN FORM POKRYCIA TERENU W ZLEWNI RZEKI LLAPI (W PÓŁNOCNO-WSCHODNIEJ CZĘŚCI KOSOWA)

ABSTRAKT

Cel pracy

W ostatnich dziesięcioleciach Kosowo jako całość, a zlewnia rzeki Llapi w szczególności, doświadczyły transformacji krajobrazu. W jej następstwie pojawiły się znaczące zmiany użytkowania gruntów i form pokrycia terenu (LULC), głównie na terenach równinnych, które zamieszkuje większość populacji kraju. Poza obszarem nizinnym, inne tereny i krajobrazy również podlegały zmianom, choć na mniejszą skalę. Celem badań było opisanie przemian krajobrazu oraz czynników, które je powodują.

Materiały i metody

Przestrzenno-czasowe zmiany użytkowania gruntów i form pokrycia terenu (LULC) zostały prześledzone przy użyciu technik GIS. Przeanalizowano dane dotyczące pokrycia terenu z systemu Copernicus Land Monitoring Service (CLMS) o rozdzielczości przestrzennej 100 m dla trzech różnych lat: 2000, 2006 i 2018. Do oszacowania gradientu (pochylenia terenu) i wysokości zlewni wykorzystano DEM o rozdzielczości przestrzennej 10 m. Dane dotyczące populacji zamieszkującej ludzkie osady na terenie dorzecza Llapi pozyskano z Agencji Statystycznej Kosowa – obejmują one liczbę ludności na potrzeby oficjalnych spisów powszechnych w latach 1948–2011. Do analizy wykorzystano środowisko ArcMap 10.8.

Wyniki i wnioski

Korzystając z techniki GIS, analizując dane dotyczące użytkowania gruntów i pokrycia terenu (LULC) oraz inne dane z ogólnodostępnych źródeł, ustalono, że powierzchnia gruntów rolnych zmniejszyła się o 9,53%, podczas gdy obszar powierzchni zabudowanej wzrósł o 160,87%. W przeliczeniu na wartości bezwzględne oznacza to, że całkowita powierzchnia użytków rolnych w 2000 r. wynosiła 37 827 ha, zaś w 2018 r. 34 334 ha – a więc 0,3 ha na jednego mieszkańca, czyli poniżej średniej europejskiej. W celu ochrony gruntów rolnych należy wdrożyć właściwe plany zagospodarowania przestrzennego.

Słowa kluczowe: zlewnia rzeki Llapi, pokrycie terenu/użytkowanie gruntów (LULC), grunty rolne, zasoby glebowe, Kosowo