IMPERVIOUS SURFACE TREND ANALYSIS AND ITS IMPACTS ON KOSOVO'S LANDSCAPE CHANGE FROM 2006 TO 2015

***Ferat KRASNIQI*[1], *Florim ISUFI*[1*]**

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ABSTRACT:
The growth of cities and human demands for a better life have influenced the transformation of land use from natural land or vegetation to an artificial area-impervious surface (IS). The IS is an important indicator to measure the process of urbanization and its impact on the ecological environment. This article aims to analyze the trends of impervious surface and exert influence on land cover/land use occupation based on High-Resolution Layers (HRL) of imperviousness time-series data from 2006 to 2015 obtained from the European Copernicus Programme for seven Kosovo's regions. For the spatiotemporal distribution of the IS changes to be expected, the overlay of the GIS method was utilized. The results show that the absolute and relative rate of IS increased in all Kosovo's districts in four time periods: 2006, 2009, 2012, and 2015. Whereas, in the three periods of impervious change: 2006 - 2009, 2009-2012, and 2012 – 2015 regional distinctions were distinguished, where Prishtina and Prizren regions occupy the most spatial increases of IS. To highlight the consumption of land cover/land use area by the IS increase change results of the periods 2009 -2012, and 2012 – 2015, five-first class categories of CORINE Land Cover inventory from 2012 and 2018 year utilized. In both periods, the most affected land cover class by IS increases was the artificial area, followed by agricultural area and forest and semi-natural area, where wetlands and water land cover classes showed no affection in all of Kosovo's regions.

Keywords: *impervious surface (IS), growth rate, change, land use, district*.

1. INTRODUCTION

We are witnessing that due to the extraordinary/rapid development of the economy and the continuous increase of the population, the surface of the Earth is continuing to be urbanized quite drastically (Liu et al., 2019). With this rapid socio-economic development, expected that, by 2050, the urban population will exceed the participation of 60% (UN, 2014), while, by 2092, this participation will approach 100% (Batty, 2011; Liu et al., 2019). As a result of this development, the demands for land space for urban human life have intensified to the maximum. Consequently, the transformation of land use/cover is in constant conflict and competition by human activity such as preserving the environment or building infrastructure, recreational areas, or agriculture, which can be changed and lead to create a new type of land use (Scalenghe & Marsan, 2009). As we all know, one of the characteristics – which is most prominent – of urbanization is the growth and expansion of impervious surfaces. Undoubtedly, such things forge our living environment under unprecedented pressure (Grimm et al., 2008; Seto et al., 2012; Weng, 2012). This land conversion often occurs from urban growth, which transforms the permeability of the soil from water to impervious (McMahon, 2007).

Impervious surfaces such as roads, sidewalks, parking lots, roofs, and others, which prevent water infiltration into the soil, are defined as anthropogenic materials (Weng, 2008). Such an expansion of these areas' highlights – in addition to the process of urbanization – also anthropogenic manifestations with their effects make our living environment change (Weng, 2012; Liu et al.,2019). In addition to the direct impact on the environment, the increase of soil sealing due to the urbanization process has raised numerous field-related studies. This increase of these surfaces causes the floods from water flows to intensify/frequent (Brun and Band, 2000), and the increased of the surface temperature

[1]*Department of Geography, Faculty of Mathematical and Natural Sciences, University of Prishtina, Prishtina, Republic of Kosovo, ferat.krasniqi@uni-pr.edu , *Corresponding author: florim.isufi@uni-pr.edu*

becomes the reason for the use of materials that have small values of albedo – urban heat island effect (Yuan and Bauer, 2007). The awareness of the impacts of the urbanization process of the hydrological processes (Deng and Wu, 2013), climate changes (Boggs and Sun, 2011; Hao et al., 2015), and on human health (Gong et al., 2012) are shown to be fundamental factors for the investigation of the impervious surface dynamics. Paul and Meyer (2008) reported an influence of the impervious increase on physical (hydrology and geomorphology), chemical, biological and ecological streams urban landscape. The IS was treated as an essential environmental key indicator (Chester & Gibbons, 2007) for population density estimation (Morton & Yuan, 2009), changes in storm runoff (Miller, et al., 2014), water balance (Strohbach, et al., 2019) and quality (Schueler, 1994), and urban heat island (Weng, et al., 2004).

Numerous research methodologies were emerged to map impervious surfaces using whether low or high spatial resolution remotely sensed data. For instance, the Landsat-7 ETM+ and IKONOS and Digital Orthophoto Quadrangles (DOQ) imageries used for mapping large areas of impervious in the United States by applying regression tree (CART) algorithm (Yang, et al., 2003), the normalized spectral mixture analysis (NSMA) method used on Landsat TM and US census data (Morton & Yuan, 2009), pixel-based, segmentation based and a hybrid classification method applied on Quickbird high-resolution imagery (Lu, et al., 2011).

Remote sensing is considered a more suitable technique to extract and map IS compared to traditional methods due to many satellite-acquired image values such as multi-temporal image resolution, large covered scene area, and lower cost (Slonecker, et al., 2009). The medium-resolution image (like Landsat constellations) is widely endorsed to observe the urban spatial structure distributions due to their repeated measurement at moderate spatial resolution and orbit revisit time (Sexton, et al., 2013). In the last decades, the increase in open free source remotely sensed data and software policies has increased the ability to map and quantify the impervious area for a larger unit-continental unit. One such series of products covering 39 European countries and capture the percentage and change of soil sealing have been created under Copernicus Land Monitoring Service (CLMS) and is freely available for scientific purposes. Cooperation between the EEA and Swiss Federal Office for the Environment (FOEN) analyzed for the first time the extent of the urban sprawl over the period 2006 -2009 using the HRL imperviousness layer maps. The study involved 32 countries and revealed that the IS area could be used as a new indicator to monitor the urban sprawl (EEA-FOEN, 2016). The European Environment Agency (EEA) has created an online platform for time-series imperviousness changes based on impervious products. Every 3 years between 2006 and 2015, based on 100 m raster cell size of imperviousness change products for each country unit using data cube approach, aiming to measure the extent and dynamics of soil sealing caused by urban development and other artificial land use classes in Europe (EEA, 2020). The information on IS area differentiates between countries on administrative levels provided by this platform. The impervious change statistics analysis for Kosovo could be derived only per country unit. Based on the importance of the soil sealing trend, this study aims to highlight the spatial distribution of IS area changes for the seven regions units of Kosovo over 10 years (2006 - 2015) using GIS overlay methods and imperviousness time series data with 20m spatial resolution.

Moreover, the study addresses these three main questions:

1. What are the absolute and relative status and change of imperviousness layer in Kosovo and its regions?
2. What are the imperviousness change dynamics (trends) among seven regions, and why?
3. Which type of land cover or land use is more affected by the increase of impervious among the regions?

2. STUDY AREA

The Republic of Kosovo is located in the southeastern part of Europe respectively lies in the center of the Balkan Peninsula (**Fig. 1**). It borders Albania (south-west), Montenegro (northwest), Serbia (northeast), and Northern Macedonia (southeast) and has a total geographical area of 10905.25 km^2. The territory lies between 41 ° 51 ' N to 43 ° 16' N latitudes and between 19 ° 59 ' E and 21 ° 47'

E longitude, characterized by different altitudes, from 270 m to 2656 m. The relief of Kosovo consists of mountains and plains. Mountains occupy 63% of the territory and are divided into peripheral mountains that form the framework of Kosovo and central mountains. The lowest point of Kosovo is located in the valley of the river Drini i Bardhë, on the border with Albania, and reaches an altitude of 270 m above sea level. The highest point is located in the west of Kosovo, in Gjeravica - 2,656 m. In terms of hydrography, Kosovo is divided into three river basins: Drini i Bardhë, Ibri, Morava e Binçës and Lepeneci. Kosovo Rivers flow into three marine catchments: the Black Sea, the Adriatic Sea, and the Aegean Sea. The climate of the Republic of Kosovo is mainly continental, resulting in summer warm and cold winters, with Mediterranean and continental influences (Kosovës, 2020). The state of Kosovo is characterized by a very young population structure, where the average age is 30.2 years. According to the census conducted in April 2011, the population is over 1.7 million inhabitants, where 61% of the population lives in rural areas.

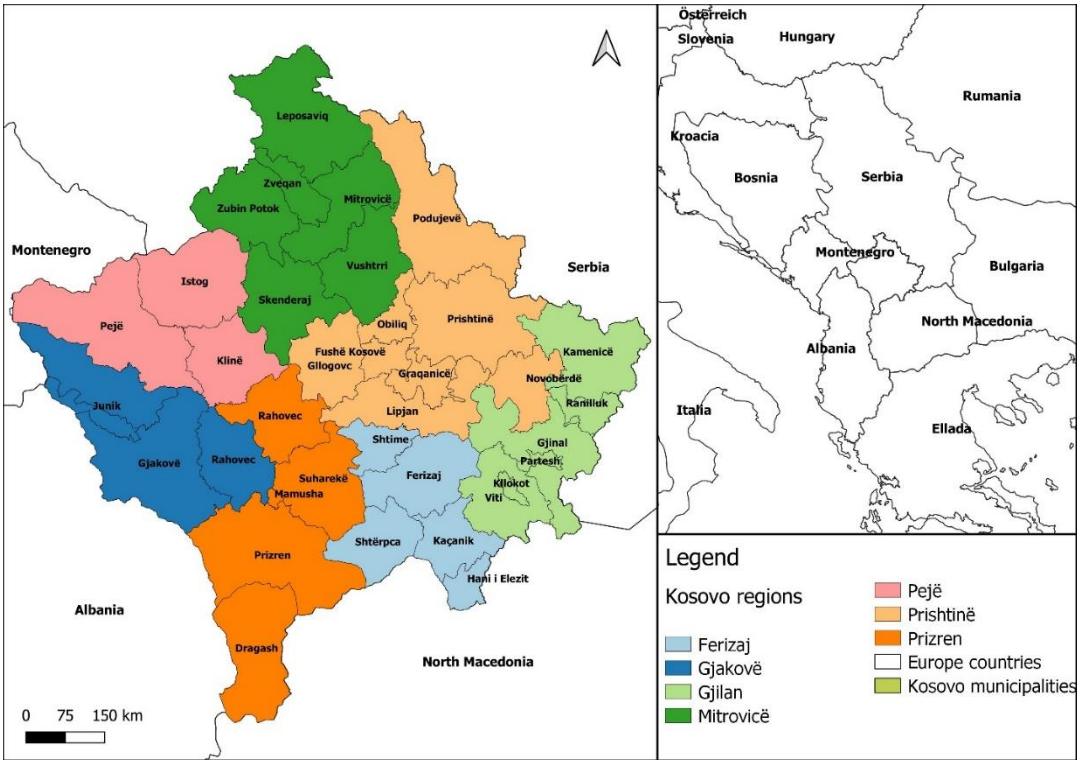

Fig. 1. Location of the Kosovo Republic in Balkan Peninsula and its administrative regional division.

The country is divided into seven administrative regions (**Fig. 1**). Data by size by region and estimated population from 2011 to 2015 are presented in **Table 1**. The name of the regions corresponds to the name of the regional centers, with Prishtina and Prizren regions being the most populated ones. Prishtina is the country's capital and is the largest regional economic, political, administrative, educational, and cultural center. Like any country that is in the phase of economic and demographic transition, Kosovo, respectively, these regional centers, have undergone significant spatial changes due to the growth of their urban area. In particular, changes had taken place in the last 20 years (after the 1999 war), namely, after 2008, when the country gained the right to state independence. The expansion of regional urban areas has been influenced by many factors, which can be related to the post-war migration of the rural population in the direction of urban areas to education, employment and then resulted in a permanent residence, the growth of rural settlements on the border with urban areas, development of inter-regional and state road infrastructure. The region of Prishtina and Prizren is among the regions which have had the most significant increase in artificial areas, frequently uncontrolled, causing occupation and loss of fertile land. From 1981 to 2011, of the total population that had emigrated within the national borders between municipalities (196,429 inhabitants), most of them migrated towards Prishtina (45,905 inhabitants) or over 23.1% of its population, followed by the municipality of Prizren with 7.98% Ferizaj 6.79%, Gjilan with 5.31%, and Fushë Kosova with 4.74% (Kastrati, et al., 2014). Therefore, it is crucial to study the spatial distribution and changes of the impervious area of Kosovo, to better understand the trend and direction of urban development and its impact on transformation land use.

Table 1.

The size of the area and estimated population from 2011 to 2015 of Kosovo regions. Source: Kosovo Agency of Statistics, https://ask.rks-gov.net/en/kosovo-agency-of-statistics.

Region		Area in km²	2011	2012	2013	2014	2015	Region's center
1.	Ferizaj	1 024	185695	189507	190299	186252	178754	Ferizaj
2.	Gjakova	1 236	196867	200348	200582	200956	201006	Gjakova
3.	Gjilan	1 331	181459	182991	182698	176700	166834	Gjilan
4.	Mitrovica	2 051	192637	235691	235386	231548	224420	Mitrovica
5.	Peja	1 366	174235	177854	177387	177266	176702	Peja
6.	Prishtina	2 157	477312	489975	493944	489846	480040	Prishtina
7.	Prizren	1 747	331620	339240	340335	342376	343848	Prizren
Total		**10, 912**	**1739825**	**1815606**	**1820631**	**1804944**	**1771604**	

3. DATA AND METHODS

The data utilized in this study compromise both raster and vector spatial datasets provided free of charge from Copernicus – European Union's Earth observation program. The imperviousness HRL (High- Resolution Layer) data time series are raster data format and contain information on imperviousness status and change layers. The imperviousness status layer captures the percentage form 0-100% of IS increase or decrease for the following four years: 2006, 2009, 2012, and 2015. Imperviousness change layers are classified thematic change products that map the most relevant categories of IS such as unchanged areas, new cover, loss of cover, and impervious degree increase and decrease for each of the 3-year periods: 2006-2009, 2009-2012, and 2012-2015 (**Table 2**). The imperviousness layers represent the spatial impermeability distribution of the soil per unit area. They are created using the semi-automatic classification method on NDVI calibrated products based on continuous multi-temporal seasonal image composites (3 per year) satellites (IRS-P6/ResourceSat-2 LISS-III, SPOT 5, and Landsat 8) with a spatial resolution of 20 x 20 m (LANGANKE, 2016). The CORINE Land Cover (CLC) time series inventory contains information on land cover/land use up to 44 classes at the three-level hierarchical category, using a Minimum Mapping Unit (MMU) of 25 hectares (ha) for area feature and a minimum width of 100 m for the linear feature (**Table 3**). The CLC Level 1 category compound of five class categories for this study includes artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands, and water bodies are used.

Table 2.

Imperviousness products' main metadata information. Source: Copernicus – Land Monitoring Service (https://land.copernicus.eu/pan-european).

Product type	Product name	Reference years	Pixel size	Projection	Tile ID
Status layers	IMD - Imperviousness degree	2006, 2009, 2012, 2015	20 m	EPSG:3035 (ETRS89, LAEA)	E50N20
Change layers	IMCC Imperviousness change classified	2006-2009, 2009-2012, 2012-2015	20 m	EPSG:3035 (ETRS89, LAEA)	E50N20

Table 3.

CORINE Land Cover inventories' main metadata information. Source: Copernicus – Land Monitoring Service (https://land.copernicus.eu/pan-european).

Name	Year	Data type	Data format	Projection
Corine Land Cover - GeoPackage	2012	Vector	SQLite Database	EPSG:3035 (ETRS89, LAEA)
Corine Land Cover - GeoPackage	2018	Vector	SQLite Database	EPSG:3035 (ETRS89, LAEA)

After collecting the data described above, the first step was to pre-process the data for the study, such as clipping and re-projection. To exhale the absolute spatial distribution in IS pixel (2006, 2009, 2012, and 2015) and IS changes (2006-2009, 2009-20012, and 2012-2015) per each region, the GIS raster overlay method is employed, using QGIS tools. Overlay analysis is a GIS operation for overlaying the multiple layers of datasets representing different themes to identify layer relationships (Clarke, 1997). To produce the spatial distribution of the impervious surface in pixel, for each land cover category on each region, both vector and raster overlay analysis tools are applied on the CORINE Land Cover data set for 2012 and 2018. Then, the results of the GIS overlay analysis were exported to Excel spreadsheets for further analysis. From the data on the excel spreadsheet, the absolute (in km2) and relative (in percentage) area for the imperviousness status and change layers, annual IS change increase was calculated as well as land cover type consumption by IS per each region. This change was witnessed from the linear trend, calculated for the period 2006-2015. The linear trend equation can be represented by the equation (Pushka, 2008):

$$Y_t = A + BX \tag{1}$$

where:

Y_t - the trend;

A - the value of the constant when X is zero;

B - the trend coefficient, which shows how much the dependent variable Y changes for a given period;

The parameters A and B are derived from two normal equations:

$$\Sigma Y = NA + B\Sigma X \tag{2}$$

$$\Sigma YX = A\Sigma X + B\Sigma X^2 \tag{3}$$

Degree of change (DCh), percentage of change (PCh), and annual rate increase (ARI) of IS area during each period time for each region were calculated based on the following formulas (Alawamy, Balasundram, Hanif, & Sung, 2020) :

$$Dch = (t1 - t2) \tag{4}$$

$$Pch = \frac{(t1-t2)}{Gt} * 100 \tag{5}$$

$$Ari = \frac{(t1-t2)}{(Gt*n)} * 100 \tag{6}$$

where:

t1 - the imperviousness area of the region in the initial time;

t2 - is the imperviousness area of the region at the final time;

Gt - the sum of the total country imperviousness area, and

n - the number of years between one period of change.

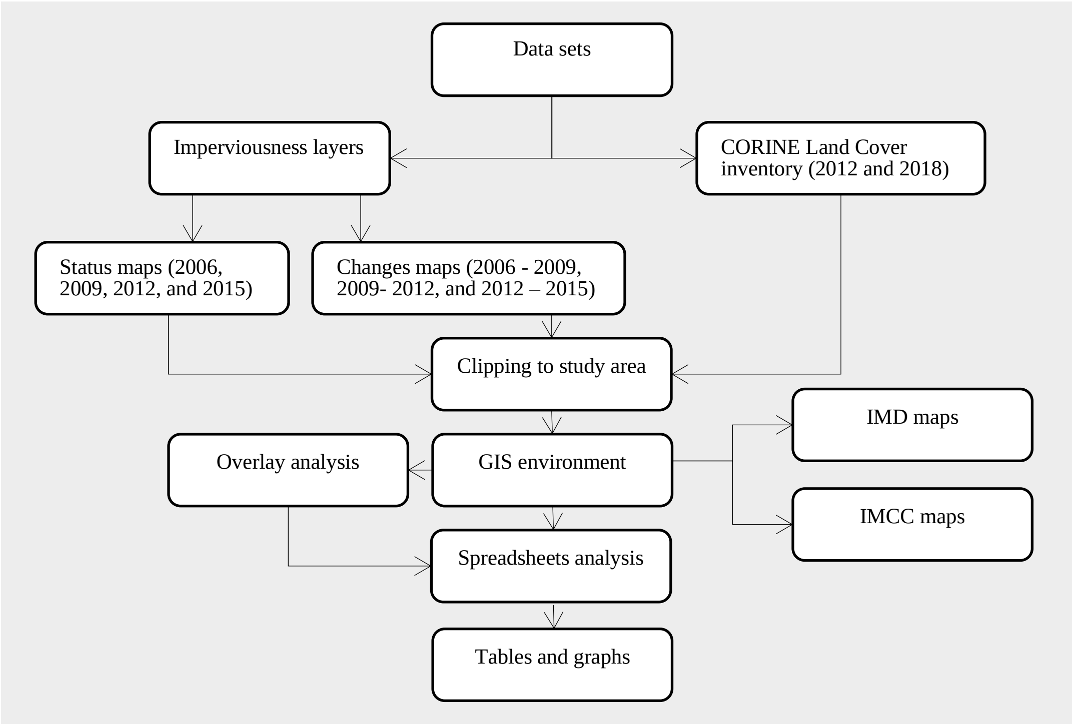

Fig. 2. Flowchart depicting methodology

4. RESULTS AND DISCUSSIONS

Based on the data and methodology applied, three types of results were obtained and analyzed in this study area: the degree of the impervious for the four-time periods (2006, 2009, 2012, 2015) in absolute and relative values, degree of impervious classes change (IMCC) in absolute and relative changes values and the annual increase of the impervious for the three periods of changes (2006-2009, 2009-2012, 2012-2015), and the consumption of land cover or use class category by the impervious trends for the two-period time of changes 2009-2012 and 2012-2015.

4.1. Degree of soil sealing from 2006 to 2015 (Degree of imperviousness = IMD)

The maps (**Fig. 3**) show the degree of soil sealing ranging from 0% to 100 % for all Kosovo regions. Light brown color (range 1-20) shows areas with a slight degree of imperviousness, while dark brown color (range 81 – 100%) shows an entirely impervious area of each region, indicating the trend of the impervious increase each year detected in all degree imperviousness time series products.

Table 4 shows the absolute and relative distribution of soil impermeability for the study area for the period 2006 - 2015. From the tabular data, it can be estimated that IS has grown continuously in all regions. At the country level, the IS area increased from 225.80 km2 to 250.42km2 from 2006 to 2015. From 2006 to 2012, the IS area increased slowly, while from 2012 to 2015, the IS area increased quickly, from 234.90 km2 to 250.42 km2.

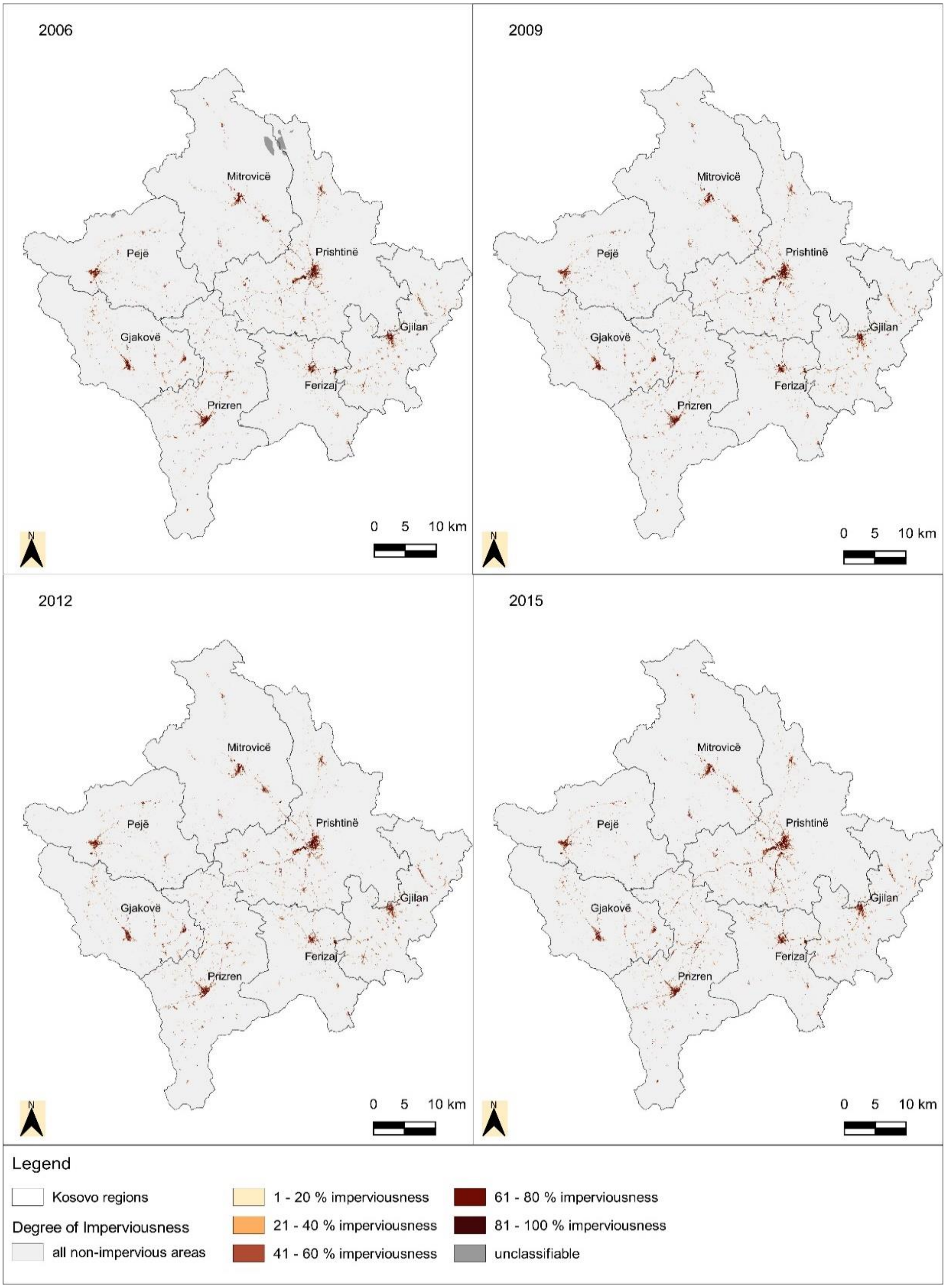

Fig. 3. Distribution of imperviousness degree rate in Kosovo and regions presented for four years (2006, 2009, 2012 and 2015).

Table 4.

The absolute and relative soil sealing of the regions in the study area.

Region	**2006**		**2009**		**2012**		**2015**	
	Area (km2)	**%**	**Area (km2)**	**%**	**Area (km2)**	**%**	**Area (km2)**	**%**
Gjakova	27.56	0.25	27.66	0.25	27.8	0.3	28.01	**0.26**
Ferizaj	22.33	0.20	22.46	0.21	22.9	0.2	24.70	**0.23**
Peja	23.54	0.22	23.72	0.22	23.9	0.2	23.97	**0.22**
Prishtina	57.64	0.53	58.55	0.54	61.5	0.6	69.83	**0.64**
Mitrovica	23.07	0.21	23.22	0.21	23.7	0.2	24.43	**0.22**
Prizren	38.90	0.36	39.21	0.36	41.9	0.4	45.02	**0.41**
Gjilan	32.77	0.30	32.98	0.30	33.4	0.3	34.46	**0.32**
Grand Total	225.80	2.07	227.80	2.09	234.9	2.2	250.42	**2.30**

Fig. 4 shows the linear trend and R2 (R-Squared) calculated for IS in Kosovo from 2006 to 2015. The result of the calculated trend has the following values: Y = 8.0995 + 214.49. The trend coefficient B = 8.0995 shows that for every three years, IS in Kosovo has increased by 8km2, while the value of the coefficient A = +214.49 represents the constant for the period zero. The values of the linear trend model calculated in three-year intervals, from 2006 to 2015 are Y (2006) = 222.59 km2, Y (2009) = 230.69 km2, Y (2012) = 238.79 km2 and Y (2015) = 246.90 km2. Based on these results, the projected value of IS growth for 2018 is Y (2018) = 254.99 km2. The value of R-squared = 0.88 explains that the linear model regression has fit well our observation data.

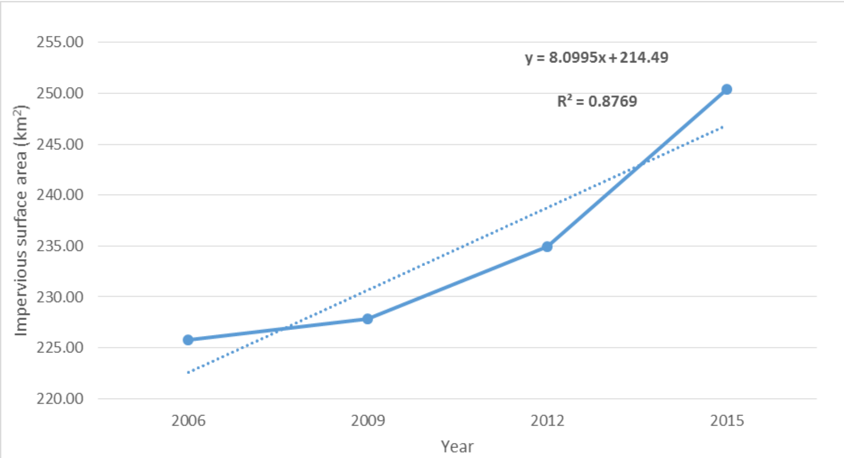

Fig. 4. The trend of impervious surface area in Kosovo, from 2006 to 2015.

Fig. 5 presents the IS area distribution of Kosovo's regions at different periods. In the initial year (2006), most changes occurred in the Prishtina region (57.64 km2 or 0.53 %), followed by the Prizren region (38.90 km2 or 0.36 %) and the Gjilan region (32.77 km2 or 0.30 %). The other regions like Gjakova, Peja, Mitrovica, and Ferizaj share almost the same percentage of sealing on the country level.

The calculations for the imperviousness status layer of the second period (2009) indicate very little increase on both the absolute and relative values of the impervious with around two km2 for the whole country. During this period, the most soil-sealed regions are Prishtina and Prizren, while in the other regions, the growth rate of impervious is relatively low. In the 2012 period, the impervious increased to 234.9 km2 or 2.2 % for the whole country. Regional impervious increasing distinction occurs again in the region of Prishtina with 61.5 km2 or 0.6 % and Prizren 41km2 or 0.4% of the country area, while other regions show a slight IS growth (**Fig. 5**).

In the final year (2015), the biggest absolute IS increased to 250.42 km2 or 2.30 % within the Republic of Kosovo. As seen in **Fig. 5**, except for Prishtina (69.98 km2 or 0.64) and Prizren (45.02 km2 or 0.41%) regions, a growth trend of IS increased in Ferizaj, Gjilan, and Mitrovica regions, while the Peja region indicates a very low IS growth rate.

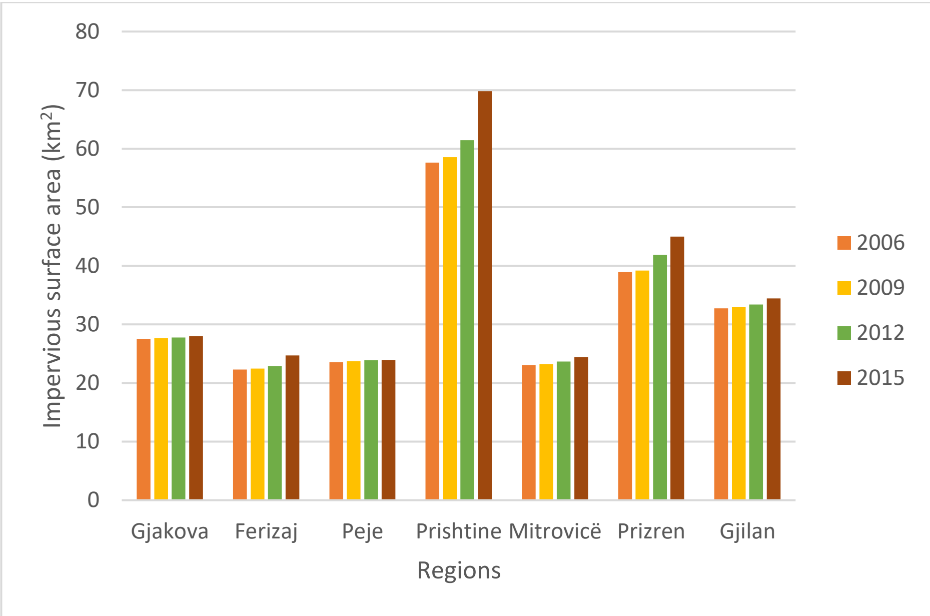

Fig. 5. The absolute increase of the IS in km^2 in Kosovo Region's from 2006 to 2015.

The IS growth rate in Kosovo and its regions continues to increase quickly. Based on the 2011 national population census data, 61% of the population is rural, while 39% is urban in Kosovo. Although, recently, there has been an improvement in the construction of road and water infrastructure in the deepest hilly-mountainous villages of the country, the migration of inhabitants continues towards the regional centers to better meet the living needs and opportunities for education and employment for the future. This has affected the growth of urban areas in each regional center, especially in Prishtina, which constantly attracts residents from border cities and all over the country. Examples of urban population lifestyle and their living change manner, as well as changes in economic activities of the population such as transport, trade, and tourism, may take to the construction of infrastructure and urban expansion, rather than the increase in the size of population (Scalenghe & Marsan, 2009). The new construction of highways, national and regional roads in Kosovo has increased the rate of IS area. The data calculated for the construction of the new highway in Kosovo show that from 2011 to 2020, about 137.2 km of highways were built (Krasniqi, et al., 2020), which has dramatically influenced the growth of the IS area and transformed the land use destination.

4.2. Degree of imperviousness change (IMCC)

The classified impervious change maps (**Fig. 6**) indicate the spatial pattern of soil increase changes for the three periods over all regions of Kosovo. The colors presented in the IMCC legend indicate the attribute category of impervious classified changes. The white color represents the unchanged impervious areas with zero degrees: the red color indicates the new layer of increasing imperviousness area, which was zero on the first date of reference: the green color represents the degreased of the impervious surface, which was zero on the second reference date: the gray color represents the unchanged impervious surfaces between the two periods: the yellow color represents the increase of the imperviousness density in both the reference dates and color magenta - unclassified IS in any of the years, in the absence of raster data or cloud cover. However, a piece of more detailed information about the rate of the sealing of region's distinction is illustrated in **Table 5** and **Fig. 7**.

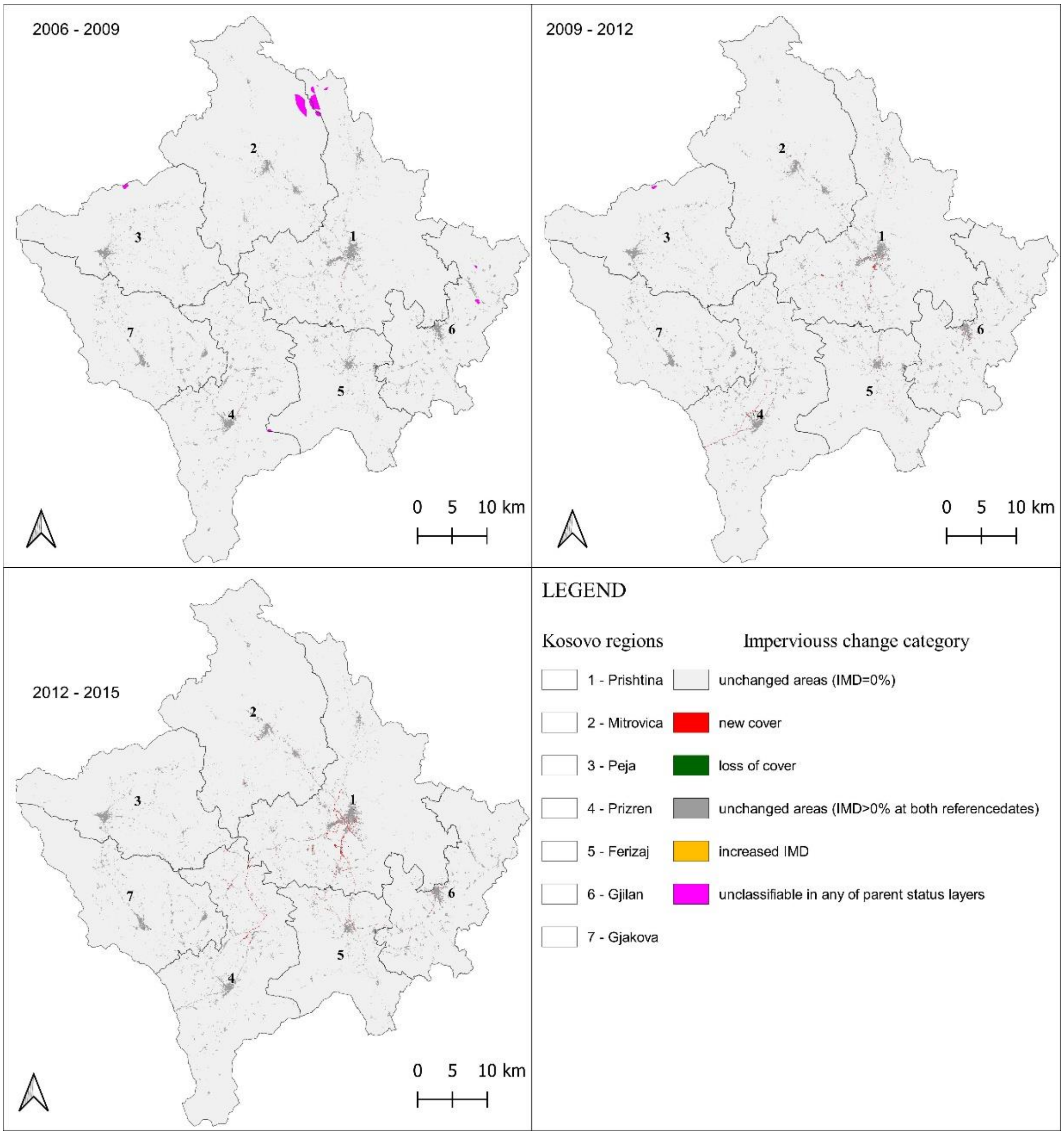

Fig. 6. The thematic classified impervious change in Kosovo regions for the three periods: 2006-2009, 2009-2012 and 2012-2015.

Table 5 shows the statistics of imperviousness changes in three time periods; 2006-2009, 2009 – 2012, and 2012 -2015 according to each Kosovo region.

Table 5.

The absolute, relative and annual sealing changes between 4-periods.

Region	**2006-2009**			**2009-2012**			**2012-15**			**2006-2015**		
	Area (km2)	**%**	**Annual %**	**Area (km2)**	**%**	**Annual %**	**Area (km2)**	**%**	**Annual %**	**Area (km2)**	**%**	**Annual %**
Gjakova	0.1	0.04	0.01	0.12	0.05	0.02	0.23	0.1	0.03	0.45	0.20	0.06
Ferizaj	0.13	0.06	0.02	0.44	0.19	0.06	1.8	0.77	0.26	2.37	1.05	0.32
Peja	0.18	0.08	0.03	0.15	0.07	0.02	0.1	0.04	0.01	0.43	0.19	0.06
Prishtina	0.92	0.41	0.14	2.9	1.27	0.42	8.38	3.57	1.19	12.19	5.40	1.62
Mitrovica	0.15	0.07	0.02	0.44	0.19	0.06	0.77	0.33	0.11	1.36	0.60	0.18
Prizren	0.36	0.16	0.05	2.82	1.24	0.41	3.16	1.34	0.45	6.12	2.71	0.81
Gjilan	0.2	0.09	0.03	0.43	0.19	0.06	1.05	0.45	0.15	1.69	0.75	0.22
Total	2.04	0.9	0.3	7.3	3.21	1.07	15.49	6.59	2.2	24.62	10.90	3.28

4.2.1. IMCC 2006-2009

In the first period (2006 -2009), the absolute change was 2.04 km2 or 0.90% of the total changes. The highest region in the degree of IS changes occurred in Prishtina with 0.92 km2 or with an annual growth rate of 0.14%, followed by Prizren region with 0.36 km2 or with a yearly growth rate of 0.05%, and other regions like Gjakova, Ferizaj, Peja, Mitrovica, and Gjilani, share almost the same absolute and their annual growth of rate changes ranging from 0.01 to 0.03 %.

4.2.2. IMCC 2009-2012

From 2009 to 2012, the absolute change was 7.3 km2 or 3.21 % of the total changes in the second period of changes. Prishtina and Prizren regions experienced the most IS area changes: Pristina with 2.90 km2 or 1.27 %, followed by the Prizren region with 2.82 km2 or 1.24 %. The characteristic of impervious surface changes in this period is that Ferizaj, Gjilan, and Mitrovica district show impervious surface area increase rate compared to the 2006-2012 period. While, Gjakova region is relatively the same, and Peja starts a small relative impervious surface decrease (**Fig. 7**).

4.2.3. IMCC 2012-2015

In the third period of impervious surface changes from 2012-2015, the absolute difference was 15.49 km2 or 6.59 % of the total changes. The highest region in the degree of impervious changes is Prishtina with 8.38 km2 or with an annual growth rate of 1.19%, followed by Prizren region with 3.16 km2 or with a yearly growth rate of 0.45%, and other regions like Ferizaj, Gjilan, Mitrovica, Gjakova and Peja, share almost the same absolute and their annual growth of rate changes ranging (from 1.80km2 to 0.10km 2 or 0.26 to 0.01 %). (**Fig. 7**).

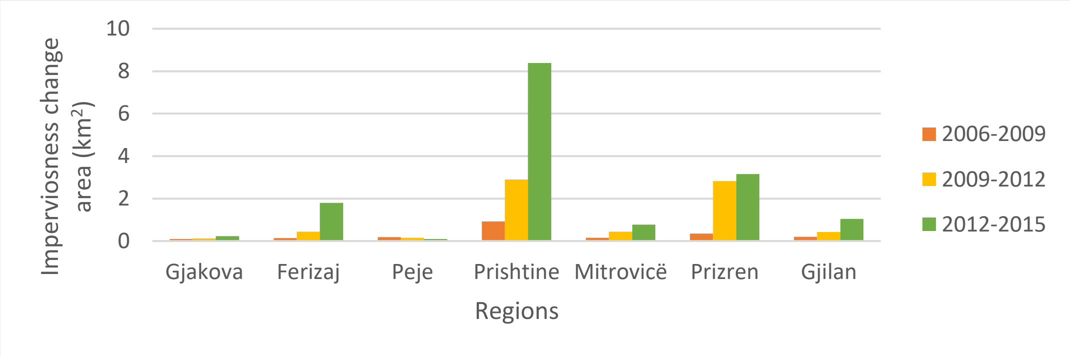

Fig. 7. Impervious surface changes are in km^2 of the regions for three periods.

4.2.4. IMCC 2006-2015

Fig. 8 presents the annual growth rate of IS changes. The annual growth of IS area at the national level from 2006 - 2015 is 24.62 km2, or 3.28 % of the annual rate IS area changes. The largest share of this change has the region of Prishtina with 12.19 km2 or 1.62% of the territory, followed by the region of Prizren with 6.12 km2 or 0.81%, Ferizaj shares 2.37 km2 or 0.32 %, Gjilan 1.69 km2 with 0.22% annual growth rate of IS changes, Mitrovica 1.36 km2, with 0.18 % annual growth rate of changes, while Gjakova and Peja regions, share the same annual growth rate of changes with 0.06 %.

The absolute and relative changes increase of the IS area in Kosovo continues to be prominent in the three periods of changes. In the regional aspect, except for the Peja region, which has a decrease in changes in IS, all other regions have a continuous increase. The decrease of changes in the region of Peja, can be related to its most extreme (peripheral) geographical position. The Prishtina region continues to have the largest increase of changes of the IS during the study period. In addition to the country's capital, Prishtina, in this region are located its neighboring cities such as Fushe-Kosova, Obiliq, Lipjan, Podujeva, Drenas, Gracanica, which have undergone a tremendous physical and spatial change. Based on the research "Increase of urban areas in Kosovo Municipalities" by the Institute for Spatial Planning of Kosovo (Nushi, Murseli, Nela, Kallaba, & Behrami, 2018), urban expansion is mainly done along national, regional, and local roads, especially when rural settlements have been very close to cities. In addition, such cases are the connection of Hajvali and Cagllavice with the city of Prishtina, the connection of the village of Uglare with the town of Fushë Kosova, and the internal connection of the town of Fushë Kosova with Prishtina.

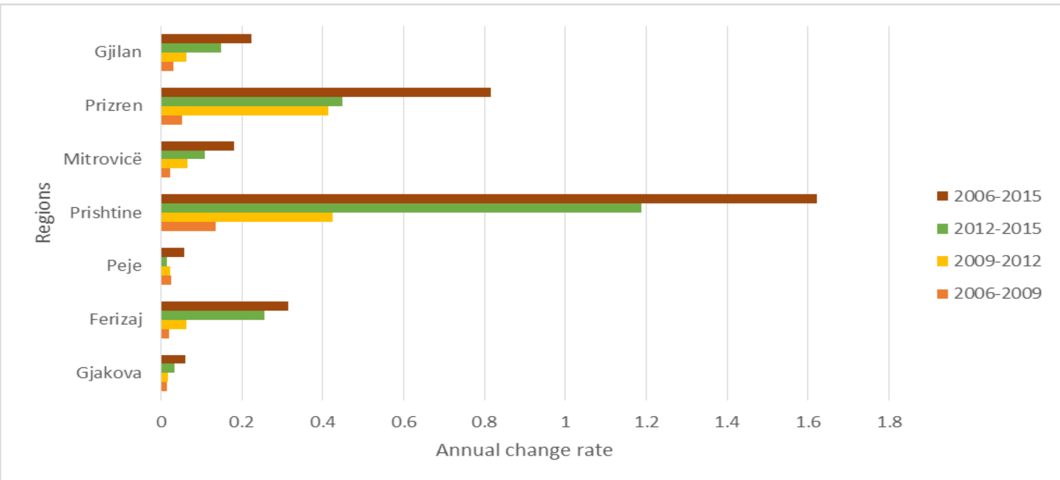

Fig. 8. The annual growth rate of IS changes of the regions for 4 time periods.

4.3. The impact of the impervious surface increase on land use

Table 6 presents the absolute and relative area of three main category land cover classes occupied by impervious surface change expansion in the seven counties of Kosovo during the two periods (2009–2012 and 2012–2015). Artificial areas were the main land cover classes occupied by IS change in each period. The proportion of artificial area in the first period (2009-2012) was 70.26 % occupied by IS change increase, then in the second period (20012-2015) show a proportion decrease with 58.66 % of occupation by IS change increase. The proportion of agricultural area in the first period was 27.91% occupied by IS increase, then in the second period show an increase occupation by IS to 38.47%. As a third land cover class, forest, and semi-natural area, in the first period was 1.83% occupied by IS and increased slowly in the second period to 2.85%.

Table 6.

The absolute and relative values of the land cover consumption by IS are increased during two periods of time series impervious changes in Kosovo regions.

Regions	2009 - 2012		2012 - 2015	
Land cover	**Area km2**	**%**	**Area km2**	**%**
Ferizaj	**0.44**	**6.00**	**1.80**	**11.62**
Artificial surfaces	0.29	3.92	0.96	6.20
Agricultural areas	0.15	2.00	0.83	5.33
Forest and semi-natural area	0.01	0.09	0.01	0.08
Gjakova	**0.12**	**1.65**	**0.23**	**1.51**
Artificial surfaces	0.03	0.38	0.09	0.59
Agricultural areas	0.08	1.14	0.14	0.89
Forest and semi-natural area	0.01	0.13	0.00	0.03
Gjilan	**0.43**	**5.93**	**1.05**	**6.76**
Artificial surfaces	0.35	4.78	0.49	3.17
Agricultural areas	0.08	1.11	0.53	3.44
Forest and semi-natural area	0.00	0.04	0.02	0.15
Mitrovica	**0.44**	**6.07**	**0.77**	**4.96**
Artificial surfaces	0.35	4.79	0.54	3.51
Agricultural areas	0.09	1.25	0.22	1.40
Forest and semi-natural area	0.00	0.03	0.01	0.05
Peja	**0.15**	**2.07**	**0.10**	**0.66**
Artificial surfaces	0.09	1.17	0.03	0.21
Agricultural areas	0.06	0.87	0.06	0.41
Forest and semi-natural area	0.00	0.03	0.01	0.03
Prishtina	**2.90**	**39.66**	**8.38**	**54.10**
Artificial surfaces	2.53	34.58	5.84	37.69
Agricultural areas	0.35	4.86	2.53	16.33
Forest and semi-natural area	0.02	0.22	0.01	0.08
Prizren	**2.82**	**38.62**	**3.16**	**20.40**
Artificial surfaces	1.51	20.64	1.13	7.29
Agricultural areas	1.22	16.68	1.65	10.67
Forest and semi-natural area	0.09	1.29	0.38	2.43
Grand Total	**7.30**	**100.00**	**15.49**	**100.00**

The graphic proportion area of each land cover class occupied by the increase of impervious surface changes in the two time-period of investigations for the seven districts of Kosovo is shown in **Fig. 9**. In the first period (2009-2012), artificial surfaces have been mostly occupied by the increase of impermeability in six of the regions, except the Gjakova region, where agricultural surfaces have the highest participation. The region of Prishtina has the highest percentage with 34.58% and the region of Prizren with 20.64%. Then, regions with more minor participation have Mitrovica (4.79%), Gjilan (4.78%), Ferizaj (3.92%), Peja (1.17), and Gjakova (0.38%). The region of Prizren (16.16%) has the largest occupation of the agricultural area due to the increase of the impervious surface, followed by regions such as Prishtina (4.86%), Ferizaj (2.0%), Mitrovica (1.25%), Gjakova (1.14%), Gjilan (1.11%), and Peja (0.87%). A smaller percentage of forest and the semi-natural area is affected by the impervious surface increase in this period. Prizren (with 1.29%) and Prishtina (with 0.22 %) districts occupy the largest proportion of this class. The other regions share the smaller percentage; Gjakova (0.13%), Ferizaj (0.09), Gjilani (0.04%), Mitrovica, and Peja with 0.03%.

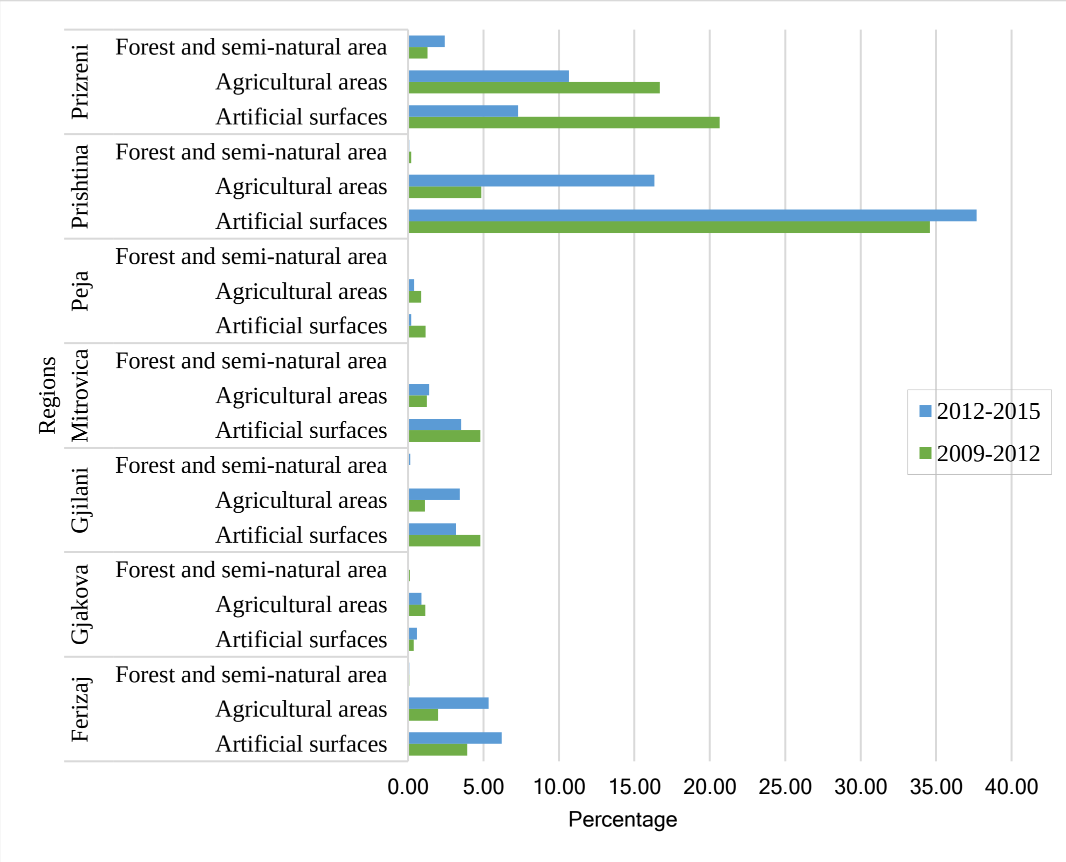

Fig. 9. Land cover consumption by IS are increases in Kosovo regions for to periods: 2009-2012 and 2012-2015.

In the second period (2012-2015) of impervious surface change, an increase and decrease great trend occupation of the artificial and agricultural land cover area experienced in Prishtina, Ferizaj, and Prizren districts. The district of Prishtina has the highest percentage occupation (with 37.69%) and continues to increase, followed by Prizren districts/region with 7.29% that show a decrease proportion comparing to the first period of impervious change.

A growth trend increases occupation of the artificial land cover area occurred in Ferizaj district with 6.20%. Then, regions with a smaller area of the artificial land cover proportion have Mitrovica (3.51%), Gjilan (3.17%), Gjakova (0.59%), and Peja (0.21). The region of Prishtina (16.33%) has the largest occupation of agricultural areas due to the increase of impervious surface are increased in this period, followed by Prizren district (7.29%), which had a decrease in the impervious surface area in this period, Ferizaj district (5.33%) which showed a fast impervious surface during this period and the other regions, Gjilan (3.44%), Mitrovica (1.40%), Gjakova (0.89%) and Peja (0.41%). An increased percentage occupation of forest and semi-natural area affected by impervious surface in this period. Prizren district occupies the largest proportion of this class (2.43 %), which increased this class's occupation during the second period. While the other districts and Prishtina (with 0.22 %) districts. The other regions share the smaller percentage; Gjilani (0.15%), Ferizaj and Prishtina (0.08%), Mitrovica (0.05%), Gjakova and Peja with 0.03%.

The reason why artificial surfaces have been occupied mainly by the increase of the impervious area in both periods taken in the analysis is due to the artificial surface class nomenclature and its definition and the increase of building density within cities and constructions along with existing buildings and roads. In the second period, 2012-2015, it is evident that the space and agricultural area begin to shrink more occupied by the impervious surface because one of the important reasons is that from 2011 begins the construction of highways in Kosovo and their extension has significantly reduced the area of fertile land. According to (Nizeyimana, et al., 2001), the expansion of cities tends to consume the best agricultural lands and affects the change of the boundary of the fertile land areas in the direction of the movement of lands with less productivity, such as hilly-mountainous areas.

5. CONCLUSION

Rapid and uncontrolled urban growth has affected the development of the impervious area, bringing about chain changes in the living environment. Numerous studies have analyzed the IS spatial change increase in local and regional terms, caused by social and economic factors such as road infrastructure requirements and new recreational areas, new residential areas outside of the dense city area, and creation of economic and industrial zones, Etc. Because of these factors, the IS area, among other things, has disrupted the natural circulation of water, and their consequence is the flooding of rain.

In this study, the trend of the IS in the seven administrative districts of Kosovo is analyzed during the years 2006, 2009, 2012, and 2015 based on the time-series data of imperviousness High-Resolution Layers (HRL) downloaded free of charge by the European Copernicus Program. Also, the IS increase rate in the three periods of changes was discussed: 2006-2009, 2009-2012, and 2012. The increase of IS areas is in constant conflict with the land use classes, especially agricultural ones. The findings of this study reveal the impact of IS changes of the two period-times 2009-2012, and 2012-2015, has affected the agricultural area shrinkage compared with the CORINE land cover inventories of the year 2012 and 2018.

Results show that during 9 years (2006-2015), the IS in Kosovo has increased to 24km2 or an annual increase of changes to 3.28%. In the regional aspect, IS transformation has occurred in all administrative regions, except the Peja region, where there is a trend of IS decrease. The region of Prishtina continues to have a growing IS trend because this region is located in the capital of the country - Prishtina, where most of the tertiary and quaternary economic activities are concentrated. Furthermore, it was found that an increase in IS has had an effect on the narrowing of green spaces within urban areas and increased their boundary by consuming agricultural, forest, and semi-forest land. Spatial growth of land impermeability through regions provides important information to understand the growth rate of cities and their connection, sustainable regional urban planning in the future, environmental protection in general, and protection of water or natural plant reserves especially. Further studies at the city level may be conducted in the future, in case spatial data with higher resolution can be provided and other ancillary data to see in more detail the environmental impact of the IS increase.

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