ASSESSING THE SPATIO-TEMPORAL DYNAMICS OF LANDSCAPE TRANSFORMATION IN WESTERN BALKAN METROPOLITAN AREAS

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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **"Assessing the spatio-temporal dynamics of landscape transformation in western Balkan metropolitan areas"** and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

ASSESSING THE SPATIO-TEMPORAL DYNAMICS OF LANDSCAPE TRANSFORMATION IN WESTERN BALKAN METROPOLITAN AREAS

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Maintaining the continuity of the ecosystem has become a core aspect of urban planning policies. Human-caused LF represents a serious danger to the conservation of the Earth's natural habitats. Several researchers identify human-caused environmental, also known as LF as one of the primary drivers of biodiversity loss. Landscape fragmentation as a result of transportation infrastructure and urban development poses a threat to human and environmental health by increasing traffic noise and pollution, reducing the size and viability of wildlife populations, facilitating the spread of invasive species, and reducing the scenic and recreational qualities of the landscape. The phenomenon consists of the transformation of larger habitat patches into smaller ones or fragments. It is especially noticeable in urban areas, including settlements and numerous transport and mobility infrastructures. The aim of this thesis is to promote protection of natural landscape and biodiversity, promoting forms of sustainable development. By evaluating in this study the LF dynamics of landscape of Tirana, central region of Albania comparing with two cities of western Balkan, respectively Skopje and Sarajevo, by focusing in urban metropolitan area to find the dynamic between fragmented areas and less fragmented ones. To analyze LF and measure the impact on environment and biodiversity, quantitative metrics capable of assessing landscape patterns and changes are used. To quantify/measure LF in this study, the effective mesh size (meff) method is applied by using QGIS 3.10 software, and Urban Atlas dataset, which enables comparison of urban spatial patterns.

Keywords: *landscape, fragmentation, urban fragmentation, territorial fragmentation, connectivity, patches, biodiversi*

ABSTRAKT

VLERESIMI I DINAMIKES SPATIO-TEMPORALE TE TRANSFORMIMIT TE PEISAZHIT NE ZONAT METROPOLITANE TE BALLKANIT PERENDIMOR

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Mbarevajtja e vazhdimësisë së ekosistemit është bërë një aspekt thelbësor i politikave të planifikimit urban. LF e shkaktuar nga njerëzit përfaqëson një rrezik serioz për ruajtjen e habitateve natyrore të Tokës. Disa studiues identifikojnë mjedisin e shkaktuar nga njerëzit, i njohur gjithashtu si LF si një nga faktorët kryesorë të humbjes së biodiversitetit. Fragmentimi i peizazhit si rezultat i infrastrukturës së transportit dhe zhvillimit urban paraqet një kërcënim për shëndetin e njeriut dhe mjedisit duke rritur zhurmën e trafikut dhe ndotjen, duke zvogëluar madhësinë dhe qëndrueshmërinë e popullatave të botës së egër, duke lehtësuar përhapjen e specieve invazive dhe duke zvogëluar cilësitë skenike dhe rekreative të peisazhi. Fenomeni konsiston në transformimin e pjesëve më të mëdha të habitateve në copa ose copa më të vogla. Veçanërisht vërehet në zonat urbane, duke përfshirë vendbanimet dhe infrastrukturat e shumta të transportit dhe lëvizjes. Qëllimi i kësaj teze është të promovojë mbrojtjen e peizazhit natyror dhe biodiversitetit, duke promovuar forma të zhvillimit të qëndrueshëm, duke vlerësuar në këtë studim dinamikën LF të peizazhit të Tiranës, rajonit qendror të Shqipërisë krahasuar me dy qytete të Ballkanit Perëndimor, përkatësisht Shkupin dhe Sarajevën, përqëndruar në zonën metropolitane urbane për të gjetur dinamikën midis zonave të fragmentuara dhe atyre më pak të fragmentuara. Për të analizuar LF dhe për të matur ndikimin në mjedis dhe biodiversitetin, përdoren metrika sasiore të afta për të vlerësuar modelet dhe ndryshimet e peizazhit. Për të përcaktuar / matur LF në këtë studim, metoda efektive e madhësisë së rrjetës (meff)

zbatohet duke përdorur softuerin QGIS 3.10 dhe databazën Urban Atlas, i cili mundëson krahasimin e modeleve hapësinore urbane.

Fjalë kyçe: *peisazh, fragmentim, fragmentim urban, fragmentim territorial, lidhshmeri, njolla, biodiversitet*

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CHAPTER 1

INTRODUCTION

1.1 Problem statement

Worldwide, urbanization is rapidly growing. In the next decades, the population living in cities is expected to increase. Urban development seems to be an unavoidable fact. Processes such as urban sprawl and fragmentation also follow the urban expansion of cities. (Canedoli, Crocco, & Comoll, 2017). The spatial distribution of metropolitan areas is rising much higher than the rise of urban populations. Biodiversity is directly linked to human presence.

Urbanization, on the other hand, kills, alters, and dissects existing and semi-natural ecosystems while concurrently creating new habitats on a smaller spatial scale. (Blair, 1999)

With the urbanization, the size of semi-natural patches shrinks, and heavily populated areas are distinguished by small patches divided by highways, towns, or intensively maintained agricultural land. (Di Giulio, Holderegger, & Tobia, 2009)

Small semi-natural areas such as forests and natural elements such as single trees, in heavily inhabited areas, improve the wellbeing of human beings and contributing to the health of residents. (Kaplan , 2001)

An adaptation of nature and urban surroundings in densely populated areas has the ability to support native species and enhance human health.

Landscape fragmentation is considered to be a significant cause of the disturbing reduction of many wildlife species in Europe due to transport networks and urban sprawl.

Wildlife ecosystems are adversely impacted by roads and railroads by reducing habitat and quality, increasing mortality due to car collisions, limiting or blocking access to services across transport networks with barrier effects, and separating and isolating animal populations into smaller and more vulnerable communities. (Forman et al., 2003; Jaeger et al., 2005).

Due to its diversity of geography and habitats, the countries of the western Balkans, are studied in this thesis, are rich in biodiversity. In recent years, urban sprawl, abandonment of land, habitat loss, infrastructure projects, and other pressure threatened the natural wealth. Countries in the region have undertaken essential initiatives to protect biodiversity and nature areas: particularly in recent years, the size of protected areas in the region has risen gradually. However, the EU goal of preventing the loss of biodiversity by 2010 has not been reached.

The area has undergone major land cover shifts in regard to the usage of natural resources. In 2000 about 45% of the land was used in agriculture in the Western Balkans and another 40% was covered by forests. However, many areas of agricultural land, particularly small farms in remote zones, especially mountainous and mining areas have been abandoned in recent years. There have been expansions in urban areas; tourist development in coastal areas has also developed. Climate change is expected to have a major effect on the region's biodiversity, in addition to the general changes in biodiversity that are already happening at a global level — global losses could influence the region's rich biodiversity; moreover, loss of biodiversity in the region could directly impact biodiversity and ecological services important even for other areas of Europe.

1.2 Research objectives

Most countries in Europe are now stressing the need to protect biodiversity and to maintain connectivity between the remaining natural areas for the movement of species, including migration and dispersal, access to various habitat types and other resources, recolonization of empty environments and genetic exchange between populations. (Saunders, Forman, & Jaeger, 1995). As a fragmentation measure, one aim of this paper is to determine effective mesh size (Jaeger, 2000). As roads and urban growth are associated with a variety of human behaviors, effective mesh scale, meff, may also serve as a proxy for other human disruptions.

This study raise the following questions, in order to determine the suitability and reliability of Meff as a measure of the landscape:

1. Which are the factors that determine the degree of urban landscape fragmentation in Western Balkan?

2. What are the spatio-temporal transformation dynamics among western Balkan metropolitan areas based on urban atlas evidences.

3. How does the degree of landscape fragmentation in Tirana differ from comparable regions in Balkan?

4. What is the degree and spatial extent of landscape fragmentation in Tirana today?

5. What are potential causes of why some regions are more or less fragmented than expected?

6. How to manage landscape transformation and territorial fragmentation to find a really effective sustainable solution?

7. what are the recommendation for a better management of transformation and territorial fragmentation to find a really effective sustainable solution?

1.3 Organization of the thesis

The thesis is divided in 5 main chapters. The organization is done as follows:

In the Chapter 1, the problem statement, thesis objective is presented.

Chapter 2, includes the literature review which is divided into 7 subchapters including definition of LF, habitat fragmentation, fragmentation geometries, landscape connectivity, LF assessment methods and materials, methods and material used.

Continuing with the Chapter 3, which consists of the methodology followed in this study, Urban Atlas which is the dataset used and spatial metrics explained in that subchapter, the study area and the workflow.

In Chapter 4, are listed the results for different phases and discussions.

Ending with the Chapter 5, where the conclusions and recommendations for further research are stated.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of LF

LF is the result of turning large patches of habitat into smaller, more fragmented pieces of habitat. This phenomenon is most evident in intensively used regions, where fragmentation is the result of linear infrastructure, such as roads and railroads, connecting built-up areas. (Saunders, Forman, & Jaeger, 1995)

It creates a series of habitat segments that are more or less isolated, the type of habitat or land-use surrounded by a mix of more intensively exploited areas and lines changing the biological interrelationships between segments, e.g. serving as barriers to animal dispersal. It therefore not only characterizes the structural state of a landscape, but is also considered to be a process (Forman & Jaeger, 1995, 1999)

Despite many regulatory changes to help protect biodiversity, urban sprawl continues to increase in Europe and modern transport infrastructure is being developed at a rapid rate. Fragmentation has a large impact on diverse environmental resources and wildlife populations.

The landscape nowadays is determined by human activity and geological processes. Especially human actions, such as transport networks and urban development, are fragmenting the environment and thus non-fragmented ecosystems around the world have been diminished in recent decades. (Nurlu, Kesgin, & Barut, 2015)

Fragmentation of the landscape is the result of dynamic interactions between policies, ecosystem geophysical features and socio-economic growth factors. (Munroe, Croissant, & York, 2005). There are a variety of ecological consequences of habitat fragmentation caused by transportation infrastructure and urban areas, (*Figure 1*). Such impacts are seen on land use/cover, local environment, pollution, water, flora and fauna, landscape scenery. The effects of landscape fragmentation on land usage/cover are increased accessibility of human beings by highways, traffic and urban planning pressures.

To avoid fragmentation of the landscape and its impacts, it is advantageous to control the degree of landscape fragmentation. The need to use the indicator "landscape fragmentation" in surveillance systems for sustainable growth, biodiversity and landscape is therefore increasing. (Nurlu, Kesgin, & Barut, 2015)

Urban environments are not homogeneous, they have major geographic variations in their demographic, physical and ecosystem functions. Metropolitan areas as described in Neutelings' words (1994) as a *Patchwork Metropolis*. (Wandl, 2017; Wandl, 2017)

Or as Huhlmann & Promski (2007, p. 7) In other words,' the sharp contrast between town and country has melted into an ecological and cultural framework of a constructed system between town and landscape'. (Wandl, 2017)

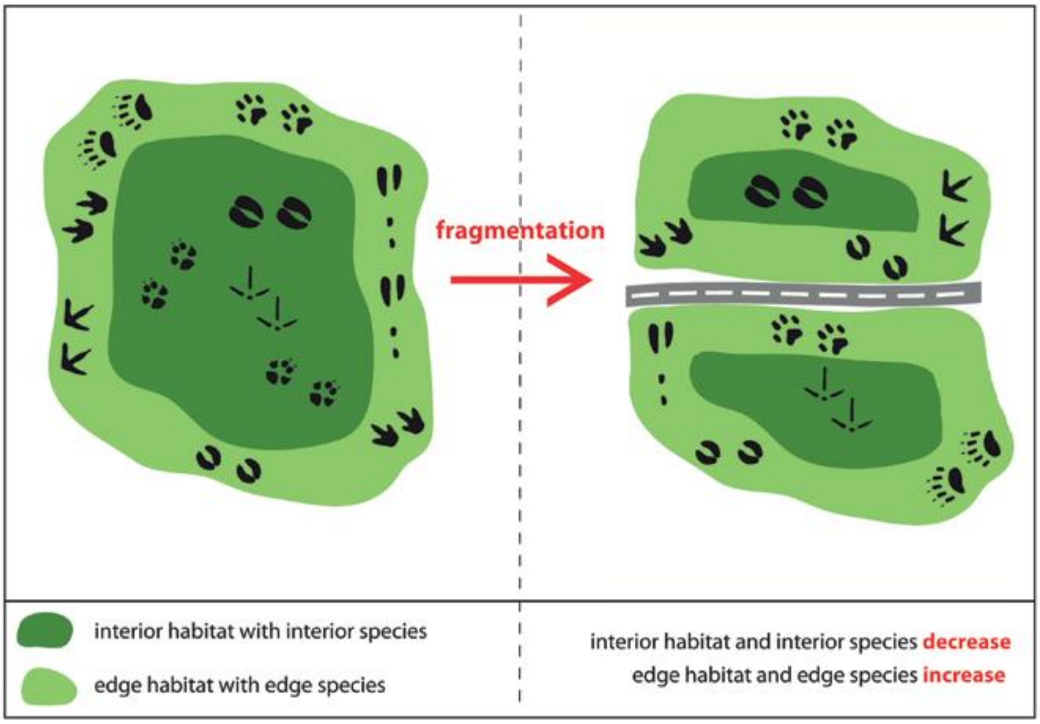


Figure 1 Illustration of the loss of core habitat (or interior habitat) caused by road construction cutting through a patch of habitat (EEA, 2011)

2.2 Habitat fragmentation

Natural habitat fragmentation is typically a product of the expansion of land use that follows human population development. If fragmentation occurs, the average size of fragments and the overall fragment area decreases and fragment insularity increases. (Moore 1962; Burgess & Sharpe 1981) (Luque, Paganini, Vogt, & Szantoi, 2017)

One of the important environmental issue today is habitat fragmentation. When the continuous forest landscape is split into large numbers of smaller land areas, fragmentation occurs. This tiny patches of previously continuous forest are separated by matrix regions from each other. (Jadav)

Changes in the microclimate in and around the fragmented region are the main consequence of habitat fragmentation, contributing to changes in biotic relationships and ecosystem functioning. Changes in population size, forest composition, landscape trend adjustments, species migration, seed dispersal are several immediate changes following fragmentation.

Analysis of habitat fragmentation by landscape metrics enables the study of a mechanism in which contiguous ecosystems are increasingly subdivided into smaller, more geometrically complex areas. (McGarigal, McComb, Cervelli, Pindozzi, & di Perta, 1999, 2020)

Effective mesh size analysis follows a practical measure to determine the effect on habitat fragmentation and accessibility of future transport initiatives. (Cervelli S. P., 2020)

2.3 Fragmentation geometries

Fragmentation of the landscape is caused by several different elements of fragmentation. In order to measure the fragmentation of the landscape, it is first important to define which landscape components are significant to the ecological process or organism influenced by fragmentation. (Gontier et al., 2006).

The specific selection of fragmenting elements determines the so-called "fragmentation geometry." Fragmentation Geometry (FG) is a collection of different types of barriers that are considered important to the landscape. (Nurlu, Kesgin, & Barut, 2015)

Related fragmenting elements that characterize fragmentation geometries include but are not limited to: highways, railroads, urban growth areas, industrial zones and agricultural fields. Broad rivers and other bodies of water and high mountains can also serve as barriers to animal movement (Gerlachand Musolf, 2000) and may be used in order to detect the integrated barrier effect of the related natural and anthropogenic elements of the environment. (Girvetz, Thorne, Berry, & Jaeger, 2008)

The four major impacts of highways and traffic that have a negative impact on animal habitats are reducing the volume and quality of habitat; enhancing habitat; mortality from vehicle collisions; restrict access to services on the other side of the road; and subdivide animal groups into smaller and more insecure parts, *(Figure 2)* (Jochen A. G. Jaeger)

Roads also increase human access to wildlife ecosystems and promote the spreading of native species, and meta-population interactions are interrupted by sub-population fragmentation andsolation. (Hanski, 1999)

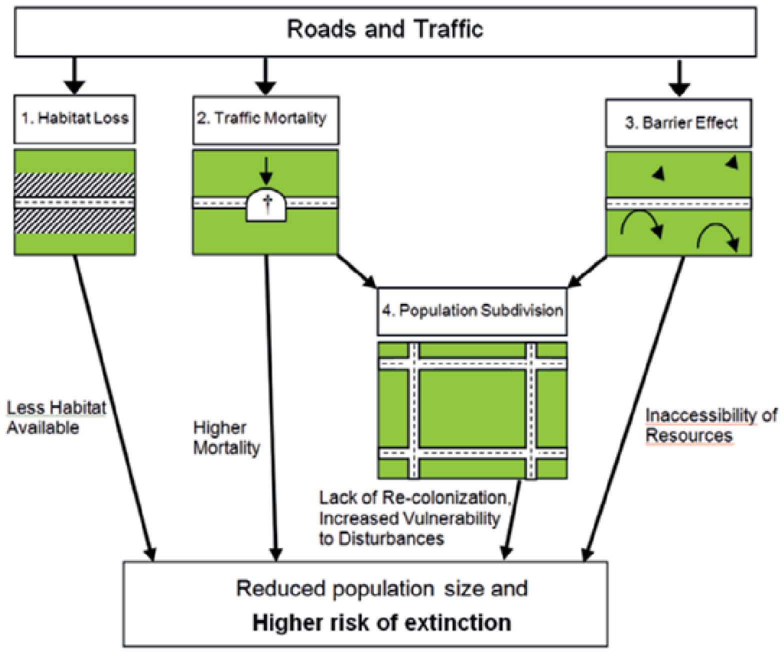


Figure 2 The four main effects of transportation infrastructure on wildlife populations (EEA, 2011)

2.4 Landscape connectivity

Since different organisms are more vulnerable to environmental stress factors, such as natural disruptions (e.g. weather conditions, res, diseases), i.e. less resilience, land division increases the risk for populations to become extinct. A prerequisite for the persistence of animal species is the ability for two animals of the same genus to meet each other in the landscape. (Jochen A. G. Jaeger)

Connectivity is an attribute of the landscape, which illustrates the relationship between the structure and function of the landscape. Generally speaking, connectivity refers to the degree to which the landscape promotes or prevents the flow of energy, materials, nutrients, species, and people through the landscape. (Ahern, 2007)

Connectivity is an emergency attribute of landscapes, produced by the interaction of the structure and function of the landscape, such as: water flow, nutrient cycling, and maintenance of biodiversity. (Leitão, Miller, Ahern, & McGarigal, 2006)

Connectivity is substantially diminished in highly changed landscapes, particularly in urban contexts, resulting in fragmentation - the separation and isolation of landscape features with major consequences on the environment. Connectivity is required for ecological processes. (Ahern, 2007)

Roads are the most significant obstacle to connection in urban and constructed areas, and they are the major cause of fragmentation. (Forman T.T, et al., 2003)

As a conservation strategy to address the detrimental impacts of biodiversity degradation, fragmentation, and climate change, landscape connectivity is continually encouraged. In view of its significance as a crucial environmental technique, connectivity research is an increasingly growing discipline. However, most landscape connectivity models assume connectivity to be a single snapshot in time, ignoring the common awareness that ecosystems and ecological processes are complex.

Since ecosystems are rapidly evolving across scales, connectivity cannot be uniformly extended over time for a single instance; thus, integrating dynamics into connectivity modeling has the potential to result in a more practical and precise connectivity understanding.

Dynamism is a key component of connectivity and an important part of connectivity research for the future. Connectivity is becoming a crucial conservation technique to preserve biodiversity, amid widespread habitat destruction, land-use transition, and fragmentation, and models are needed that better represent the natural world's intrinsic dynamism (Zeller, Lewsion, Fletcher, Tulbure, & Jennings, 2020)

2.5 Landscape fragmentation assessment methods and materials

2.5.1 Methods

Various metrics were used by researchers to measure landscape fragmentation. A method which was introduced by Jaeger is the one of effective mesh size and effective mesh density. This methodology was used in researches on landscape fragmentation in Europe because it has many benefits over most other metrics. (Jochen A. G. Jaeger).

This method has its benefits for its simplicity in mathematics and innate understanding while being an area that is proportionately significant (that means it is independent of the size of the region investigated). Effective mesh size represents the chance that certain two points randomly picked in a region are linked; that is, not divided by obstacles such as transport networks or built-up areas, illustrated in (*Figure 3*) (Jaeger, 2000). The lower the barriers that fragment the terrain, the higher the chance of two points being connected (and the lower the meff). (Canedoli, Crocco, & Comoll, 2017).

The effective mesh size has been commonly applied by different countries as a measure for environmental monitoring. A tool for evaluating and monitoring the biodiversity status of cities and offering insights into how to enhance conservation efforts was created, called the City Biodiversity Index (CBI), or the Singapore Index. (Deslauriers M. R., Asgary, Nazarnia, & Jaeger, 2017).

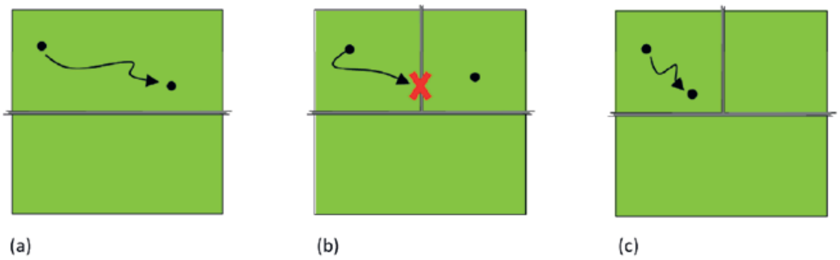


Figure 3 Illustration of the basic idea of the effective mesh size metric (EEA, 2011)

The index consists of 23 indicators, identified as 'native biodiversity in the city; ecosystem services provided by native biodiversity; and native biodiversity governance and management. (Chan, et al., 2014). Connectivity is defined as the degree to which landscape movement through resource patches is encouraged or impeded and "measured by the probability of movement among all points or resource patching in a landscape" (Deslauriers M. , Asgary, Nazarnia, & Jaeger, 2016).

The preservation or establishment of greenways, also known as 'green' infrastructure, consisting of a number of interconnected natural areas is a common method for improving city connectivity. Greenways may enhance survival rates between different species groups by allowing movements within and between ecosystems within urban infrastructure. (Deslauriers M. , Asgary, Nazarnia, & Jaeger, 2016).

To achieve accurate results without compromising practicality in the implementation of the metric, it is suggested to strengthen the previous approach used for the CBI to measure connectivity. The effective mesh size method is used in this version of Indicator 2 (Jaeger, 2000). The intra-patch and inter- patch connectivity is included in the improved method, which is easy to calculate.

$IND2_{CBI\_prev}$ =Total area of natural areas that are connected

(≤100 m apart)/Total area of natural areas

The formula expresses a percentage of connectivity and is easy to calculate. However, since they are situated less than 100 m apart, it does not take in account boundaries between patches of natural areas. The formula does not even take into consideration the intra-patch connectivity in the and therefore lacks the movements of organisms through patches.

In $IND2_{CBI\_prev}$ patches are recognized connected if they are 100 meters or less apart located and if the significant barriers among patches are not identified. The results for $IND2_{CBI\_impr}$ is also used to calculate and compare connectivity around cities and within cities for particular geographical areas. (Deslauriers M. , Asgary, Nazarnia, & Jaeger, 2016)

$$IND2_{CBI\_impr} = 1/A_{total} (A^2_{G1} + A^2_{G2} + A^2_{G3} + . . . + A^2_{Gn})$$

A_{total} corresponds to the total area of a landscape of all natural area patches instead of to the total area of the landscape itself. For this reason, $IND2_{CBI\_impr}$ measures in its entirety the connectivity of natural environments instead of the connectivity of landscapes.

FRAGSTATS provides a broad variety of landscape measurements and was developed to be as adaptable as possible. Over the past three decades, technical advancements in remote sensing and geographic information systems have continued to advance the availability and interpretation of geospatial data, however it may be claimed that the introduction of the FRAGSTATS software analysis package nearly 20 years ago helped to revolutionize landscape structure study and firmly entrench landscape pattern. Many of the original FRAGSTATS metrics have been implemented by other commonly used standalone and GIS-integrated landscape analysis applications. Landscape metrics are quantitative indices that use data from maps, remotely sensed images, and GIS coverages to define the compositional and spatial dimensions of landscapes. (Kupfer, 2012)

FragScape is a plugin for QGIS 3. Its aim is to quantify the landscape fragmentation metrics defined by Jaeger (Jaeger, 2000). The effective mesh size is one of these metrics that has been commonly used to measure landscape fragmentation. FragScape defines a 4-step process of raw data for computed metrics and allows the user to save the configuration so that the results can be reproduced with the same context, *Table 1*.

FragScape establishes a four-step raw data processing procedure for computed measurements and requires the user to save the setup so that the effects can be repeated in the same context.

Table 1. Representative landscape metrics calculated by FRAGSTATS v3.3

FRAGSTATS METRICS	PATCH	CLASS	LANDSCAPE
Area/Density/Edge	Patch Area	Percentage of Landscape	Number of Patches/Patch Density
	Patch Perimeter	Number of Patches/Patch Density	Total Edge/Edge Density
	Radius of Gyration	Total Edge/Edge Density	Landscape Shape Index
		Landscape Shape Index	Largest Patch Index
		Largest Patch Index	Patch Area Distribution
		Patch Area Distribution	Radius of Gyration Distribution
		Radius of Gyration Distribution	
Shape	Perimeter-Area Ratio	Perimeter-Area Fractal Dimension	Perimeter-Area Fractal Dimension
	Shape Index/Fractal Dimension	Perimeter-Area Ratio Distribution	Perimeter-Area Ratio Distribution
	Index	Shape Index/Fractal Index Distribution	Shape Index/Fractal Index Distribution
	Linearity Index	Linearity Index Distribution	Linearity Index Distribution
	Related Circumscribing Circle	Contiguity Index Distribution	Contiguity Index Distribution
	Contiguity Index		
Core Area	Core Area	Total Core Area	Total Core Area
	Number of Core Areas	Number/Density of Disjunct Core Areas	Number/Density of Disjunct Core Areas
	Core Area Index	Core Area Distribution	Core Area Distribution
	Average Depth Index	Disjunct Core Area Distribution	Disjunct Core Area Distribution
	Maximum Depth Index	Core Area Index Distribution	Core Area Index Distribution
Isolation/Proximity	Proximity Index	Proximity Index Distribution	Proximity Index Distribution
	Similarity Index	Similarity Index Distribution	Similarity Index Distribution
	Euclidean Nearest Neighbor	Euclidean Nearest Neighbor Distance	Euclidean Nearest Neighbor Distance
	Distance	Distribution	Distribution
	Functional Nearest Neighbor	Functional Nearest Neighbor Distance	Functional Nearest Neighbor Distance
	Distance	Distribution	Distribution

Table 1. (Continued)

FRAGSTATS METRICS	PATCH	CLASS	LANDSCAPE
Contrast	Edge Contrast Index	Contrast-Weighted Edge Density	Contrast-Weighted Edge Density
		Total Edge Contrast Index	Total Edge Contrast Index
		Edge Contrast Index Distribution	Edge Contrast Index Distribution
Contagion/ Interspersion		Percentage of Like Adjacencies	Percentage of Like Adjacencies
		Aggregation Index	Contagion
		Interspersion and Juxtaposition Index	Aggregation Index
		Mass Fractal Dimension	Interspersion and Juxtaposition Index Landscape
		Landscape Division Index Splitting Index	Splitting Index
		Effective Mesh Size	Effective Mesh Size
Connectivity		Patch Cohesion Index	Patch Cohesion Index
		Connectance Index	Connectance Index
		Traversability Index	Traversability Index
Diversity			Patch Richness/Patch Richness Density
			Relative Patch Richness
			Shannon’s and Simpson’s Diversity Indices
			Shannon’s and Simpson’s Diversity Indices

2.5.2 Materials used

There are several materials, software maps and datas that can be used for analyzing landscape fragmentation. The mapping performed using ArcGIS software (version 10.0, ESRI Inc.) is one of the common used. As input information, used a land-use map and data on resident population, the cartographic database. (Canedoli, Crocco, & Comoll, 2017)

Corine Land cover is another data package which offers a trans-national definition and framework for the selection and assessment of land cover and improvements therein. This pan-European method of data collection, based on geographical information compiled via satellite, is based on. The CORINE is intended to put together all the various contributions made over the years at different levels (international, Community, national and regional) to collect more environmental knowledge and how it is evolving. GIS software were used also. (Cervelli S. P., 2020)

QGIS serves as geographic information system (GIS) applications, allowing users to evaluate and edit spatial information, in order to create and export graphical maps. A 1:25 000 scale GIS dataset of four different time spans of urbanized and transport network layers extracted from LANDSAT 5 TM photos, using a monitored classification technique according to the CORINE Land Cover Classification (LCC). (Nurlu, Kesgin, & Barut, 2015)

Metropolitan areas are the fastest growing landscaping areas. It is also crucial to provide reliable and appropriate knowledge on the progress and improvements of LU/LC in these rapidly changing regions. (Micek, Feranec, & Stych, 2020)

In the framework of the Copernicus programme, a significant LU/LC urban-driven database was developed which is known as the Urban Atlas (UA). In recent years, UA data has been a major source of knowledge for LU/LC studies in urban areas.

The Urban Atlas provides high-resolution data for land use based on exactly the same limitations as the Urban Audit for its broader urban area

CHAPTER 3

METHODOLOGY

3.1 Method used in this study

The method of the effective mesh size (meff) is applied to quantify/measure LF in this study. Among other methods we choose meff because it has benefits including its mathematical simplicity and intuitive understanding.

The effective mesh landscape metric (meff) determines the connectivity of the landscape. It indicates that the two randomly selected points in the landscape would be connected and not isolated by barriers such as roads or urban areas. The possibility of the experience is translated to the size of an environment named the effective mesh size. The further barriers in the landscape, the lower the chance of linking the two places, and the lower the effective mesh size. The lower the effective mesh size, the more the landscape becomes fragmented. With an absolutely unfragmented area, the maximal value of the effective mesh size is reached: meff is then the size of the whole area. If an area is separated into equal-size patches, so meff is equal to the size of these patches. (Jochen A. G. Jaeger)

The mapping performed using QGIS 3.10 software, and Urban Atlas dataset. which enables comparison of urban spatial patterns, based on combination of statistical image classification and the visual interpretation of very high resolution of satellite imagery with a minimum mapping unit 0.25 ha. Vector format (every land use entity is a polygon), is used by the database and it has been developed from satellite images of 2006±1 year with a map scale 1:10000. The Urban Atlas collects together thousands of European satellite imagery and offers extensive and cost-effective mapping of large urban areas, including detailed statistics on land cover and use. (Prastacos, Chrysoulakis, & Kochilakis, 2011)

3.2 Materials of the study: Urban Atlas

Urban Atlas provides a high-resolution land use map of urban regions, including 300 European cities with populations of over 100,000 people, for the years

2012 and 2018. According to the Functional Urban Area, each UA product is created over the city and its surrounding (FUA). Corine Land Cover is used to create the UA Land Use/ Land Cover categorization. In total, 27 classes are used to map the Urban Atlas cities, of which 17 are urban classes. The classification of the Urban Atlas is more detailed (4 Levels). With the UA dataset, it is possible to study European cities in several different ways. One method is to quantify the percentage coverage of various forms of land use. By the study of spatial metrics, this may be revealed. Indicators estimated from a patch based representation of the landscape are spatial metrics initially introduced in landscape ecology. (Prastacos, P.; Lagarias, A.; Chrysoulakis, N., 2017)

20 separate land use divisions are identified in the Urban Atlas land use classification scheme, 17 are 'artificial surfaces' that is developed/built-up areas and 3 are undeveloped/natural areas, as shown in *Table 2*.

Six classes of artificial surfaces, the 'urban fabric,' define built-up stages, so that they could be used instead of land-use classes as land cover. The 5 different classes for transport (fast transit roads, other roads, railroads, ports and airports) and 6 for other purposes (including industrial, commercial, public, mineral mines, building fields, property, vacant land, green urban areas and recreational/sporting facilities). (Prastacos, Lagarias, & Chrysoulakis, 2017)

According to the UA classification, in this study the UA classes were re-categorized in four major classes shown in *Table 3*: artificial, semi-artificial, semi-natural and natural, therefore to make the comparison easier and clearly understandable.

Table 2. The Urban Atlas nomenclature (Meirich (2008)

Class code	**Nomenclature**
11100	Continuous urban fabric S.L.: >80%
11210	Discontinuous dense urban fabric S.L.: 50-80%
12100	Industrial, commercial, public, military and private units
11220	Discontinuous medium density urban fabric S.L.: 30-530%1
13300	Construction sites
12210	Fast transit roads and associated land
12220	Other roads and associated land
12230	Railways and associated land
12300	Port areas
12400	Airports
11230	Discontinuous low density urban fabric S.L.: 10-30%
11240	Discontinuous very low density urban fabric S.L.: <10%
11300	Isolated structures
13100	Mineral extraction and dump sites
13400	Land without current use
14200	Sports and leisure facilities
21000	Arable land(annual crops)
22000	Permanent crops (vineyards, fruit trees, olive groves)
24000	Complex and mixed cultivation patterns
14100	Green urban areas
23000	Pastures
31000	Forests
32000	Herbaceous veg. associations (natural g\rassland, moors...)
33000	Open spaces with little or no veg. (beaches, dunes, bare rocks)
40000	Wetlands
50000	Water

Table 3. Reclassification in 4 main categories

Reclassification	**Nomenclature**
ARTIFICIAL	11100 Continuous urban fabric S.L.: >80%
	11210 Discontinuous dense urban fabric S.L.: 50-80%
	12100 Industrial, commercial, public, military and private units
	11220 Discontinuous medium density urban fabric S.L.: 30-530%1
	13300 Construction sites
	12210 Fast transit roads and associated land
	12220 Other roads and associated land
	12230 Railways and associated land
	12300 Port areas
	12400 Airports
SEMI-ARTIFICIAL	11230 Discontinuous low density urban fabric S.L.: 10-30%
	11240 Discontinuous very low density urban fabric S.L.: <10%
	11300 Isolated structures
	13100 Mineral extraction and dump sites
SEMI-NATURAL	13400 Land without current use
	14200 Sports and leisure facilities
	21000 Arable land(annual crops)
	22000 Permanent crops (vineyards, fruit trees, olive groves)
	24000 Complex and mixed cultivation patterns
NATURAL	14100 Green urban areas
	23000 Pastures
	31000 Forests
	32000 Herbaceous veg. associations (natural g\rassland, moors...)
	33000 Open spaces with little or no veg. (beaches, dunes, bare rocks)
	40000 Wetlands
	50000 Water

3.3 Spatial Metrics

Spatial metrics are used to describe landscape indices which can be used to compare the structures of different cities. The spatial metric analysis of urban environments has become increasingly relevant over the last ten years, to investigate specific intra and intercity systemic spatial elements and the dynamics of development. (Prastacos,, Chrysoulakis, & Kochilakis, 2011)

Spatial metrics are factors that assess the patterns of land usage in urban areas. They are classified as mathematical expressions of patch features, such as field, perimeter, geometries (form), urban relativity and others. Class metrics are measured using the study of patches of the same land use class and thereby define class characteristics. Patches in all land use classes are determined by analysis and thus a feature of land use trends in the entire urban area are represented with one indicator. (Prastacos, Lagarias, & Chrysoulakis, 2017)

CLC data are applied as a medium for assessing landscape fragmentation. During the first two layers of the LF assessment, OSM open source data offers the primary spatial information about road network geometry, which are the primary fragmenting agents (FG1 and FG2). (Hasa, Hysa, & Teqja, 2021)

The 1st phase of the study consist on general statistical analysis of regional metropolitan area, where the total area and count of patches is calculated.

Continuing in the 2nd phase with the reclassification of the UA classes into 4 main categories, where the focus now is periurban and urban zone of each city, where is calculated again the total area and count of patches.

In the 3rd phase *meff* is calculated and the focus is Tirana's urban area,

3.4 Study Area

This study is focused in analyzing the landscape fragmentation dynamics of Tirana, central region of Albania comparing with three other cities in Balkan regions such Skopje, and Sarajevo, to find the dynamic between fragmented areas and less fragmented ones. The study represents a comparative study of metropolitan regions in Western Balkan nations.

The chosen cities (*Figure 4*) are the capitals of Albania, Macedonia and Bosnia Herzegovina. Each selected city has in common lot of similarities and differences, characterized by social, economic, and geophysical factors, since they all are part of Western Balkan countries.

Tirana is the capital and the main city of the Republic of Albania by area and population. It is situated at the middle of Albania, with the mountains and hills of Mount Dajt on the east and a narrow valley in the northwest that provides an endless view of the Adriatic Sea.

Following governmental changes in 1991, Tirana, Albania's capital city, increased exponentially in size and population. The city's accelerated growth, heavy traffic, and booming construction of stores, homes, and squatter communities.

Demographic data indicates that Tirana’s population in 2021 is expected to be 502,734. Since 2015, Tirana has increased by 9022.

Tirana city and the nearby metropolitan area is a typical and complex example of a constantly changing city, with mixed institutions and historical events. Tirana is a representation of a metropolitan society between mountains and the sea. It is one of Europe's most diverse cities, and it clearly portrays a region in the middle of a normal and prolonged transformation, which is still the most challenging and dramatic problem of our time. (Aliaj, Lulo, & Myftiu, 2003)

Tirana is located in the center of Albania, between the Dajti Mountain in the east, the Krrabe, Sauk, and Vaqarr hills in the south, and a valley in the north that overlooks the Adriatic Sea. Around 110 meters above sea level is the average altitude, with a peak of 1,828 meters.

While, Skopje is home to almost a third of the population of the country. The current population is 600,708, population of Skopje has risen by 5433, since 2015.

Skopje situated in the country's northwestern corner, in the heart of the Balkan peninsula, and roughly midway between Belgrade and Athens. The City of Skopje spans for more over 33 kilometers inside its administrative boundaries, yet it is just 10 kilometers wide. Skopje is around 245 meters above sea level and covers 571.46 square kilometers. The urbanized area is just 337 km2, with a population density of 65 inhabitants per hectare.

In the other hand Sarajevo is the capital and the most populous city of the country. The population of the city boundaries is just over 275,000 people, according to current statistics. When the entire metropolitan region is considered, however, the number increases to over 555,000 inhabitants.

The city is surrounded by dense forest hills and mountains, covering 142 km2 and located at 500 meters above sea level.

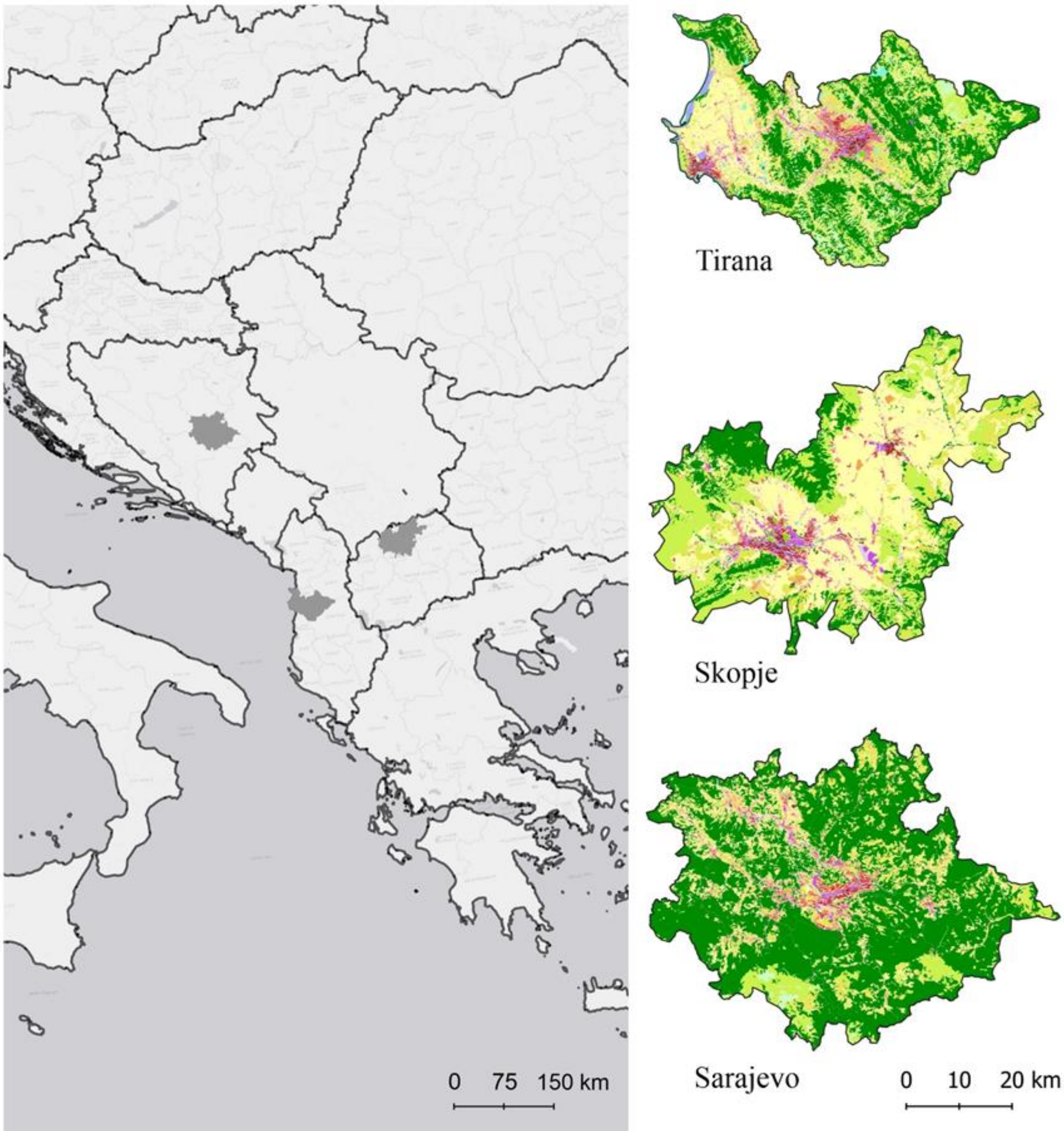


Figure 4 Study area of Tirana, Skopje and Sarajevo

3.5 Workflow

After generating maps from Urban Atlas 2012 and 2018 for each study area, the study is divided into 3 phases of analysis. *(Figure 5).* The 1st phase consist on general statistical analysis of regional metropolitan area of the 3 cities comparing between years.

Continuing in the 2nd phase with the reclassification of the UA classes into 4 main categories, where the focus now is periurban and urban zone of each city and comparative statistical analysis according to these 4 main categories

In the 3rd phase the focus is Tirana's urban area, where a buffer of 100m is applied firstly and only natural areas are selected to be analyzed, by adding them different buffers such, 4m, 8m, 16m and 32m, which are illustrated in (*Figure 6)* where is taken in consideration that the standard road width is 3.65m.

After this, the formula of effective mesh size (meff) is applied to measure the LF only for Tirana City.

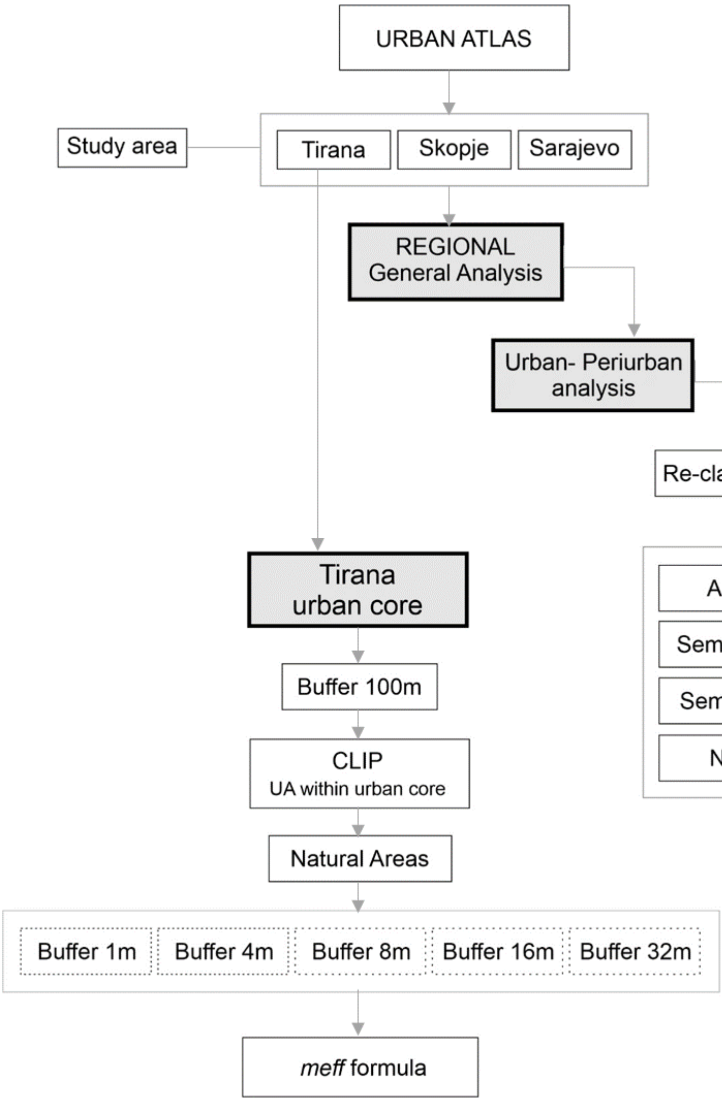


Figure 5 The workflow of the method applied

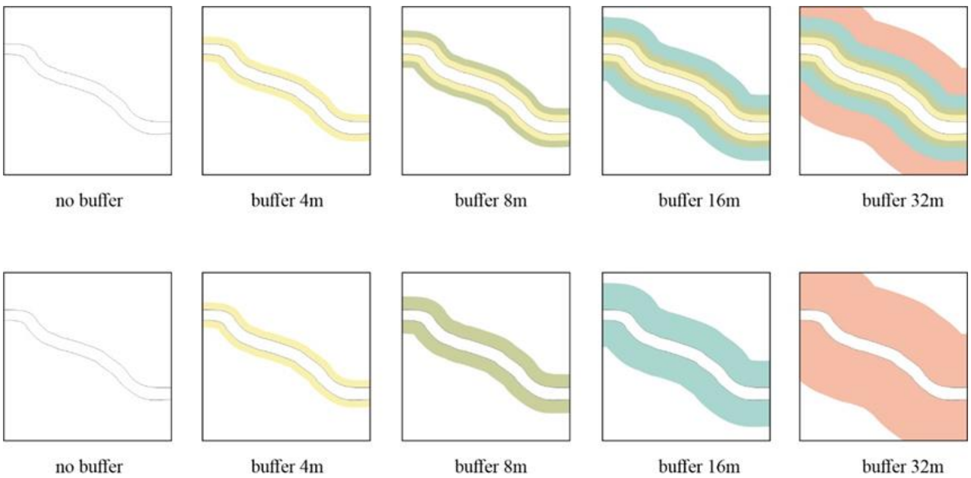


Figure 6 Illustration of buffer zones, where road width is 3.65m

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 First Phase

In this study, the Landscape Fragmentation assessment and comparative spatio-temporal analysis of landscape dynamics is completed using QGIS 3.10 software and is divided into 3 phases; general statistical analysis of regional metropolitan area by the distribution of each Urban Atlas classes, for the selected city, comparing them between 2012-2018 years, showing the differences of these years focusing in periurban and urban area of each city and then calculation of effective mesh size *meff* for Tirana city

In this phase statistical comparison is calculated according to sum and count of patches and total area for each category. In the case of Tirana, shown also in the charts *(Figure 7,8)* forests have the highest percentage value 36.83% in 2012 and 36.7% in 2018, as total area, while as number of geometries forests have a percentage of 4.72% in 2012 and 4.67% in 2018, which means that forests areas have large geometries and they are connected. As count of patches the highest value has pastures 14.26% in 2012 and 14.12% in 2018.

Railways and associated land have the lowest value 0.05% as total area in both 2012 and 2018, followed by sport and leisure facilities 0.06% in 2012 and an increasing value in 2018 0.09%, while also as number of geometries they have the lowest values.

According to the comparison 2018-2012 *(Figure 9)* we have highest value increasing by 0.22% in industrial, commercial, public, military and private units, followed by construction sites with 0.09% and decreasing values for arable land, pastures and forests. In *Table 4* are shown in detail the results for each class.

Therefore, in Skopje the highest values for total area are in agricultural areas, where the highest is arable land 37.24% in 2012 and 36.85% in 2018 followed by herbaceous vegetation associations and forests. And lowest values are for complex and mixed cultivation patterns and construction sites.

While as count of patches the highest value has discontinuous very low density urban fabric S.L.: <10% with 20.29% in 2012 and 20.6% in 2018. And lowest values have complex and mixed cultivation patterns and wetlands, shown in charts *(Figure 10,11)*

According to the comparison 2018-2012 *(Figure 12)* we have highest value increasing by 0.27% in industrial, commercial, public, military and private units, followed by construction sites with 0.1% and decreasing values for arable land, pastures and forests, same as in the case of Tirana. In *Table 5* are shown in detail the results of total area and count of patch for each class.

In the case of Sarajevo, the highest values for total area are forests 65.2% in 2012 and 65.13% in 2018 followed by pastures and arable land. And lowest values are for construction sites, fast transit roads and associated land and permanent crops for 2012, while for 2018 are permanent crops followed by construction sites, continuous urban fabric S.L.: >80% and railways.

While as count of patches the highest value has discontinuous very low density urban fabric S.L.: <10% with 17.93% in 2012 and 17.91% in 2018. And lowest values have permanent crops, fast transit roads and railways, shown in charts*(Figure 13,14)*

According to the comparison 2018-2012 *(Figure 15)* we have highest value increasing by 0.27% in industrial, commercial, public, military and private units, followed by fast transit roads 0.06% and decreasing values for, pastures, forests and arable land. In *Table 6 are* shown in detail the results of total area and count of patch for each class.

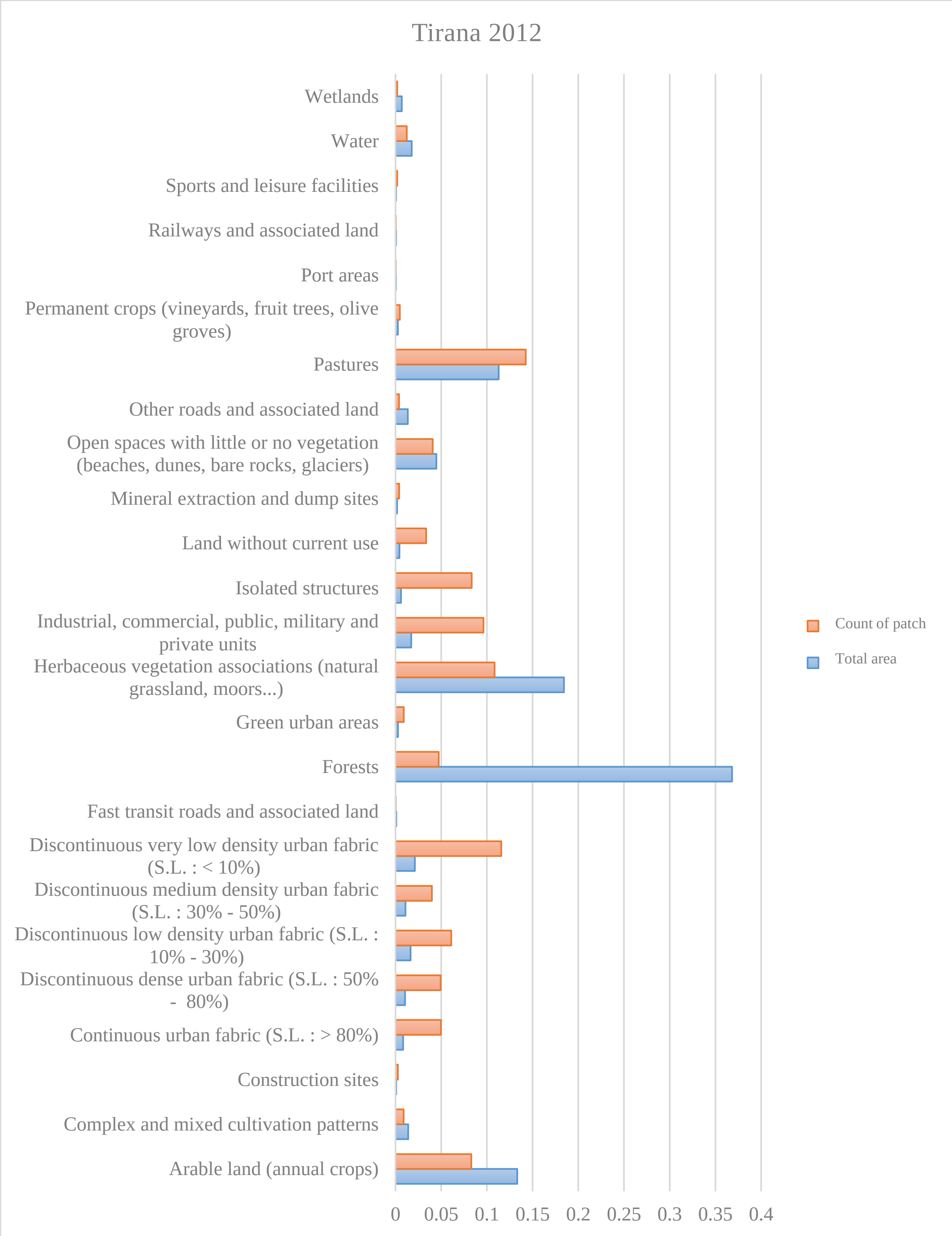


Figure 7 Statistical analysis of count of patches and total area for Tirana 2012

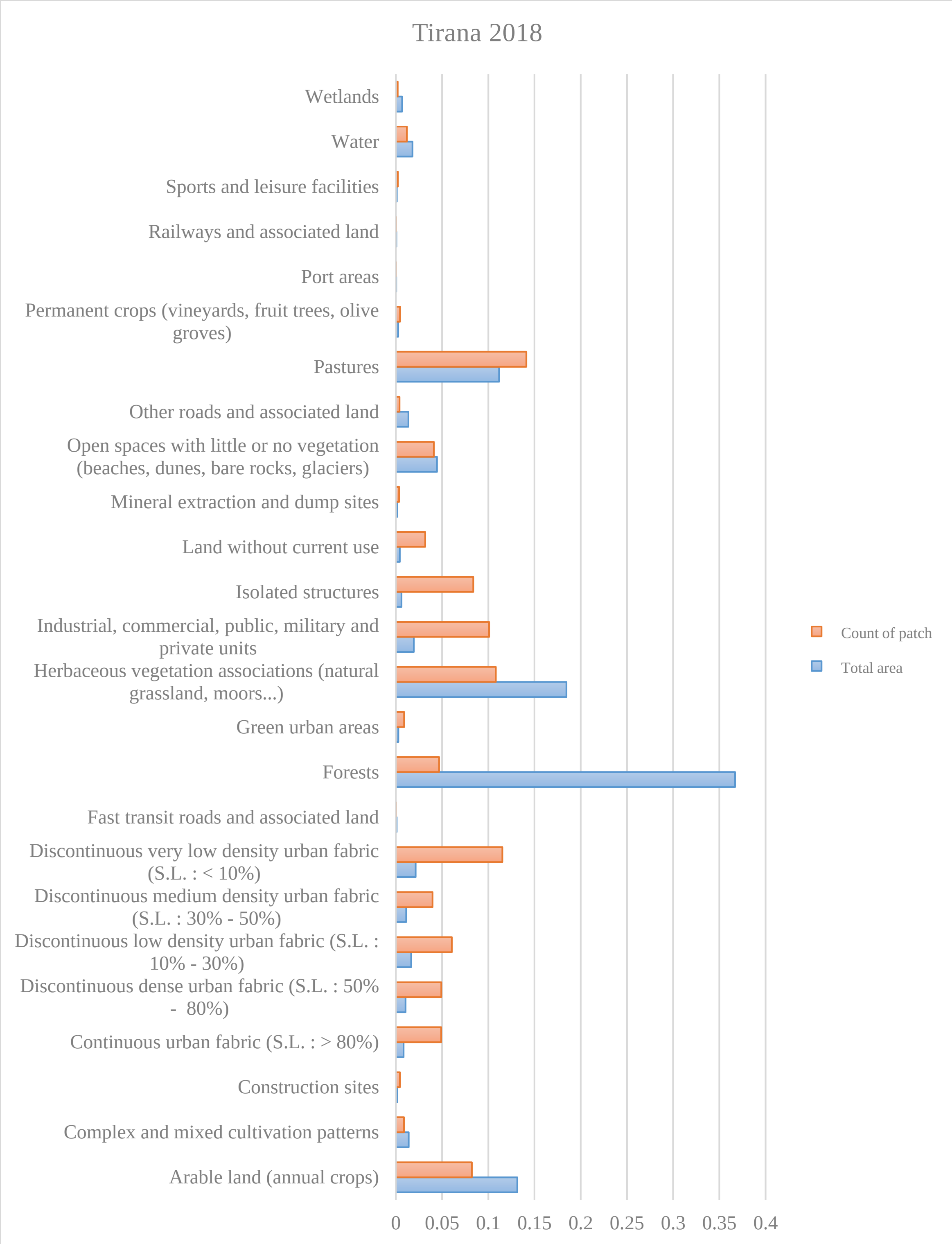


Figure 8 Statistical analysis of count of patches and total area for Tirana 2018

Figure 9 Statistical analysis of difference count of patches and total area for Tirana 2018-2012

Table 4. Total area and Count of patches of Tirana for 2012-2018 and differences, showing 4 highest and 4 lowest values

Classification	Sum of area TR 2012	Sum of area TR 2018	Count of area TR 2012	Count of area TR 2018	Difference sum '18-'12	Difference count '18-'12
11100 Continuous urban fabric S.L.: >80%	0.83%	0.83%	4.97%	4.91%	0.01%	-0.06%
11210 Discontinuous dense urban fabric S.L.: 50-80%	1.04%	1.05%	4.95%	4.92%	0.00%	-0.02%
11220 Discontinuous medium density urban fabric S.L.: 30-50%	1.09%	1.11%	3.98%	3.96%	0.02%	-0.01%
12100 Industrial, commercial, public, military and private units	1.72%	1.94%	9.63%	10.09%	0.22%	0.47%
13300 Construction sites	0.07%	0.16%	0.25%	0.44%	0.09%	0.19%
11230 Discontinuous low density urban fabric S.L.: 10-30%	1.64%	1.66%	6.10%	6.05%	0.02%	-0.05%
11240 Discontinuous very low density urban fabric S.L.: <10%	2.12%	2.14%	11.57%	11.52%	0.03%	-0.05%
11300 Isolated structures	0.60%	0.61%	8.33%	8.38%	0.01%	0.05
13100 Mineral extraction and dump sites	0.18%	0.16%	0.40%	0.35%	-0.02%	-0.05%
12210 Fast transit roads and associated land	0.08%	0.08%	0.01%	0.01%	0.00%	0.00%
12220 Other roads and associated land	1.34%	1.35%	0.39%	0.40%	0.01%	0.01%
12230 Railways and associated land	0.05%	0.05%	0.03%	0.03%	0.00%	0.00%
12300 Port areas	0.05%	0.05%	0.01%	0.00%	0.00%	0.00%
13400 Land without current use	0.43%	0.42%	3.35%	3.17%	-0.01%	-0.18%
14100 Green urban areas	0.27%	0.27%	0.90%	0.89%	0.01%	-0.01
14200 Sports and leisure facilities	0.06%	0.09%	0.18%	0.21%	0.03%	0.02%
21000 Arable land(annual crops)	13.32%	13.14%	8.30%	8.21%	-0.18%	-0.08%
22000 Permanent crops (vineyards, fruit trees, olive groves)	0.25%	0.25%	0.46%	0.46%	0.00%	-0.01%
23000 Pastures	11.29%	11.16%	14.26%	14.12%	-0.13%	-0.13%
24000 Complex and mixed cultivation patterns	1.39%	11.38%	0.89%	0.88%	-0.01%	-0.01%
31000 Forests	36.83%	36.70%	4.72%	4.67%	-0.13%	-0.05%
32000 Herbaceous veg. associations (natural g\rassland, moors...)	18.43%	18.45%	10.85%	10.82%	0.02%	-0.03%
33000 Open spaces with little or no veg. (beaches, dunes, bare rocks)	4.47%	4.45%	4.07%	4.10%	-0.02%	0.04%
40000 Wetlands	0.68%	0.69%	0.18%	0.20%	0.01%	0.02%
50000 Water	1.77%	1.80%	1.22%	1.19%	0.03%	-0.04%

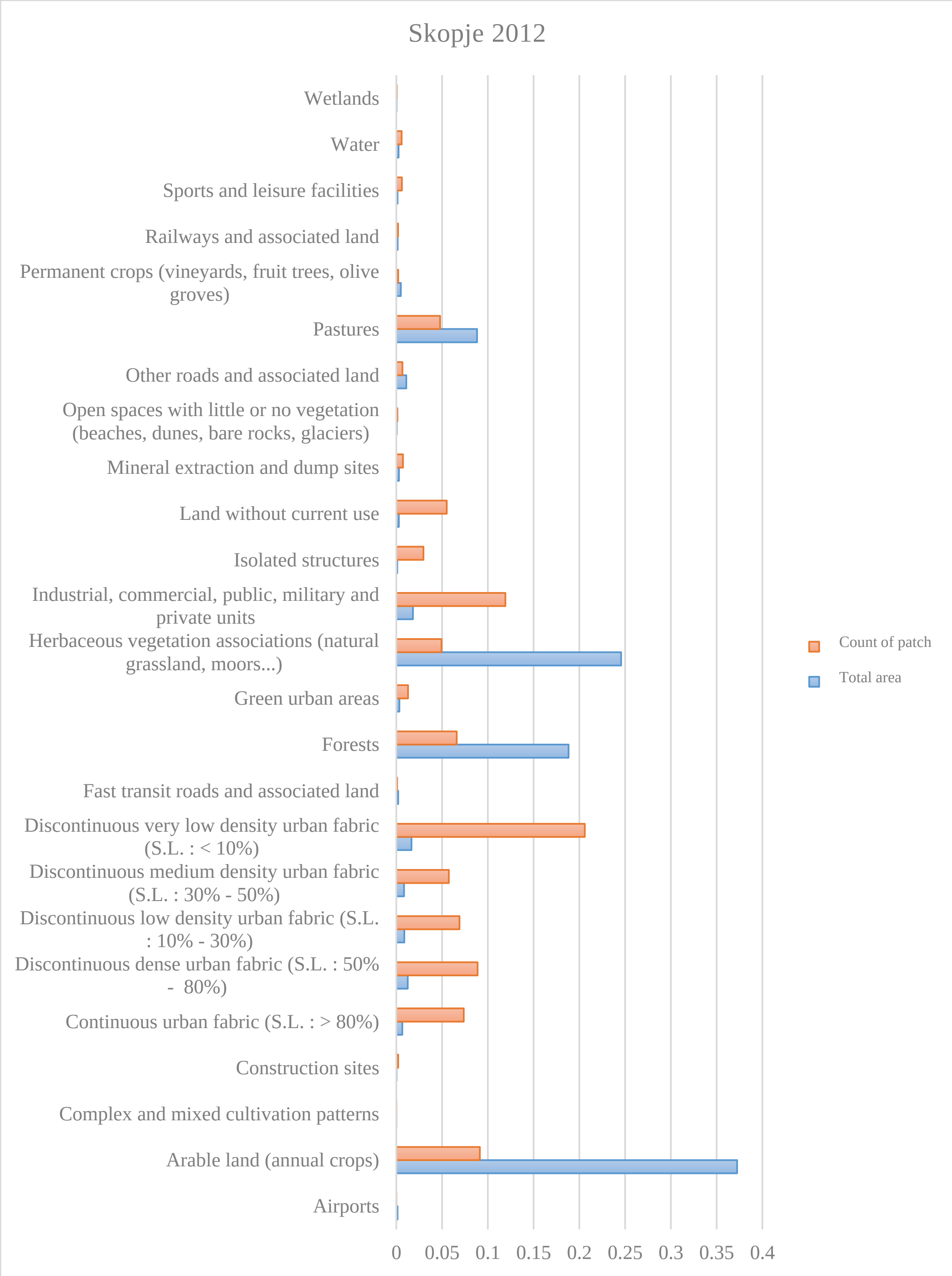


Figure 10 Statistical analysis of count of patches and total area for Skopje 2012

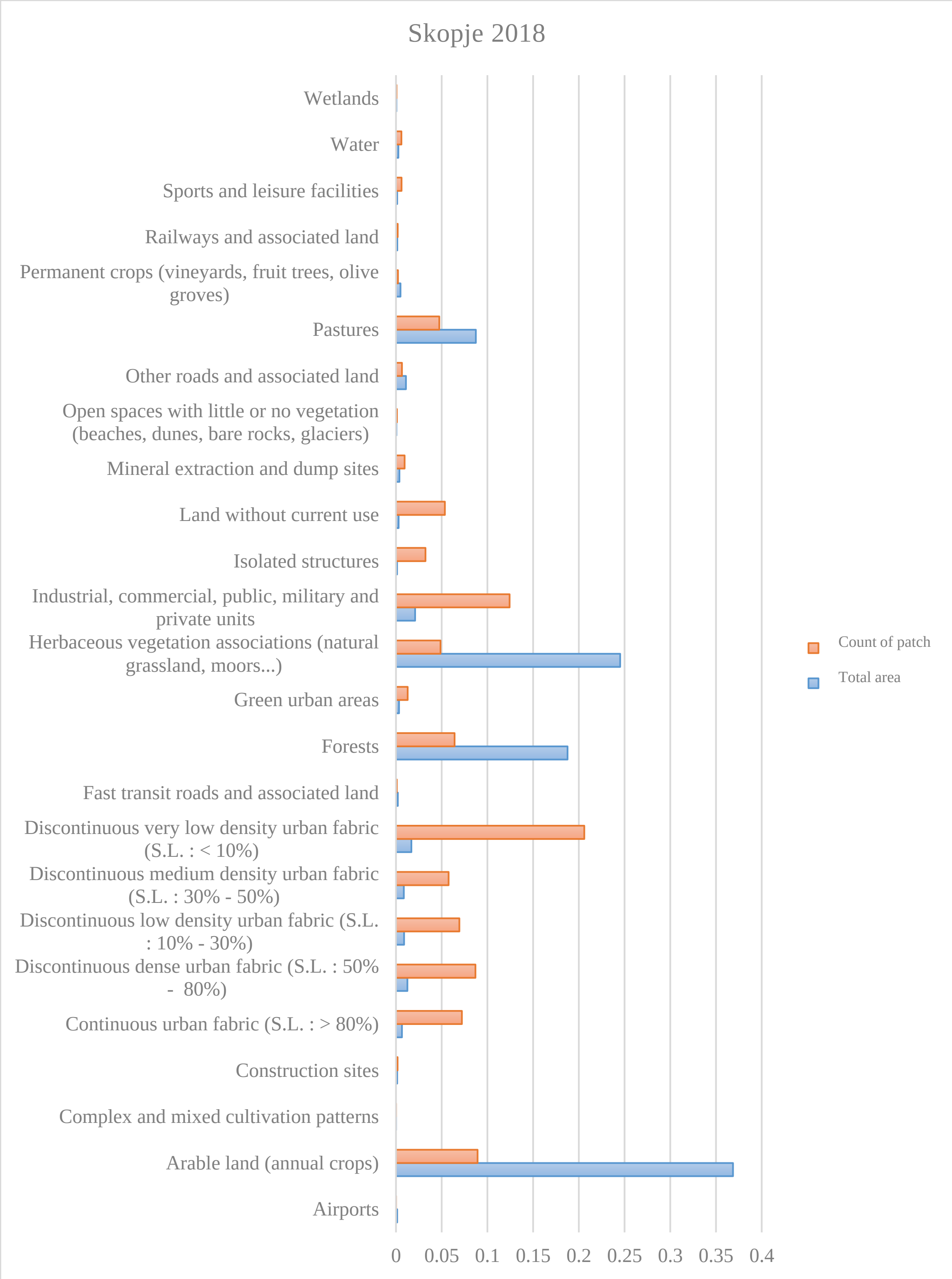


Figure 11 Statistical analysis of count of patches and total area for Skopje 2018

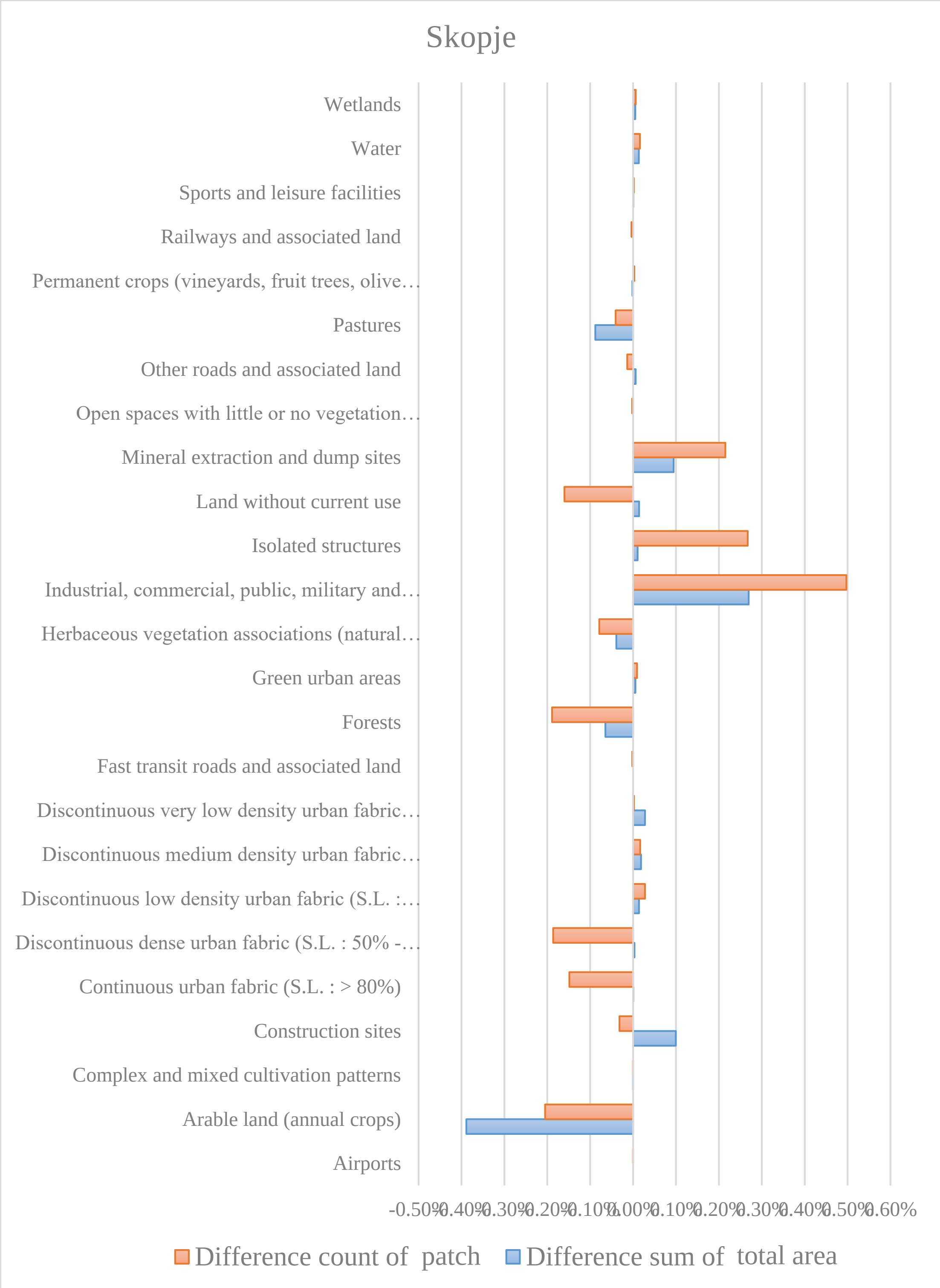


Figure 12 Statistical analysis of difference count of patches and total area for Skopje 2018-2012

Table 5. Total area and Count of patches of Skopje for 2012-2018 and differences, showing 4 highest and 4 lowest values

classification	Sum of area SK 2012	Sum of area SK 2018	Count of area SK 2012	Count of area SK% 2018	Difference sum '18-'12	Difference count '18-'12
11100 Continuous urban fabric S.L.: >80%	0.64%	0.64%	7.36%	7.21%	0.00%	-0.15%
11210 Discontinuous dense urban fabric S.L.: 50-80%	1.25%	1.25%	8.88%	8.69%	0.00%	-0.19%
11220 Discontinuous medium density urban fabric S.L.: 30-50%	0.83%	0.85%	5.73%	5.75%	0.02%	0.02%
12100 Industrial, commercial, public, military and private units	1.81%	2.08%	11.92%	12.42%	0.27%	0.50%
13300 Construction sites	0.02%	0.12%	0.20%	0.17%	0.10%	-0.03%
11230 Discontinuous low density urban fabric S.L.: 10-30%	0.86%	0.88%	6.90%	6.93%	0.01%	0.03%
11240 Discontinuous very low density urban fabric S.L.: <10%	1.66%	1.69%	20.29%	20.60%	0.03%	0.00%
11300 Isolated structures	0.10%	0.12%	2.96%	3.23%	0.01%	0.27%
13100 Mineral extraction and dump sites	0.28%	0.38%	0.72%	0.94%	0.09%	0.22%
12210 Fast transit roads and associated land	0.20%	0.20%	0.09%	0.08%	0.00%	0.00%
12220 Other roads and associated land	1.08%	1.09%	0.67%	0.65%	0.01%	-0.01%
12230 Railways and associated land	0.15%	0.15%	0.19%	0.19%	0.00%	0.00%
12400 Airports	0.12%	0.12%	0.01%	0.01%	0.00%	0.00%
13400 Land without current use	0.28%	0.29%	5.51%	5.35%	0.01%	-0.16%
14100 Green urban areas	0.32%	0.33%	1.27%	1.28%	0.01%	0.01%
14200 Sports and leisure facilities	0.12%	0.12%	0.60%	0.61%	0.00%	0.00%
21000 Arable land(annual crops)	37.24%	36.85%	9.13%	8.92%	-0.39%	-0.21%
22000 Permanent crops (vineyards, fruit trees, olive groves)	0.49%	0.49%	0.21%	0.21%	0.00%	0.00%
23000 Pastures	8.82%	8.74%	4.78%	4.74%	-0.09%	-0.04%
24000 Complex and mixed cultivation patterns	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%
31000 Forests	18.82%	18.75%	6.60%	6.41%	-0.06%	-0.19%
32000 Herbaceous veg. associations (natural g\rassland, moors...)	24.56%	24.52%	4.94%	4.86%	-0.04%	-0.08%
33000 Open spaces with little or no veg. (beaches, dunes, bare rocks)	0.05%	0.05%	0.11%	0.10%	0.00%	0.00%
40000 Wetlands	0.03%	0.04%	0.04%	0.05%	0.01%	0.01%
50000 Water	0.24%	0.25%	0.58%	0.60%	0.01%	0.02%

Figure 13 Statistical analysis of count of patches and total area for Sarajevo 2012

Figure 14 Statistical analysis of count of patches and total area for Sarajevo 2018

Figure 15 Statistical analysis of difference count of patches and total area for Sarajevo 2018-2012

Table 6. Total area and Count of patches of Sarajevo for 2012-2018 and differences, showing 4 highest and 4 lowest values

Classification	Sum of area SA 2012	Sum of area SA 2018	Count of area SA 2012	Count of area SA 2018	Difference sum '18-'12	Difference count '18-'12
11100 Continuous urban fabric S.L.: >80%	0.07%	0.07%	0.84%	0.83%	0.00%	-0.01%
11210 Discontinuous dense urban fabric S.L.: 50-80%	0.63%	0.65%	4.45%	4.43%	0.02%	-0.01%
11220 Discontinuous medium density urban fabric S.L.: 30-50%	0.86%	0.88%	3.89%	3.92%	0.01%	0.03%
12100 Industrial, commercial, public, military and private units	0.94%	1.00%	5.79%	6.18%	0.06%	0.38%
13300 Construction sites	0.04%	0.04%	0.26%	0.25%	0.00%	-0.01%
11230 Discontinuous low density urban fabric S.L.: 10-30%	1.56%	1.58%	8.58%	8.56%	0.02%	-0.02%
11240 Discontinuous very low density urban fabric S.L.: <10%	2.14%	2.17%	17.93%	17.91%	0.03%	-0.01%
11300 Isolated structures	0.33%	0.32%	7.01%	6.83%	0.00%	0.18%
13100 Mineral extraction and dump sites	0.21%	0.22%	0.69%	0.72%	0.01%	0.03%
12210 Fast transit roads and associated land	0.04%	0.09%	0.01%	0.06%	0.06%	0.05%
12220 Other roads and associated land	0.90%	0.90%	0.37%	0.45%	0.01%	0.08%
12230 Railways and associated land	0.07%	0.07%	0.03%	0.03%	0.00%	0.00%
12400 Airports	0.04%	0.04%	0.00%	0.00%	0.00%	0.00%
13400 Land without current use	0.09%	0.11%	1.54%	1.62%	0.02%	0.08%
14100 Green urban areas	0.22%	0.22%	1.84%	1.84%	0.00%	0.00%
14200 Sports and leisure facilities	0.08%	0.08%	0.41%	0.43%	0.00%	0.02%
21000 Arable land(annual crops)	8.19%	8.14%	17.37%	17.15%	-0.05%	-0.23%
22000 Permanent crops (vineyards, fruit trees, olive groves)	0.03%	0.02%	0.01%	0.02%	0.00%	0.01%
23000 Pastures	11.34%	11.24%	16.09%	15.96%	-0.10%	-0.13%
24000 Complex and mixed cultivation patterns	0.36%	0.36%	0.29%	0.30%	0.00%	0.01%
31000 Forests	65.20%	65.13%	6.15%	6.13%	-0.07%	-0.02%
32000 Herbaceous veg. associations (natural grassland, moors...)	5.85%	5.85%	5.60%	5.56%	0.00%	-0.04%
33000 Open spaces with little or no veg. (beaches, dunes, bare rocks)	0.66%	0.66%	0.29%	0.28%	0.00%	-0.01%
50000 Water	0.16%	0.16%	0.56%	0.56%	0.00%	-0.01%

***Table* 7.** Difference of total area and Count of patches of each city for 2012-2018, showing 4 highest and 4 lowest values

classification	TR Difference sum '18-'12	TR Difference count '18-'12	SK Difference sum '18-'12	SK Difference count '18-'12	SA Difference sum '18-'12	SA Difference count '18-'12
11100 Continuous urban fabric S.L.: >80%	0.01%	-0.06%	0.00%	-0.15%	0.00%	-0.01%
11210 Discontinuous dense urban fabric S.L.: 50-80%	0.00%	-0.02%	0.00%	-0.19%	0.02%	-0.01%
11220 Discontinuous medium density urban fabric S.L.: 30-50%	0.02%	-0.01%	0.02%	0.02%	0.01%	0.03%
12100 Industrial, commercial, public, military and private units	0.22%	0.47%	0.27%	0.50%	0.06%	0.38%
13300 Construction sites	0.09%	0.19%	0.10%	-0.03%	0.00%	-0.01%
11230 Discontinuous low density urban fabric S.L.: 10-30%	0.02%	-0.05%	0.01%	0.03%	0.02%	-0.02%
11240 Discontinuous very low density urban fabric S.L.: <10%	0.03%	-0.05%	0.03%	0.00%	0.03%	-0.01%
11300 Isolated structures	0.01%	0.05	0.01%	0.27%	0.00%	0.18%
13100 Mineral extraction and dump sites	-0.02%	-0.05%	0.09%	0.22%	0.01%	0.03%
12210 Fast transit roads and associated land	0.00%	0.00%	0.00%	0.00%	0.06%	0.05%
12220 Other roads and associated land	0.01%	0.01%	0.01%	-0.01%	0.01%	0.08%
12230 Railways and associated land	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12300 Port areas	0.00%	0.00%				
12400 Airports			0.00%	0.00%	0.00%	0.00%
13400 Land without current use	-0.01%	-0.18%	0.01%	-0.16%	0.02%	0.08%
14100 Green urban areas	0.01%	-0.01	0.01%	0.01%	0.00%	0.00%
14200 Sports and leisure facilities	0.03%	0.02%	0.00%	0.00%	0.00%	0.02%
21000 Arable land(annual crops)	-0.18%	-0.08%	-0.39%	-0.21%	-0.05%	-0.23%
22000 Permanent crops (vineyards, fruit trees, olive groves)	0.00%	-0.01%	0.00%	0.00%	0.00%	0.01%
23000 Pastures	-0.13%	-0.13%	-0.09%	-0.04%	-0.10%	-0.13%
24000 Complex and mixed cultivation patterns	-0.01%	-0.01%	0.00%	0.00%	0.00%	0.01%
31000 Forests	-0.13%	-0.05%	-0.06%	-0.19%	-0.07%	-0.02%
32000 Herbaceous veg. associations (natural grassland, moors...)	0.02%	-0.03%	-0.04%	-0.08%	0.00%	-0.04%
33000 Open spaces with little or no veg. (beaches, dunes, bare rocks)	-0.02%	0.04%	0.00%	0.00%	0.00%	-0.01%
40000 Wetlands	0.01%	0.02%	0.01%	0.01%		
50000 Water	0.03%	-0.04%	0.01%	0.02%	0.00%	-0.01%

4.2 Second Phase

In the 2nd phase the analysis is focused in urban and peri urban area of each city, where we define firstly the urban core and surrounding. Since all three cities are in development, present-day peri urban zones have become intimately bound up with notions of (more) sustainable urbanization and urban development.

In this phase, the study's attention is according to the reclasiffication done, in 4 categories, artificial, semi-artificial, semi-natural and natural.

As seen in *(Figure 19)* the charts show the results for 3 cities, where all have decreasing in natural areas.

In case of Tirana *(Figure 16)* we have an increasing value by 218 ha in semi-natural areas followed by 184 ha in artificial areas, and 9 ha in semi-artificial, and a decreasing value for natural areas by 220 ha.

Skopje also have increasing in artificial and semi-artificial areas by 566 ha and 120 ha respectively. While different from Tirana in Skopje semi-natural areas have a decreasing by 593 ha and natural areas increased by 965 ha, *(Figure 17)*

Sarajevo has the highest decreasing value in natural areas by 250 ha followed semi natural areas by 17 ha and increasing values for artificial and semi-artificial, an increasing by 168 ha and 57 ha shown in *(Figure 18).*

In the (*Figure 20)* are shown the results of 3 cities compared to each other, where it is noticed that Skopje has the highest increasing in artificial areas and highest decreasing in semi-natural and natural areas. The *Table 8* shows in detail the results of each city for 2012-2018 and their difference values.

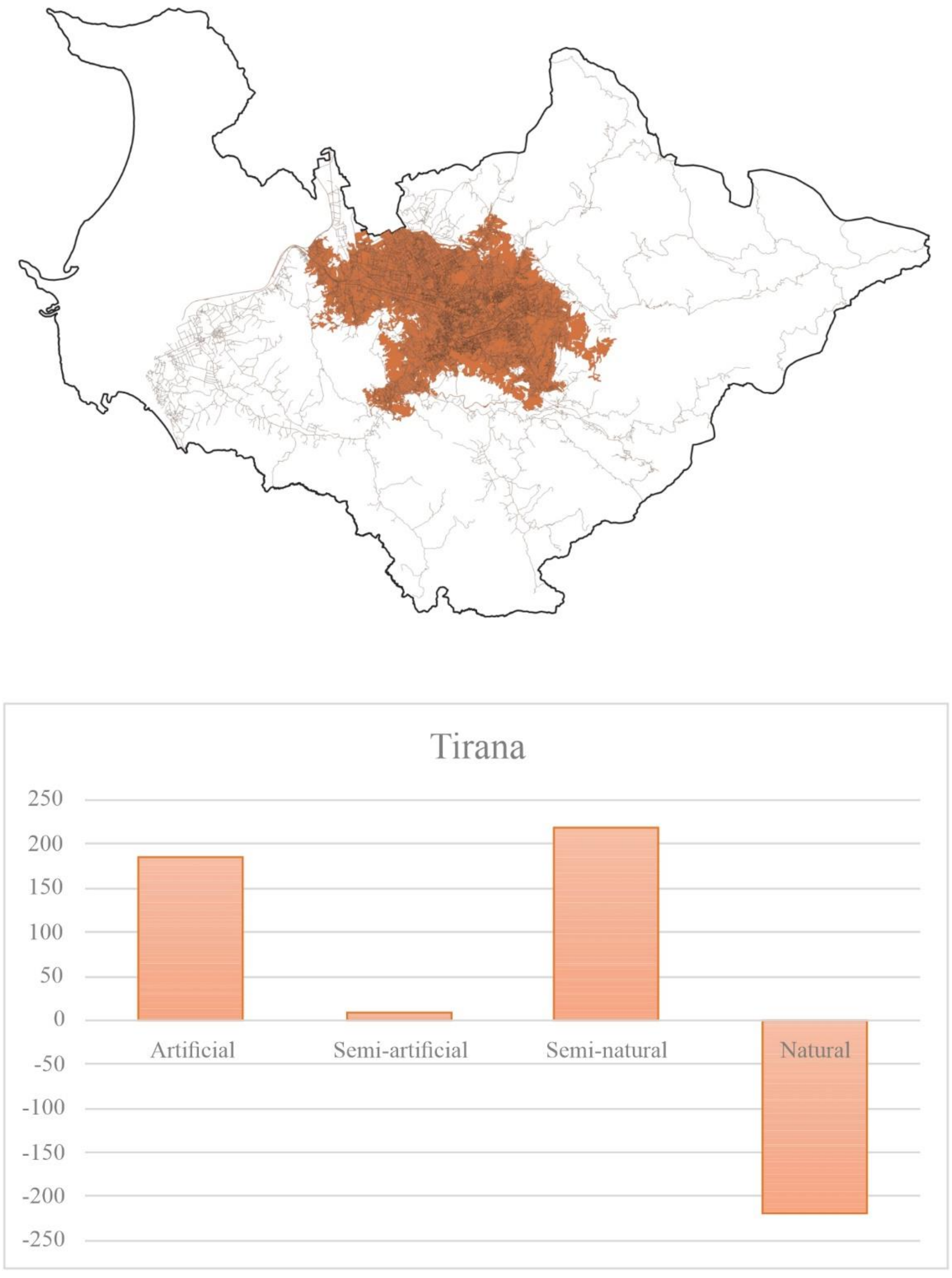
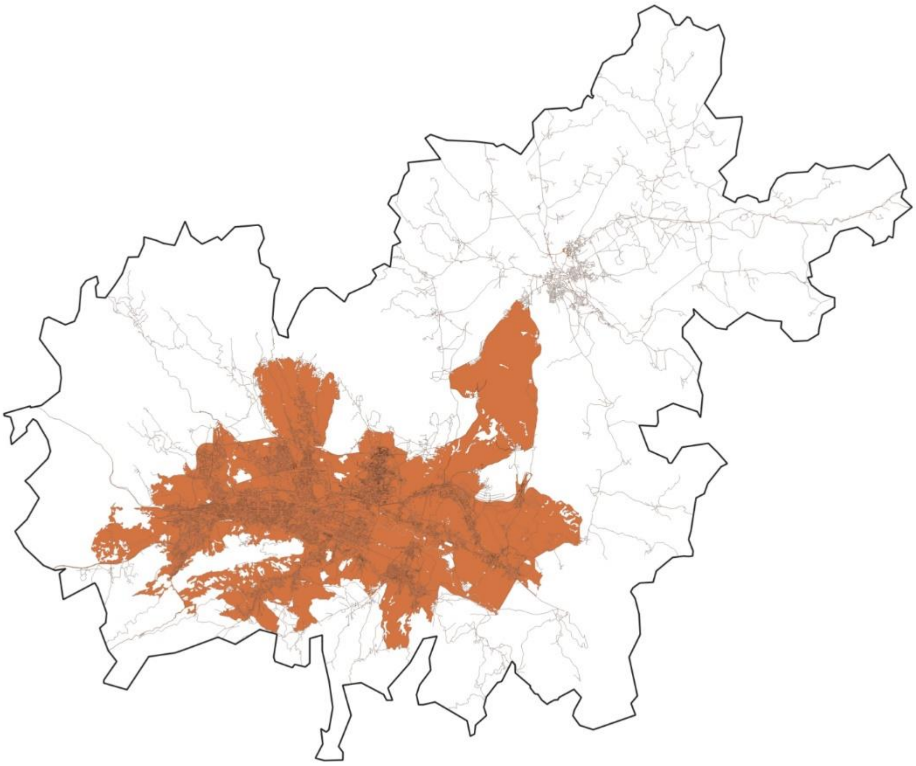


Figure 16 Map defining the urban-periurban boundary for Tirana city and statistical analysis according to 4 main categories



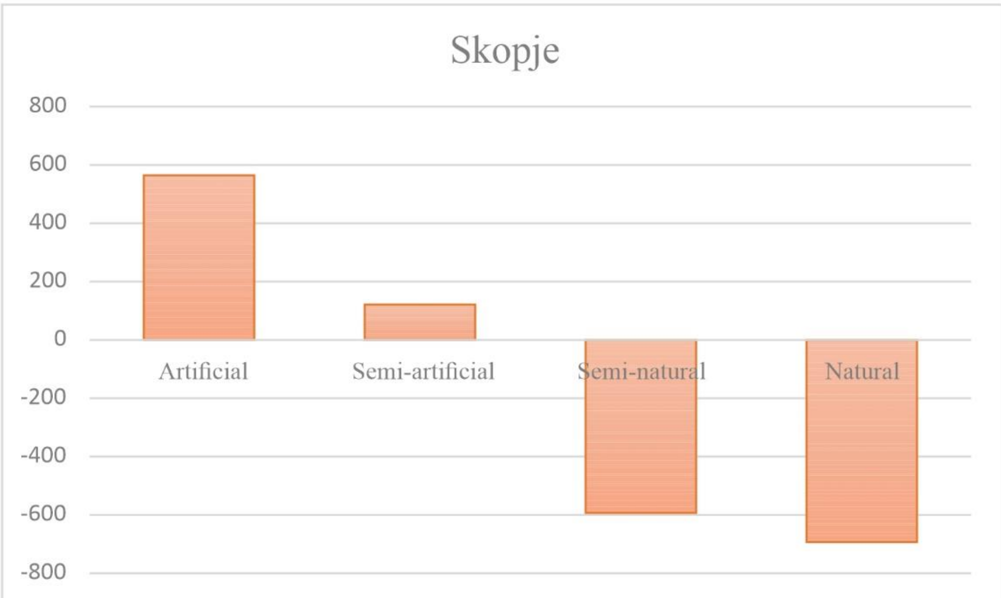


Figure 17 Map defining the urban-periurban boundary for Skopje city and statistical analysis according to 4 main categories

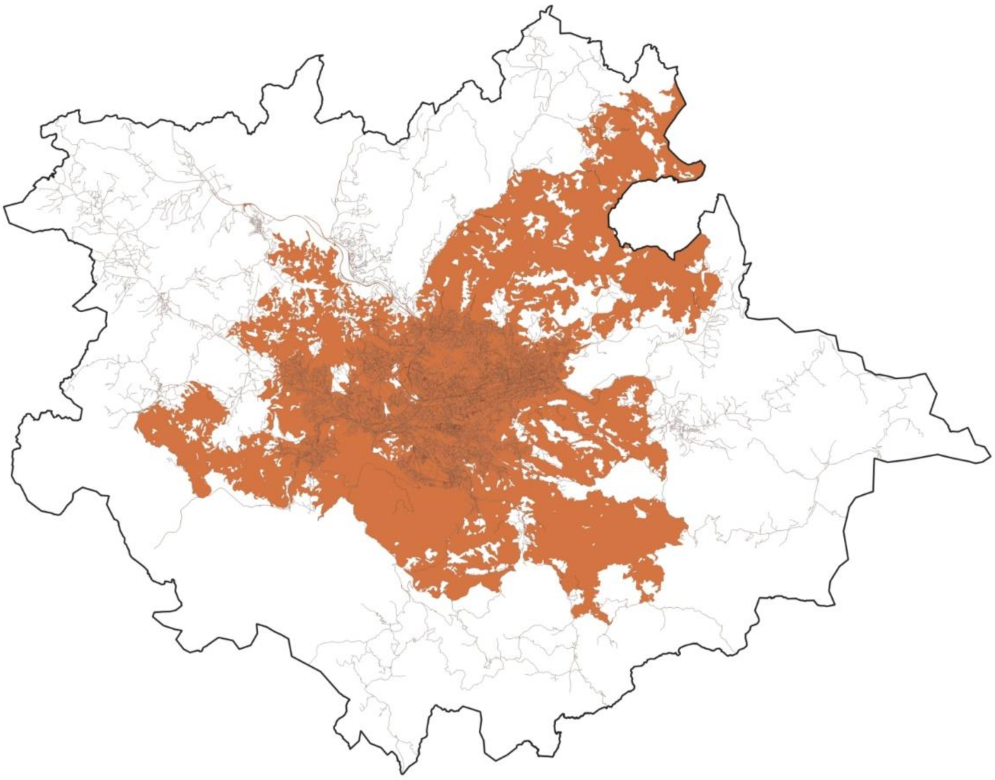


Figure 18 Map defining the urban-periurban boundary for Sarajevo city and statistical analysis according to 4 main categories

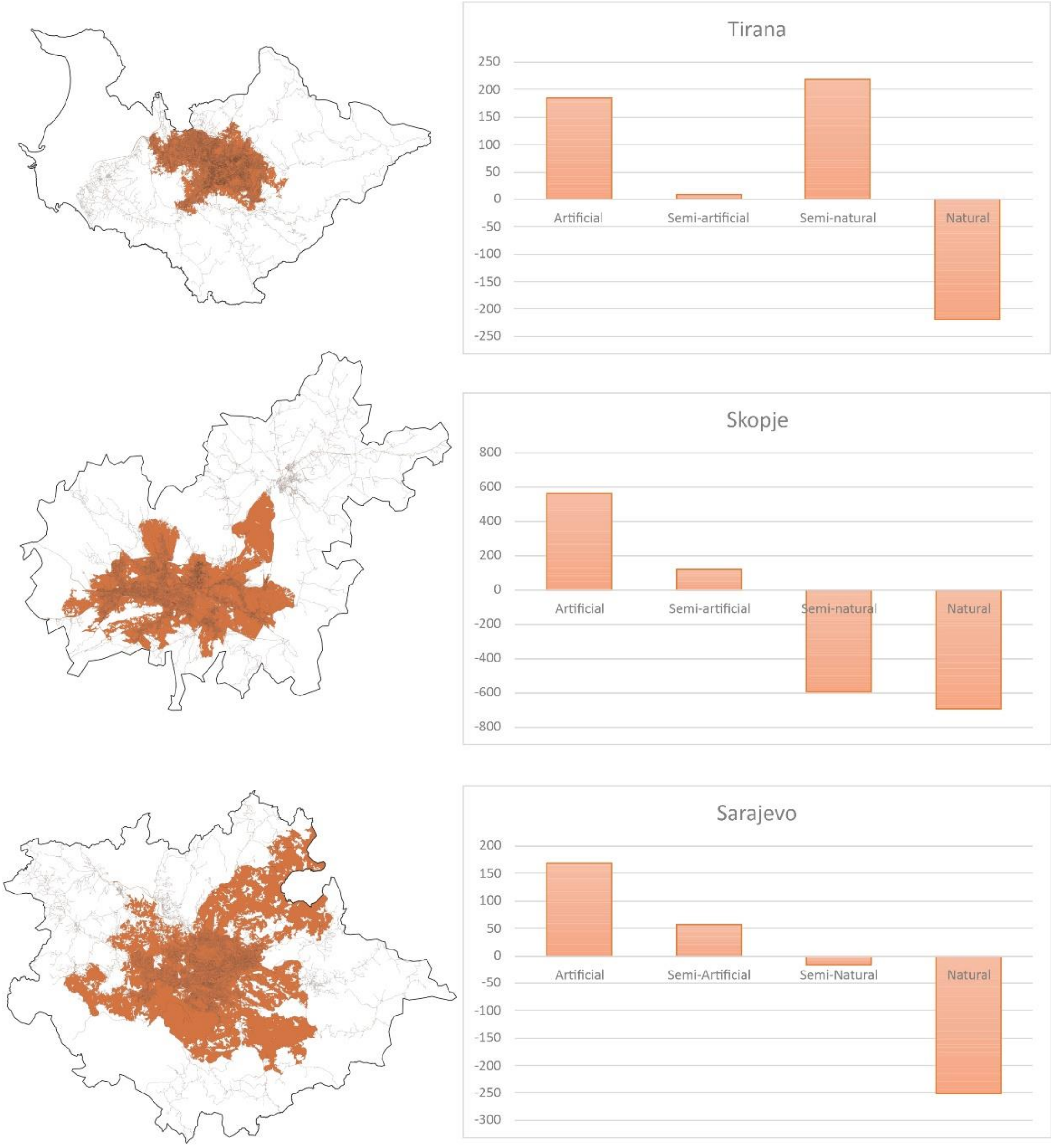


Figure 19 Maps defining the urban-periurban boundary for each city and statistical analysis according to 4 main categories

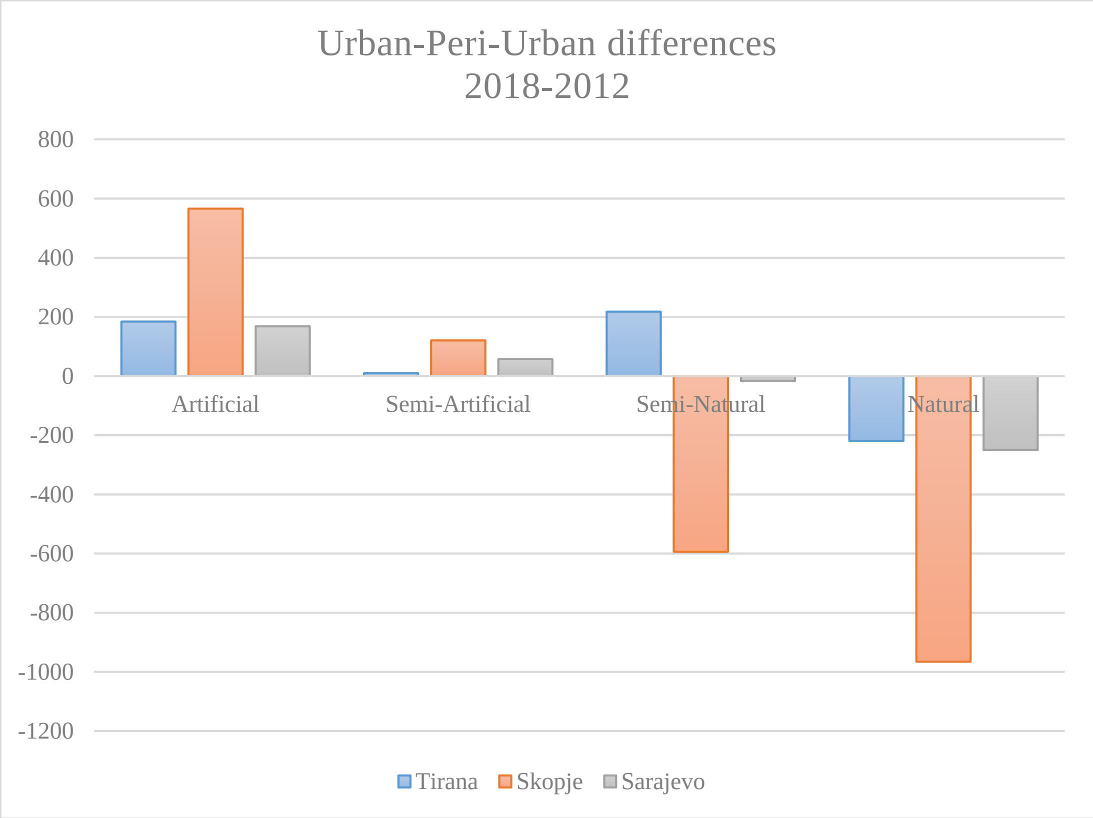


Figure 20Statistical analysis, comparing Urban-Periurban differences 2018-2012 for each city according to the reclassification into 4 categories

Table 8. Results in Ha of each city for 2012-2018 and their difference values.

Reclassification	Nomenclature	Tirana 2012	Tirana 2018	Difference	Skopje 2012	Skopje 2018	Difference	Sarajevo 2012	Sarajevo 2018	Difference
Artificial	11100 Continuous urban fabric S.L.: >80%	787.69	796.5	8.81	1111.11	1111.34	0.23	166.56	168.15	1.59
	11210 Discontinuous dense urban fabric S.L.: 50-80%	1174.19	1180.94	6.75	1851.2	1857.71	6.51	1460.04	1488.56	28.52
	11220 Discontinuous medium density urban fabric S.L.: 30-50%	1139.72	1165.53	25.81	969.37	1005.34	35.97	1643.22	1655.13	11.91
	12100 Industrial, commercial, public, military and private units	1630.61	1756.11	125.5	2864.93	3371	506.07	1513.35	1569.12	55.77
	13300 Construction sites	95.42	110.55	15.13	20.52	24.13	3.61	73.76	48.3	-25.46
	12210 Fast transit roads and associated land	59.25	59.25	0	284.76	284.76	0	81.04	168.26	87.22
	12220 Other roads and associated land	1675.77	1677.98	2.21	2266.07	2279.69	13.62	2105.44	2114.3	8.86
	12230 Railways and associated land	48.72	48.72	0	241.23	241.23	0	156.28	156.21	-0.07
	12300 Port areas									
	12400 Airports				275.98	275.98	0	103.69	103.69	0
		6611.37	**6795.58**	**184.21**	**9885.17**	**10451.18**	**566.01**	**7303.38**	**7471.72**	**168.34**
Semi-Artificial	11230 Discontinuous low density urban fabric S.L.: 10-30%	1325.19	1345.79	20.6	970.2	983.26	13.06	1675.85	1697.74	21.89
	11240 Discontinuous very low density urban fabric S.L.: <10%	899.29	914.84	15.55	896.27	920.2	23.93	1294.95	1313.49	18.54
	11300 Isolated structures	117.89	119.77	1.88	14.04	17.16	3.12	66.78	64.86	-1.92
	13100 Mineral extraction and dump sites	66.65	38.2	-28.45	42.1	122.59	80.49	195.91	214.57	18.66
		2409.02	**2418.6**	**9.58**	**1922.61**	**2043.21**	**120.6**	**3233.49**	**3290.66**	**57.17**
Semi-Natural	13400 Land without current use	497.92	479.97	-17.95	411.73	444.76	33.03	127.32	167.07	39.75
	14200 Sports and leisure facilities	46.47	40.79	-5.68	176.59	176.68	0.09	128.28	129.8	1.52
	21000 Arable land(annual crops)	1537.31	1779.36	242.05	27611.67	26988.69	-622.98	1392.88	1353.24	-39.64
	22000 Permanent crops (vineyards, fruit trees, olive groves)	26.98	26.98	0	229.01	225.47	-3.54	46.33	33.64	-12.69
	24000 Complex and mixed cultivation patterns	41.86	41.45	-0.41	5.57	5.01	-0.56	377.21	370.68	-6.53
		2150.54	**2368.55**	**218.01**	**28434.57**	**27840.61**	**-593.96**	**2072.02**	**2054.43**	**-17.59**
Natural	14100 Green urban areas	316.58	321.59	5.01	640.71	650.64	9.93	471.72	465.34	-6.38
	23000 Pastures	3752.21	3578.79	-173.42	2894.9	2846.64	-48.26	3548.52	3431.63	-116.89
	31000 Forests	2972.68	2902.75	-69.93	418.72	413.83	-4.89	60188.33	60065.27	-123.06
	32000 Herbaceous veg. associations (natural g\rassland, moors...)	1907.53	1914.55	7.02	4339.89	3398.37	-941.52	422.55	411.89	-10.66
	33000 Open spaces with little or no veg. (beaches, dunes, bare rocks)	65.61	71.65	6.04	2.59	2.59	0	1.76		-1.76
	40000 Wetlands	12.09		-12.09	8.56	8.56	0			
	50000 Water	274.29	291.54	17.25	192.32	211.53	19.21	165.87	173.94	8.07
		9300.99	**9080.87**	**-220.12**	**8497.69**	**7532.16**	**-965.53**	**64798.75**	**64548.07**	**-250.68**

4.3 Third Phase

After the analysis of urban context, the 3rd phase of the analysis is focused only in Tirana's urban area, to calculate the meff, we determined only the natural areas of urban core. *Figure 21)* According to the results of statistical comparison of Tirana's Urban area, there is an increasing areas for Industrial, commercial, public, military and private units and decreasing areas of arable lands and pastures. Also there is an increasing trend for all artificial, semi-artificial classes (Continuous urban fabric S.L.: >80%, Discontinuous dense urban fabric S.L.: 50-80%, Discontinuous medium density urban fabric S.L.: 30-50%, Discontinuous low density urban fabric S.L.: 10-30%, Discontinuous very low density urban fabric S.L.: <10%, Construction sites) shown in the chart (*Figure 22*).

Taking in consideration that the standard width of a road is 3.65 m we applied different buffer zones, correspondly 4m, 8m, 16m, 32m for 2012-2018 years, by stimulating the existing condition to identify the spatial patterns of fragmentation. (Figure 23-32) So by increasing the buffer value we can understand the potential connectivity, the larger the buffer, more fragmentation geometries can be connected as we can notice also from the results of *Table 9* and *Table 10*.

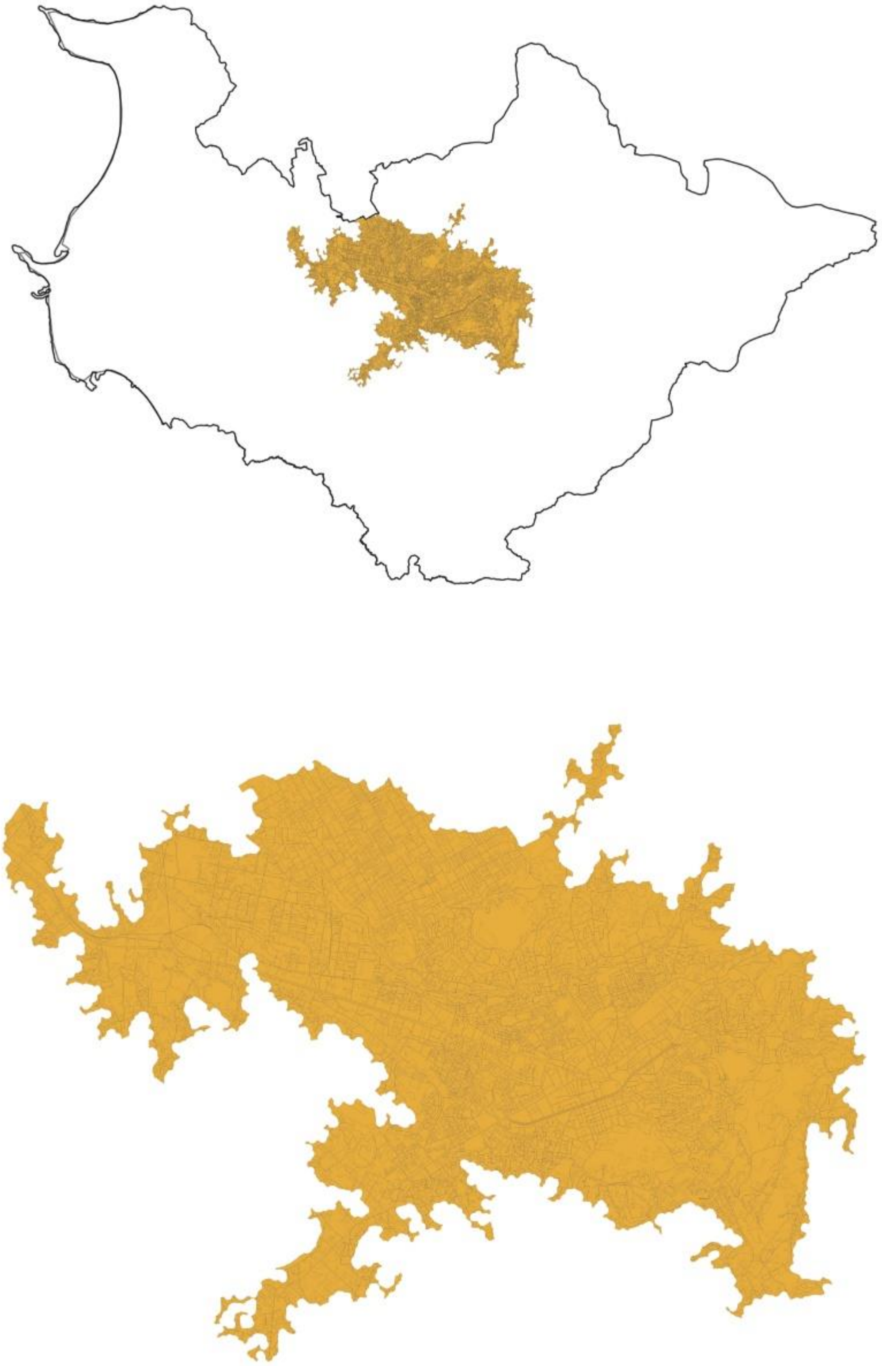


Figure 21 Tirana's urban area within Tirana's region

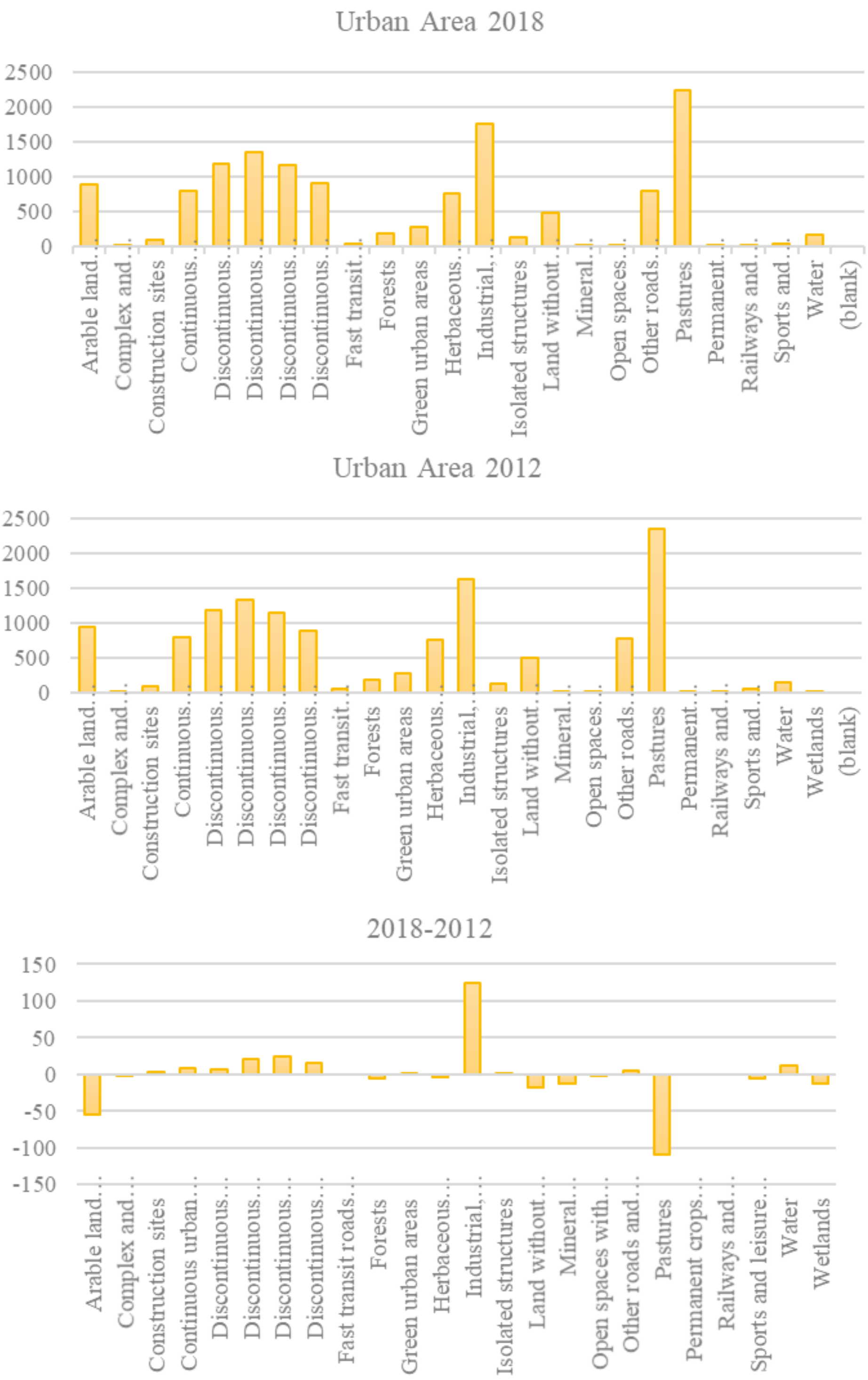


Figure 22 Tirana's urban area, statistical comparison of UA classes for 2018-2012

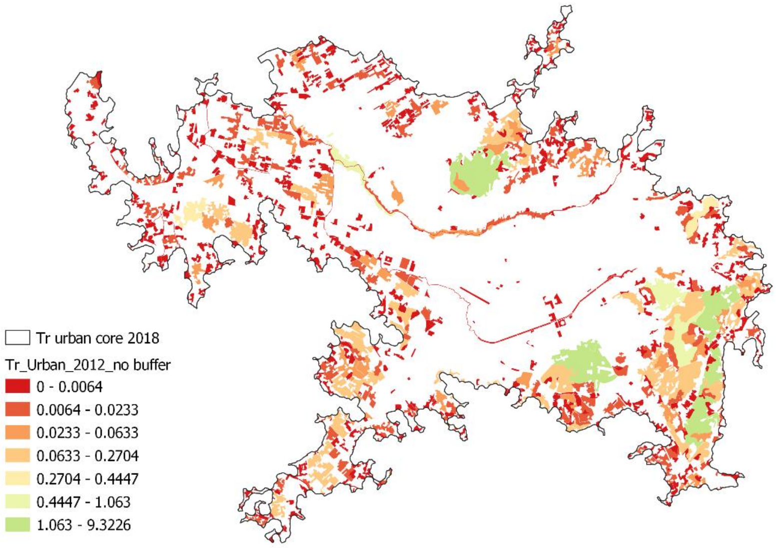


Figure 23 Tirana's urban area 2012, no buffer applied

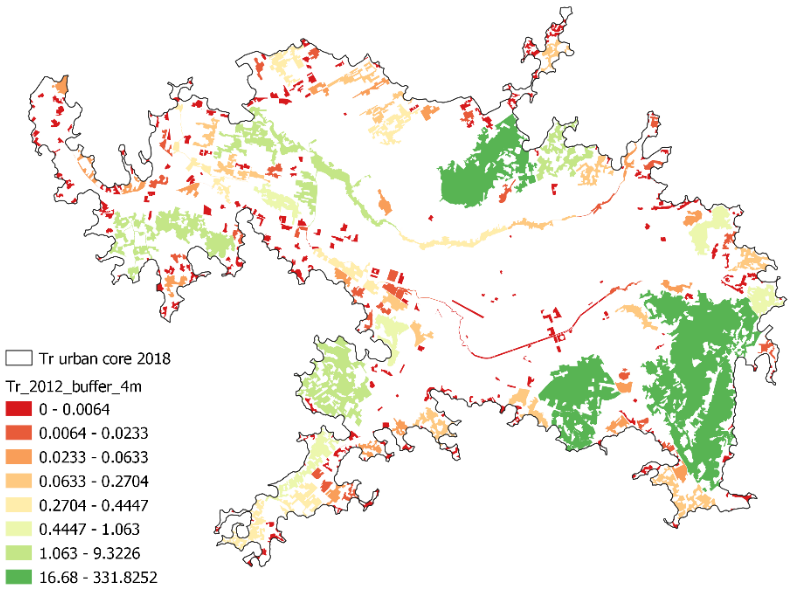


Figure 24 Tirana's urban area 2012, 4 m buffer applied

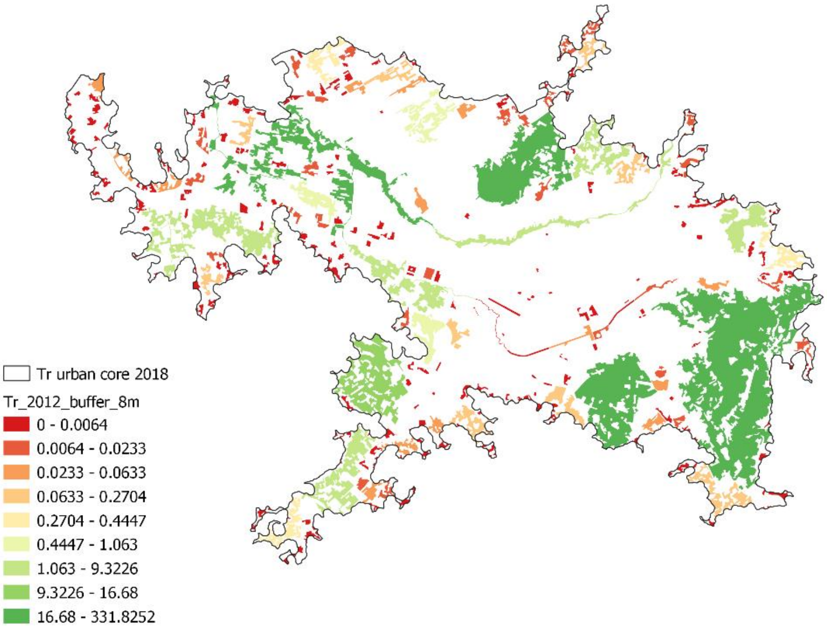


Figure 25 Tirana's urban area 2012, 8m buffer applied

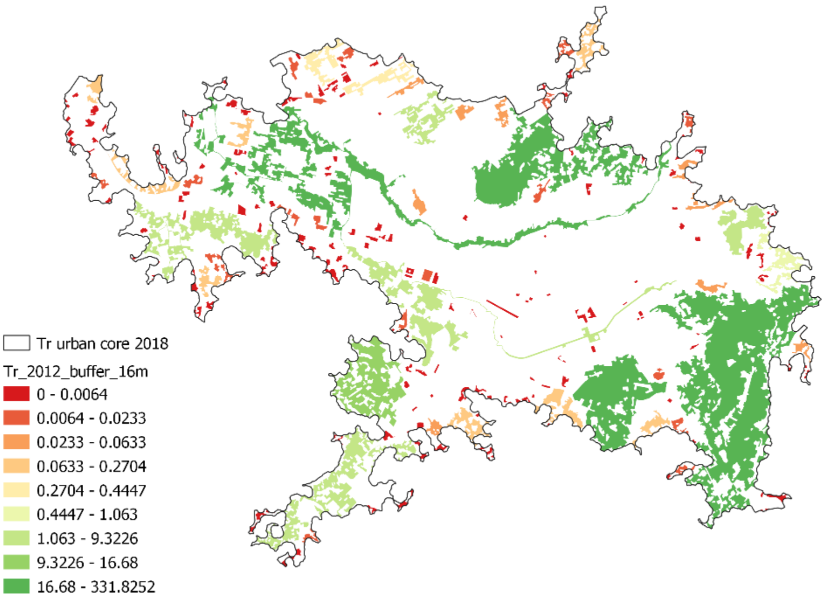


Figure 26 Tirana's urban area 2012, 16m applied

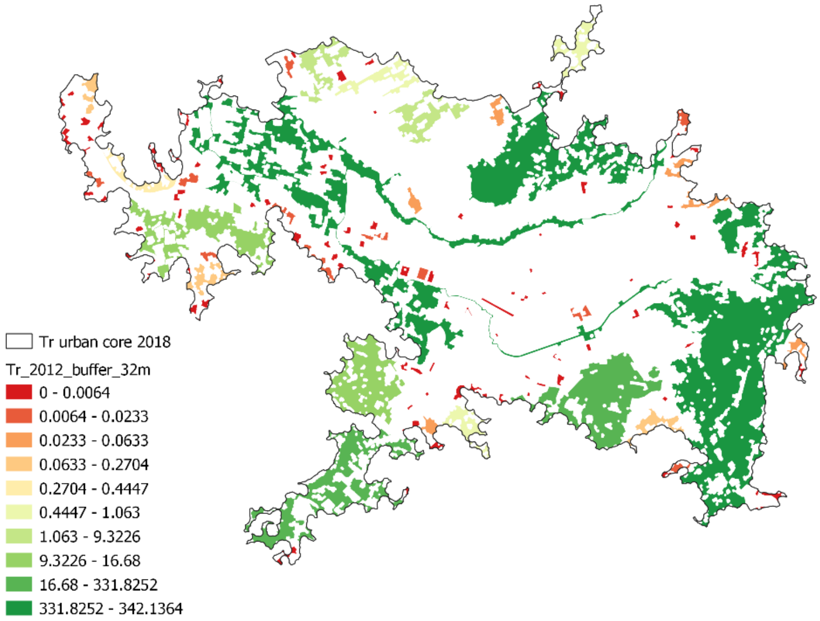


Figure 27 Tirana's urban area 2012, 32m buffer applied

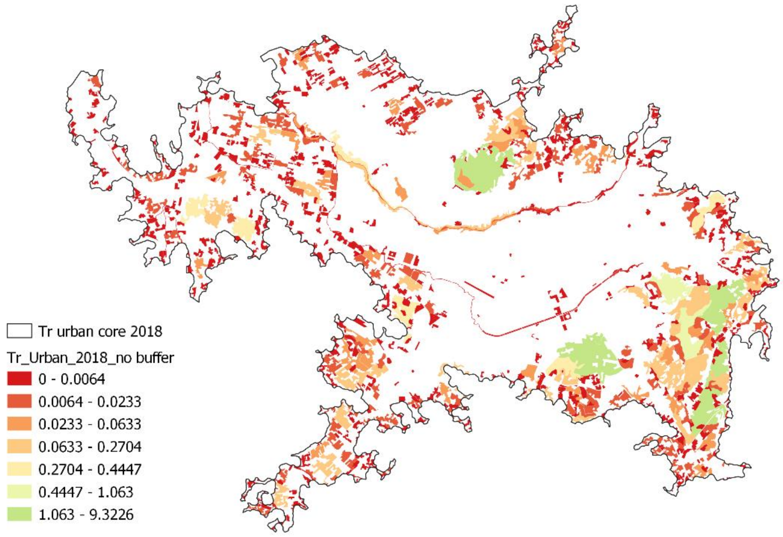


Figure 28 Tirana's urban area 2018, no buffer applie

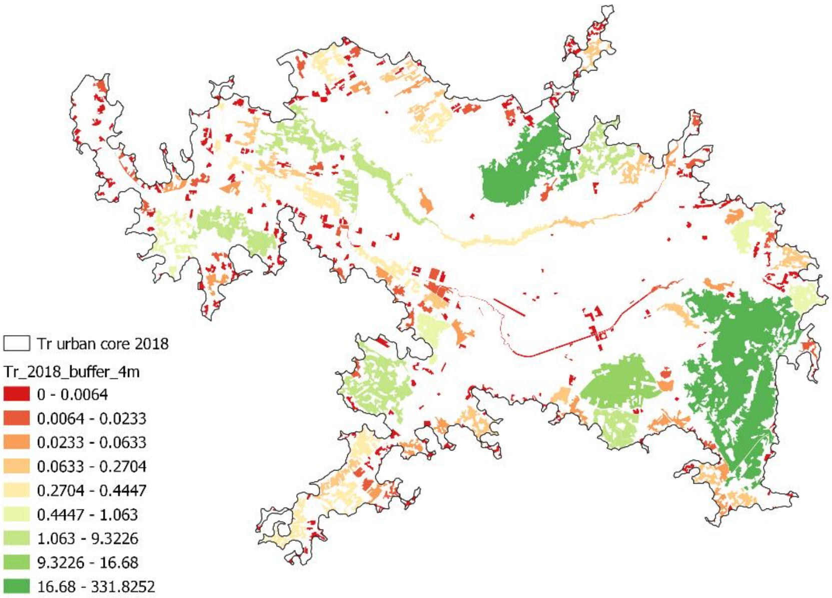


Figure 29 Tirana's urban area 2018, 4m buffer applied

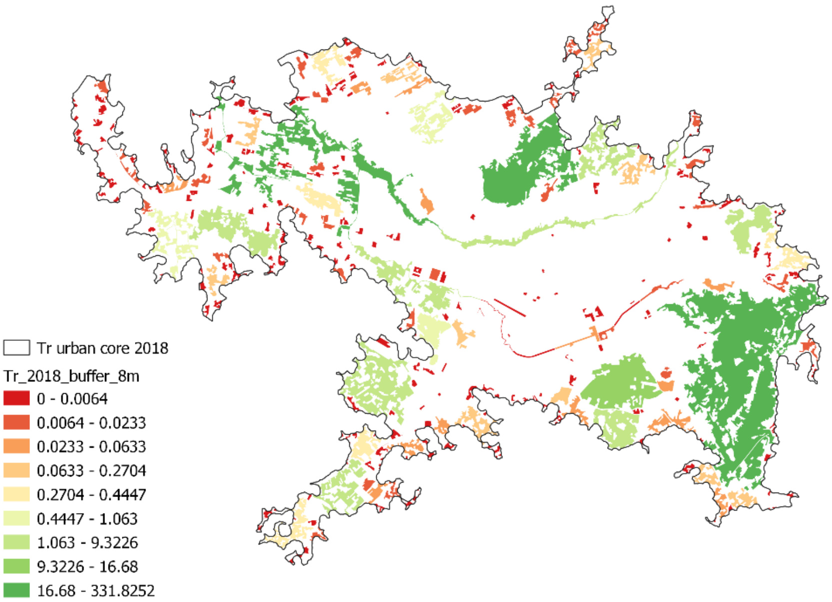


Figure 30 Tirana's urban area 2018, 8m buffer applied

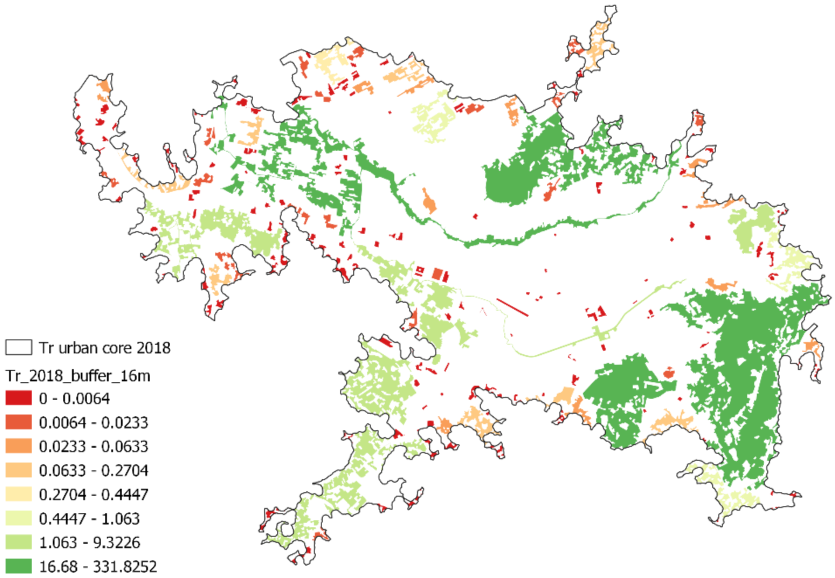


Figure 31 Tirana's urban area 2018, 16m buffer applied

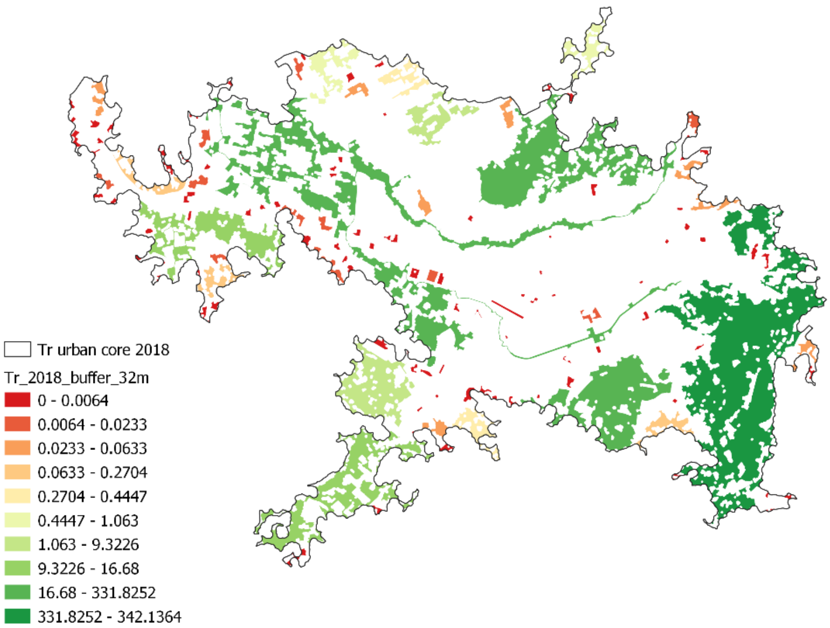


Figure 32 Tirana's urban area 2018, 32m buffer applied

Table 9. Result of meff for 2012

	2012				
Buffers	0	4	8	16	32
Total area(ha)	3715.937	3743.07	3764.385	3794.052	4186.495
Total meff(ha)	**25.86040535**	**251.4593764**	**311.4409077**	**405.798178**	**750.6417115**
No. of geometries	1004	886	578	368	174

Table 10. Result of meff for 2018

	2018				
Buffers	0	4	8	16	32
Total area(ha)	3609.529	3634.373	3654.405	3689.241	4091.373
Total meff(ha)	**25.5546867**	**235.7869958**	**294.393295**	**375**	**745.4720198**
No. of geometries	1016	928	605	385	179

(Figure 33) and *(Figure 34*) presents the box plot of landscape fragmentation for 2012-2018 years at 5 levels of buffers. The *meff* values are represented in logarithmic values to make the interpretation of the results clearer. As we can see, the larger the applied buffer, the higher *meff* values or more fragmented geometries can be connected. This indicates the available potential connectivity at each buffer (road width) at city scale.

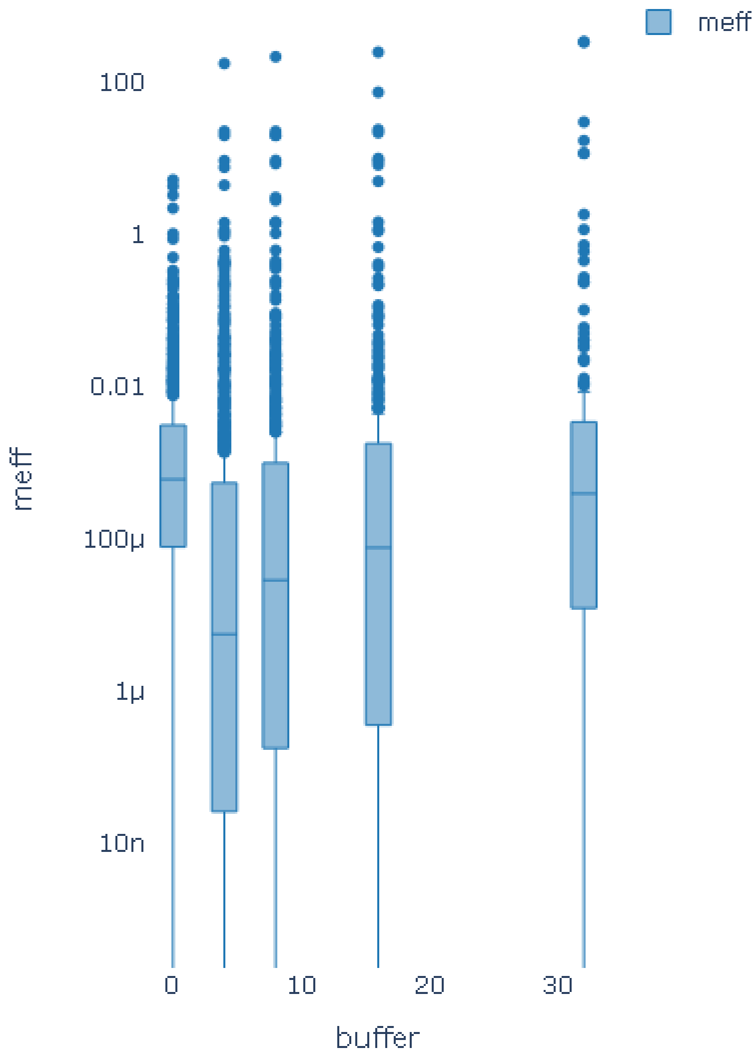


Figure 33 Box Plot showing meff values for applied buffer 2012

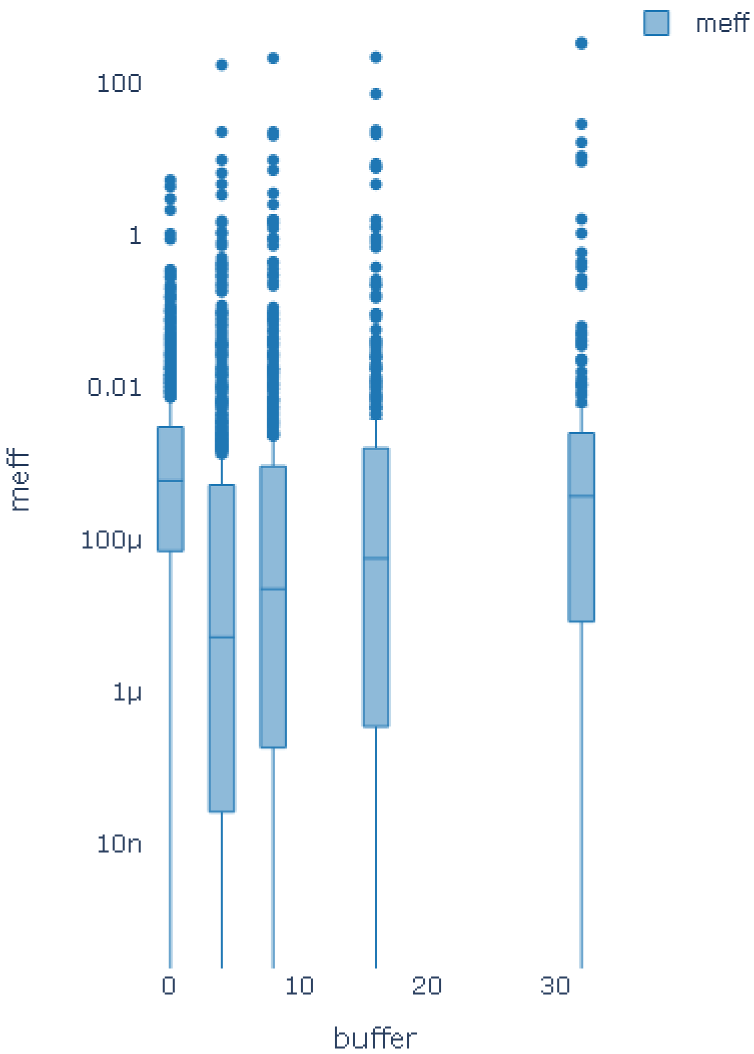


Figure 34 Box Plot showing meff values for applied buffer 2018

4.4 Discussion of results at finer spatial scale

The results of the *meff* calculation revealed the widespread impact of the LF phenomena, which is mostly driven by transportation infrastructure. Urbanization, transportation infrastructure, and industrial development are the main factors. Urban expansion, new infrastructure projects, and agricultural activities are examples of LULC dynamic developments that might occur in the future as a consequence of population increase, consumption, migration, and other factors.

We advertise this method as a fast quantitative landscape evaluation methodology that provides accurate graphical and statistical findings to organizations in charge of spatial planning and management decision-making in Albania and abroad.

The results of this study can help responsible parties evaluate the barrier impact for each type of intervention and promote connectivity-oriented initiatives to reduce territory fragmentation and enhance endemic fauna and flora communities' minimum requirements.

We have identified four focal areas within the urban core (zoom in spots), which after the applied buffers, have the potentials to reach connectivity through small interventions, to reduce LF.

First area is located in Domje-Berxull area showed in *(Figure 35).* Second zoom in area is found near Paskuqan region which is shown in Figure 36. Continuing with the 3rd selected area, which is located in Yzberisht-Mezez. *(Figure 37)* And the 4th, largest one, Shkoze-Farke-Lunder. *(Figure 38)*

Figure 35 Domje-Bërxull, zoom in spot

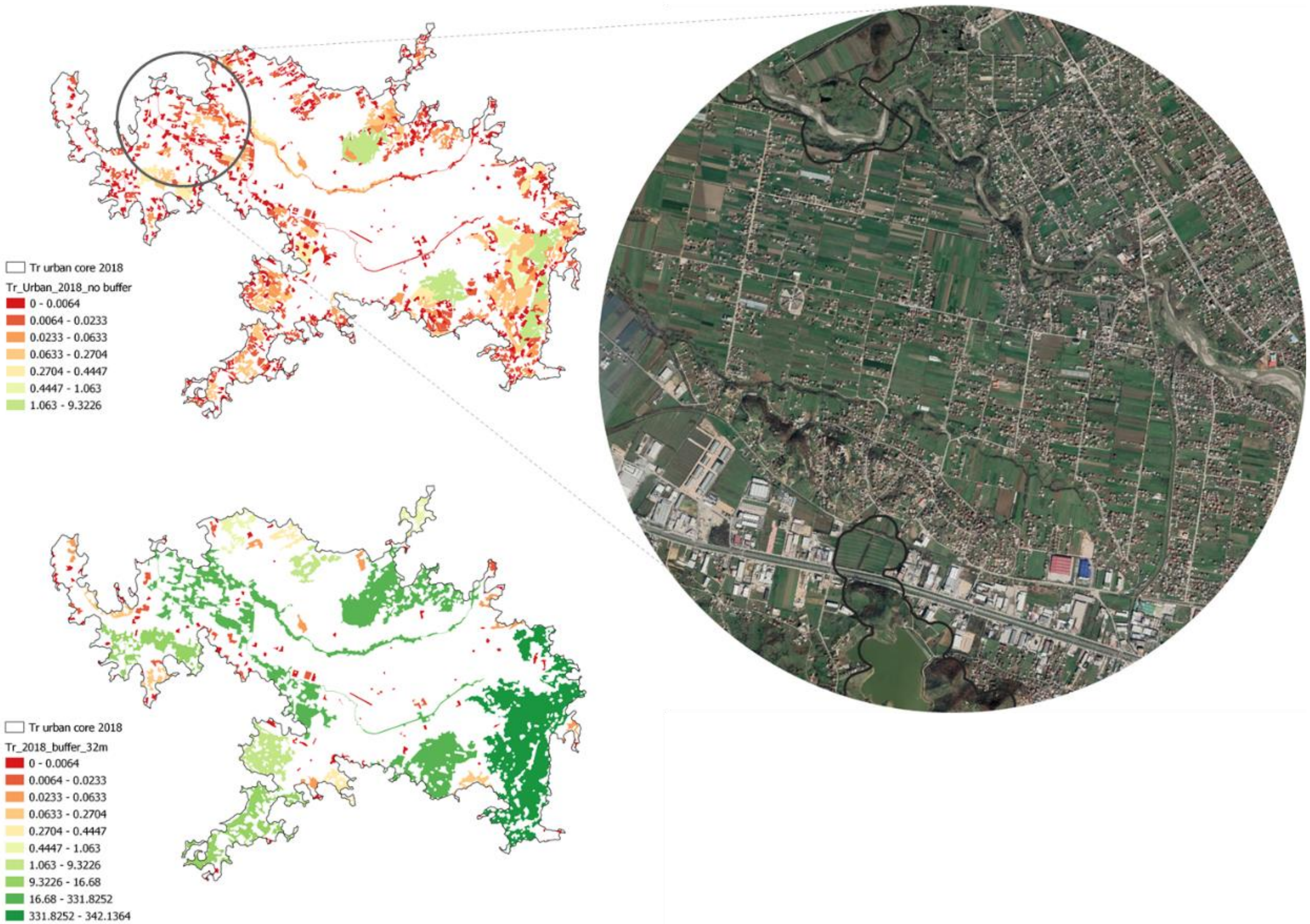


Figure 36 Paskuqan region, zoom in spot

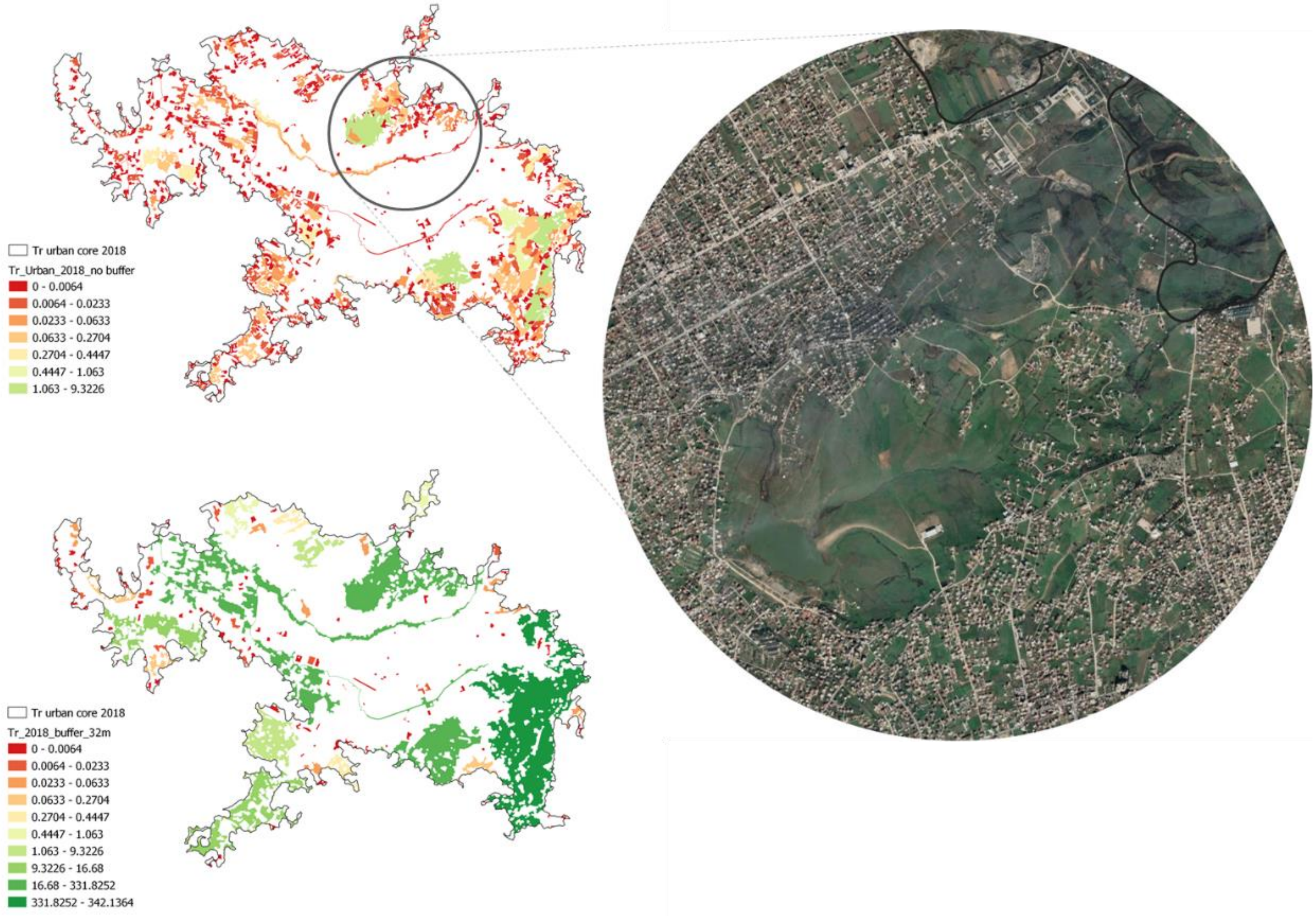


Figure 37 Yzberisht-Mezez, zoom in spot

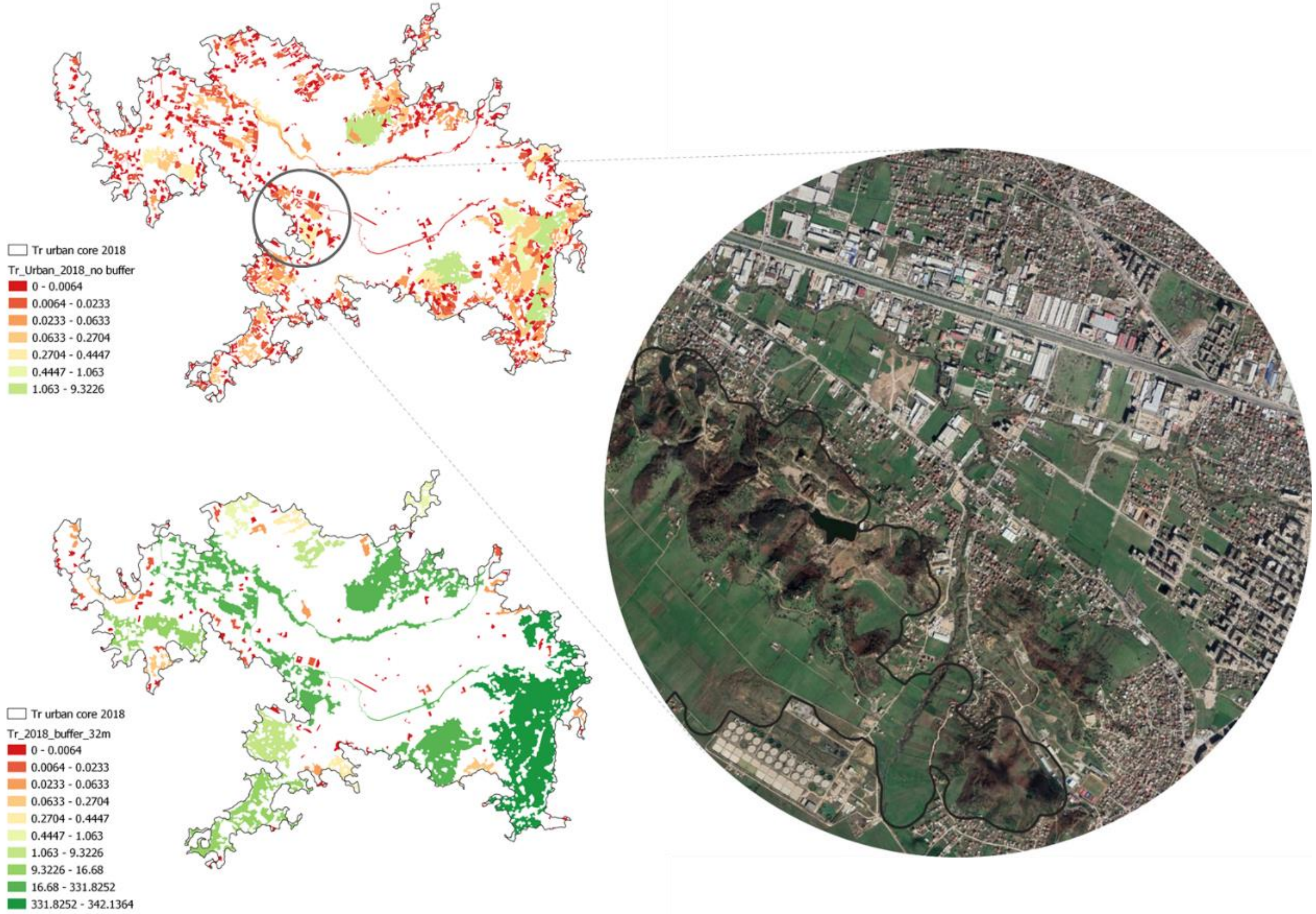
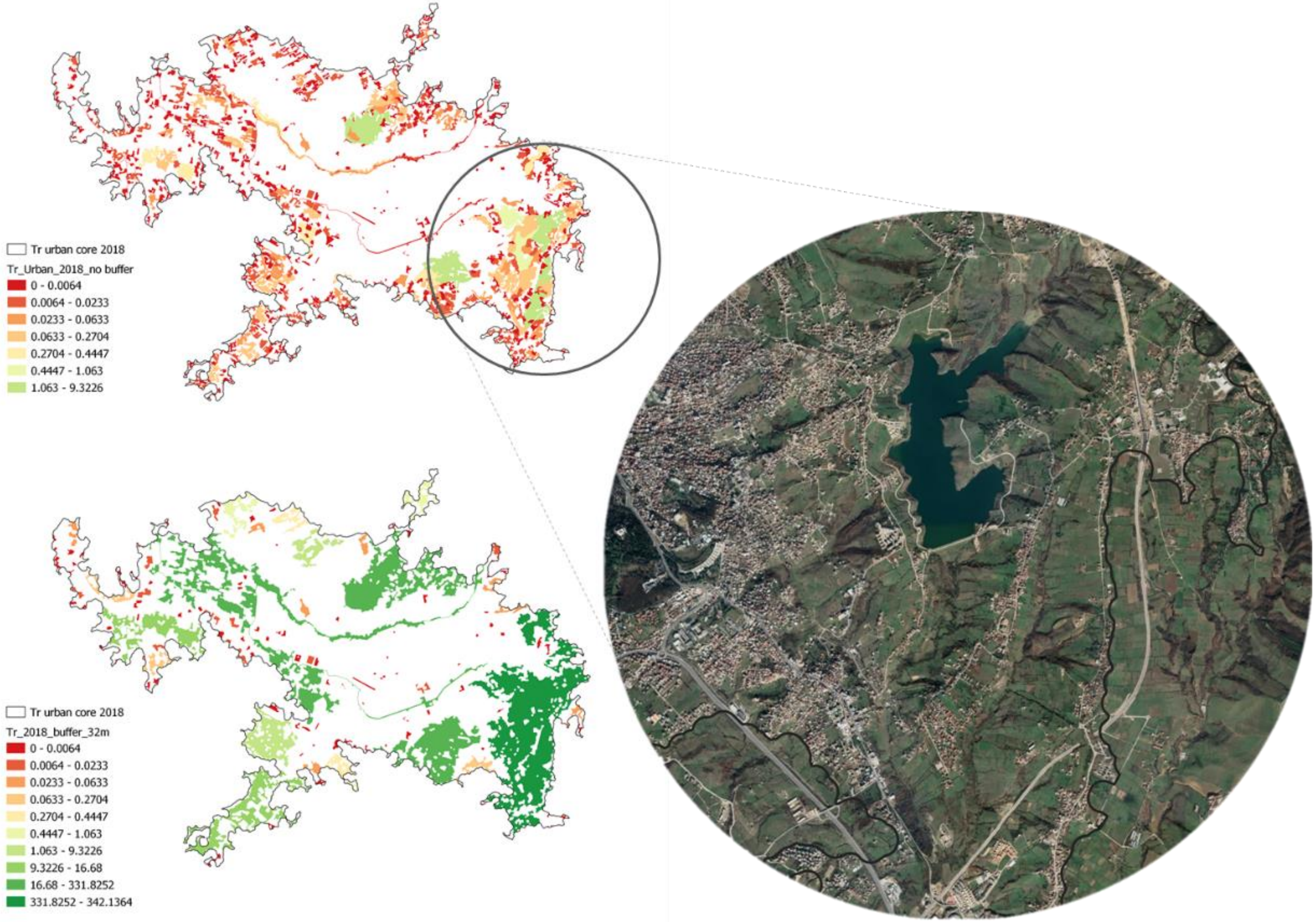


Figure 38 Shkoze-Farke-Lunder, zoom in spot



CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This study presented the analysis of spatio-temporal dynamics of landscape transformation in western Balkan metropolitan areas. The studied area consists of Tirana’s metropolitan region compared with two Balkan cities, Skopje and Sarajevo.

The raw data is based on a set of open source geographic data sources that provide information on the LULC. LF analysis is based on the effective mesh size(meff) landscape metrics. A hierarchical process with three phases is defined by the method used, where the analysis starts from a macro scale, regional general study of each selected study area and then focusing in a micro scale such as urban area of Tirana city.

According to the results of these different phases, it is noticed that is a trend of decreasing values in natural areas, which are substituted with construction sites, industrial, commercial, public, military and private units and also fast transit roads and associated land.

LF defined in the result shows that by increasing the buffer zones, connectivity in different areas can be reached. Since Tirana is a developing city with significant transportation network investments yet to be made, it is important that decision-makers address LF issues while designing new plans.

The transportation network not only fragments natural lands, but it also increases the risk of wildfire ignition and interferes with the vegetated surfaces of wilderness areas.

The results of this study can help responsible parties evaluate the barrier impact for each type of intervention and promote connectivity-oriented initiatives to reduce territory fragmentation and enhance endemic fauna and flora communities' minimum requirements.

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