A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the Degree of Master of Science

Application of GIS and Remote Sensing Methods in Monitoring of Urbanization of National Parks in Serbia And Montenegro

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ABSTRACT OF THESIS submitted by:
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Protected areas in Serbia and Montenegro have in the past 30 years been exposed to adverse effects of urbanization processes while the quality of environmental protection decreased due to various economic and political reasons. This master thesis and the research which led to it were conducted in order to establish a baseline for the level of urbanization of these protected areas. A mix of GIS and remote sensing methods were used to determine what is the area occupied by manmade facilities and activities damaging to the natural environment of the national parks.

Results have shown that the urbanization level of national parks is, on average, 15-30% higher in Serbian parks. Two of them had seen a drastic negative change in the last 5-10 years. However, urbanization status of national parks in Montenegro is not alarming as it is in Serbia. In one of the cases in Montenegro even a continuous improvement of the environment in the national park was noted.

Keywords: national park, protected area, GIS, remote sensing, urbanization, Serbia, Montenegro

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List of Abbreviations

GIS	Geographic Information System
NP	National Park
USGS	United States Geological Survey
RGB	Red-Green-Blue

1. Introduction

1.1 Problem Statement

A worrying level of deterioration of the environment is taking place in protected areas in Serbia, and in Montenegro. One of possible causes for this deterioration is the process of urbanization inside, and around, these protected areas.

Different types of construction works continuously happen in national parks and other protected areas. A large percentage of the construction is due to illegal building of summerhouses and other kinds of temporary settlements. This type of unauthorized urbanization happens alongside the construction which is authorized by local municipalities, but in contradiction with current laws and regulations. These two types of urbanization put together have many adverse effects on the environment in and around the areas which are supposed to be protected.

Another negative effect on the environment in these protected areas is caused by various agricultural practices implemented by the local population. Deforestation for obtaining biomass as a fossil fuel, along with drying out wetlands to gain more fertile agricultural land and freshwater supply contribute significantly to the problem.

Nowadays in both countries, Serbia and Montenegro, a lively public discussion is taking place on accounts of these adverse anthropogenic effects that are damaging protected areas. In Serbia, there is an imminent threat of legalizing illegally constructed facilities under the umbrella of new laws and regulations on construction, and new cadastre project taking place in the government system.

In Montenegro, the problem of urbanization in protected areas might be intensified by developing tourism industry of this country, but the general problem, and its drivers, are potentially of the same character as in Serbia.

Attempts to resolve the problem of deterioration of national parks become faced with many difficulties. These difficulties stem from the fact that the exact levels of urbanization, or different types of devastation of national parks, are unknown. This master thesis represents an effort to establish the baseline for determining the levels of urbanization and devastation of national parks.

1.2 Research Aim and Objectives

The aim of this research was to conduct a preliminary assessment of the degree of urbanization of national parks in Serbia and in Montenegro. This was done in order to generate information for the governmental authorities and policy makers of the two countries which would allow them to make an informed decision on how to proceed with the protection of national parks. The results of this research could also be used to shape the decision on whether these construction sites and facilities should be legalized, or should measures be taken to remove these objects. The problem of the encroachment of the protected areas by agricultural activities was also assessed.

In order to accomplish the main aim of the research, several research objectives were delineated. In a chronological order, these objectives are:

- to identify national parks in Serbia and Montenegro which are under potential threat of urbanization;
- to collect digital spatial data on the relevant national parks over the period of the last 30 years, and to process these data;
- to calculate the percentage of surface area of national parks which is currently affected by anthropogenic activities;
- to evaluate possible negative impacts of human encroachment of national parks in Serbia and in Montenegro;

- finally, to recommend the steps which could be taken in the future in order to improve the current situation.

All of the objectives listed above serve as tools to establish current degree of urbanization of national parks in Serbia and Montenegro and its development over time.

2. Literature Review

2.1 National Parks in Serbia and Montenegro

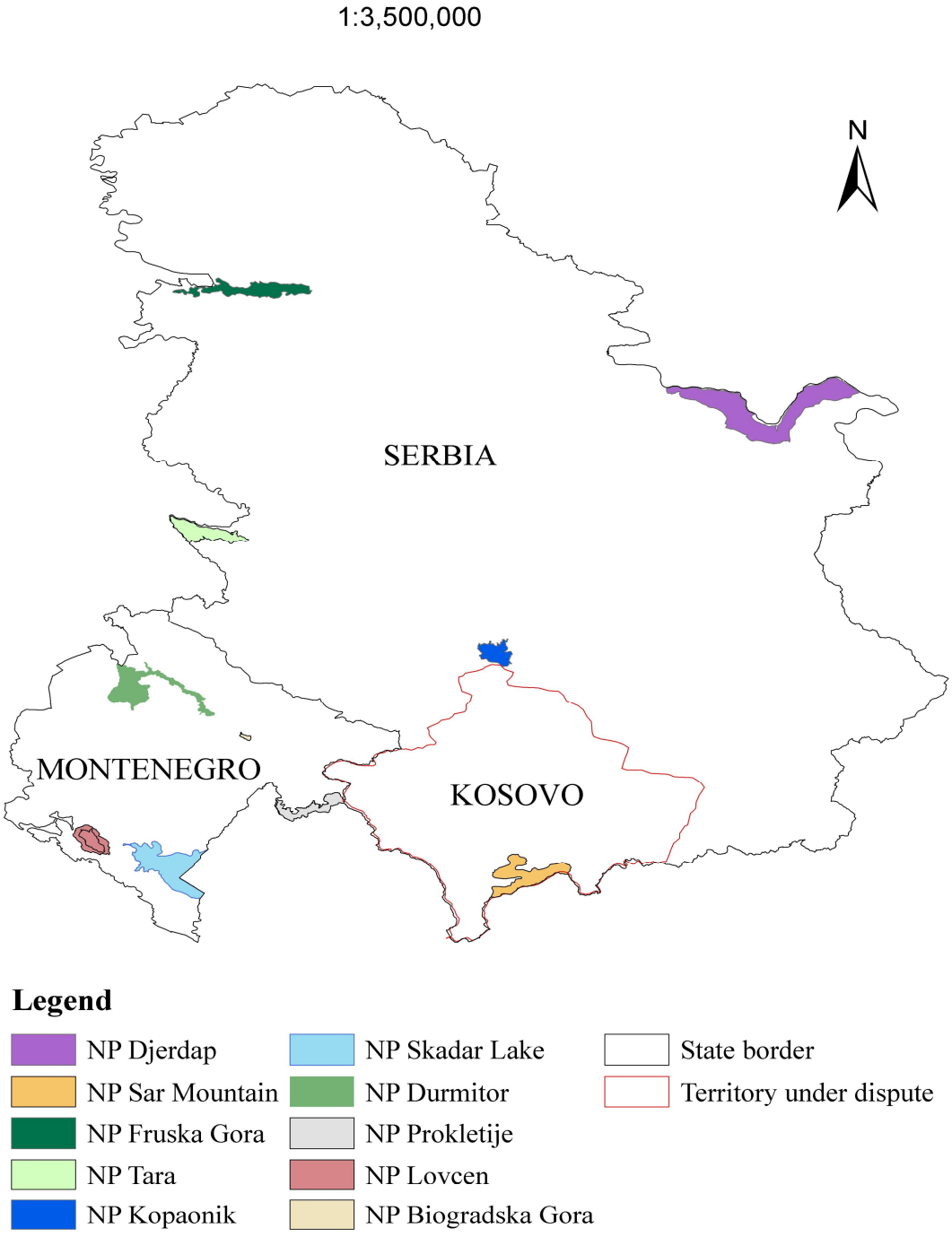

Fig. 1. National Parks in Serbia and Montenegro
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

2.1.1 National Parks in Serbia

National parks represent one of six categories of protected areas in Serbia (Fig. 1) which in total amount to 5180 km^2 or 5.86% of the total territory of Serbia (Institute for Nature Conservation of Serbia 2011a). According to the current Spatial Plan of Serbia (*Spatial Plan of Serbia* 2010) the protected areas should by 2015. take up 10% and by 2021. up to 12% of the surface area of Serbia (Institute for Nature Conservation of Serbia 2011a).

National park Djerdap

National park Djerdap resents the largest national park in Serbia, with the surface area of 636.08 km^2 (Institute for Nature Conservation of Serbia 2011b) and 939.68 km^2 with its protective zone (Kladovo Municipality 2009). It is located in the western part of Serbia, on the right bank of Danube river, directly across the state border with Romania. Djerdap stretches over 100km (NP Djerdap 2011a) covering parts of three municipalities: Golubac, Majdanpek, and Kladovo (Institute for Nature Conservation of Serbia 2011b). It was officially proclaimed as a national park in 1974 (Institute for Nature Conservation of Serbia 2011d), and today it caries IUCN IV category (IUCN and UNEP-WCMC 2010). According to national classification of protected areas (*Law on Nature Conservation* 2010), the park has three categories of protection and 10 areas of the I category are regarded as strictly protected nature reserves (Svetozarevic I. *et al.* 2010).

The most prominent natural characteristic of Djerdap national park is the Iron Gate, Europe's longest, largest, deepest, and narrowest gorge (NP Djerdap 2011a). The morphology of the area, along with its specific microclimate, offers a rare habitat for ancient species of flora and fauna in Europe (Institute for Nature Conservation of Serbia 2011d). So far, 1,100 plant species have been registered on the territory of the park, and there is a very rare case of fifty forest and shrub communities alternating in this area (Institute for Nature Conservation of Serbia 2011d). Thirty-five of those are considered to be relicts (Institute for Nature

Conservation of Serbia 2011d). Animal world in this park is very diverse, and this fact has been assigned mainly to the existence of large forest systems which provide a habitat for large mammals such as lynx, wild boar, deer, roe deer, and reptiles such as salamander and viper (NP Djerdap 2011b). More than one hundred and fifty bird species have been spotted in the park, among which the most attractive are golden eagle, short-toed eagle, white-tailed eagle, black stork, gray heron (Institute for Nature Conservation of Serbia 2011d).

Table 1. Djerdap national park surface area allocation

Land allocation	surface (km^2)	percentage (%)
Forests	448.51	70
Agricultural land	63.37	17.2
Urbanized areas	20	3.2
Danube river	58.82	9.2
Rest	45.38	7.1
Total	636.08	100

Data source: (Svetozarevic I. *et al.* 2010)

Table 1. shows that only 72.9% of the park represents natural reserve, while more than 27% has been altered by various anthropogenic activities. Beside agriculture, human factors which significantly contribute the functioning of the park's environment are: the hydro-electric power plant "Djerdap", and the slowly developing tourism industry of the area. The results of a SWOT analysis presented in the Sustainable Tourisms Strategy for National Park Djerdap (Svetozarevic I. *et al.* 2010) have identified certain infrastructural problems and waste management issues as the main weaknesses of tourism development in the park.

National park Sar Mountain

This national park is currently on the territory disputed between Serbia and Kosovo, a former autonomous region in Serbia. Because of these unresolved issues, this park will be considered only as a protected area, without defining on which territory it is located.

Directly north of the border of Macedonia, lays the second largest national park Sar Mountain set up in 1986 (Mnemosyne 2003). Officially, it covers 390 km^2. However, the unofficial protective zone stretches over 970km^2 (Institute for Nature Conservation of Serbia 2011e). The complete area includes ten local municipalities (Institute for Nature Conservation of Serbia 2011b) and it consists out of a ridge of mountain peaks reaching more than 2600m (Institute for Nature Conservation of Serbia 2011e). It represents a IUCN II category protected area with major characteristics of a high-mountain forest habitat with 100 peaks higher than 2000m and 30 of them higher than 2500m (Mnemosyne 2003).

Relief was mainly created by glacial processes which were very strong in this area during the last ice age (Institute for Nature Conservation of Serbia 2011e). Geological activity created cirques, vertical rocks, steep gorges and small glacial lakes known as “mountain eyes” (Mnemosyne 2003) which together with 1,800 plant species , 147 different butterflies, 45 kinds of amphibians and reptiles, close to 200 species of birds, and 32 species of mammals distinguishes Sar Mountain as one of biodiversity hot-spots in Europe (Institute for Nature Conservation of Serbia 2011e).

Major threats to the environment of this park are illegal logging, forest fires, illegal building, erosion and poaching (Mnemosyne 2003). Considering these threats, it is important to note the political and administrative situation on Kosovo since the war in 1999.

National park Kopaonik

Located on the Serbian side of the administrative border of Serbia and Kosovo and Metohija, national park Kopaonik is the smallest national park in Serbia with only 118 km^2 of surface area, or 199.86km^2 together with the protective zone (NP Kopaonik 2011b). This mountainous region is shred by two municipalities: Raska and Brus (Institute for Nature Conservation of Serbia 2011b), both relatively urbanized due to the existence of a large ski resort on the mountain. Highest peak reaches 2017m and it is named Pancic's peak, honouring the Serbian botanist Dr. Josif Pancic who discovered new specie of Spruce on this mountain (Institute for Nature Conservation of Serbia 2011f). It represents a hot-spot of Balkan endemic high-mountain flora with 11.9% of species growing on the territory of Kopaonik national park (Institute for Nature Conservation of Serbia 2011f) having 825 plant species in 80 families (20% of Serbian flora) (NP Kopaonik 2011a). Like Sar Mountain, Kopaonik has been affected by glacial processes which left relic plant species behind (NP Kopaonik 2011a). Fauna of this park is very diverse with large population of butterflies, 170 kinds of birds and 39 mammal species (Institute for Nature Conservation of Serbia 2011f). Major environmental threats are urbanization due to tourism activities, erosion and illegal logging (InfoKop 2011).

National park Tara

National park Tara is situated in the south-west part of Serbia along the border with Bosnia and Herzegovina. It occupies the area of 191.75km^2, on the territory of Bajina Basta municipality (Institute for Nature Conservation of Serbia 2011b), or 375.84 km^2 with the protective zone. This area was proclaimed as a national park in 1981 because of the preserved forest complexes, the existence of Pancic's Spruce and the biodiversity of flora and fauna of the region (NP Tara 2011e).

Geomorphology or the park is dominated by the Tara mountain, whose highest peak "Koziji Rid" has 1591m, as much as by a very deep Drina river canyon which reaches to 1000m of

depth in certain places (NP Tara 2011d). As for the flora of this national park, Tara is considered to be the most wooded mountain of Europe due to its dense coniferous forest and thirty five forest and nine meadow communities (Institute for Nature Conservation of Serbia 2011g). Fauna of the Tara mountain is also unique because of the Pancic's Grasshopper, an insect specie existing only in this region (NP Tara 2011c). There are also around 53 species of mammals, 135 species of butterflies, 12 kinds of reptiles, 13 amphibian species and 19 bird species (NP Tara 2011b).

Within the boundaries of the national park there are around 3000 inhabitants in several villages (NP Tara 2011a) and they are most often engaged in agricultural activities or river rafting tourism and its supporting services.

National park Fruska Gora

Fruska Gora, the only national park on the territory of autonomous province of Vojvodina, set up in 1960 (Institute for Nature Conservation of Serbia 2011c), occupies the area of 253.93km^2 spread out over 8 municipalities (Institute for Nature Conservation of Serbia 2011b) in the north-western part of the country. Its protective zone stretches 3km around the park and in total gives 660.9km^2 of surface area (Institute for Nature Conservation of Serbia 2011c). This small (549m) but very long (80km) and wide (15km) mountain chain (NP Fruska Gora 2011a) was located in the middle of no longer existing Pannnian sea, and today it offers a lot of geological information about that period (Institute for Nature Conservation of Serbia 2011c).

Forests cover 90% of the park (NP), and the area is known for its richness in plant and animal species primarily because of the 1,500 plant species (NP Fruska Gora 2011d) and 211 bird species out of which 130 are nesting in the park (Institute for Nature Conservation of Serbia 2011c). Presence and diversity of fungi is also registered (NP Fruska Gora 2011c).

Since it is very close to the city of Novi Sad, Fruska Gora presents one of the favourite picnic and recreational areas for the local population. The park itself is very well equipped with tourist infrastructure (hotels, restaurants, bicycle trail, etc.) (NP Fruska Gora 2011b).

2.1.2 National Parks in Montenegro

Montenegrin five national parks: Durmitor, Biogradska gora, Skadar lake, Lovcen and Prokletije make up around 10% of the surface of the country (NP Montenegro 2011). The following section of the thesis will describe and discuss in more detail their geographical, geo-morphological, and other natural and anthropogenic characteristics.

National park Durmitor

NP Durmitor, proclaimed in 1952, is the oldest out of all ten national parks in Serbia, and in Montenegro. It has been placed on the UNESCO's list of world's natural and cultural heritage (NP Durmitor 2011b). According to the spatial plan of the park, it covers 334km^2 (Gregovic R. and Dragicevic D. 2011c) or 390km^2 with the protective zone (NP Durmitor 2011b), and it is located in the north-western part of Montenegro. Its main parts are Durmitor mountain range and Tara River canyon (NP Durmitor 2011b) which together occupy the territory of five municipalities. Geo-morphologically, it is characterised by 48 mountain peaks higher than 2000m, the highest being Bobotov kuk (2523m)(NP Durmitor 2011b). The canyon of Tara river is the second deepest canyon in the world (1300m, Tara), right after Colorado river's Grand Canyon (Gregovic R. and Dragicevic D. 2011c). Five basic ecosystems could be found in this park: high-mountains pastures, ecosystem of rocks and cliffs, coniferous forests, deciduous forests and water ecosystem (NP Durmitor 2011a). These ecosystems host some of the very rare plant species like Edelweiss and different species of Pine tree (Gregovic R. and Dragicevic D. 2011c).

Anthropogenic activities are mainly focused on upkeep of cattle and the development of winter ski tourism around the small town of Zabljak and river-rafting tourism in the Tara canyon (Gregovic R. and Dragicevic D. 2011c)

National park Biogradska Gora

South-west from Tara River canyon, and 10km away from Durmitor national park, is situated the smallest national park in both Montenegro and Serbia. Biogradska gora takes up only 56.5km^2 distributed over four local municipalities (NP Biogradska Gora 2011a). Nevertheless it is another old national park since it was proclaimed also in 1952 (Gregovic R. and Dragicevic D. 2011b).

Natural characteristics of this park are unique in the pool of Europe's protected areas, due to the existence of five glacial lakes (NP Biogradska Gora 2011a) in the park and 16km^2 of rain forest around those lakes. The rain forest is one of the last three in Europe (Gregovic R. and Dragicevic D. 2011b). Mountain ranges higher than 2000m surround the lakes and protect their rich biodiversity in flora and fauna, with bird species like white-throat, finches, booths and couple of species of birds of prey (NP Biogradska Gora 2011b).

Main anthropological factors in the area of the park are communication infrastructure (railway Belgrade-Bar), agricultural activities of local population which cause occasional erosion cores, and the upkeep of the park's infrastructure itself (Gregovic R. and Dragicevic D. 2011b).

National Park Skadar Lake

Skadar Lake, the largest national park in Montenegro, constitutes part of the border with Albania. Approximately ⅔ of the lake area is located in Montenegro (Regional Ecological Center 2011). Proclaimed in 1983., it covers 400km^2 together with the territory surrounding the lake (Gregovic R. and Dragicevic D. 2011a). It is known as one of the rare crypto-depressions in Europe with the deepest point laying around 55m bellow the sea surface (Gregovic R. and Dragicevic D. 2011a;Regional Ecological Center 2011).

The main reason to protect this area is the existence of wetlands and swamps rich with rare bird species. Dalmatin pelican (Gregovic R. and Dragicevic D. 2011a) is one of them, serving even as a logo and a brand of the park. Flora of the lake has more than 900 species of algae, and it also includes a very rare Skadar Oak which is almost extinct in the region (Gregovic R. and Dragicevic D. 2011a).

Within the boundaries of the park, the most significant factors causing environmental deterioration are: 1) intensive agriculture on the lake shores, 2) eutrophication processes due to the pollution of the water coming from Moraca River, and 3) urbanization due to communication infrastructure passing through the national park (Gregovic R. and Dragicevic D. 2011a).

National Park Lovcen

Covering two municipalities and the area of 62.2km^2 in the southern part of Montenegro (NP Lovcen 2011a), national park Lovcen represents a mountain chain situated directly behind the coast line of the Adriatic sea. Due to its geographical position and prevailing meteorological and climatic conditions (Radojicic B. 2008), this national park has a significant amount of rainfall throughout the year. In return, this region has good conditions for high-mountain plant ecosystems (Gregovic R. and Dragicevic D. 2011d). This results in 70% of the park being covered with forests and the other 30% with pastures, medows and some agricultural land (Gregovic R. and Dragicevic D. 2011d;NP Lovcen 2011c). Red fox and the Eurasian sparrowhawk are listed as the most attractive animal species of this region and the park represents a very suitable habitat for them (NP Lovcen 2011b). Anthropogenic pressures in the park is mainly generated by the upkeep of cattle by the local population, both in the lower and the higher sector of the mountain (Gregovic R. and Dragicevic D. 2011d) which has led to some occurrences of erosion and forest degradation. Tourism also takes its toll, considering the existing infrastructure (Gregovic R. and Dragicevic D. 2011d).

National Park Prokletije

National park Prokletije is the youngest park (2009) of the previously listed (NP Prokletije 2011) and it covers 166.3 km^2 in the northwestern part of Montenegro (NP Prokletije 2011). This area encompasses five local municipalities (NP Prokletije 2011) in the region of Prokletije mountain range and it was proclaimed largely due to its geo-morphological characteristics (NP Prokletije 2011;Radojicic B. 2008). Its steep gorges, Alpine river valleys, high rocky mountain peaks bare a high resemblance with similar regions in the Alps (Radojicic B. 2008).

Mild-continental climate made it possible for various forest, water and grassland ecosystem to develop in this region (NP Prokletije 2011;Radojicic B. 2008) and they are fostering 1,700 plant species, most prominent of which are beech, fir and spruce (NP Prokletije 2011;Radojicic B. 2008) . Fauna consists mainly out of various birds (161 specie), large mammals (bear, wild boar, deer, linx, etc.) and some reptiles (the Alpine newt, tree frog, salamander, etc.)(NP Prokletije 2011).

In this national park tourism has not been developed yet, so the existing infrastructure does not take-up as much space as agricultural work of the local population.

2.2 Legal Aspect of Protection and Monitoring of Nature and National Parks in Serbia and Montenegro

The two states chosen for this research, Serbia and Montenegro, had constituted part of the same state for the past six decades, up until 2007. They were parts of the Socialist Federative Republic of Yugoslavia from 1945-1991., then Federative Republic of Yugoslavia from 1991-2003. and, in the end, State Union of Serbia and Montenegro from 2003-2006. These circumstances have resulted in a very similar legal framework for nature protection and monitoring. Main characteristics of this framework will be presented in this section, for Serbia, and for Montenegro, respectively.

2.2.1 Serbia

The largest duties and responsibilities in the field of the environment, environmental protection and monitoring in Serbia are assigned to the Ministry of Environment, Mining and Spatial Planning. This ministry is in charge of recommending and approving all legislature pertaining to the environment and its protection. This ministry, and all its related agencies and other governmental bodies, conduct their activities according to and in compliance with a couple of major legal acts, which will be briefly discussed.

The most important, and the most encompassing, major legal document is the Law on Nature Conservation (2010). This law sets standards for all governmental efforts and activities to protect and preserve natural treasures on the territory of the Republic of Serbia, whether they are biological, geological or landscape (*Law on Nature Conservation* 2010). It is very important to point out that this law was ratified recently, and it has been completely harmonized with the European Union (EU) legislature on environmental protection and nature. This constitutes a part of the larger process of harmonization of legal frameworks in Serbia, required for the successful accession to the EU (*Law on Nature Conservation* 2010).

The second most important piece of legislature on the topic of environment in Serbia is the Law on Environment Protection (*Law on Environment Protection* 2009). This law prescribes the acceptable conditions of the living environment, and it regulates human activities which present a potential damage to the environment. The Law on Environment Protection states:

"*Planning and management of environmental protection shall be secured and implemented via National Program of Environmental Protection … to be promulgated by the National Assembly, for the period of 10 years, minimum.*"

(*Law on Environment Protection* 2009)

This National Program of Environmental Protection (*National Program for Environmental Protection* 2010) represents the supreme strategic document produced by the Serbian government in order to plan and execute all necessary measures to improve the current condition of the environment. In that document, an extensive list of goals and objectives in the field of environmental protection is presented, and the due-dates are set for the period between 2014-2020. Apart from this list, National Program for Environmental Protection is in charge of a number of important tasks:

- it establishes criteria which will be used to assess progress in fulfilling set goals and objectives,
- furthermore, it discusses long-term and short-term steps that need to be taken in order to improve the environmental condition,
- finally, it plans the provision of financial resources which will be used to implement this program (*Law on Environment Protection* 2009).

The speed of the implementation of the Program is scheduled by the Action plan incorporated in the program along with the setup of legal and institutional framework for realizing numerous projects using the EU pre-accession funds (EkoBlog 2010).

The main flaw of the current environmental legislature pertaining to one specific part – the environmental protection of national parks in Serbia – is the fact that at present there is no law about national parks in force. The older version of the Law on National Parks (1993) was taken out of force (Institute for Nature Conservation of Serbia 2011h) and until new law is ratified, which according to the National program should happen by the end of 2014. (*National Program for Environmental Protection* 2010), the existing national parks in Serbia will be run in compliance with the provisions of the new Law on Nature Conservation which are closely connected with protected areas and national parks in Serbia(Institute for Nature Conservation of Serbia 2011h).

According to provisions of the law (*Law on Nature Conservation* 2010), a national park is an area under protection of the state because of its distinct natural characteristics and treasures (*Law on Nature Conservation* 2010). It is governed by a public authority which has the obligation to apply the principle of nature protection and sustainable development (*Law on Nature Conservation* 2010) in its functioning. It is forbidden by law to conduct any kind of procedures and activities which might threaten the existence of species, ecosystems and landscapes in the area of a national park (*Law on Nature Conservation* 2010).

Although laws and regulations regulate the aspect of prevention of degradation and devastation of protected areas, the problem of urbanization of national parks is still very much present. A possible solution for that might be found in the government's effort to start dealing with the illegal construction problem all over the country (*Law on Planning and Construction* 2009). Here, the main concern may arise from low reliability of data based on which local and republic authorities will decide whether or not certain construction sites, buildings, or other facilities, should be legalized. Poor land management and illegal cultivation of the areas under protection present another part of this problem.

2.2.2 Montenegro

In comparison with Serbia, environment and its protection have a much stronger foundation in the legislature of Montenegro. The notion of preservation of nature in Montenegro was deeply implanted in the previous, and in the current constitution, the highest legislative act in the country. The preamble of the Constitution, ratified in 2007, states that Montenegro is an independent country of its citizens, democratic, ecologic, based on the rule of law and social justice (*Constitution of Montenegro* 2007). The preamble of the constitution clearly implies that the protection of the environment has a stronghold in the state's legal acts and institutions.

In the political and legal system of Montenegro, the highest position in monitoring and protecting the environment is reserved for Ministry for Sustainable Development and Tourism. A special section of the Ministry is in charge of regulating and supervising legislative acts pertaining to the environmental protection. The three most important laws in this area will be described in this section. These three laws regulate various aspects of national parks and the area around them. Similar to Serbia, these acts are the Law on Environment Protection, the Law on Nature Conservation and the Law on National Parks.

The Law on Environmental Protection sets up the chain of responsibilities and relationships between relevant subjects in the sphere of environment (*Law on Environment* 2008). It regulates hierarchy of governmental documents pertaining to the environment in the following way (*Law on Environment* 2008):

- National strategy for Sustainable Development;
- National program for environmental protection;
- Local plans for environmental protection;
- Strategies, plans and programs made for special purposes and areas.

It should be noted that the National program for environmental protection in Montenegro is enacted every five years, instead of every ten years as in Serbia (*Law on Nature Protection* 2009). It also prescribes the activities and measures which must be taken in order to monitor the environment in a proper way. One of these measures refers to building the Informational system for environmental protection (*Law on Environment* 2008). Part of this Informational system is the GIS platform which urgently needs to be developed, even more so considering the fact that currently there is a serious lack of available digital spatial data in Montenegro.

The Law on Nature Conservation (*Law on Nature Protection* 2009) represents more specific, and also more detailed, set of rules and regulations which are governing all activities in the nature. It also prescribes natural values which should be preserved, and the way of doing this

(*Law on Nature Protection* 2009). As a candidate country, on its way to join the EU, Montenegro obliged itself to harmonize its legislature with the laws and regulations of the EU in all spheres of legal system. Environmental legislature is part of this. The law from 2008. and 2009. takes a new concept from the EU efforts to protect the environment (*Law on Nature Protection* 2009). That concept is the ecological network of natural areas under protection NATURA 2000. Montenegro will set up this network in the next 2 years, in parallel with its own network of protected areas (*Law on Nature Protection* 2009). The main subject of this research and of this thesis – national parks – are a significant member of that future group network. National parks represent the most valuable natural landscapes and areas in the country. Because of that, a special law that regulates organisation and ways of functioning of national parks has been ratified.

The Law on Natural parks in Montenegro is the most recent legislative act regulating the status or protected areas of national parks in Montenegro (*Law on National Parks* 2009). It was ratified in 2009. and it has been long overdue, for a reason that the previous law regulating this matters was ratified in 1993. and 1994. According to the provisions of the new law, these protected areas are run by the Public Authority for National Parks of Montenegro (*Law on National Parks* 2009), the body in charge of all relevant issues pertaining to national parks. This legal and administrative entity has the jurisdiction in monitoring, protecting, and improving the environment and environmental conditions in these protected areas (*Law on National Parks* 2009). This entity also serves as a cover institution for all national parks in Montenegro, and for authorities and management systems of individual national parks (*Law on National Parks* 2009).

Since each national park has its own managing authority, these separate bodies are in charge of day-to-day activities in the area of a particular national park. These daily activities include nature protection and conservation, scientific research, tourism, as well as supervision of the

activities of local communities in order to prevent the degradation and damage in the park (*Law on National Parks* 2009). Montenegro's national parks are not affected by illegal construction as much as national parks in Serbia are. However, they are still exposed to this factor, as well as to anthropogenic adverse effects like overgrazing of cattle, poor land management connected with agriculture and forest fires.

2.3 Geographic Information Systems and Remote Sensing

2.3.1 Geographic Information Systems (GIS) and its application

As a scientific term, Geographic Information Systems (GIS) can be, and very often is, defined in many different ways. In this thesis, the author will understand and use the term GIS according to the definition of the GIS software producing company ESRI, which is a leader in this area. The definition states:

"*A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.*

GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.

A GIS helps you answer questions and solve problems by looking at your data in a way that is quickly understood and easily shared.

GIS technology can be integrated into any enterprise information system framework."

(ESRI 2011b)

In accordance with this definition of GIS, its application in environmental sciences provides researchers with a powerful tool for natural resources management, facilities management, land management and street-networks management (Foote K. and Lynch M. 2000).

In order to make use of as many potential advantages of GIS as possible, ArcGIS 9.3 was used. ArcGIS 9.3 is one of the most prominent software packages used for various GIS tasks, since it offers full functionality and freedom in data analysis, management and representation (ESRI 2011c). Due to its modal system structure, it can also be accompanied with the add-on software extensions making it possible to enhance productivity and make the full use of advanced spatial analysis (ESRI 2011a).

2.3.2 Remote Sensing and its application

Remote sensing, a method used for researching and analyzing spatial aspects of environmental issues, represents one of the youngest tools in modern environmental science. This makes it still open for different interpretations and definitions. In this thesis, the term *remote sensing* will be defined as follows:

"*The science of remote sensing comprises the analysis and the interpretation of measurements of electromagnetic radiation that is reflected from or emitted by a target and observed or recorded from a vantage point by an observer or instrument that is not in the contact with the target.*"

(Mather P. and Koch M. 2011)

The general principle of remote sensing via satellite platform is depicted on Fig. 2. and it shows types of objects and background features which could primarily be spotted and visually represented using this method.

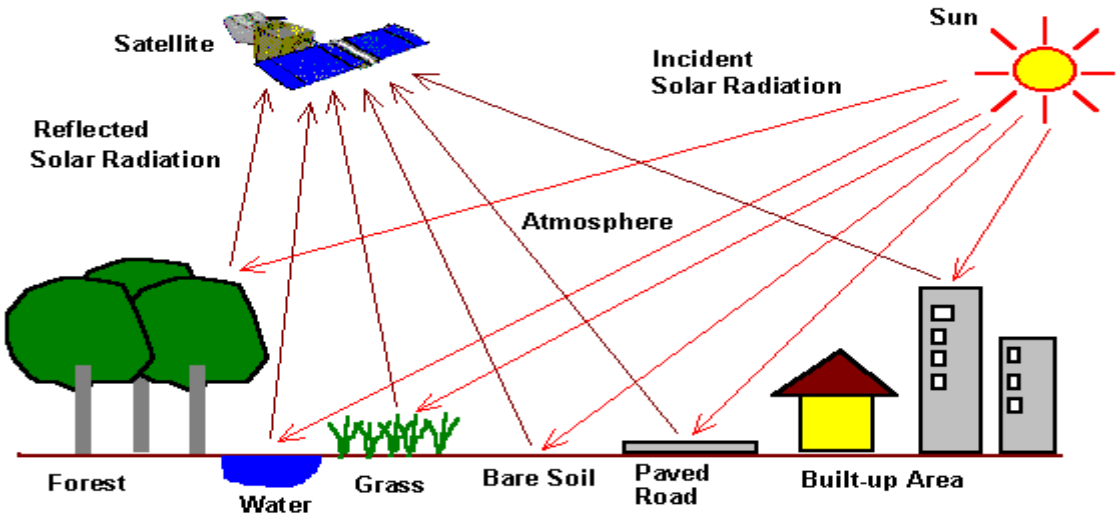

Fig. 2. Remote sensing principle
Source:(Chin L. S. 2001)

Data obtained by remote sensing are digital images which are comprised out of discrete picture elements (pixels) (Richards J. A. and Jia X. 2006). The real size of the surface represented with one pixel is defined as the resolution of the satellite image (Schowengerdt R. 2007). The final product of this method is often further analyzed using GIS software, and this process of complementing GIS and remote sensing methods increases the potential and significance of both methods (Jong S. d. *et al.* 2004). In most cases remote sensing provides the best results for land cover mapping (Jong S. d. *et al.* 2004)

More details will be presented in the next section concerning the source and the form of the satellite image data used in this research.

2.3.3 Landsat Satellite Platforms and its Data Sets

Satellite images used for civilian purposes have strongly demonstrated the significance and the value of the Landsat program, initiated by National Aeronautics and Space Administration (NASA) in 1972 (Wende C. 2003). Up until today, seven Landsat satellite platforms have been launched into the orbit of the Earth in order to observe the planet, collect data and send it back to the processing stations on the ground for further analysis (Wende C. 2003). These

data have helped to observe and analyze environment, natural resources and changes on the Earth for nearly four decades (Wende C. 2003).

Except for Landsat 6 satellite (which never became operational due to technical problems it encountered right after launching), all of the remaining satellite platforms have been successfully using four types of scanning equipment (Wende C. 2003). Return Beam Vidicons (RBV) and Multi-Spectral Scanner (MSS) were used on the first three satellites, MSS and the Thematic Mapper (TM) on the Landsat 4 and 5 and the Landsat 7 is equipped with Enhanced Thematic Mapper-plus (Wende C. 2003).

The most reliable of all Landsat satellites has proven to be Landsat 5. It produces satellite images with the resolution of 30m and it uses seven different electromagnetic bands ranging from 0.45-12.5 um (Wende C. 2003). Images obtained in these seven bands are later used for various purposes, and in various three-colour combinations, Red-Green-Blue (RGB) combinations which are produced by superimposing them one over the other (Wende C. 2003).

For analyzing urbanization processes on the surface of the Earth, using the Landsat imagery, RGB combination (7, 4, 2) has shown the best results so far (Wende C. 2003). When this combination is used to create images, urbanized areas are represented with surfaces of magenta, pale pink or lavender colour which makes them easily detectable (Wende C. 2003). Apart from urbanized areas, only bare soil or rocks are represented with a similar colour but with a different shade and that characteristic can be digitally modified in later stages of the analysis (Wende C. 2003). The following section will discuss different ways of application of data obtained by satellite platforms in analyzing both urbanization and protected areas.

3. Research Methodology

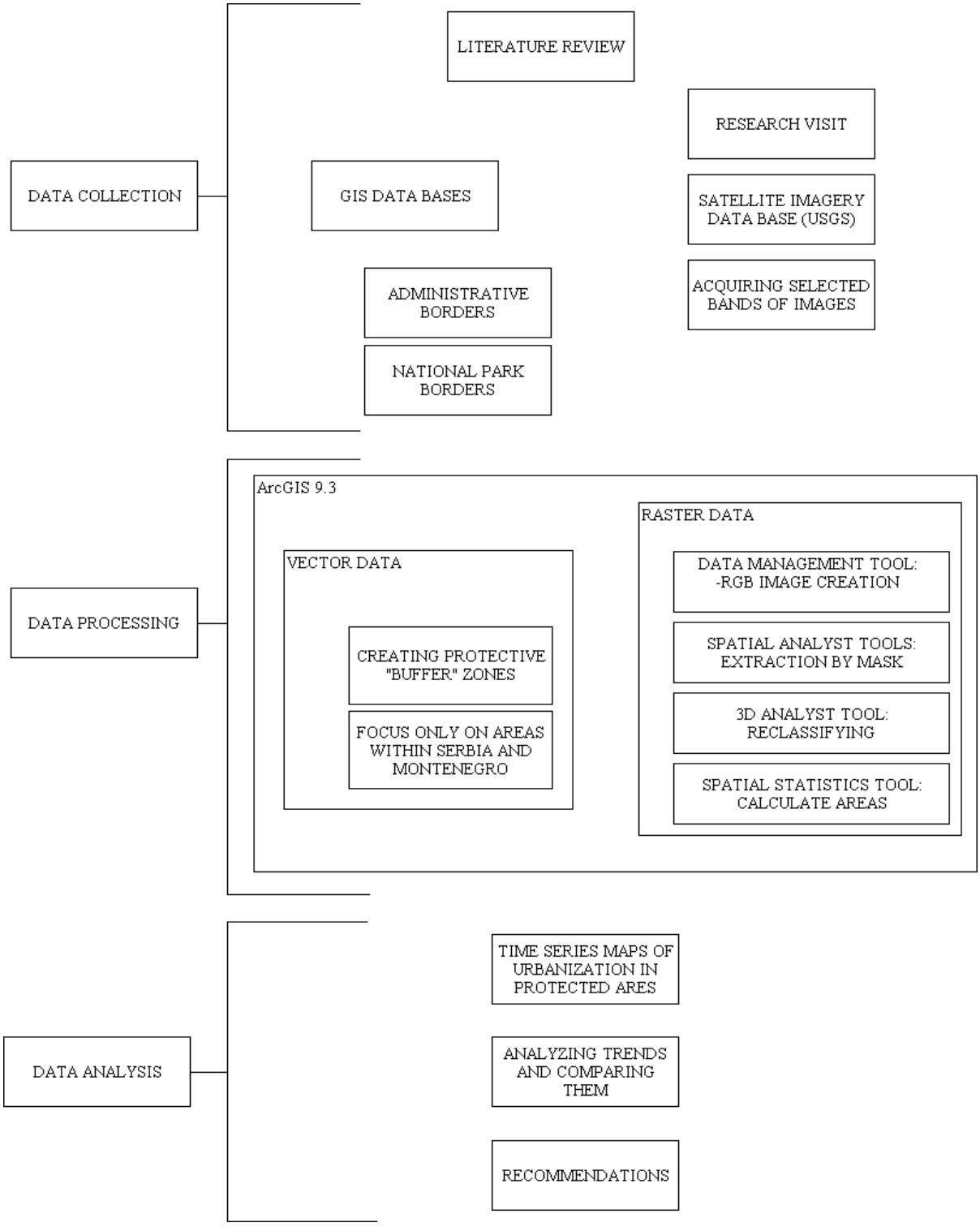

Fig. 3. Scheme of the research methodology

3.1 Data Collection

Methodology used for this research is represented on Fig. 3. The first phase of research was conducted researching current scientific literature and by gathering digital spatial data in vector format on the physical position and the area of the national parks in Serbia and Montenegro and the protective zones around them. Data gathered from this procedure was used in combination with raster Landsat 5 TM satellite image data of highest quality and in appropriately chosen time series over the period of 20-27 years between 1984 and 2011 which are showing exactly these protected areas.

In order to create an overview of the current status of national parks in Serbia and Montenegro and the adverse (anthropogenic) effects that they are facing with (urbanization, poor land management, forest fires, etc.) an archival research was conducted. An up-to-date review of national parks in Serbia and Montenegro was created discussing past and present development of those areas. Based on the extensive literature review, a list of anthropogenic pressures, which are detectable from satellite images, was devised and all national parks were analyzed through their scope.

A separate part of the archival research consisted of a review of context-specific legal regulations in Serbia, and in Montenegro, i.e. legislative aspects of protection from devastation of national parks were reviewed. Since legal regulations in these two states have been continuously changing in the past twenty years, a review of the latest developments in the process of legalization of illegal construction in protected areas in Serbia and in Montenegro is included.

Aiming to acquire all necessary knowledge needed for using the satellite image data in this research a research visit to Marine Hydro-physical Institute, Sevastopol, Ukraine was made from May 23rd to May 31st 2011. In this institution, renown for its expertise in remote sensing, intensive learning courses were attended on improving the skills of acquiring,

processing and analyzing satellite imagery and data. During the research visit, software tools used in this area such as BEAM 4.6, and ENVI were analyzed as well. Expert consultation on specific issues pertaining to this research topic were conducted with Prof. Sergey Stanichny, a senior researcher during the visit.

National park authorities in Serbia and Montenegro were also consulted on numerous occasions, especially on the topic of digital GIS data availability and procurement. These organizations are as follows:

- Nature conservation institute, Belgrade, Serbia;
- National Park “Djerdap”, Donji Milanovac, Serbia;
- National Park “Kopaonik”, Brzece, Serbia;
- National Park “Fruska Gora”, Sremski Karlovci, Serbia;
- National Park “Tara”, Bajina Basta, Serbia;
- National Park “Sar Planina”, Strpce, Kosovo-Serbia;
- Public Enterprise “National Parks of Montenegro”, Podgorica, Montenegro;
- National Park “Durmitor”, Zabljak, Montenegro;
- National Park “Biogradska Gora”, Mojkovac, Montenegro;
- National Park “Lovcen”, Cetinje, Montenegro;
- National Park “Prokletije”, Plav, Montenegro;
- National Park “Skadar Lake”, Virpazar, Montenegro.

Digital data sets necessary to realize this research in GIS environment consist out of two main and equally important parts:

- GIS data sets on administrative borders of Serbia and of Montenegro, protected areas of national parks in these two countries, and protective zone around parks;
- satellite data imagery series for protected areas spanning over the last three decades.

GIS data was collected in vector format (.shp) and from these sources:

- data sets on administrative borders of Serbia and Montenegro was obtained from DIVA-GIS data disseminating portal;
- data sets on spatial position and the surface area of national parks Fruska Gora, Tara, Djerdap, and Sar Planina (Sar Mountain) in Serbia, as well as Durmitor in Montenegro was obtained from ProtectedPlanet.net data portal;
- data sets on spatial position of national parks Kopaonik in Serbia and Prokletije, Lovcen, Biogradska Gora and Skadar Lake in Montenegro were provided by the National Park "Kopaonik" and the Public Authority "National Parks of Montenegro" respectively.

Satellite imagery data sets covering the relevant areas were obtained through the U.S. Geological Survey's (USGS) Earth Resources Observation and Science (EROS) Center which is operating Global Visualization Viewer (GloVis) and its EarthExplorer system. Data sets are provided in sets of 7 separate images in raster (.TIF) file format. These represent the result of the 7 different radio-wave band scanner on the Landsat 5 TM satellite platform(Wende C. 2003). When combined together these images can provide satellite footage which is useful for analysis in various fields of research.

Raster data sets have a spatial resolution of 30m and the total area covered with one image has a 185km*185km dimensions (Wende C. 2003). Landsat 7 ETM data (Wende C. 2003), although having a better resolution and quality, was not used in this research due to the scanner malfunction which happened in 2003 (Wende C. 2003).It is also very important to mention the significance of the quality of images which are available. It should never be with more that 5-10% of cloud cover because water vapour in clouds is reduces visibility

3.2 Data Processing and Analysis

The geographical area of national parks in Serbia and Montenegro with their wider protective zones was isolated through ESRI ArcGIS 9.3 software package. Afterwards, these data were used in combination with Landsat 5 TM satellite image data.

Spatial Analyst, Spatial Statistics, Data Management and 3D Analyst tools (ESRI 2011a) were used within the software package to provide the specific values for surface areas that were affected by urbanization or other type of negative anthropogenic process.

Satellite data imagery was also processed in ESRI ArcGIS 9.3 software package. This software was used to produce a set of three-component red-green-blue (RGB) images, out of seven different one-band images. These seven images put together make one single satellite image.

In order to detect and analyze human-caused encroachment of protected areas, a combination of bands for the creation of RGB images was used. This combinations is: (7, 4, 2), this combination have already been successfully employed in other researches on a similar topic (Wende C. 2003).

The final product of combining GIS and remote sensing methods in this research is the calculation of the area of national parks which used to be, and is under different negative impacts caused by human activities. Statistical analysis of the changes in these areas was used to show the prevailing trends which affect this issue.

The end product of this digital data manipulation and processing are series of maps depicting changes in urbanization and other anthropogenic processes which took place in these protected areas. Total surface affected by these adverse effects was calculated using GIS software tools embedded in ESRI ArcGIS 9.3 extension tools.

Using the obtained and processed data, an analysis of created maps was conducted in order to show the urbanization levels in each park. Simple statistical calculation were used to point out predominant trends in urbanization processes.

The overall trends of urbanization of national parks in Serbia and Montenegro became visible through analysis of data gathered in this research. These trends were mutually compared, and the results of the comparison were used to develop a list of recommendations.

4. Results and Analysis

4.1 National Park Fruska Gora, Serbia

According to results acquired by analyzing 5 satellite images of National park Fruska Gora, human encroachment of it is mildly increasing. Protective "buffer" zone was almost all consumed in agricultural fields and production already in 1988 as it is shown on (Fig. 4). Percentage of urbanized space was at its minimum in 1994. when 56.07% or 370.57km^2 of the park was affected by mostly agricultural practices of the local population. Since then, the area of the park and its protective zone under human influence has shown a mild uprising trend with the maximum reached in 2006. when urbanization level got to 63% or 416.37km^2. However, in the last five years this trend started to change with currently 61.54% or 406.72km^2 being encroached but anthropogenic activities.

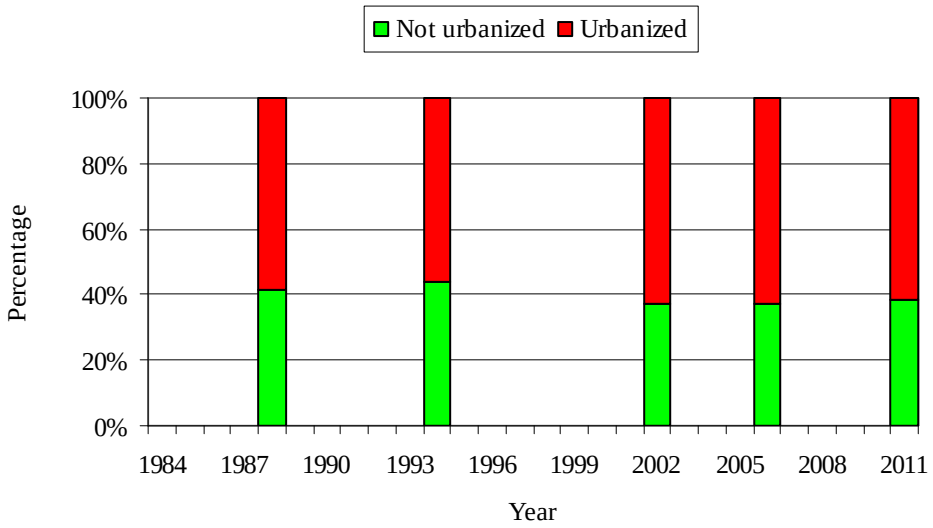

Fig. 4. Urbanization change over time for NP Fruska Gora
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

Comparing the situation from 1988. (Fig. 5.) and 2011. (Fig. 6.) the most notable changes in the park could be spotted in the far western part and the middle section where the forest cover starts showing signs of damage while the protective zone shows small changes happening in the northern section of it.

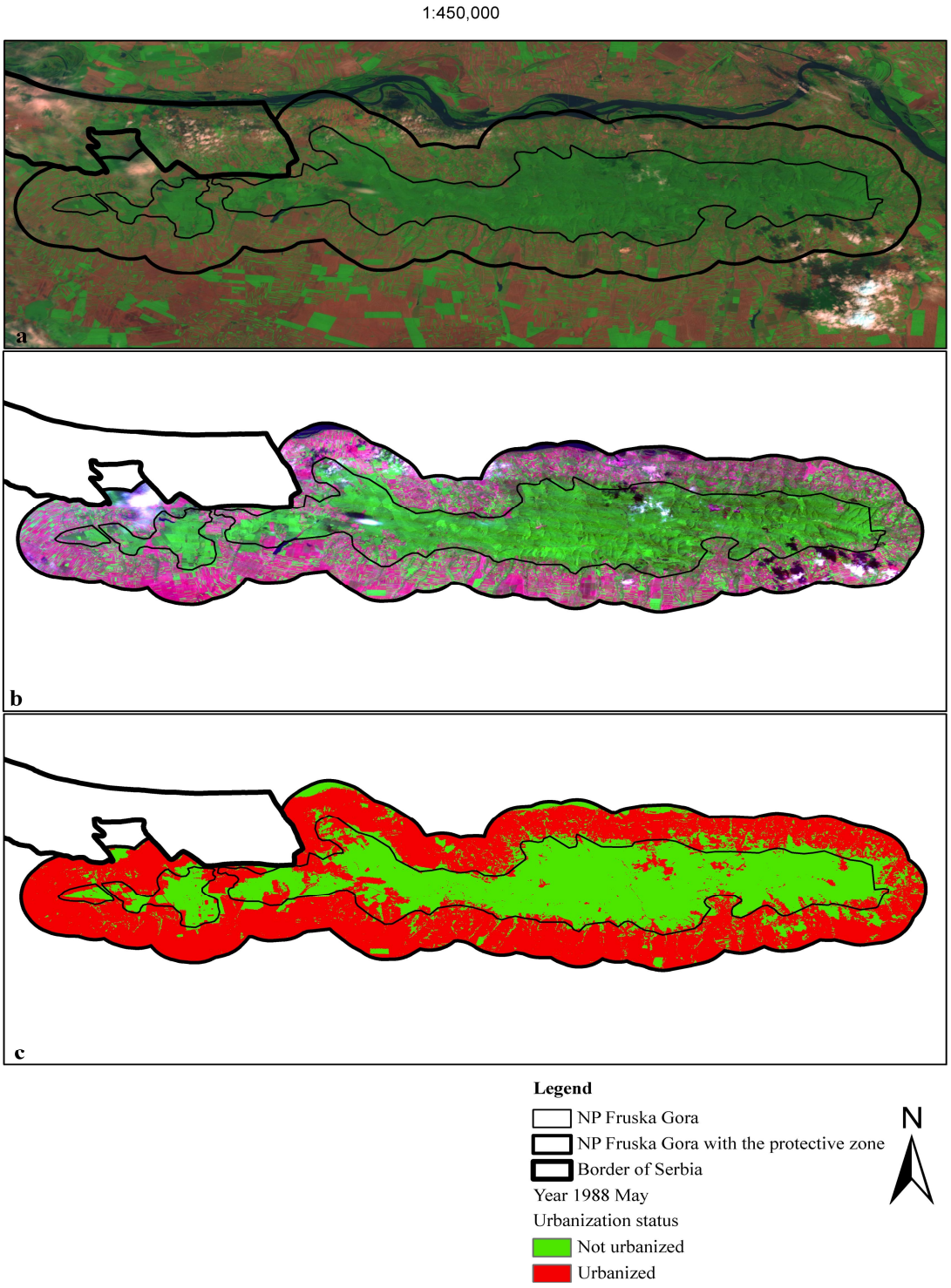

Fig. 5. Map of urbanization of NP Fruska Gora
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

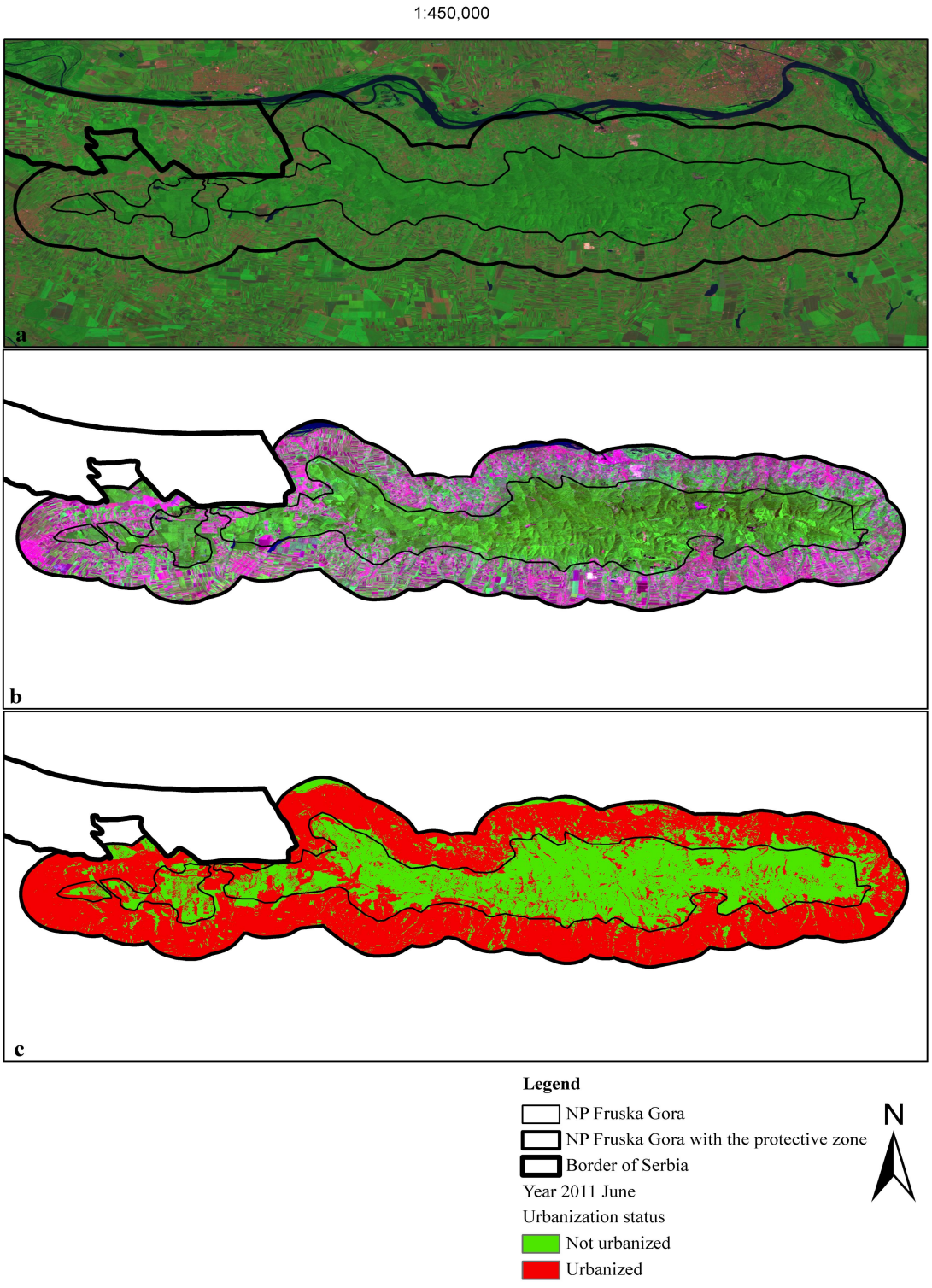

Fig. 6. Map of urbanization of NP Fruska Gora
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

4.2 National Park Kopaonik, Serbia

Analysis of 4 satallite images in the period between 1984. and 2009. representing the national park Kopaonik have shown variability in its urbanization status. From Fig. 7. it can be seen a downward trend in urbanized surface area of the park and its protective zone between 1984. and 1987. as well as from 2002. to 2009., with 1.25% and 3.95% decrease respectively. However, between 1987. and 2002. a 2.03% increase was noted.

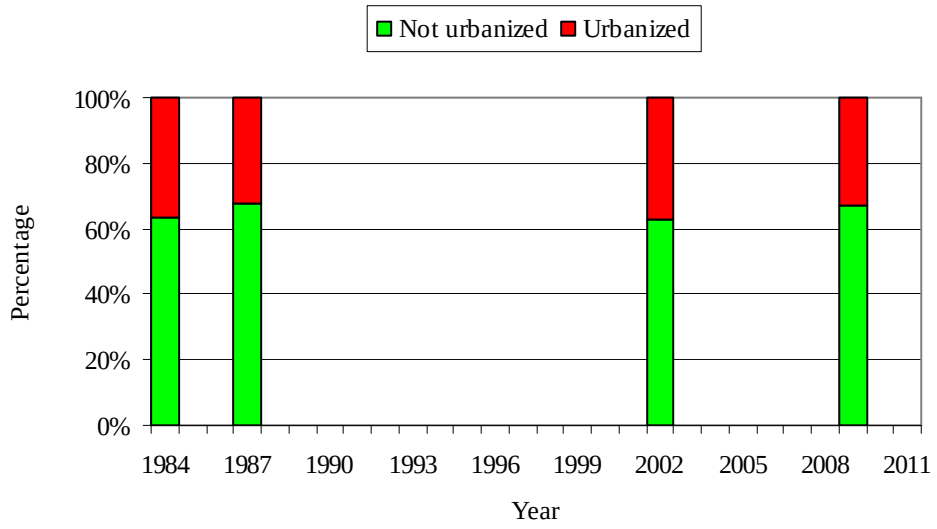

Fig. 7. Urbanization change over time for NP Kopaonik
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

This increase from the situation in 1987 (Fig. 8.) could be assigned to urban development of Kopaonik ski-center in the southern region of the park (Fig. 9.) where new accommodation capacities and facilities intended for tourism activities were built. Overall urbanization status of national park Kopaonik is currently improving but the problem of illegally built up houses around the settlement remains yet to be tackled. Minor problem for the urbanization of this park is also represented by the agricultural fields in the eastern rim of the protective zone.

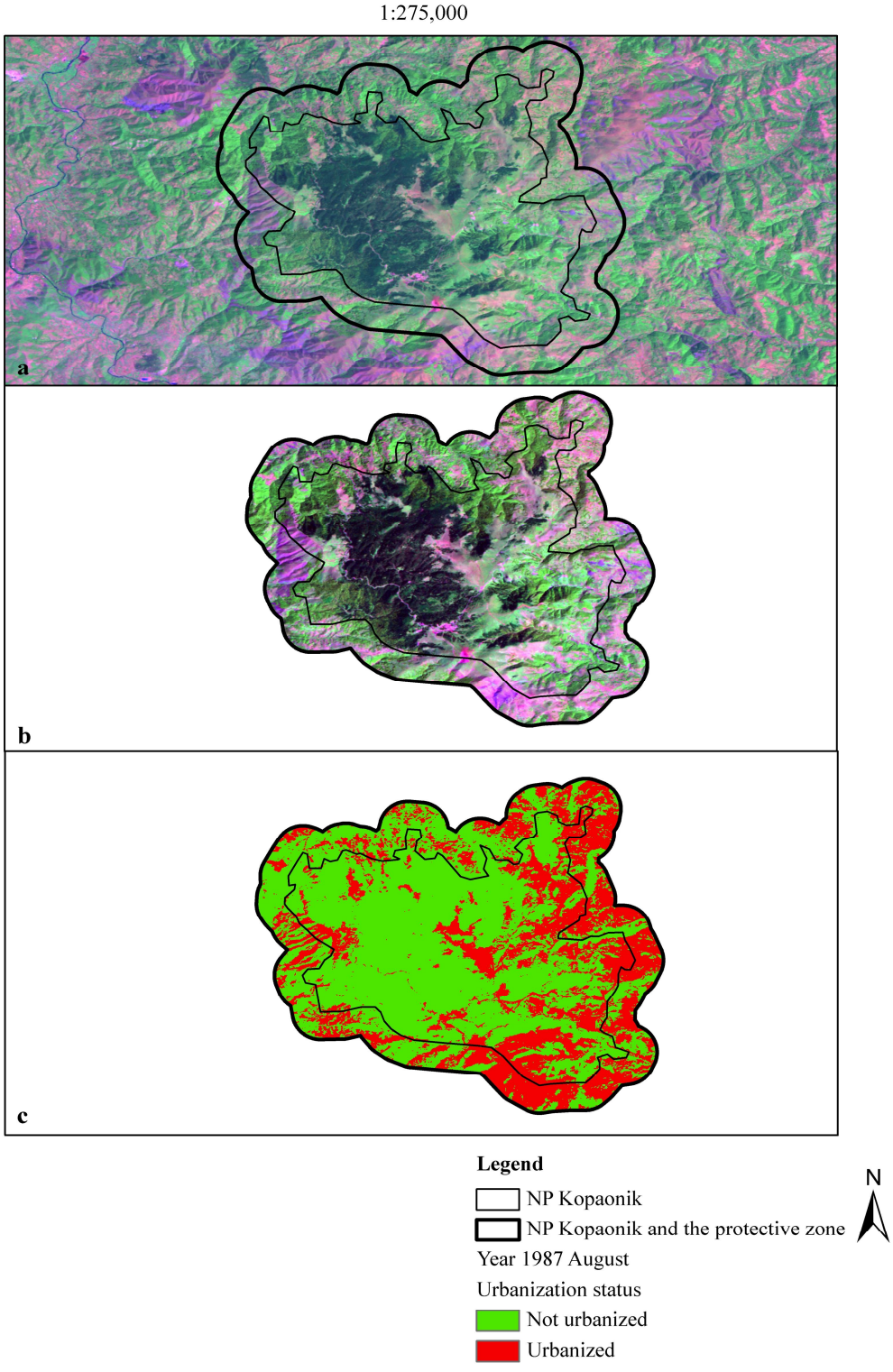

Fig. 8. Map of urbanization of NP Kopaonik
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

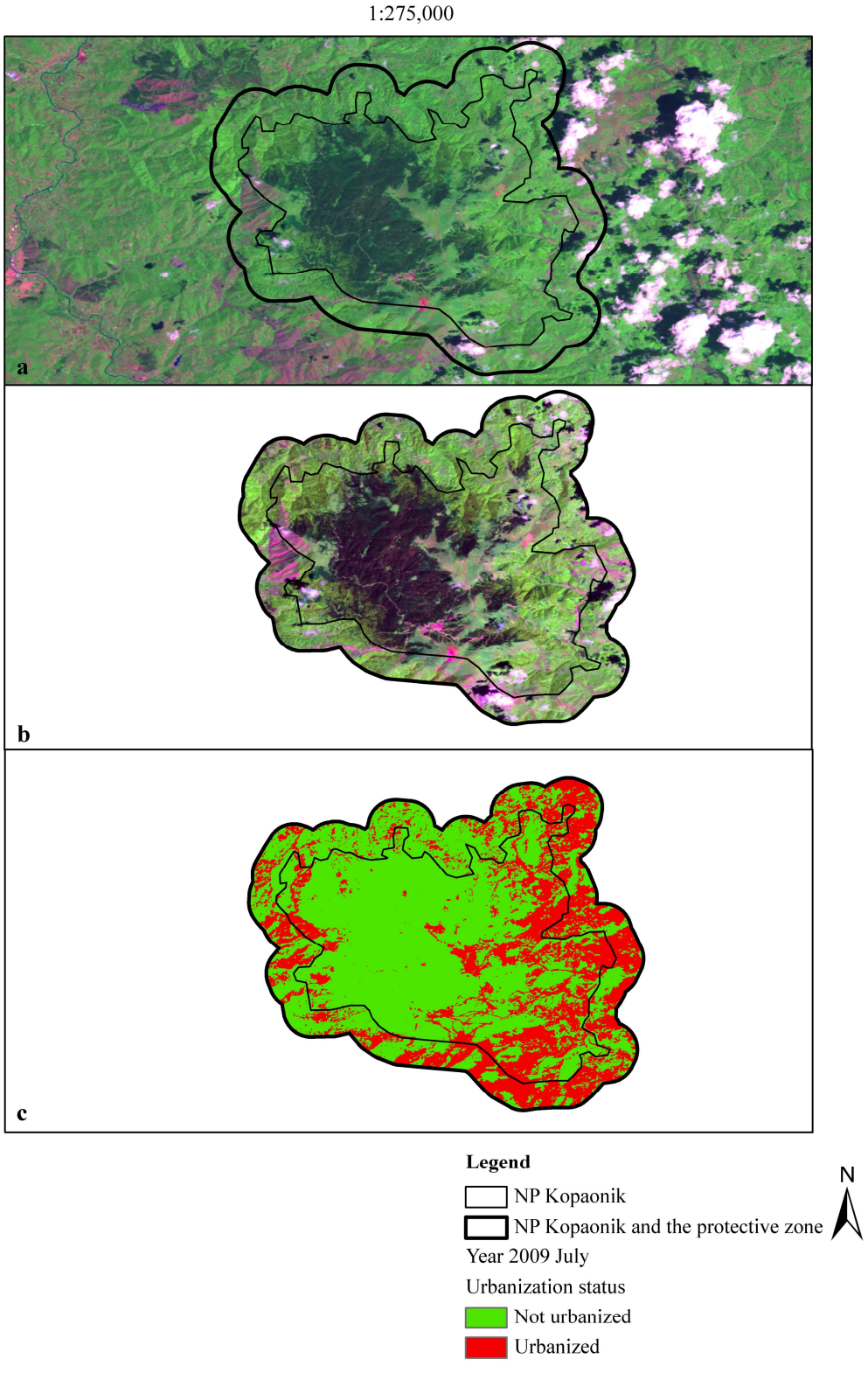

Fig. 9. Map of urbanization of NP Kopaonik
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

4.3 National Park Djerdap, Serbia

In the analysis of the urbanization processes of the national park Djerdap between 1986. and 2011. two major trends have been discovered. According to Fig. 10. from 1986. to 2001. slight decrease of the urbanized surface area is ranging from 26.7% or 250.89km^2 to 24.12% or 226.65km^2 respectively. From 2001. onwards a significant increase of urbanized space in the park and its protective zone has happened until 2011. Starting from mentioned level in 2001. human encroachement of this national park rose to 26.62% in 2003. and then it continued to rise although at a slower pace until 2009. when it reached 28.7% of the area. The biggest increase in urbanized surface are took place in the last two years when it rose to 36.29%.

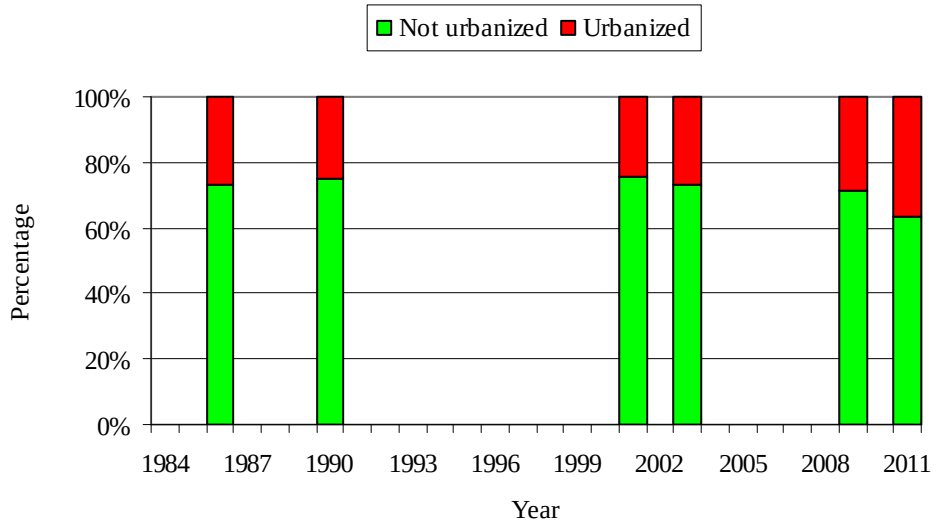

Fig. 10 Urbanization change over time for NP Djerdap
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

If we take a look at Fig. 11. and Fig. 12. it is relatively easy to notice that the southern border on the western half of the park and its protective zone are facing the increased levels of urbanization. Main cause for this might be the intensified agriculture in this region of the country due to the bad economic situation in the region and reduced industrial activity.

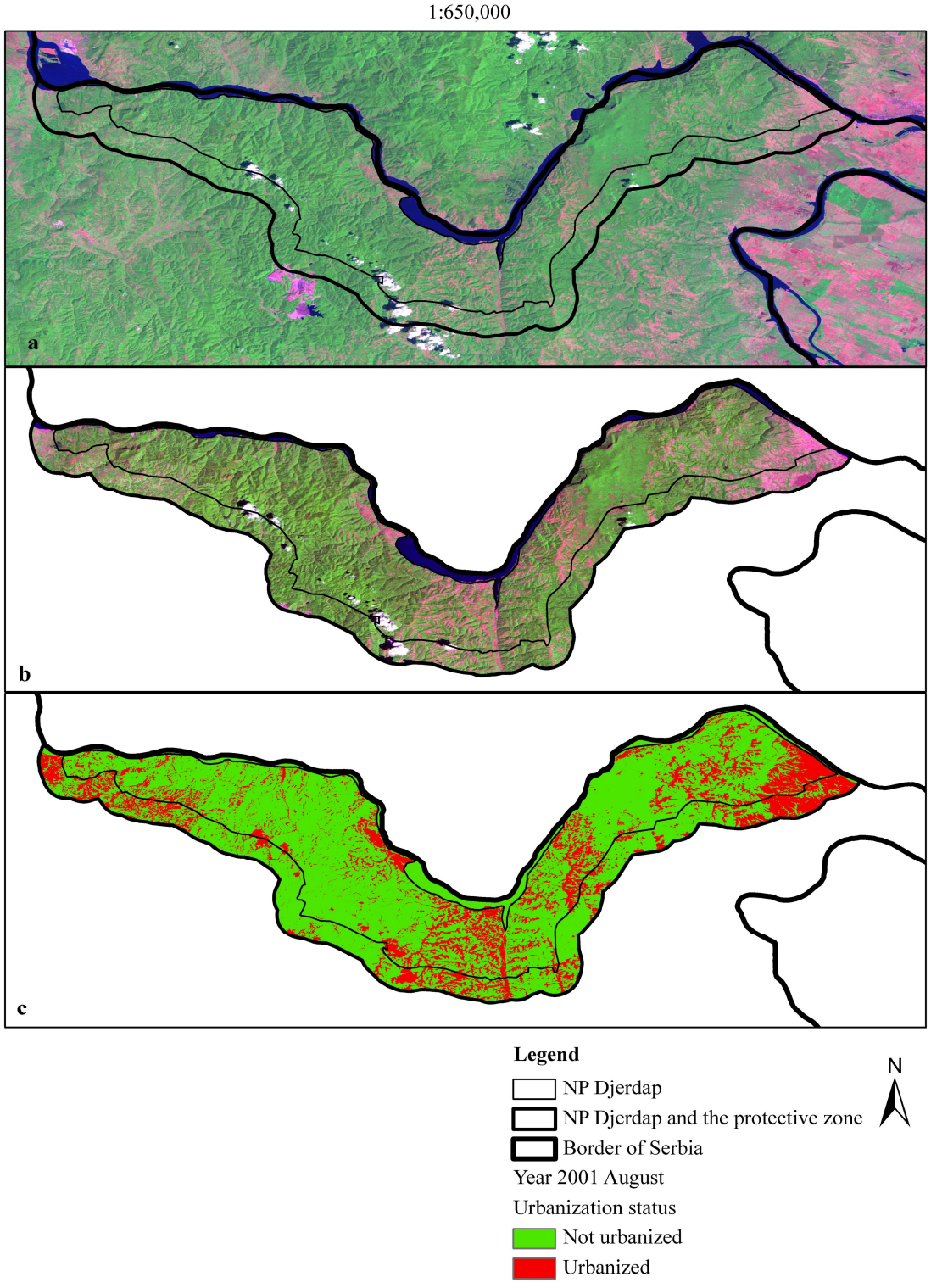

Fig. 11. Map of urbanization of NP Djerdap

a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park

Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

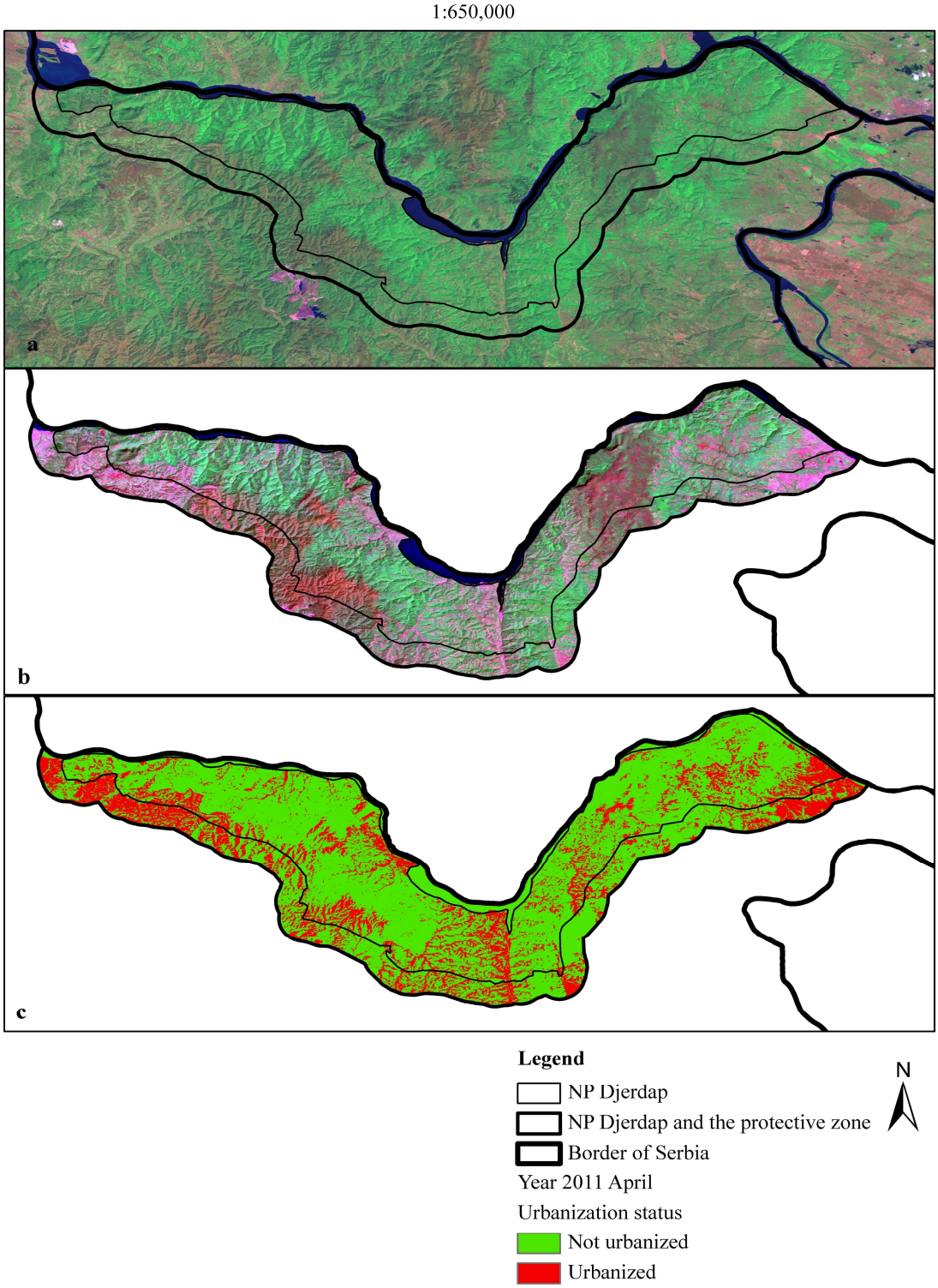

Fig. 12. Map of urbanization of NP Djerdap
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the par
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

4.4 National Park Tara, Serbia

In the past 25 years national park Tara has suffered minor detectable urbanization. What might be interesting about this park is that it has been improving constantly from 1986. when it had 31.38% or 117.94km^2 (Fig. 13) of urbanized space to 2002. when it reached 25.07% or 94.22km^2. One year after the area affected by urbanization increased to 27.82% and in the following seven years, it remained stagnant.

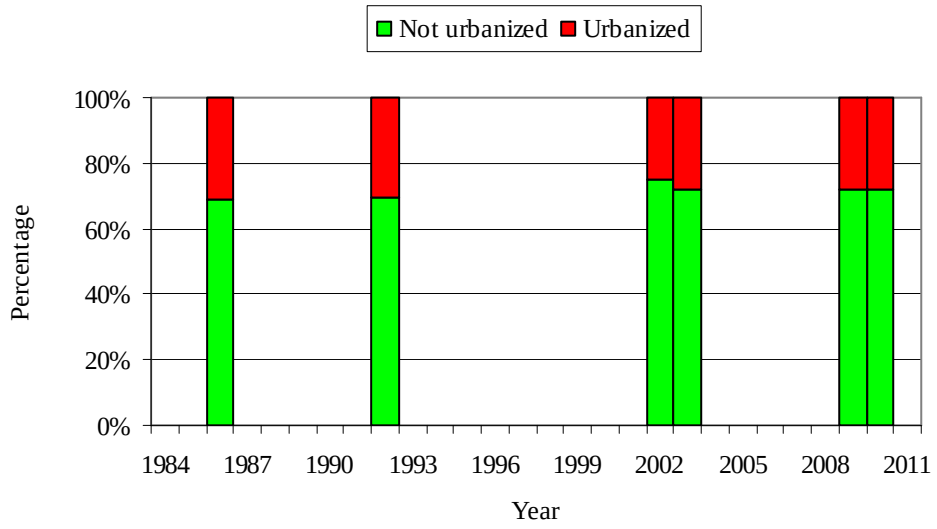

Fig. 13. Urbanization change over time for NP Tara
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

As the areas mostly under anthropogenic pressure, two of them are standing out on (Fig. 14) and (Fig. 15). Those are the agricultural estates of the local population in the upper north-western section of the park and the large area in the central southern section of the protective zone.

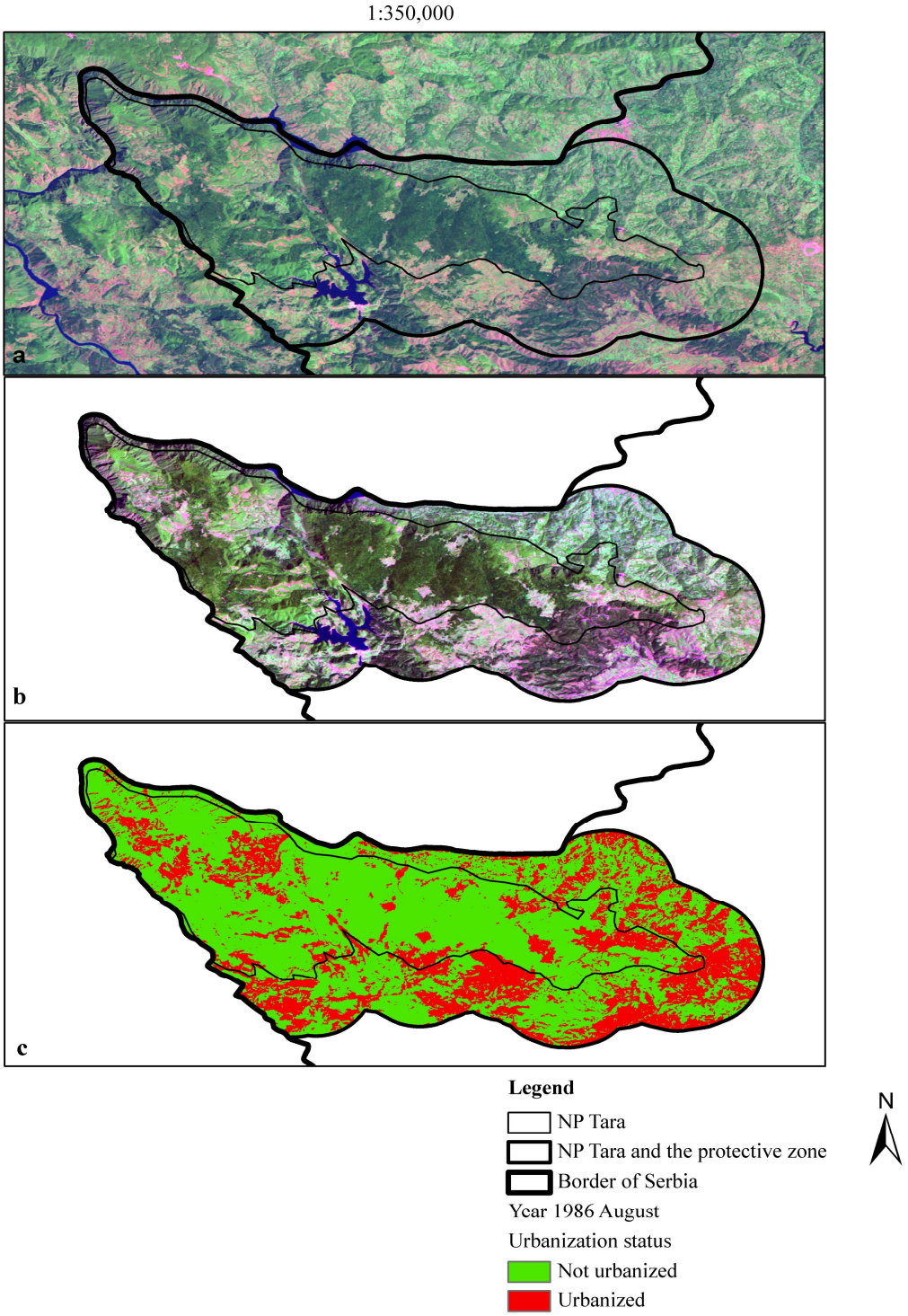

Fig. 14. Map of urbanization of NP Tara

a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park

Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

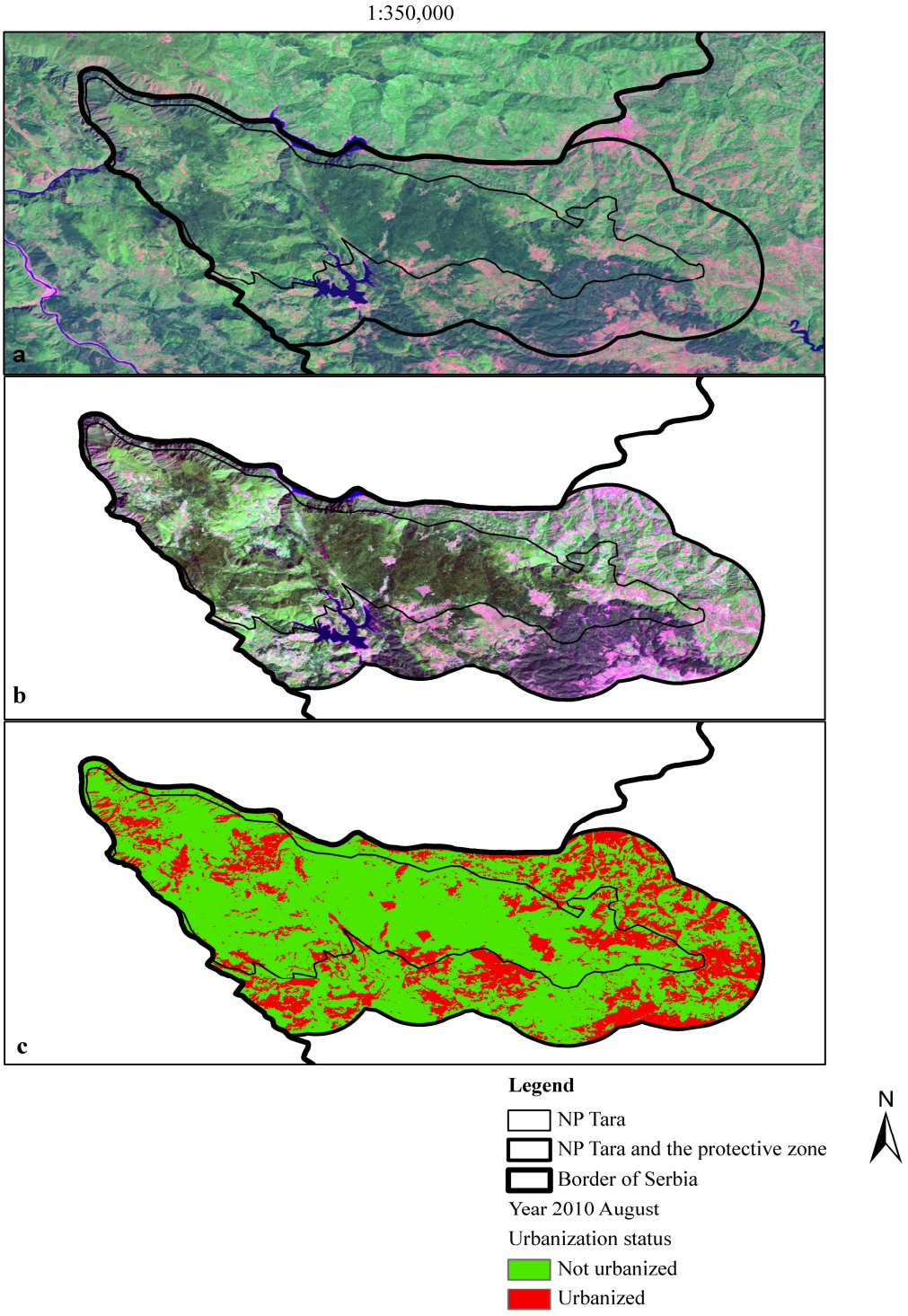

Fig. 15. Map of urbanization of NP Tara
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

4.5 National Park Sar Mountain

National park Sar Mountain has, together with the national park Djerdap, sustained the heaviest urbanization and devastation processes in the past 25 years. After analyzing 4 satellite images from 1984, 1990, 2006 and 2009. it can be seen (Fig. 16) that the level of urbanization in this park has increased from 54.94% or 532.92km^2 in 1984., over 55.4% or 537.38km^2 in 1990. to an alarming 62.65% or 607.7km^2 under human influence in 2006. This increase is currently somehow stabilized at 61.14% in 2009.

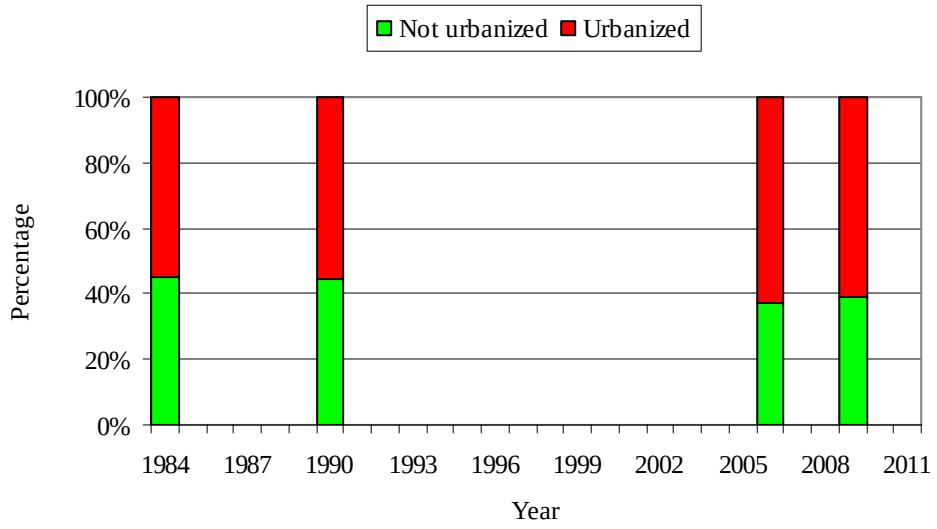

Fig. 16. Urbanization change over time for NP Sar Mountain
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

Fig. 17. in comparison with Fig. 18. gives some indices of where this devastating process took place within the park and its protected area. In almost every section of the inner protected area intensive deforestation took place along with increased surface area used for agricultural production. The most visible example is a sizable patch of deforested land in the central region of the park. Adverse effects and results of these urbanization processes are also visible on the far east and far west sections of the protective zone mainly caused by agricultural activities.

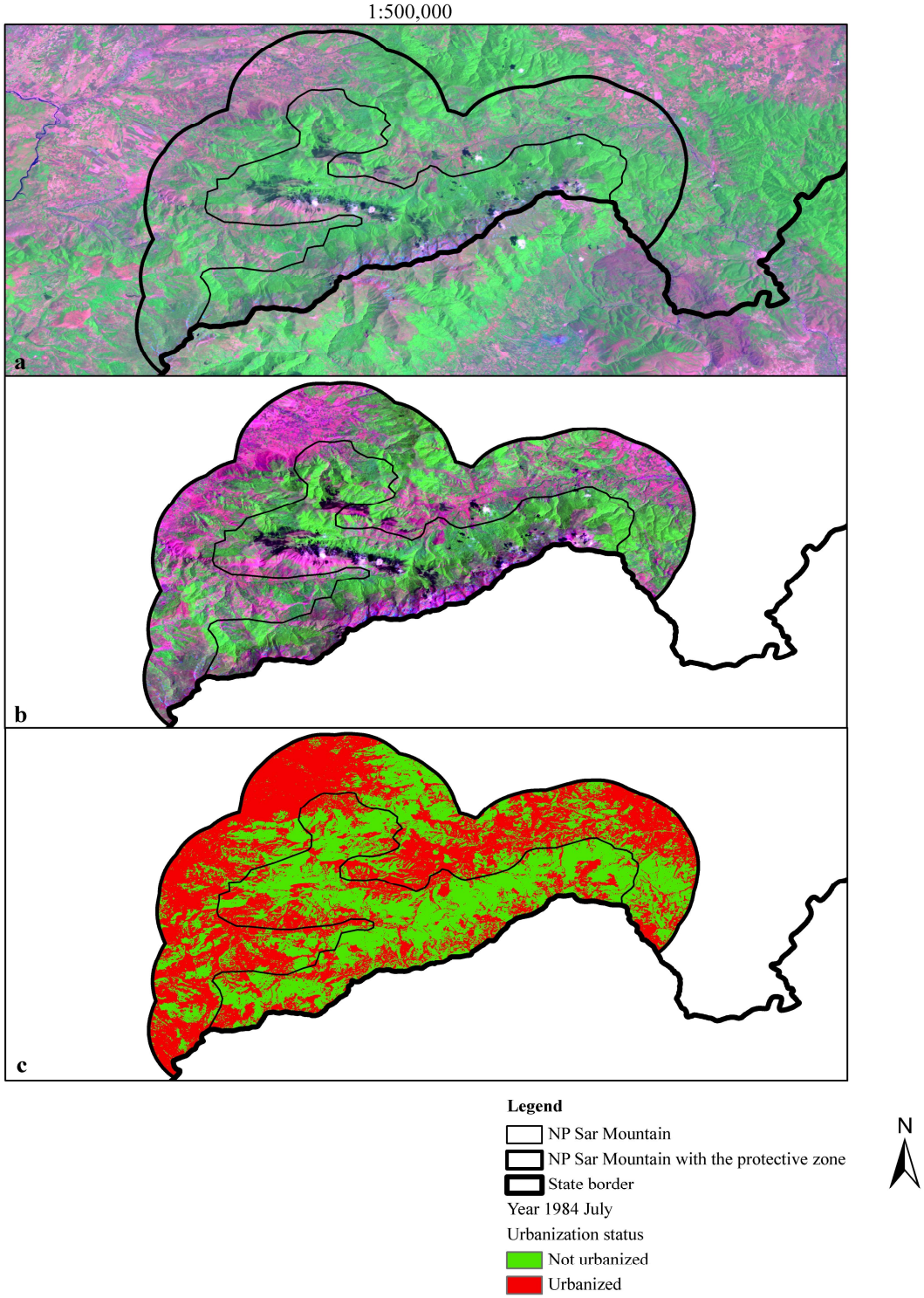

Fig. 17. Map of urbanization of NP Sar Mountain

a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park

Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

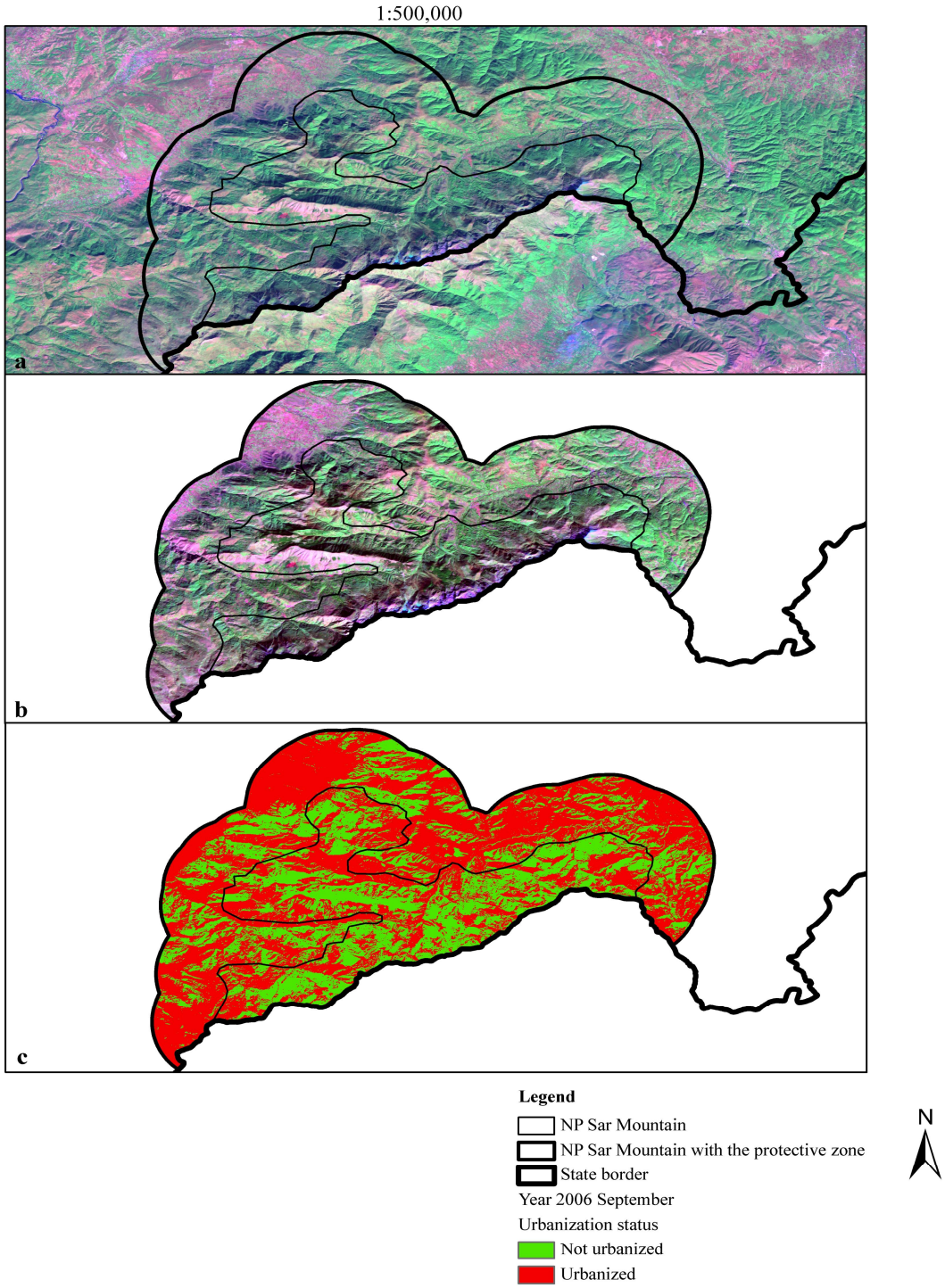

Fig. 18. Map of urbanization of NP Sar Mountain
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

4.6 National Park Durmitor, Montenegro

National park Durmitor, second largest national park in Montenegro, has mostly been stagnant in terms of the size of urbanized area within the park. Since 1986. the size of this area has been slightly changing, both increasing and decreasing, but it had always remained within less then a 3% band from 35.86% or 119.77km^2 in 1993. to 33.05% or 110.39km^2 in 2010 (Fig. 19).

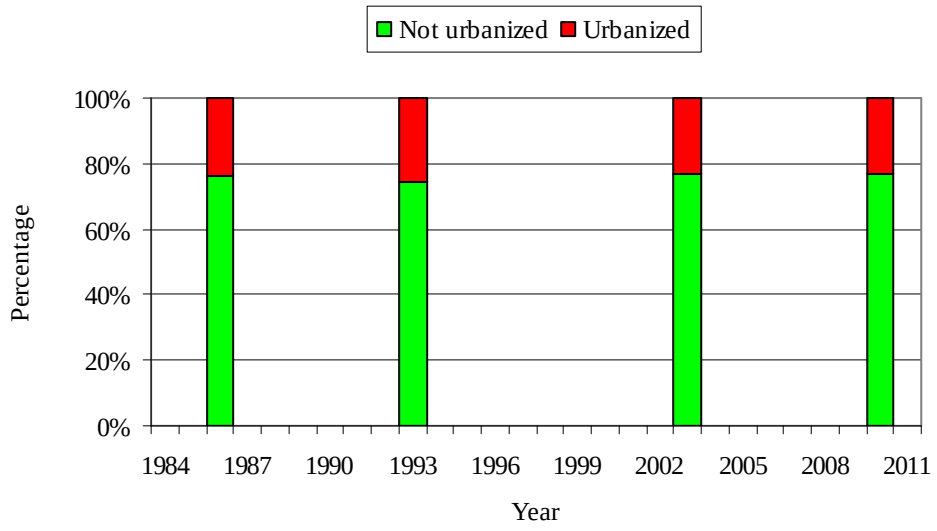

Fig. 19. Urbanization change over time for NP Durmitor
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

Although the area affected by the urbanization has not significantly changed over this period, the spatial redistribution of it might have took place which can be seen comparing Fig. 20. and Fig. 21. Area in northern part of of the park, used by farmers and their cattle in the summer shows significant signs of improvement in 2010. This improvement is counter-parted by a drastic results of urbanization in the eastern and south-western part of the mountainous section of the park. The main cause for this redistribution is the development of tourism, especially winter-ski tourism in the park and its biggest settlement Zabljak in the eastern sector of the protected area.

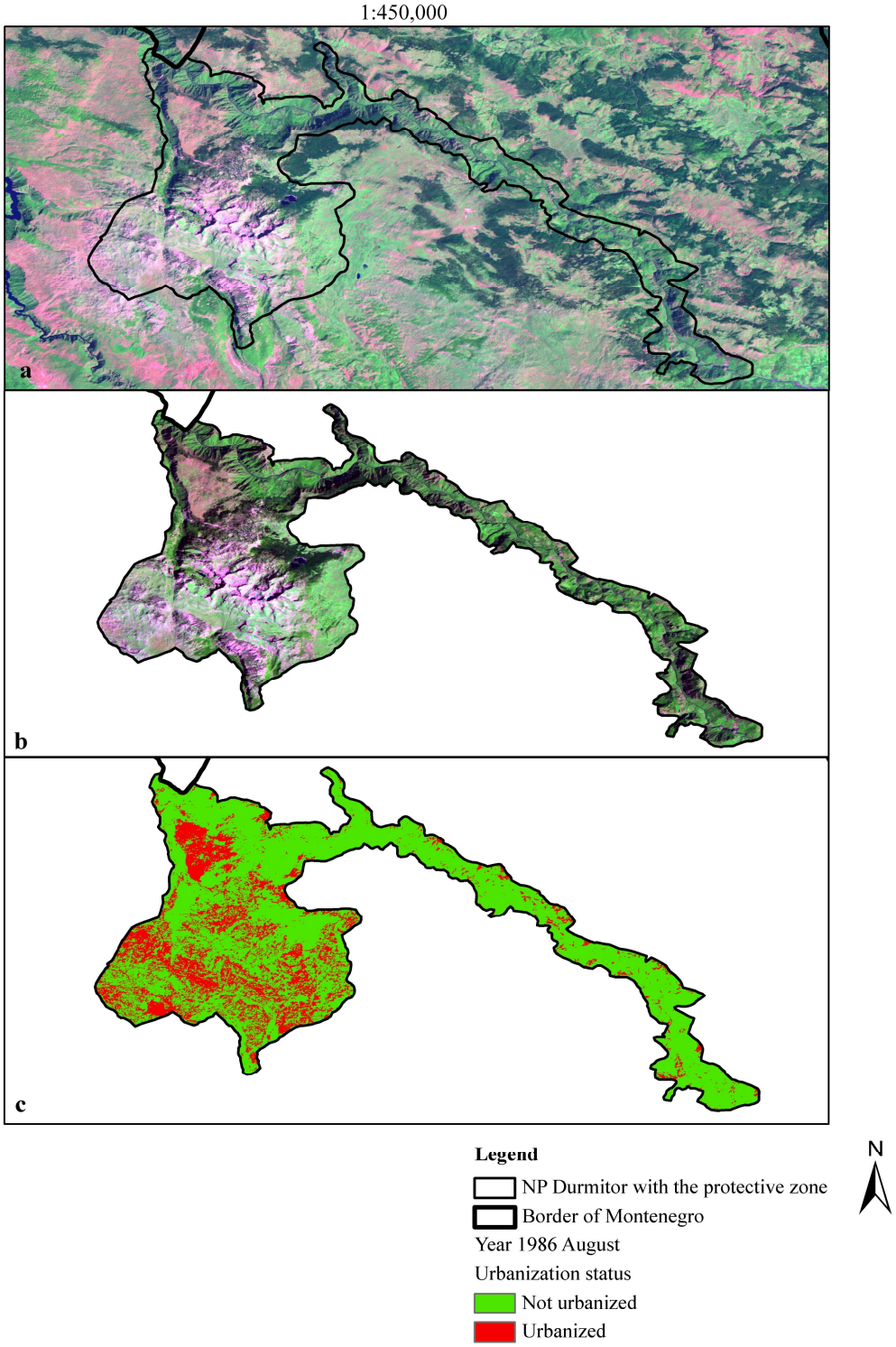

Fig. 20. Map of urbanization of NP Durmitor

a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park

Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

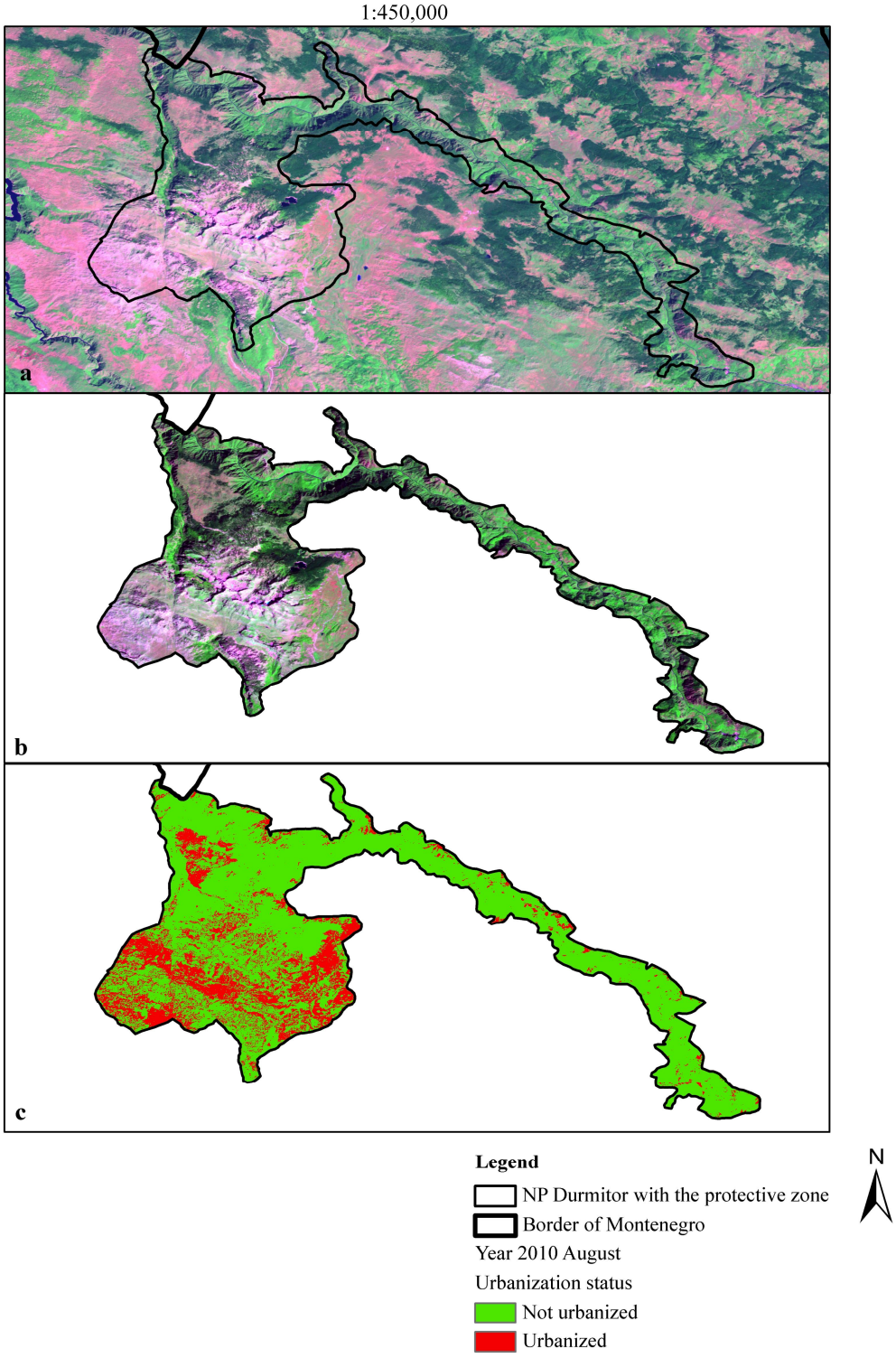

Fig. 21. Map of urbanization of NP Durmitor
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

4.7 National park Biogradska Gora, Montenegro

Although it is the smallest national park in, both Montenegro and Serbia, Biogradska gora is not spared the adverse effects human activities have on the protected areas. Fig. 22. shows that even though urbanization decreased from 1986. to 1993. from 16.71% or 9.44km^2 to 11% or 6.22km^2 this trend was interrupted by urbanization at a slower pace over the next 16 years until it reached 16.92% of the area or 9.56km2, returning to its starting point within the temporal scope of this research.

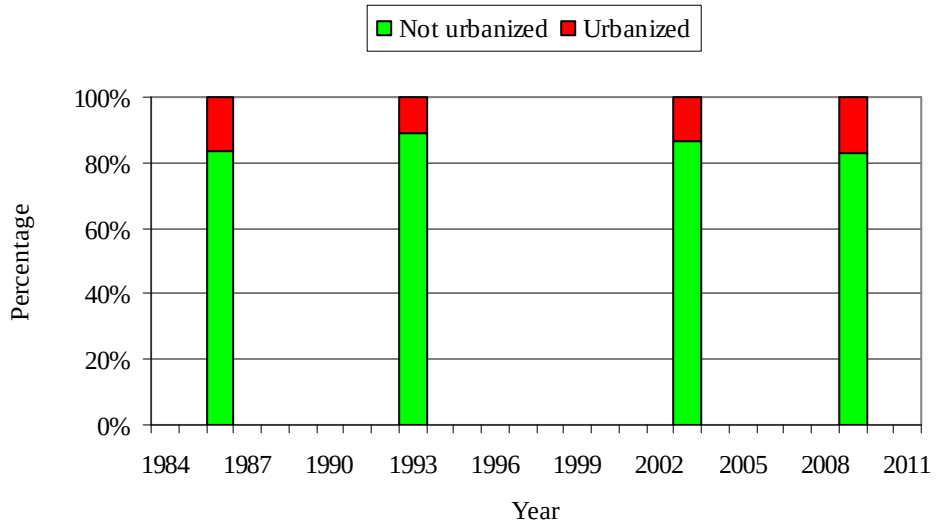

Fig. 22. Urbanization change over time for NP Biogradska Gora
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

In this protected area there are no permanent human settlements but the activities in the park and more specifically around the lake in the center of the park which represents one of its main tourist attractions have caused some damage nonetheless. One of the most significant problems is slow deforestation which is, in turn, leading to erosion occurrences like the one north-west from the Biogradsko Laka like it shown on Fig. 23. and Fig. 24.

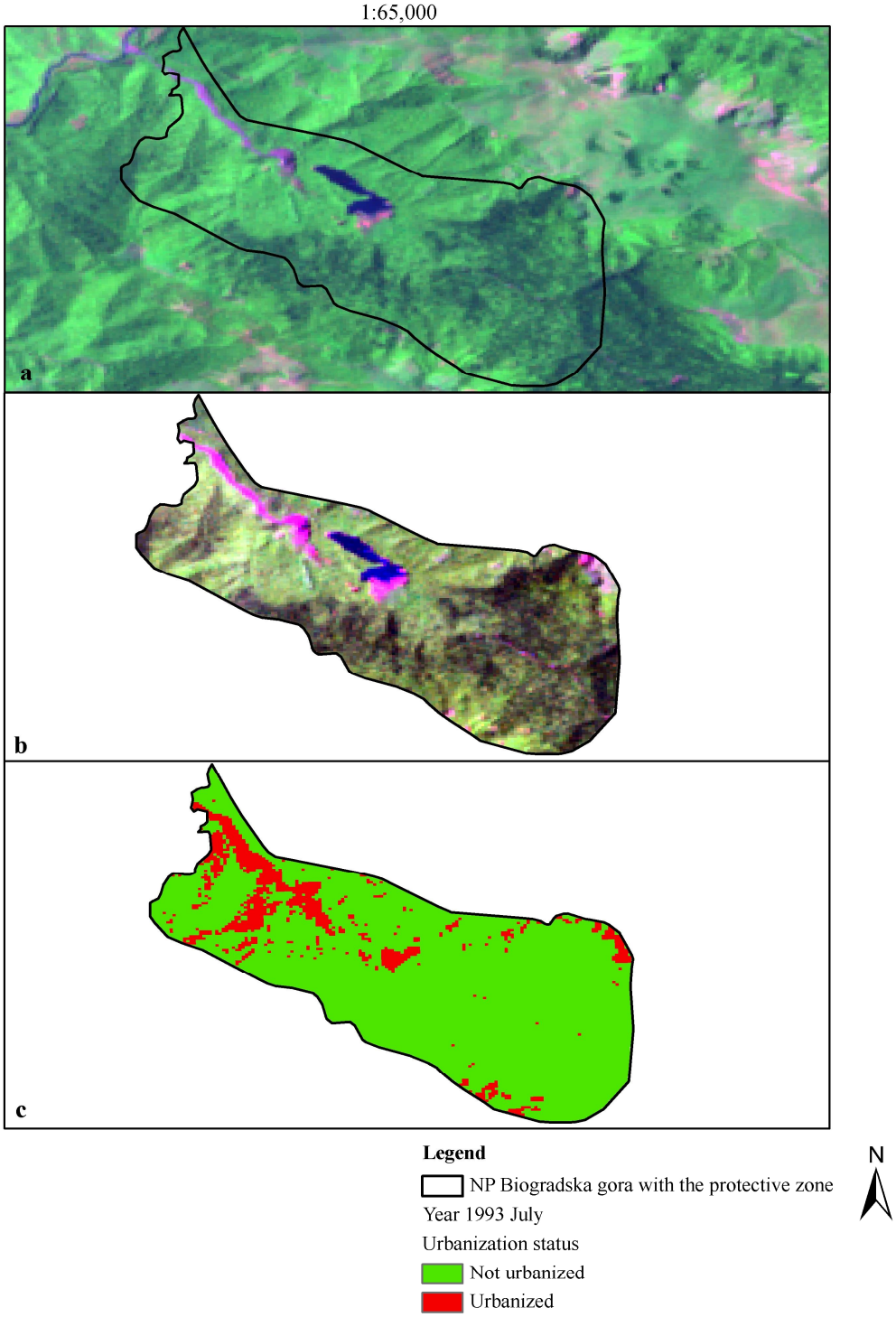

Fig. 23. Map of urbanization of NP Biogradska gora

a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park

Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

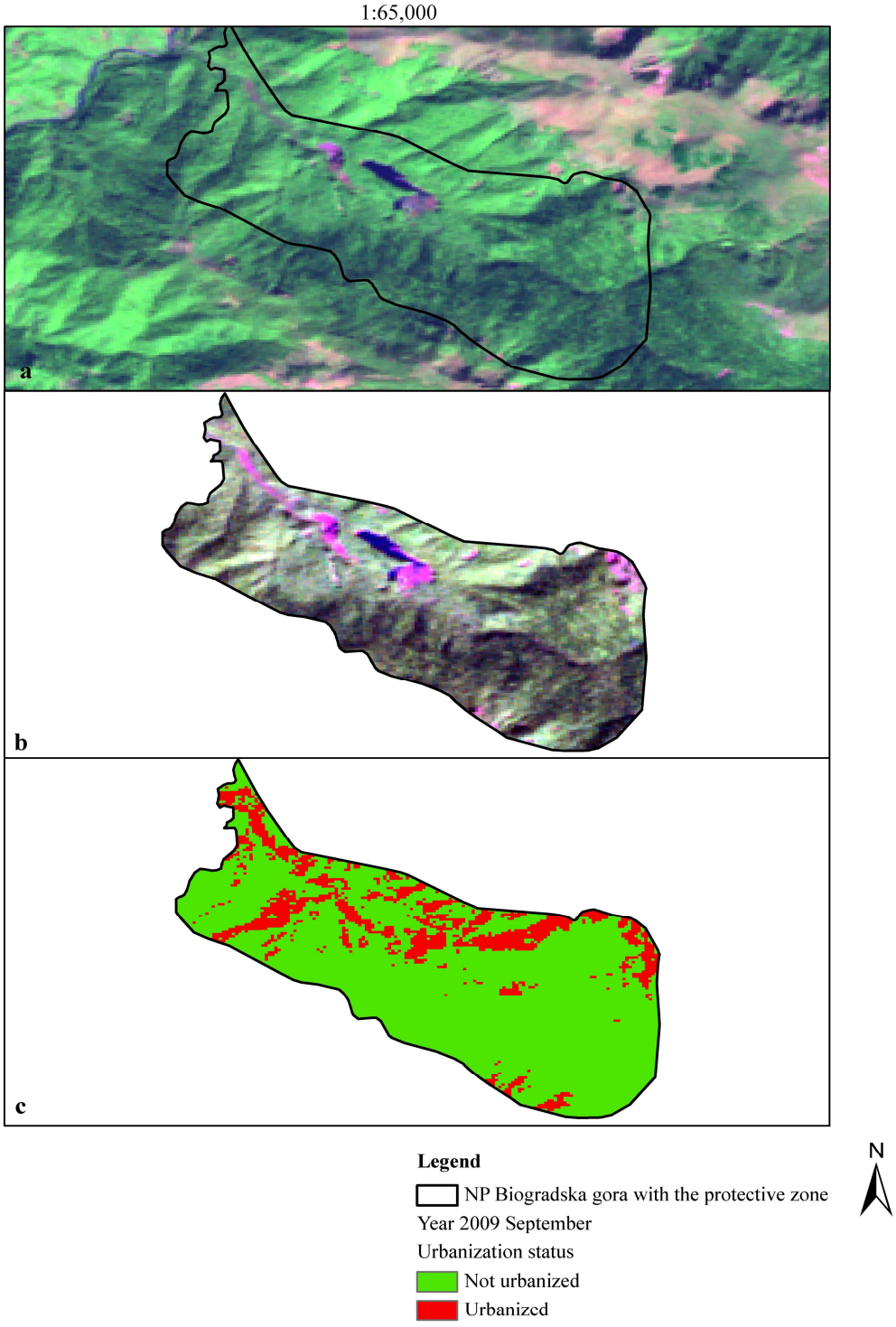

Fig. 24. Map of urbanization of NP Biogradska gora
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

4.8 National Park Lovcen, Montenegro

National park Lovcen is the only analyzed protected area that has not shown any signs of territory loss due to urbanization processes over the past 27 years. The urbanized area has, in fact, decreased by around 3.5%. Fig. 25. shows this process in more details. In 1984. 19.28% or 12km^2 were occupied by urbanized space, and slowly decreasing it reached 18.24% in 2003. Further decrease brought it to current 15.74% or 9.8km^2 or urbanized area.

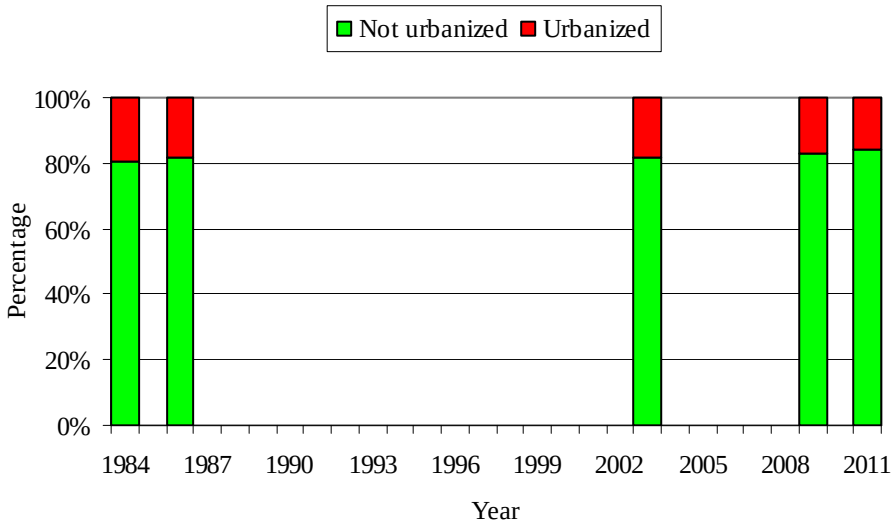

Fig. 25. Urbanization change over time for NP Lovcen
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

In this park the cause of urbanization is mainly agriculture in the northwestern section since there no large touristic facilities to speak of. Small scale agricultural fields were developed wherever it was possible to fit a terrace-looking small estates. There is also a sizable area occupied by cattle in the summer in the central section of the park (Fig. 26 and Fig. 27).

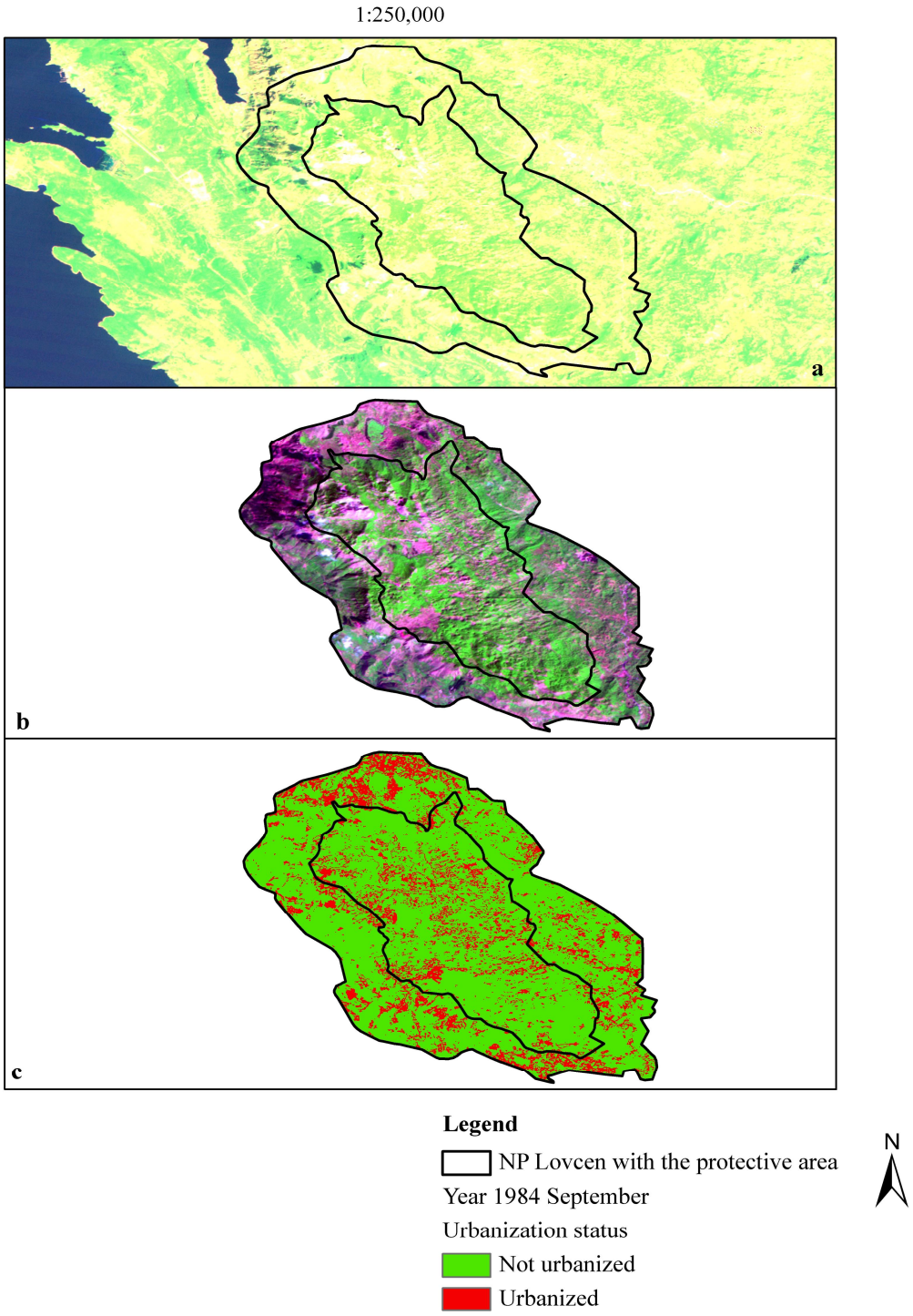

Fig. 26. Map of urbanization of NP Lovcen

a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park

Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

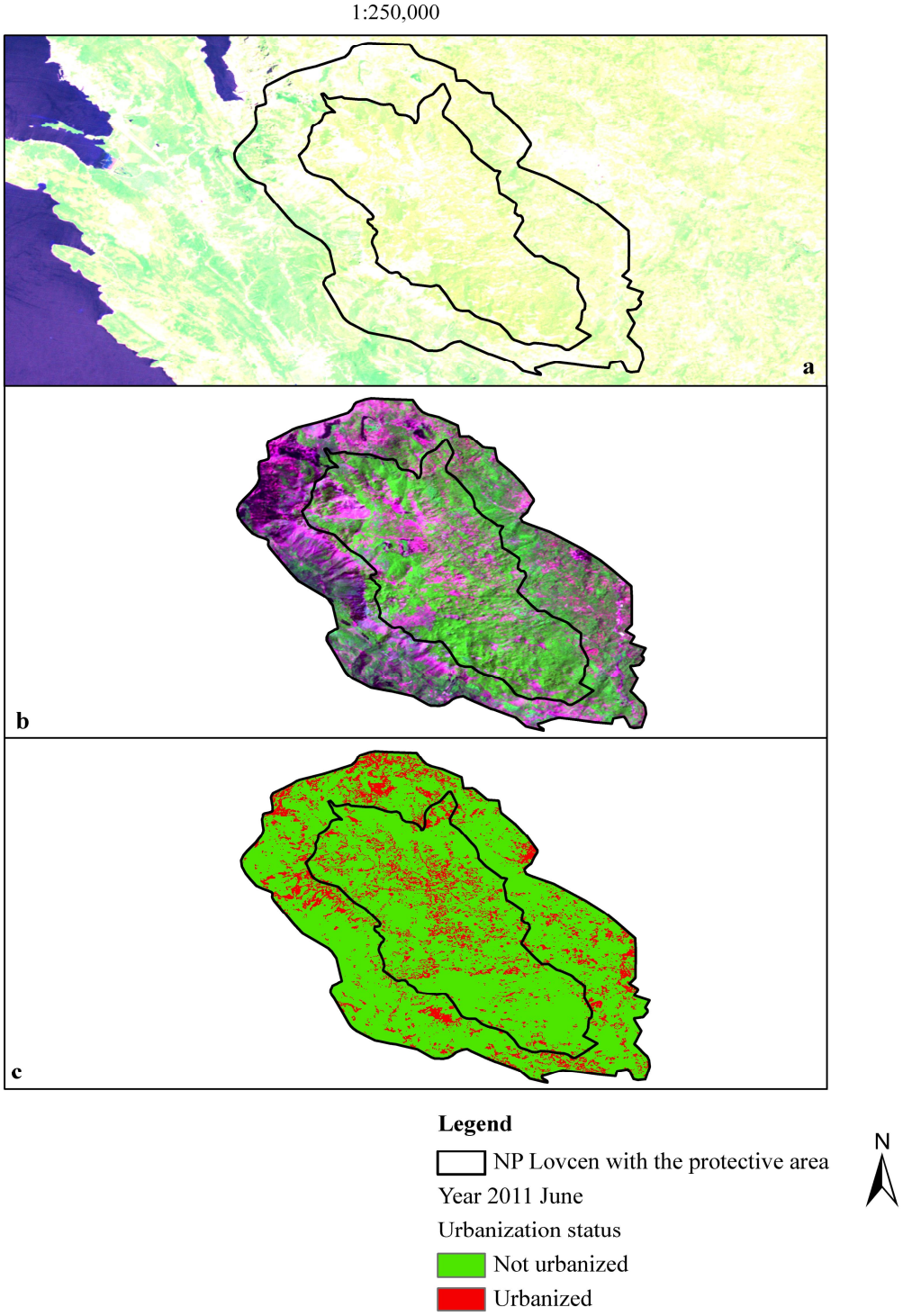

Fig. 27. Map of urbanization of NP Lovcen
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

4.9 National Park Skadar Lake, Montenegro

Nature of the national park Skadar Lake, being a large lake with seasonal changes in the surface makes the analysis less reliable but in this thesis results are analyzed under the assumption is that that the water surface is not changing. According to Fig. 28. urbanization levels in this park decreased from 15.25% in 1984. to 13.2% in 1987. Following developments increased urbanized area of the park to 14.04% in 2003. but since then the situation has improved to current 12.53% of urbanized space within the park. These changes are matching the timeline of the initial establishment of the park in 1983. which was followed by positive changes until the destabilizing events in this region during 1990's. With the improvement of the political situation in the country, environmental protection of the park led to lower levels of urbanization than previous decades.

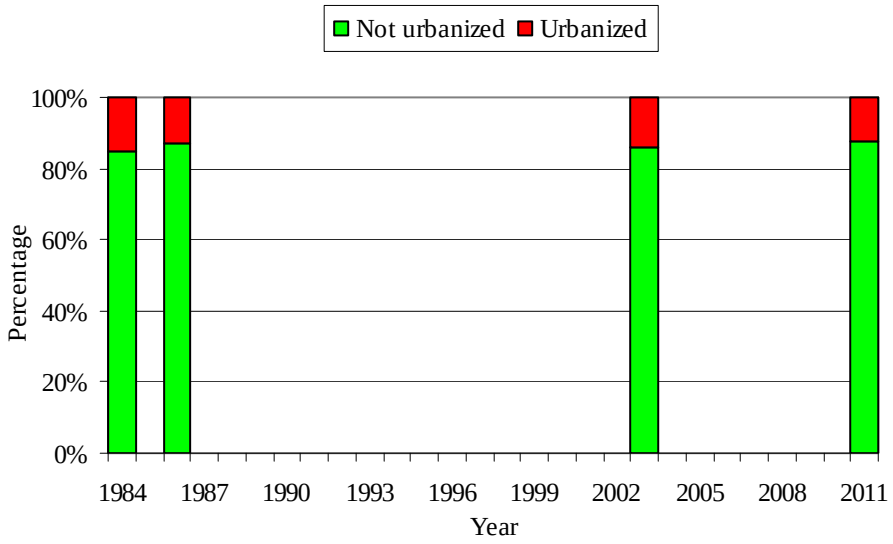

Fig. 28. Urbanization change over time for NP Skadar Lake
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

Main causes of urbanization in this area are developed small scale agriculture on both, northern and southern coast of the lake as well as road and rail communication infrastructure in the north-western section of the lake, both visible on Fig. 29 and Fig. 30.

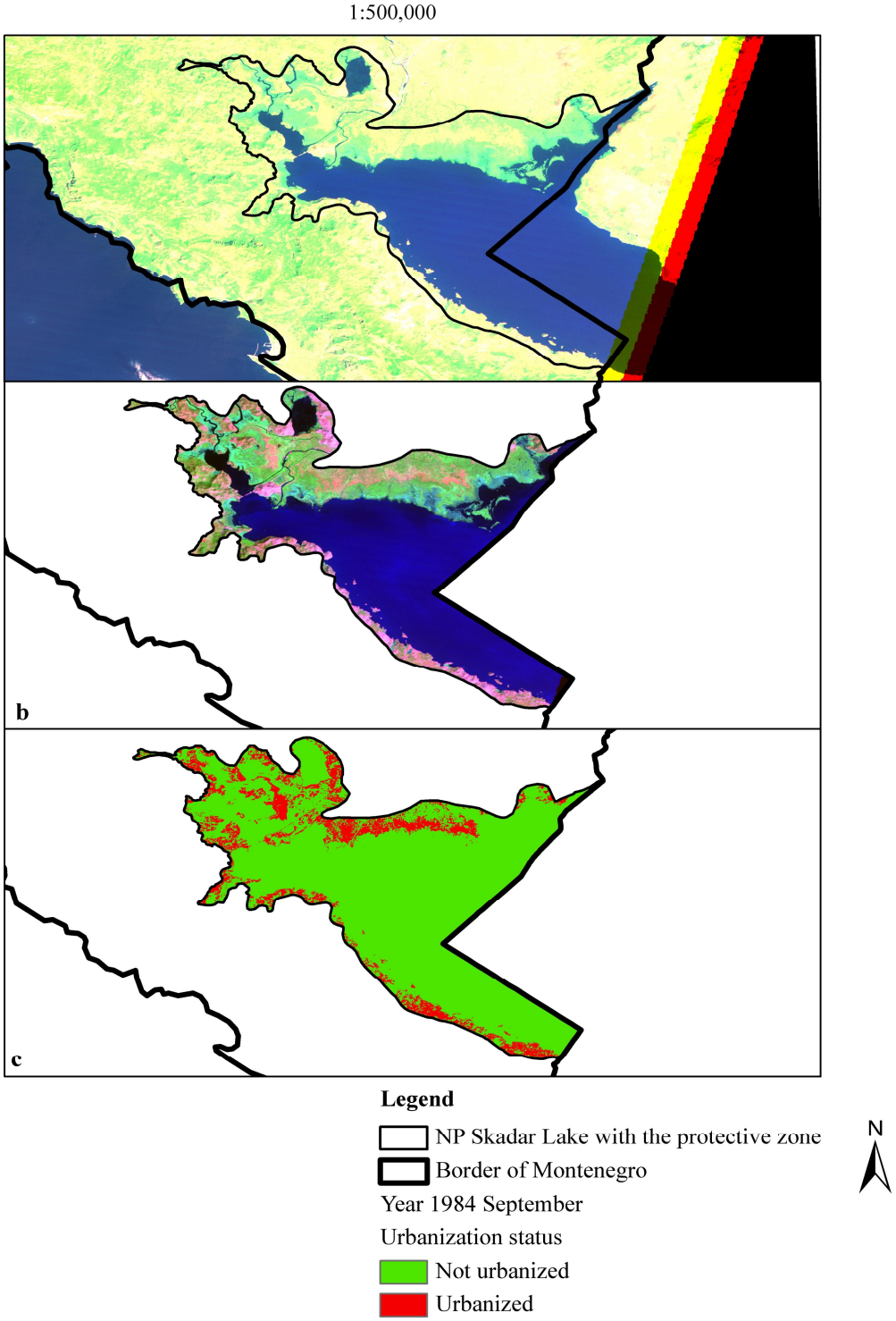

Fig. 29. Map of urbanization of NP Skadar Lake

a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park

Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

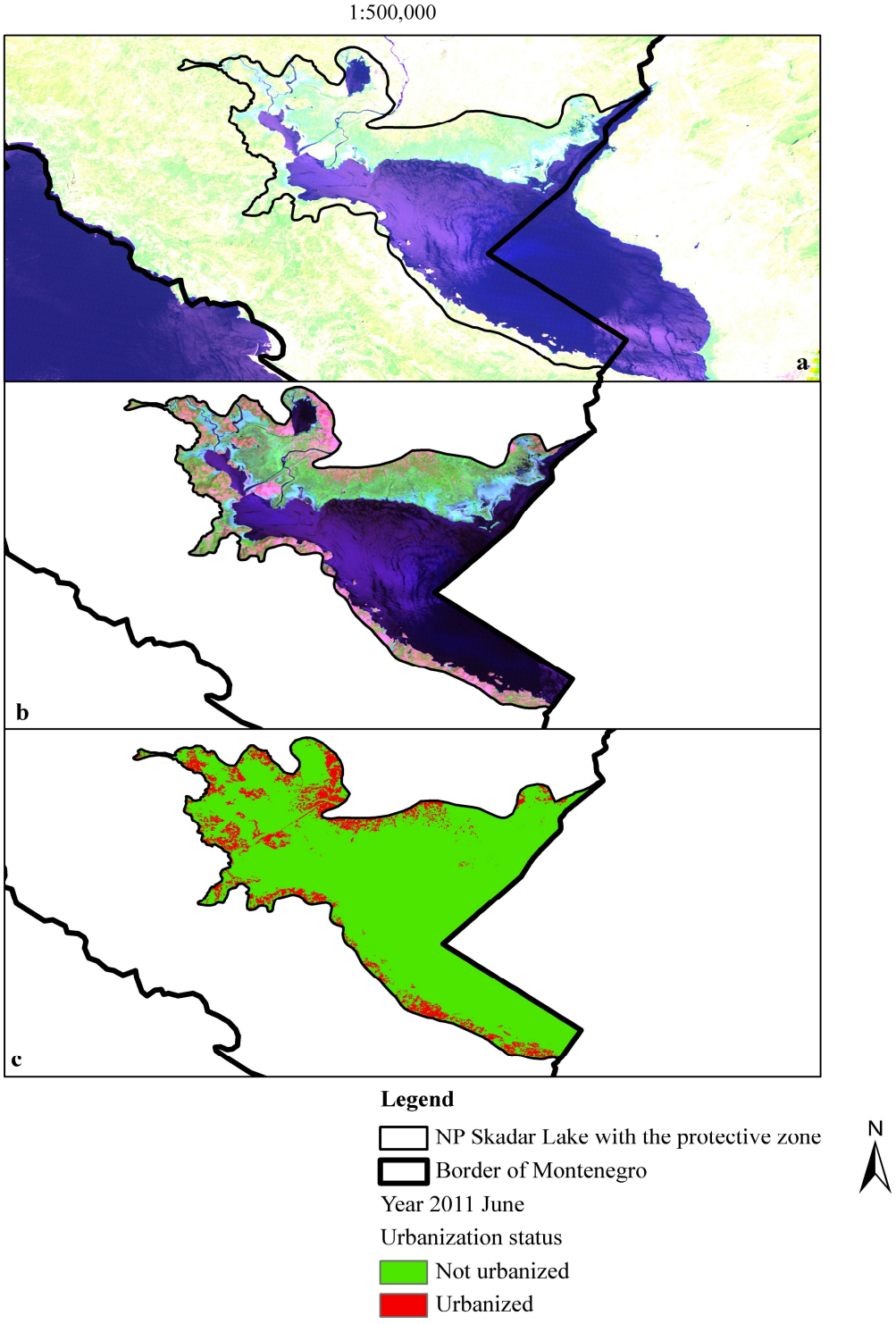

Fig. 30. Map of urbanization of NP Skadar Lake
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

4.10 National Park Prokletije, Montenegro

National park Prokletije, the youngest protected area of this type in both Montenegro and Serbia, analyzed since 1984., since then it was not protected, shows slight increase in urbanized space until 1987. and possibly even later.

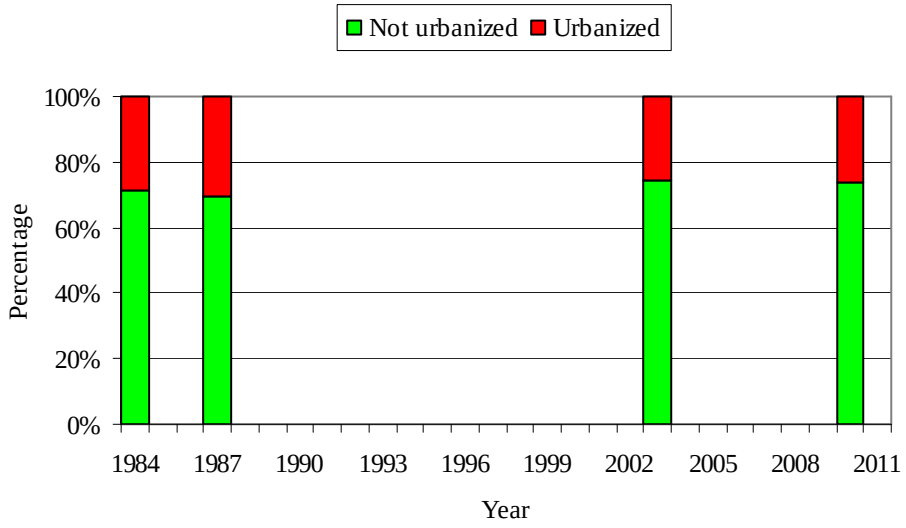

Fig. 31. Urbanization change over time for NP Prokletije
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

This can be seen on Fig. 31 where it can also be spotted that the urbanized areas are decreased by close to 5% between 1987 and 2003 to 25.42% or 42.27km^2. The latest image from 2010. shows signs of mild increase in urbanized are by 1%, which might be attributed to very unfavorable economic situation in this part of the country that might have enticed the local population to use more of the land for agriculture or to provide biomass for heating.

Main pressure areas have been located south-western section of the park for agriculture and central and north-eastern sector for deforestation and cattle upkeep. This can be observed on the Fig. 32 and Fig. 33.

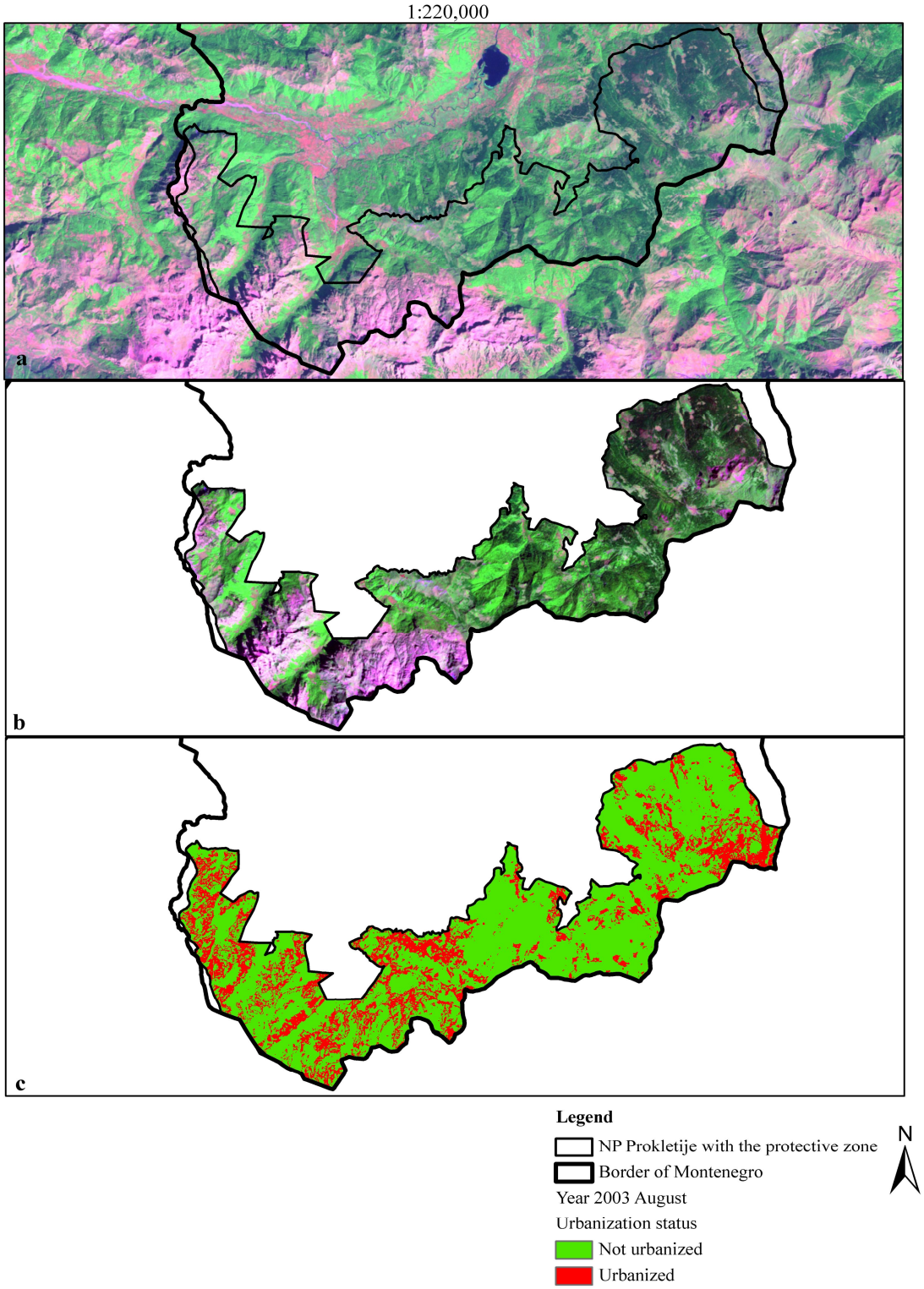

Fig. 32. Map of urbanization of NP Prokletije
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

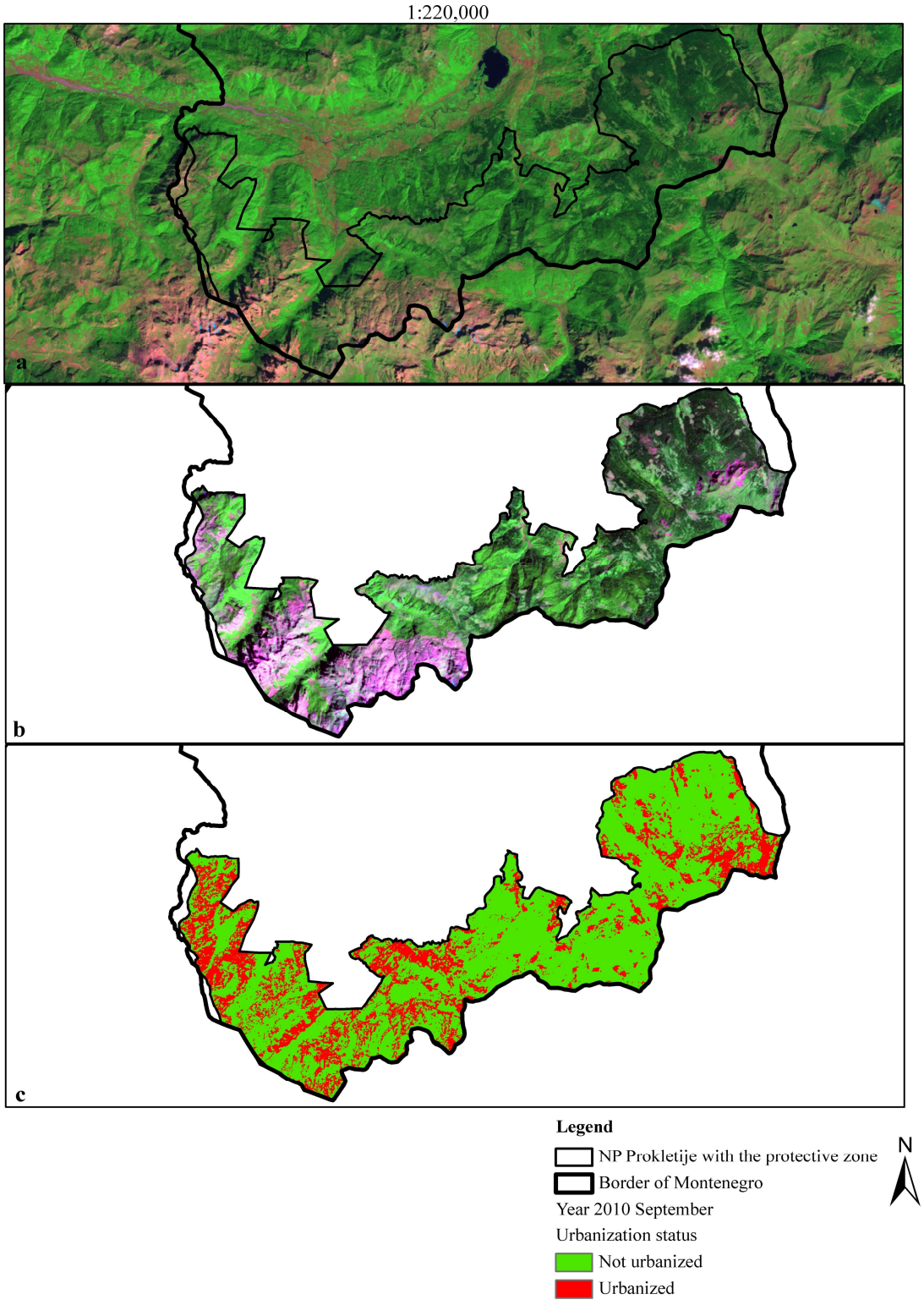

Fig. 33. Map of urbanization of NP Prokletije
a) satellite image in RGB (7, 4, 2) combination, b) reprocessed and enhanced RGB image of the park, c) urbanization map of the park
Data source: (DIVA-GIS 2011;IUCN and UNEP-WCMC 2010;U.S. Geological Survey 2011)

5. Conclusion and Recommendations

5.1 Conclusion

In conclusion of this master thesis it can be said that the urbanization of national parks presents a serious environmental problem which should be dealt with, in both Serbia and Montenegro. However it must be pointed out that the current situation is much more severe in Serbia where two out of five national parks with their protective zones are urbanized more than 50%. Even if absolute sizes of urbanized areas within the parks are not taken into account, the significance of the problem can also be seen in the fact that two out of five parks in Serbia had an increase in urbanization for close to or well over 10% in these past three decades.

Another notable characteristic of these changes in spatial distribution of in Serbian national parks is the variability since the trends have not been uniform for any of the parks and more importantly, only one of the parks has shown improvement in absolute areas, currently having the smallest urbanized area compared to previous years.

In the case of Montenegro and its five national parks, it should be emphasized that currently none of these parks are urbanized more than 30% and only one has urbanization level higher than 25% which is significantly lower than the maximum urbanization level in Serbian national parks. Only one park in Montenegro has suffered an increase of over 5% in urbanized areas, with the rest three parka varying around stagnation levels and one park in which the urbanized area is decreasing. Overall, national parks in Serbia are showing signes of urbanization and deterioration much more significant than it is the case with Montenegrin national parks.

This research and the results it provided are valuable in a way that they are explicitly showing levels of urbanization in national parks in two neighboring countries, Serbia and Montenegro. Research of similar type has not been done yet in these countries and the use of satellite data

imagery available free of charge has only opened new directions for the future research in the field of monitoring different aspects of forest cover in these protected areas, all in effort to protect these areas from further destruction.

5.2 Recommedations

Since the differences in the urbanization status of national parks in Serbia and Montenegro are clearly established, some steps and measures could be taken in managing these protected areas in Serbia in order to decrease current trends of urbanization, especially following positive practice, which is giving results in Montenegro.

These recommendations can be listed as:

- establishing an overarching state agency or an authority in charge of all national parks; by doing so, incompatibilities and inconsistencies in the management system of each park might be corrected and overall condition improved;
- national park authorities should be given larger responsibilities in enforcing the rules and regulations pertaining these protected areas; evidently the system that is now in place in Serbia is not giving desired results and therefore it is recommended to readjust it so it can fit the severity of the current situation;
- legislative gap in Serbia, created by putting the previous Law on national parks out of power and not providing another one should be overcome with a new, clear and precise act which will offer up-to-date solutions in managing these protected areas;
- provisions of the new law on national parks should have much stricter fines and punishments for braking them;
- in general, enforcing this new legislative act should include much more active service of the environmental protection inspectorate which is currently the weakest point in the national parks management system;

- last recommendation, but carrying the same significance, is the creating of both human and technical capacities to collect, process and disseminate digital spatial data and implement the latest GIS and remote sensing methods in monitoring of these protected areas which in present might not be the case.

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