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THE USE OF NDVI AND CORINE LAND COVER DATABESES FOR FOREST MANAGEMENT IN SERBIA

Miomir M. Jovanović, Miško M. Milanović, Matija Zorn

An example of illegal logging from the Municipality of Kuršumlija
in southern Serbia in 2013.

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The use of NDVI and CORINE Land Cover databases for forest management in Serbia

ABSTRACT: This article evaluates the possible use of normalized difference vegetation index (NDVI) and CORINE Land Cover (CLC) databases for better forest management in the municipalities of Kuršumlija and Topola in Serbia. The forest areas obtained using CLC were up to 11.5% larger than the official forest area estimates, whereas NDVI gave more precise results. Hence, NDVI can efficiently provide local forest managers with essential annual information about the forest inventory.This is of a crucial importance for preventing illegal logging, which is very prevalent in southern Serbian municipalities, which have substantial forested territory. NDVI thus very promising for Serbia and also for countries that rarely carry out national forest inventories. This method can also easily be applied to other Balkan countries with a similar situation regarding local forest management.

KEY WORDS: NDVI, CORINE Land Cover, forest management, illegal logging, Serbia

Raba podatkovnih zbirk NDVI in CORINE pri gospodarjenju z gozdovi v Srbiji

POVZETEK: V članku avtorji preučujejo možnost rabe podatkovnih zbirk NDVI in CORINE za boljše gospodarjenje z gozdovi v srbskih občinah Kuršumlija in Topola. Površina gozda, ugotovljena z uporabo CLC, je bila do 11,5 % večja od uradno ocenjene, medtem ko so bili rezultati NDVI točnejši. NDVI lahko lokalnim upravljavcem gozdov zagotavlja pomembne informacije o gozdu na letni ravni. To je izjemno pomembno za preprečevanje nezakonite sečnje, značilne za občine v južni Srbiji, ki so bogate z gozdom. Uporaba NDVI zato obetavna za Srbijo in tudi druge države, ki redko izvajajo nacionalne popise gozdov. Metoda je primerna tudi za druge balkanske države s podobnimi razmerami na področju lokalnega gospodarjenja z gozdovi.

KLJUČNE BESEDE: NDVI, CORINE, gospodarjenje z gozdovi, nezakonita sečnja, Srbija

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1 Introduction

Permanent clearing of forest cover was typical in the industrialized world until a few decades ago. Vast areas of Europe and North America were cleared for industrial expansion and development of infrastructure. Today deforestation is largely occurring in tropical countries in Africa, Asia, and Latin America (Steininger et al. 2001; Chowdhury 2006), as well as in taiga regions, especially in Russia (Tracy 1994; Deforestation … 2014).

Most reasons for deforestation are due to market imperfections (Jovanović 2012). Market imperfections arise when property cannot be clearly defined, when property cannot be freely transferred, when the use of goods cannot exclude others from such use, and when private rights cannot be protected (McKean 2000; Tietenberg and Lewis 2012). Evidence convincingly shows that illegal and corrupt activities are a major underlying cause of forest decline (Contreras-Hermosilla 2002; Brack 2003). The main reason for this is that governments and private landowners cannot control these illegal operations. In addition, this lack of control may be deliberate, is often corrupt, or may be determined by the limitations of administrative capacity. One way or another, illegal use of forests is rampant (Contreras-Hermosilla 2002; Amacher et al. 2009).

Remote sensing is the detection, recognition, or evaluation of objects by means of distant sensing or recording devices (Oštir 2006). Historically, digital remote sensing developed rapidly from aerial photography and photo interpretation. Information extracted visually from remote sensing is widely used in forestry (Franklin 2001; Hočevar and Kobler 2001; Hočevar and Hladnik 2006; Kobler 2012).

Given the importance and complexity of forest preservation and sustainable forest management (Pagiola et al. 2002; Lee 2008; Ojea et al. 2012), an attempt was made to evaluate the possible use of a normalized difference vegetation index (NDVI; Weier and Herring 2000) and Coordination of Information on the Environment (CORINE) Land Cover (CORINE … 1994) in local forest management. NDVI is one of the most widely used vegetation indices (VIs) and CORINE Land Cover (CLC) is in official use in the EU.

One of the main differences between NDVI and CLC is that, whereas NDVI focuses on the vegetation cover and its status, CLC has a much broader scope and distinguishes agricultural areas, forests and semi-natural areas, artificial surfaces, urban fabric, industrial, commercial, and transport units, bodies of water, wetlands, glaciers and perpetual snow, and other features (Jensen 2007).

NDVI is actually a simple graphic indicator that can be used to analyze remote sensing measurements, whether the target observed contains live green vegetation or not (Chen 2008). NDVI was one of the most successful of many attempts to simply and quickly identify vegetated areas and their »condition,« and it remains the best-known and most-used index for detecting live green plant canopies in multispectral remote sensing data (Fuller 2006; Milanović et al. 2008; Campbell and Wynne 2011; Ne Win et al. 2012). NDVI also has the advantage of allowing comparisons between images acquired at different times (Lillesand et al. 2004). It belongs to the VIs related to vegetation cover and its status, and it provides useful information on biomass productivity and health. VIs have a direct correlation with leaf chlorophyll content and leaf area index (LAI) and vary in relation to vegetation cycle and phenology (Vohland et al. 2007; Montandon and Small 2008). They are also sensitive to other external factors, such as the contribution of the soil and background optical behavior where the vegetation does not completely cover the ground, the geometry of view due to sensor angle of acquisition and to Sun position, atmospheric effects, and other factors (Franklin 2001; De Jong and Van der Meer 2005; Jensen 2007; Campbell and Wynne 2011).

NDVI, like all VIs, relates the spectral absorption of chlorophyll in the red with a reflection phenomenon in the near infrared, influenced by the leaf structure type (Wang and Tenhunen 2004).

In contrast, CLC is a European program launched in 1985 by the European Commission, aimed at obtaining a unique and comparable dataset of land cover for Europe. The aim of CLC is to gather information related to the environment on certain priority topics for the European Union: air, water, soil, land cover, coastal erosion, biotopes, and so on. The main goals of the CLC program are to acquire information about the environment to address the European Community policy, to assess the effectiveness of legislation, to integrate environmental and political aspects, to unify heterogeneous thematic cartographies of Europe at various levels (international, national, regional, local), and to update data at regular intervals, every five to ten years (Bossard et al. 2000; Neumann et al. 2007). CLC is a map of the European environmental landscape based on interpretation of satellite images.

The data have been validated using local cartography and ground surveys (Heymann et al. 1994; Perdigão and Annoni 1997; Genovese et al. 2001). CLC also has an NDVI module for creating vegetation maps, but the deviations in its final results are substantial due to the highly inappropriate scale of Serbian data.

For creating CLC maps for the municipalities of Kuršumlija and Topola, image processing was carried out and a digital elevation model was made based on the municipalities' boundaries and Landsat satellite color composites, and a pseudo-color composite with bands 4, 5, 1 and adequate contrast was applied. Datasets and maps for Serbia, mainly IMAGE2000 and CLC2000 class, were extracted from the European Environmental Agency (EEA) website, with a transfer data scale of 1 : 100,000, which resulted in a very high level of imprecision (Büttner and Kleeschulte 2005).

Of particular interest to this study is that the smallest unit is 25 ha in the original CLC project, although a recent approach yields more precise results because changes < 25 ha and > 5 ha are mapped (CLC2006 … 2007). Nevertheless, even the smallest 5 ha areas, which are highly appropriate at the EU scale, do not properly reflect the land-use situation at the local scale in a country where landscapes and land-use change across very short distances (Hočevar and Kobler 2001; Gabrovec and Petek 2004).

This article shows that remote sensing data collection and analysis methods have great importance for local forest management in Serbia. In Serbia around 30% of land is forested (of which 50% is state-owned forests and 50% privately owned). Forest management (of both privately owned and state-owned forests) is also very poor (Forestry … 2006).

The purpose of this article is to improve the local forest management system in Serbia through more precise methods for assessing land-use changes in forest areas. The study evaluated NDVI and CLC, which are viewed as very efficient tools for classifying and estimating different land cover types of large and remote areas (Meng et al. 2009). Although they both proved to be very effective in the EU, CLC is mostly used as a regional database. Nonetheless, in Serbia they both (recently) became very popular tools for studies at the local level (Report … 2009). This article shows that they are not equally effective at the local level in the Serbian context.

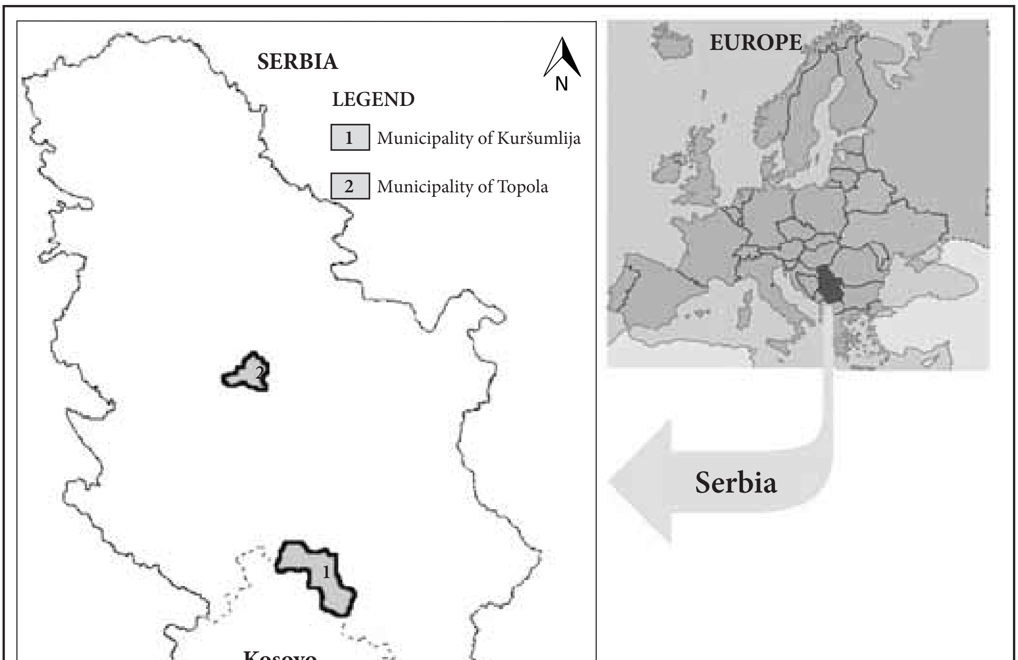

Figure 1: Location of the municipalities of Kuršumlija and Topola (Serbia).

2 Materials and methods

In the study it was not possible to make a reliable long-term comparative analysis between NDVI and CLC data and official forest inventories because national forest inventories have very rarely been carried out in Serbia. Such inventories were carried out at roughly twenty-year intervals: in 1961, 1979, and 2003–2006. Since 2007, official estimates of forest areas have been made annually.

The study was carried out for the municipalities of Topola and Kuršumlija (Figure 1). Data obtained using NDVI and CLC for spring/summer 2006 were analyzed and compared to official forest area estimates for 2006 created at the end of the same year. The Municipality of Topola is located in central Serbia, and the Municipality of Kuršumlija lies in southern Serbia.

NDVI and CLC data for both municipalities are based on Landsat 5 Thematic Mapper (TM) satellite images (Figures 2 and 3) for 2006, which were created during spring/summer (August), with minimum clouds (10 to 20%; Chavez 1996). In order to remove atmospheric effects from the NDVI final results, Idrisi software was used for data preprocessing.

For calculating NDVI, satellite (Landsat) imagery (which has a resolution of approximately 30 m) and pan-sharpening images (with 15 m resolution) were used to obtain more precise results.

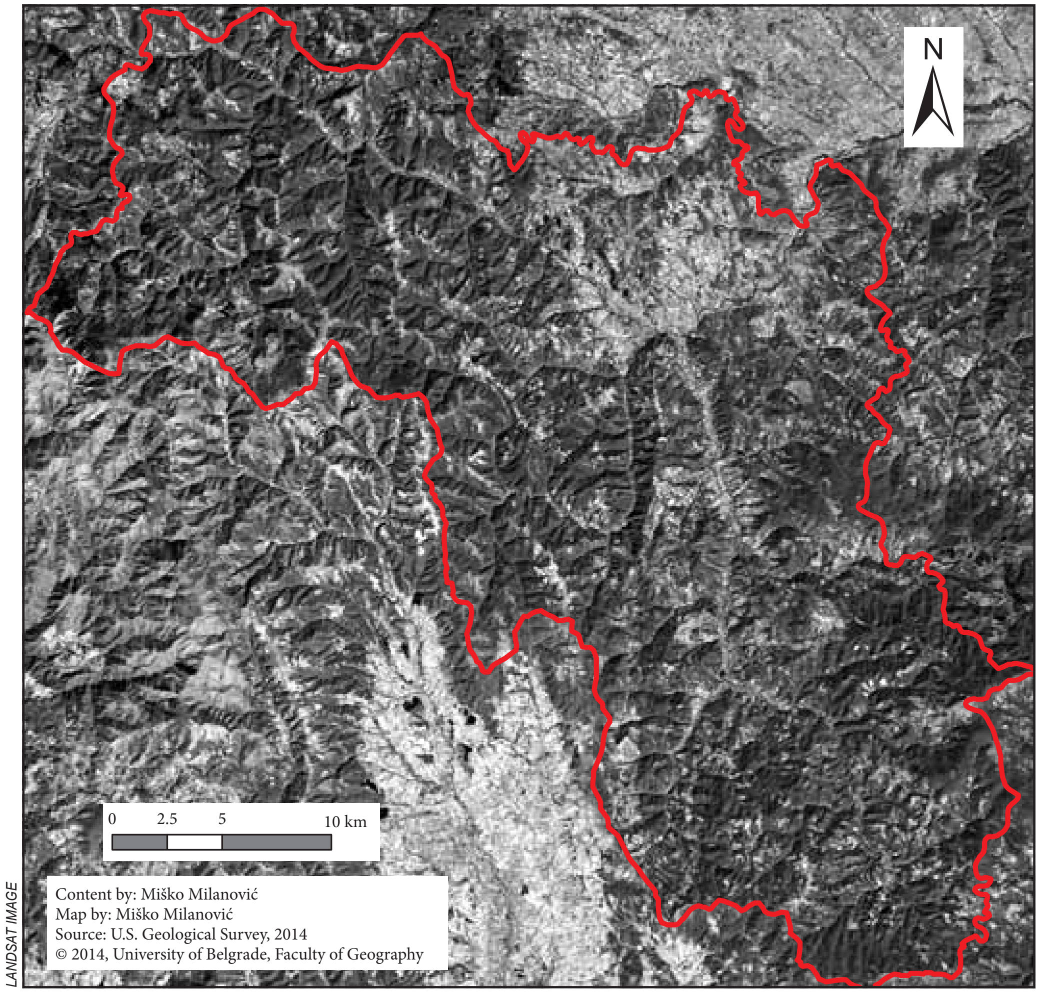

Figure 2: The Municipality of Kuršumlija.

NDVI was used and necessary corrections/transformations were applied for visible red in constellation with the infrared spectrum of satellite images using the following procedure: GIS Analysis / Mathematical Operation / Image Calculator, and then the equation NDVI = (NIR – RED) / (NIR + RED), in which NIR is the near-infrared channel and RED is the red channel from the visible part of the spectrum (Hájek 2008; Johnson and Trout 2012).

Basic tasks included analysis and photo interpretation of elements, occurrences, and processes detected on images using specialized GIS software (Idrisi 15-Andes) for processing remotely sensed images through application of NDVI.

Shadows can cause NDVI values to be lower than their actual values. In this sense, »*empirical topographic corrections have proven only marginally successful*« (Franklin 2001). Because shadow areas were less than 5% in the Municipality of Kuršumlija and less than 3% in the Municipality of Topola, no topographic corrections were made.

Characteristic NDVI signatures are as follows: NDVI of dense vegetation canopy tends to have positive values (0.3 to 0.8); clouds and snowfields are characterized by negative values of this index; bodies of water (e.g., oceans, seas, lakes, and rivers) has rather low reflectance in both spectral bands (at least away from shores), thus resulting in very low positive or even slightly negative NDVI values; soils generally exhibit a near-infrared spectral reflectance somewhat larger than the red, and thus also tend to generate rather small positive NDVI values (0.1 to 0.2); very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow; moderate values represent shrub and grassland (0.2 to 0.3); and high values (0.6 to 0.8) indicate tem-

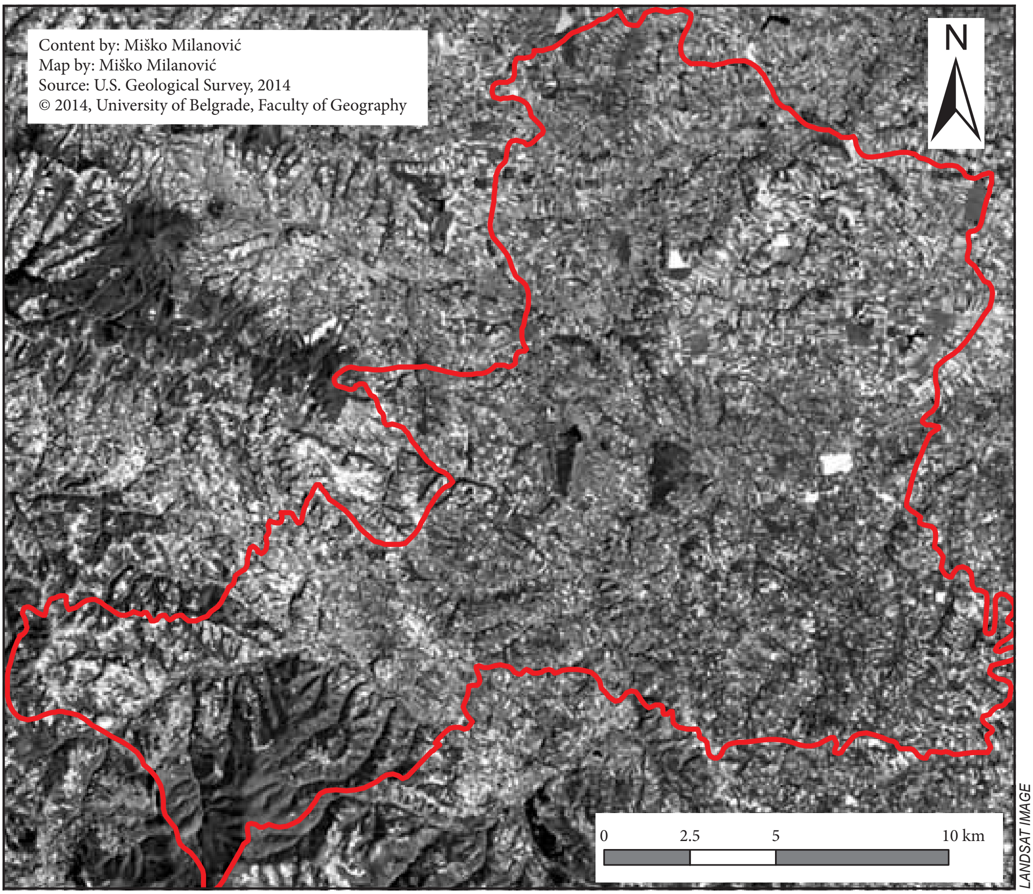

Figure 3: The Municipality of Topola.

perate and tropical rainforests (Finelli et al. 1996; Schmitt and Ruppert 1996). Negative values of NDVI ranging from 0 to –0.3 are displayed in shades from light green to dark purple. These low negative values are detected in arable agricultural land (without vegetation) and are shown in shades of light green. On the other hand, vegetation areas are presented with values between 0 and 1. Grassy areas, meadows, and pastures have values that range from zero (in yellow, due to more intense reflectance of infrared radiation) up to 0.13 (light orange tones). Shrub vegetation has an NDVI value of 0.25 because reflectance of infrared rays decreases (darker red tones). Forest vegetation, with maximal positive NDVI values of 0.85 (due to minimal reflectance of infrared rays), is easily observed. Coniferous forest has an NDVI value above 0.5, mixed forest between 0.35 and 0.5, and broad-leaved forest between 0.3 and 0.4 (Bakx 1995; De Jong and Van der Meer 2005).

3 Results

After image processing it was determined (Table 1) that forest areas encompass 529.83 km^2 or 55.7% of the total area of the Municipality of Kuršumlija, much higher than the average 30% for Serbia; and 50.73 km^2 or 14.2% of the total area of the Municipality of Topola, which is approximately half of the Serbian average.

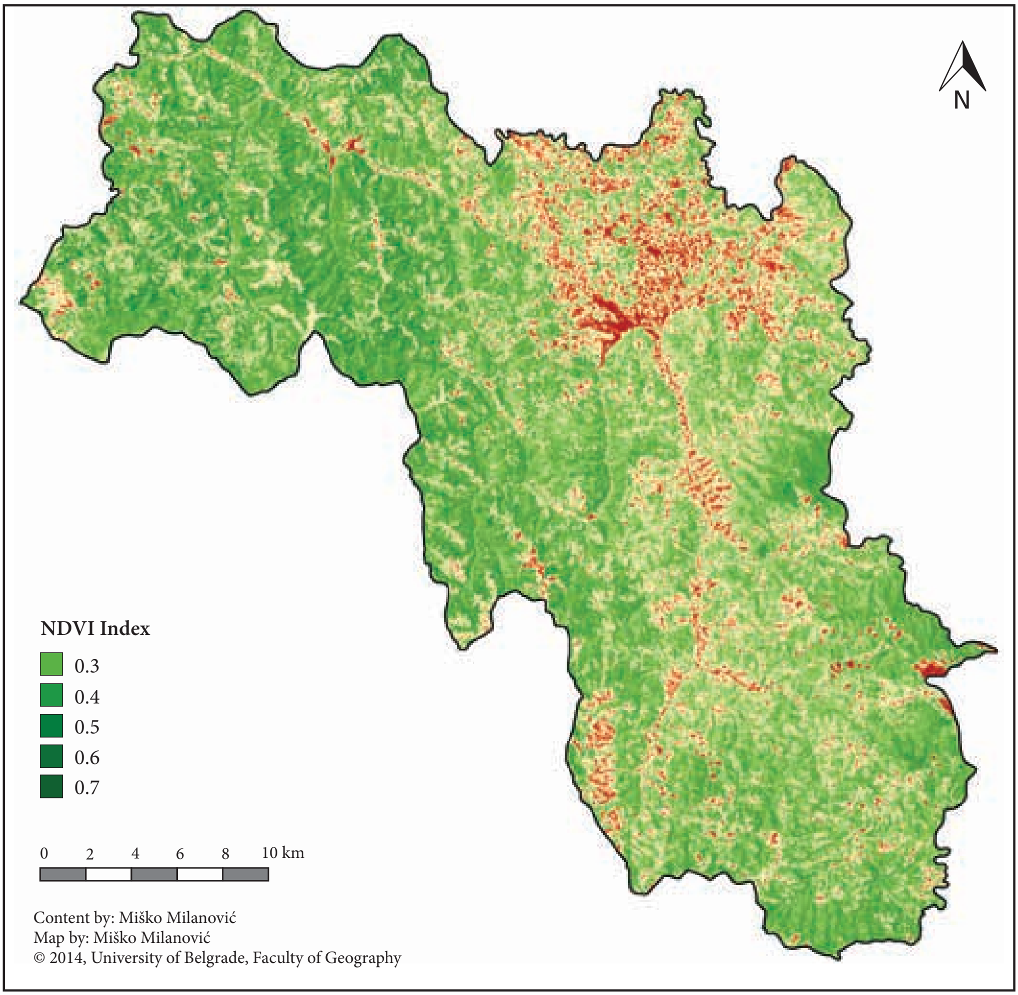

Figure 4: Vegetation cover in the Municipality of Kuršumlija for 2006 obtained from NDVI.

When these NDVI results are compared with official forest area estimates for the same year (2006) (Municipalities … 2007), there is only +0.12 km^2 of difference for Topola's forest area, and −27 km^2 difference for Kuršumlija (Table 3).

Figures 4 and 5 present a raster of NDVI (NIR band and RED band) from *Landsat* 5 TM (bands 4, 5, 1) satellite images. The images were created in August 2006. Figures 6 and 7 present vegetation cover obtained from CLC.

When the (latest available) CLC results for 2006 were compared with official forest area estimates for the same year (Tables 1–3), some inconsistencies became apparent:

- The total areas for the municipalities of Kuršumlija and Topola obtained from CLC were smaller than the official forest statistics: instead of 952 km^2 only 942.9 km^2 for Kuršumlija, and instead of 356 km^2 only 348.9 km^2 for Topola;
- Forest areas obtained from CLC were up to 11.5% larger than the official forest area estimates. Kuršumlija's forest area obtained from CLC (630.45 km^2) is 26 km^2 larger than the official forest area estimates (604.41 km^2) for this municipality (+ 4.3%), and Topola's forest area obtained from CLC (58 km^2) is 6 km^2 larger than the official forest area estimates (52 km^2, + 11.5%).

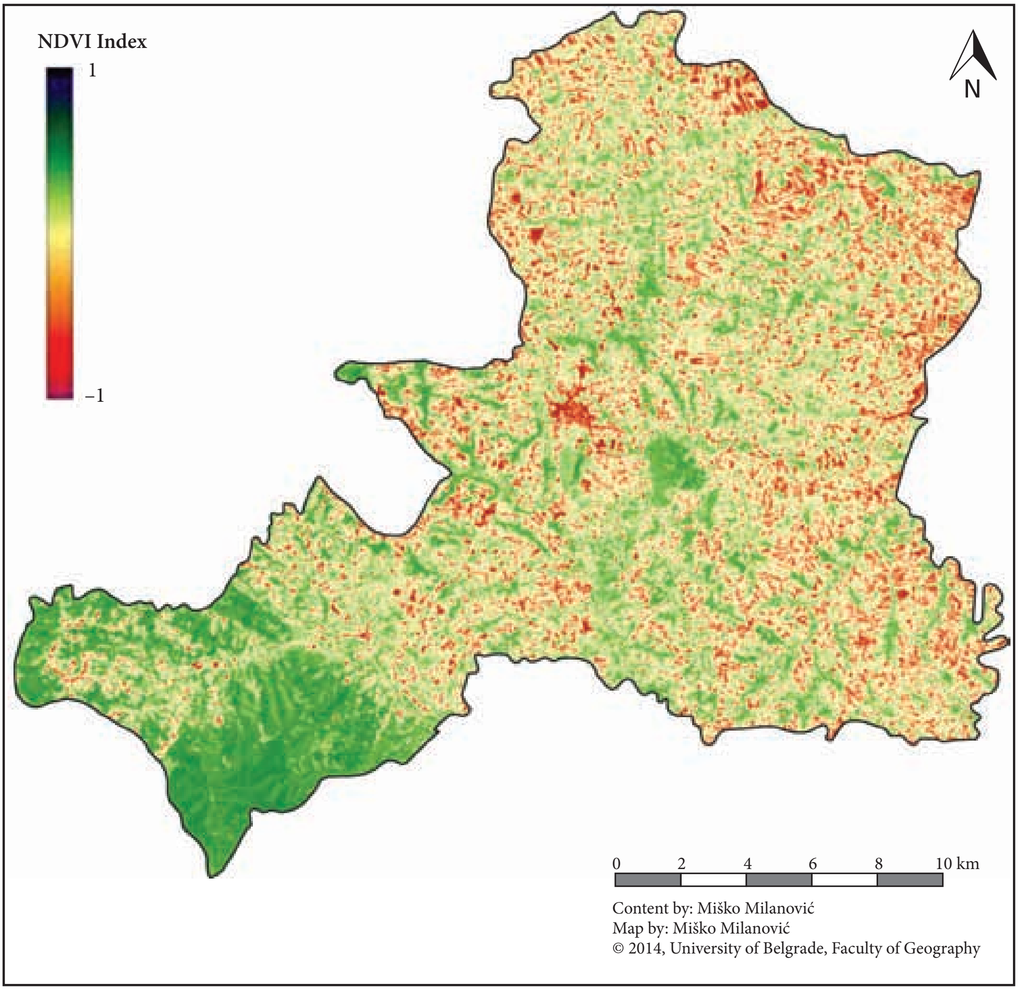

Figure 5: Vegetation cover in the Municipality of Topola for 2006 obtained from NDVI.

Table 1: Vegetation cover in the municipalities of Kuršumlija and Topola for 2006 obtained from NDVI.

Land cover	Kuršumlija		Topola	
	(km^2)	(%)	(km^2)	(%)
Broad-leaved forest	562.71	59.10	49.40	13.84
Coniferous forest	6.46	0.68	0.62	0.17
Mixed forest	8.23	0.86	2.10	0.59
Pastures	32.20	3.40	–	–
Transitional woodland-shrub	51.55	5.41	–	–
Sparsely vegetated areas	9.48	0.99	–	–
Land principally occupied by agriculture, with significant areas of natural vegetation	–	–	63.25	17.72
Other	281.37	29.56	241.63	67.68
Total	952.00	100.00	357.00	100.00

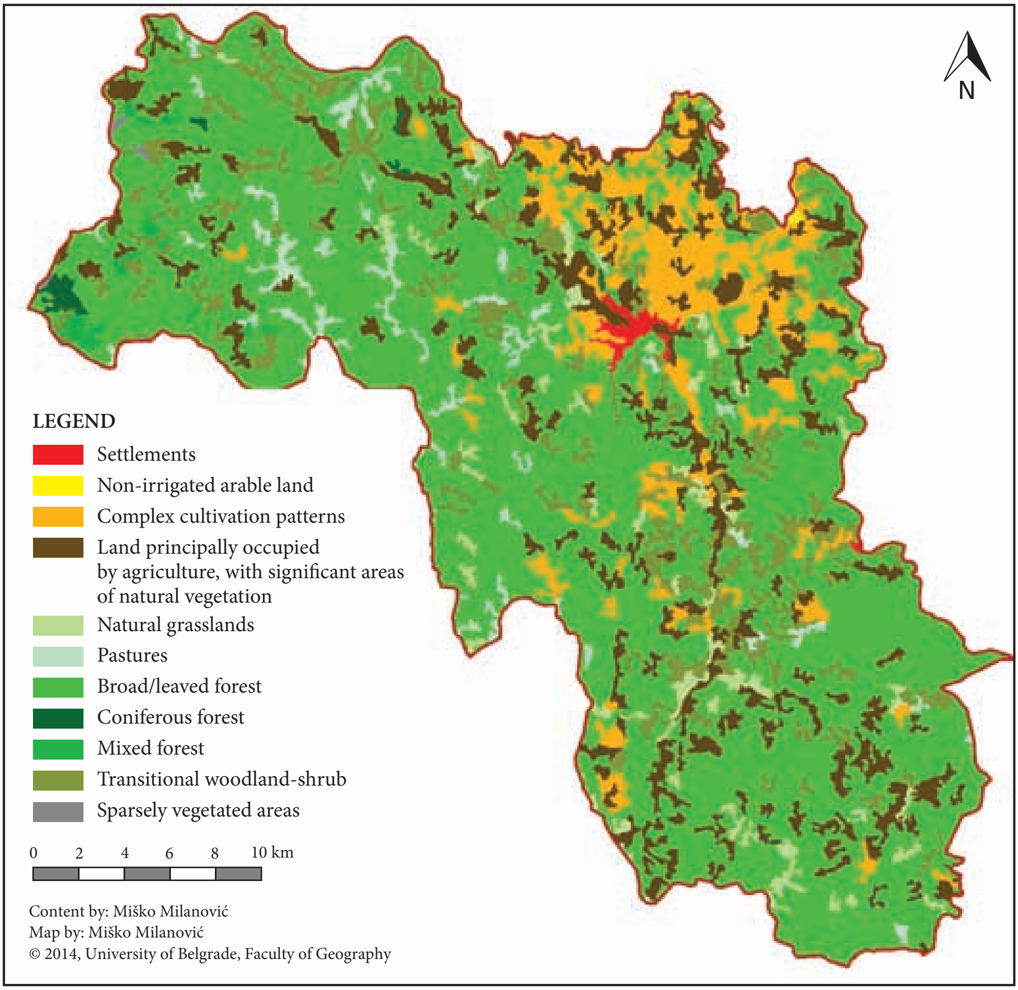

Figure 6: Vegetation cover in the Municipality of Kuršumlija for 2006 obtained from CLC.

Table 2: Land cover in the municipalities of Kuršumlija and Topola for 2006 obtained from CLC.

Land cover	Kuršumlija		Topola	
	(km²)	(%)	(km²)	(%)
Settlements	4.60	0.49	9.11	2.61
Green urban areas	–	–	0.82	0.23
Non-irrigated arable land	0.42	0.04	36.51	10.46
Natural grasslands	25.74	2.73	14.44	4.14
Complex cultivation patterns	78.73	8.35	154.94	44.41
Land principally occupied by agriculture, with significant areas of natural vegetation	102.25	10.84	73.17	20.97
Broad-leaved forest	620.68	65.82	55.68	15.96
Coniferous forest	3.63	0.38	0.19	0.05
Mixed forest	6.14	0.65	2.12	0.61
Pastures	24.18	2.56	1.11	0.32
Transitional woodland-shrub	75.78	8.04	0.81	0.23
Sparsely vegetated areas	0.78	0.08	–	–
Total	942.93	100.00	348.90	100.00

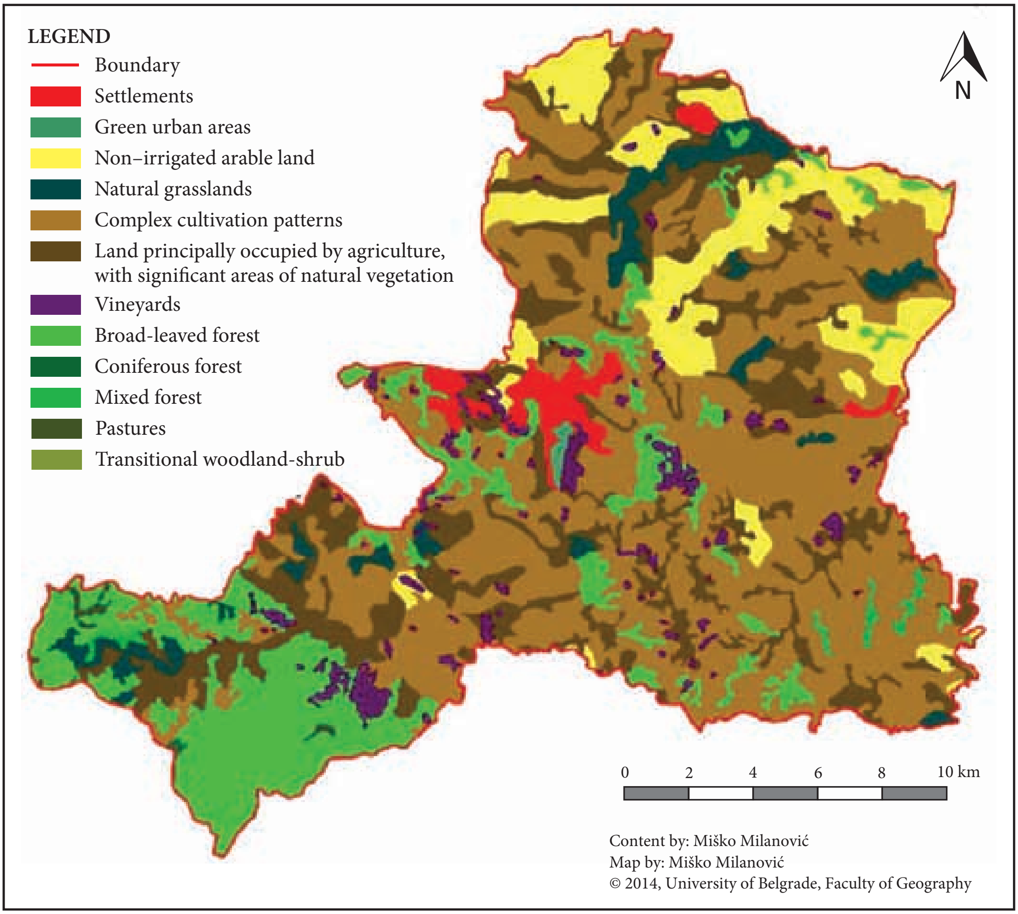

Figure 7: Vegetation cover in the Municipality of Topola for 2006 obtained from CLC.

Table 3: Forest areas according to official statistics and calculated on the basis of NDVI and CLC for 2006.

Municipality	Municipality: total area (km²)	Forest area			NDVI – official statistics difference (km²)	CLC – official statistics difference (km²)
		Official statistics (km²)*	Calculated on the basis of NDVI (km²)	Calculated on the basis of CLC (km²)		
Topola	356	52.00	52.12	57.99	+0.12	+ 5.99
Kuršumlija	952	604.41	577.40	630.45	–27.01	+ 26.04

* Source: Municipalities . . . 2008.

Table 4: Forest areas according to official statistics and calculated on the basis of NDVI for 2011 and CLC for 2006.

Municipality	Municipality: total area (km²)	Forest area			NDVI – official statistics difference (km²)	CLC – official statistics difference (km²)
		Official statistics (km²)*	Calculated on the basis of NDVI (km²)	Calculated on the basis of CLC (km²)		
Topola	357	52.0494	50.73	57.99	–1.3194	+ 5.9407
Kuršumlija	952	544.2856	529.83	630.45	–14.4556	+ 86.1644

* Source: Municipalities . . . 2013.

4 Discussion

Although both CLC and NDVI have recently been used in Serbia for studies at the local level, the main problem with CLC data is that: a) although CLC data are produced at various levels (international, national, regional, and local; Bossard et al. 2000; Neumann et al. 2007), CLC is actually a predominantly regional database, updated rarely (every five to ten years), whereas NDVI is available for every year; and b) NDVI is much more precise than CLC.

When official statistics and NDVI and CLC forest areas were compared for the same year (2006), NDVI was more precise than CLC. Because both NDVI and CLC used the same Landsat satellite images and the same (NDVI) methodology, these major differences in the data obtained were due to the different spatial resolution of NDVI and CLC.

Whereas CLC does not go below the range of 4 to 5 ha, NDVI easily deals with minimum space units of 25 m². This proved to be decisive for Serbia, where privately owned forest parcels, which account for half of the total forest area of the country, usually cover much smaller areas (the average private holding is 0.5 ha; Glavonjić et al. 2005). In short, CLC proved not to be very suitable for local forest management in Serbia (questionable results regarding forests were also determined in Slovenia; e.g., Gabrovec and Petek 2004). In addition, apart from the obvious CLC imprecision for studies at the local level, CLC data are not available for every year.

When compared with official forest area estimates, the NDVI results show a mere +0.12 km² (+0.2%) difference for the Municipality of Topola's forest area, and a –27.01 km² (–4.7%) difference for the Municipality of Kuršumlija (Table 3). Not only do these results completely fit within the ± 5% margin of error allowed for this method (Eastman 2001; Lunetta et al. 2007), but they also allow room for further analysis and investigation.

Because the NDVI aerial photos were taken during spring/summer, whereas official forest area estimates are made at the end of the year, NDVI values would be expected to be higher, not lower–at least for the Municipality of Kuršumlija (known for its illegal logging). Moreover, because additional NDVI forest area estimates were made for 2011 (Table 4), it seems that even for 2006 this study's NDVI results better fit the forest area trajectory of Kuršumlija for the 2006–2011 period than do the official statistics (the official forest inventory for 2006 is 604.41 km² and NDVI results 577.4 km²; and the official forest inventory for 2011 is 544.3 km² and NDVI results 529.8 km²).

The main reason that the (slightly smaller) NDVI results possibly better fit the forest area trajectory of Kuršumlija than the official inventory is that this municipality is known for illegal logging. According to the state-owned forest-management company *Srbijašume*, in Kuršumlija more than 40,000 m^3 of timber was illegally cut during the last thirteen years alone, and that municipality also experienced a 10% loss in forest area in the last few years alone (Forestry … 2006; Anfodillo et al. 2008; Illegal … 2009, Municipalities … 2013).

Obviously, governments often cannot efficiently control these illegal operations. As Contreras-Hermosilla (2000) points out: »*This lack of control can be either deliberate, often corrupt, or determined by the limitations of administrative capacity. One way or the other, illegal use of forests is rampant in most forested countries. By their very nature, the true extent of illegal operations in the forestry sector cannot be known with precision, but evidence suggests that such activities are important and that they constitute an important underlying cause of forest decline.*«

Because this research strongly implies that illegal logging in Kuršumlija is not properly covered by current official forest area estimates, further NDVI research on the extent of illegal logging in southern Serbian municipalities is of the utmost importance.

In short, because the Municipality of Kuršumlija has a large territory (952 km^2), with more than 544 km^2 (or 55.7%) of its total area covered by forests, and because NDVI can be performed very quickly, it is obvious that NDVI can provide local forest managers in Kuršumlija with much essential annual information about the forest inventory (Chen et al. 2004; Bellone 2009; Fensholt et al. 2009; Martinez and Gilabert 2009; Alessandrini et al. 2010; Corral-Rivas 2010). This is of crucial importance for preventing illegal logging, which is very prevalent in this southern Serbian municipality (Forestry … 2006; Anfodillo et al. 2008; Illegal … 2009).

5 Conclusion

Despite certain shortcomings (Franklin 2001; Campbell and Wynne 2011), classification and area estimation of various land-cover types based on remote sensing has obviously advanced to a point where it surpasses old wood inventory techniques, especially in the case of Serbia. Specifically:

- It is relatively cheap and quick, and it can provide forest managers with essential information;
- It is easy to implement, which is of crucial importance for Serbia, where national forest inventories have been carried out very rarely. The last three national forest inventories were carried out at roughly twenty-year intervals; however, since the last national forest inventory (2003–2006), necessary updates have been made every year, but only at the municipality level;
- The objectivity of these methods can significantly help in avoiding corruption in forest management because corruption is one of the main weaknesses of Serbia's economy.

Through this analysis of NDVI and CLC results for the municipalities of Kuršumlija and Topola, CLC was shown not to be a very suitable tool for local forest management in Serbia. On the other hand, it is evident that NDVI, especially in southern Serbian municipalities with prevalent illegal logging (like Kuršumlija), can provide local forest managers with much annual information about forest areas. This is of crucial importance for monitoring (and consequently preventing) illegal logging.

NDVI is also very promising for countries like Serbia, which very rarely carry out national forest inventories. It is easy implemented and it has objectivity that can greatly help avoid corruption and illegal logging in forest management.

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