Chapter 1

Comparing NDVI and Corine Land Cover as Tools for Improving National Forest Inventory Updates and Preventing Illegal Logging in Serbia

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Additional information is available at the end of the chapter

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Abstract

National forest inventories (NFIs) in Serbia have been carried out very rarely (every 20 years), while the last two official estimates of forest areas (for 2011 and 2014) are very imprecise, because they are based on the cadastral data (and Serbia is well known for the lack of cadastre updating). Although forest conservation policymakers in Serbia still have limited financial, human, and political resources, over the past two decades, publicly available, remotely sensed satellite data on deforestation and degradation have dramatically reduced evaluation costs. Since municipalities in Southern Serbia experienced a 15% loss of forest area in the 2006–2014 period, as the obvious result of forceful, rapid process of illegal logging, this study evaluates the possible use of two remote sensing techniques: normalized difference vegetation index (NDVI) and CORINE land cover (CLC) databases for preventing illegal logging in Serbia. It clearly shows that NDVI is very promising for Serbia and also for other post-socialist countries that very rarely carry out national forest inventories (NFIs), and where unrecorded, illegal logging can exceed the legal harvest by a factor of 10.

Keywords: CORINE land cover, illegal logging, national forest inventory, normalized difference vegetation index, Serbia

1. Introduction

Like many other developing and post-socialist countries where the basic information on the current state of forests and other ecosystems is often inadequate, fragmentary, or outdated [1], in Serbia national forest inventories (NFIs) have been carried out very rarely, at roughly

20-year intervals: in 1961, 1979, and 2003–2006. Since 2006, official estimates of forest areas have been made only for 2011 and 2014, but they are very imprecise, since they are based on the cadastral data (and Serbia is well known for the lack of cadastre updating) [2, 3].

While Serbian state-owned forests (48% of the nation's forest resources) are managed mainly by the state forest enterprises, according to the management plans prepared on the 10-year basis, the basic information on the current state of private forests is in a much worst condition. Previous forest census completed in 1979 covered only state forests and national parks, without even including private forests (new inventory completed in 2006, finally included private forests). Private forests constitute 52% of the nation's forest resources, and are characterized by very small plots (average size: 0.3 ha). Nevertheless, Serbia adopted following official definition of forest area: "The forest includes all the inventory unit areas larger than 0.5 ha covered with forest trees…" [2], which is very similar to FAO definition [4]. Actually, NFI features for individual countries have been developed over time to accommodate their unique topographies, climates, forest types, commercial interests, etc. [5–7]. Although FAO's reference definition is used as the basis for the national definitions of forest by many countries, national definitions can vary considerably: minimum forest area in Czech Republic is 0.04 ha, Austria (0.05 ha), China (0.0667 ha), Germany (0.1 ha), Estonia (0.1 ha), Ireland (0.1 ha), Latvia (0.1 ha), Lithuania (0.1 ha), Luxembourg (0.1 ha), Slovenia (0.25 ha), Slovak Republic (0.3 ha), USA (0.4 ha), etc. [8]. Unfortunately, 0.5 ha does not fit Serbia well, since privately owned forest parcels, which account for half of the total forest area of the country, cover much smaller areas—average private holding is only 0.3 ha [9].

Since illegal logging contributes up to 30% of the global market, in excess of US $20 billion a year, we cannot rely on official production statistics to capture deforestation. For example, even the latest forest resource data from official statistics in Central and Eastern European countries often do not consider forest degradation and illegal logging [10]. World Bank estimates that unrecorded, illegal logging in some of Central and Eastern European countries, like Albania, exceeded the legal harvest by a factor of 10 [3]. Also, in Serbia there are no unique records about illegal activities in forestry [11]. Illegal logging in Serbia is most intense exactly in the areas adjacent to the territories of Kosovo (Kosovo is ranked as the one of the worst illegal logging offenders in the world with Indonesia [12, 13]) which are formally under Serbian forest estates Vranje, Kursumlija, Leskovac, Raska, and Leposavic), territories to which Serbian authorities have limited access [3, 14, 15].

In order to prevent illegal logging, it is obviously most relevant to concentrate on areas where the illegal logging is most intense, and it is exactly in the southern Serbian municipalities, like Kursumlija, that are adjacent to the territories of Kosovo.

Although forest conservation policymakers in the most post-socialist European countries still have limited financial, human, and political resources, over the past two decades, publicly available, remotely sensed satellite data on deforestation and degradation have dramatically reduced evaluation costs [16, 17]. Such an approach could be much cheaper and the series of data would be quite useful for monitoring the forest cover [12].

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Remote sensing is the detection, recognition, or evaluation of objects by means of distant sensing or recording devices [18]. NDVI and CLC belong to these very promising remote sensing techniques that allow monitoring forest changes over time [19, 20]. One of the main differences between NDVI and CLC is that when 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 [21]. Normalized difference vegetation index (NDVI) [22] is one of the most widely used vegetation indices (VIs) which focuses on the vegetation cover and its status [21–28]. 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 [29]. NDVI also has the advantage of allowing comparisons between images acquired at different times [30]. On the other hand, CLC is a European program launched in 1985 by the European Commission, aimed at obtaining a 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, etc. The main goal of the CLC program is to unify heterogeneous thematic cartographies of Europe at various levels (international, national, regional, local), and to update data at regular intervals, every 5–10 years [31, 32]. 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 [33–35]. CLC also has an NDVI module for creating vegetation maps.

Advances in remotely sensed data availability have, obviously, created significant new opportunities to map changes in land cover and forest patterns and enhance understanding of the effectiveness and efficiency of forest conservation policy in Serbia [36–38].

2. Materials and methods

In order to evaluate the possible use of Corine land cover (CLC) and NDVI for preventing abrupt illegal logging in southern Serbian municipalities [39], our study was carried out for the municipality of Topola, located in central Serbia, and the Municipality of Kursumlija that lies in southern Serbia, bordering the territories of Kosovo (**Figure 1**).

NDVI data for both municipalities are based on Landsat 5 Thematic Mapper (TM) satellite images for 2006, 2011, 2012 and 2014, which were created during spring/summer (August), with minimum clouds (10–20%; [40]).

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 [41, 42]. Basic tasks included analysis and photo interpretation of elements, occurrences, and processes detected on images

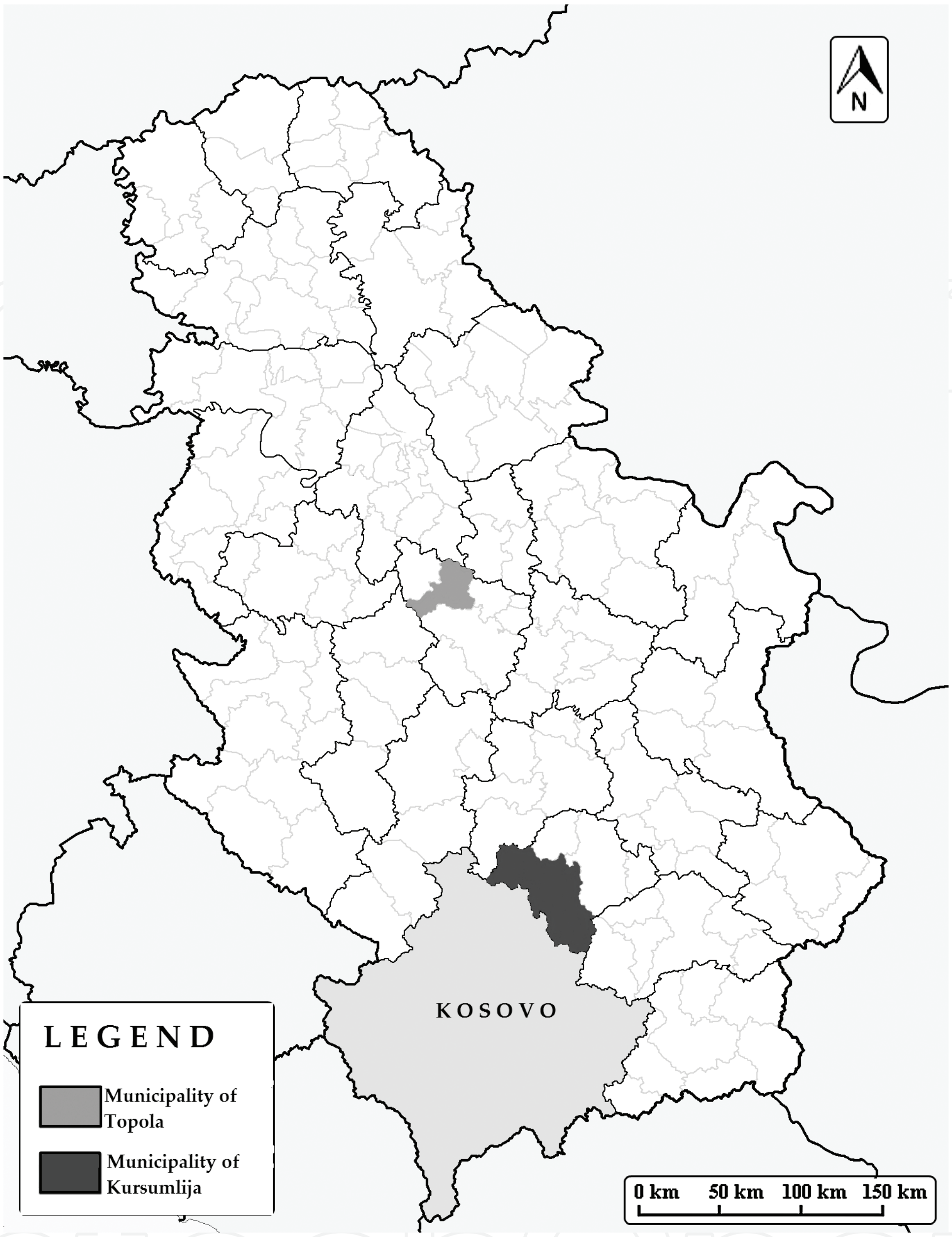

Figure 1. Locations of the municipalities of Kursumlija and Topola.

using specialized GIS software (Idrisi 15-Andes) for processing remotely sensed images through application of NDVI. Since shadow areas were less than 5% in the Municipality of Kursumlija and less than 3% in the Municipality of Topola, no topographic corrections were made (**Table 1**).

Prior to change detection, a normalized difference vegetation index (NDVI) images were generated and a threshold classification technique was applied. Using the NDVI, threshold technique involves less time and data, but selecting an accurate NDVI threshold can be difficult and still remains a challenge. For example, some surveys show that soils have a highly variable NDVI and the mean value (0.20–0.21) that is much larger than the NDVI

LANDSAT 5 (TM sensor)	Wavelength (pm)	Resolution (m)
Band 1	0.45–0.52	30
Band 2	0.52–0.60	30
Band 3	0.63–0.69	30
Band 4	0.76–0.90	30
Band 5	1.55–1.75	30

Table 1. Different spectral channels of images (produced by LANDSAT satellite) used in this paper.

commonly used (< 0.05). This problem is most severe in areas with sparse vegetation cover (e.g. grassland and shrubland) where typical seasonal NDVI values are in the sensitive range (0.2 < NDVI pixel < 0.4) [26]. Also, although the most common minimum NDVI value for broad-leaved forests is 0.4, even the 0.25 NDVI threshold was appropriate for some deciduous forest types (for northeastern China) [43] and also for temperate forests [44]. Previously, AVHRR-derived NDVI data advanced very high resolution radiometers (AVHRR) have been used to define the length of temperate forest growing seasons, using NDVI threshold values ranging from 0.25 [44] to 0.45 [45]. One survey of Northern Ghana suggests that appropriate NDVI value for forests is 0.32–0.4 [46], while study of Bangladesh it is 0.25 [47]. Also, Xiao et al. suggest that the 0.25 NDVI threshold is appropriate for the onset of greenness development of deciduous forest types in northeastern China [43]. Any generalization, as well as creation of the class itself, is often an arbitrary process. Also, threshold parameters, produce arbitrary and artificial differences in values in the real world [48]. Hence, the underlying logic of the reliable use of the threshold technique should be derived experimentally by defining classes step-by-step to know if they are correct [49]. As Jansen points out, different perspectives, or so-called 'scapes', to categorization can be taken that are all equally valid and valuable [49]. The threshold used for classification here has been chosen based on using sites of known change and stability in order to define the most suitable and reliable threshold for Serbia. Extensive field surveys were then guided with a global positioning system (GPS) receiver. The data collected during these field surveys were used to determine the major types of land use in the study areas, which helped design a land cover classification and to associate the ground "truth" of a specific type of land cover with its imaging characteristics, and which helped in making a reliable threshold. In this phase, we had to use supervised classification to correct intensity, hue and saturation of pixels, and also to correct the obtained shades (that were showing vegetation), in order to precisely distinguish forests from vineyards and orchards and to produce precise distinction between shrub and broad-leaved forest for Serbia. For broad-leaved forest in Serbia, appropriate range was between 0.292 and 0.438. The NDVI images were classified into eight classes: (1) grassy areas, meadows, and pastures, (2) sparsely vegetated areas, (3) shrub vegetation, (4) vineyard, (5) orchards, (6) broad-leaved forest, (7) mixed forest, and (8) coniferous forest (**Figures 2**–**4**). Vegetation areas are presented with values between 0 and 1. Grassy areas, meadows, and pastures have values that range from zero up to 0.122. Sparsely vegetated areas has an NDVI value from 0.123 to 0.174, shrub vegetation between

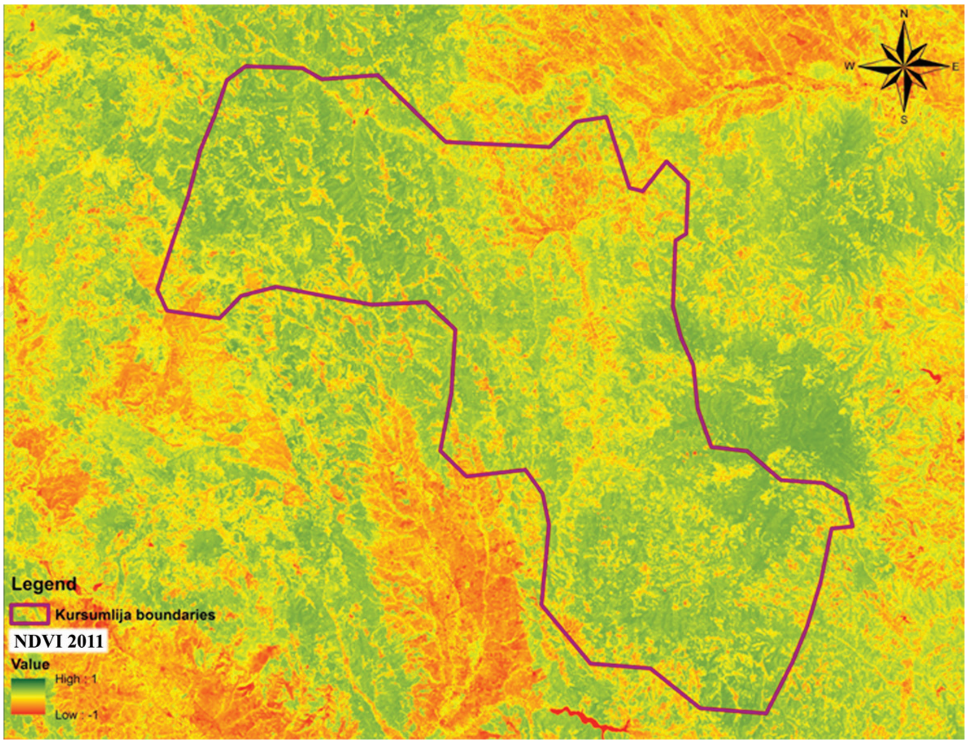

Figure 2. Vegetation cover of municipality Kursumlija for 2011 obtained by NDVI.

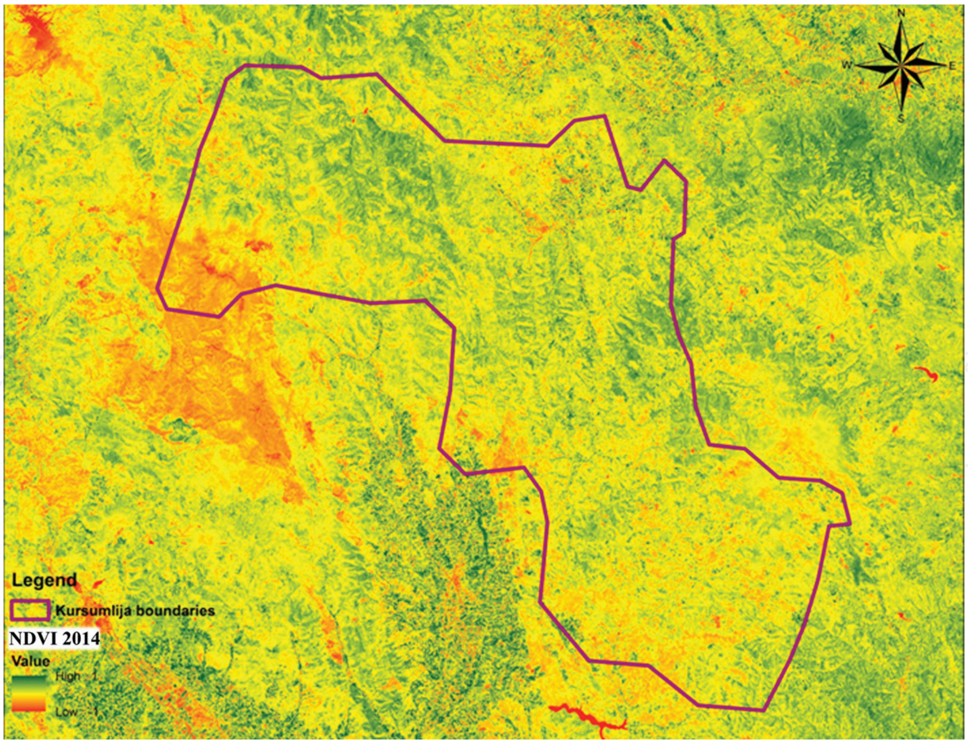

Figure 3. Vegetation cover of municipality Kursumlija for 2014 obtained by NDVI.

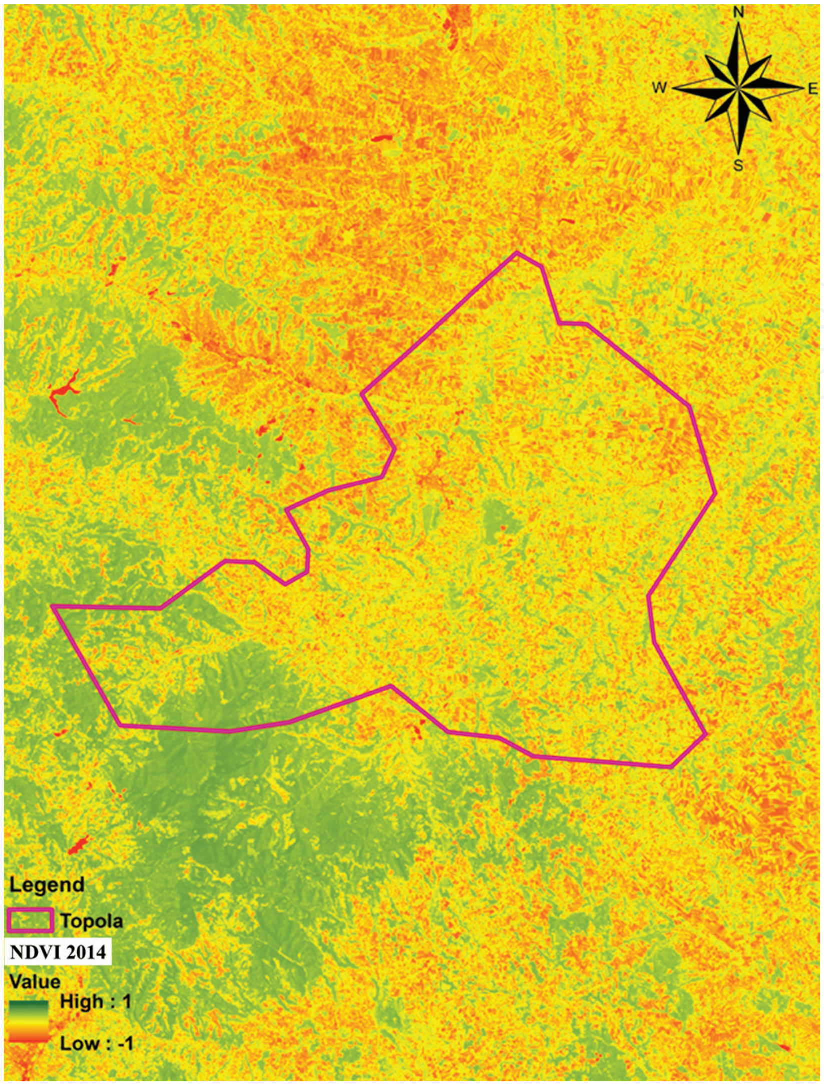

Figure 4. Vegetation cover of municipality Topola for 2014 obtained by NDVI.

0.175 and 0.230, vineyard 0.231 and 0.262, orchards 0.263 and 0.291, broad-leaved forest between 0.292 and 0.438, mixed forest between 0.439 and 0.525, and coniferous forest has an NDVI value above 0.526 [28, 50].

For creating CLC maps for the municipalities of Kursumlija 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 CLC2006 and CLC2012, were extracted from the European Environmental Agency (EEA) website, with a transfer data scale of 1:100,000 [51]. Although in the original CLC project the smallest unit is 25 ha, a recent approach yields more precise results because changes <25 and >5 ha are mapped [52]. 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 [53, 54]. Obviously CLC is an example of a top-down process of European standardization that follows a common system of nomenclature and focuses on common definitions and methods, and does not properly take into account unique features of individual countries of Central and Eastern Europe, like Serbia.

Finally, we performed the map accuracy assessment in order to evaluate the quality of our maps by comparing the mapped or predicted value to the observed or true condition. The basis of any accuracy assessment is a location-specific comparison of a map prediction and a ground observation. Accuracy assessment requires three primary components [55]: (1) the sampling design—choosing which locations are visited; (2) the response design, used to decide whether the map predicted and observed condition match; and (3) estimating accuracy parameters and summarizing the results of the assessment [55–60]. As Foody [56] points out, accuracy assessment has been a topic of considerable debate and research in remote sensing for many years. This is in part because the promoted standard methods such as the Kappa coefficient are not always appropriate [56]. Instead of Kappa, we have chosen different approach. The main problem with applying CLC for Serbia is that any (for CLC) unrecognizable spatial area (smaller than 4 ha) is automatically added to the closest recognizable larger area. Since CLC provided 135 of these small spatial areas (smaller than 4 ha) for Topola and 324 for Kursumlija, we concentrated exactly on them, and performed multiple GPS field surveys to compare our results with the "ground truth".

Hence, for our sampling design (1) we have chosen 64 (out of 135) of these spatial areas smaller than 4 ha (their size varied—from 0.02 to 4 ha), then (2) we compared our NDVI results with GPS field survey results, to decide whether the map predicted and observed condition match; and finally (3) we estimated accuracy parameters and summarized the results of the assessment (**Table 11**). This way not only that we could: (a) show the level of CLCs imprecision for spatial areas smaller than 4 ha (compared to the NDVI results), but also (b) we could check out the level of NDVI accuracy.

Also, since municipalities Kursumlija and Topola include mountainous areas (up to 1400 and 1800 m, respectively), and elevation, aspect, and slope are the three main topographic factors that control the distribution and patterns of vegetation in mountain areas [61–64], while among these three factors, elevation is most important [64–67], we performed statistical analysis to see whether different altitude zones have any impact on our NDVI results.

3. Results

When the CLC results for 2006 and 2012 were compared with official forest area estimates for the same years (**Tables 2–5**), some inconsistencies became apparent:

Forest areas obtained from CLC were up to 15.6% larger than the official forest area estimates. Kursumlija's forest area obtained from CLC for 2006 is 4.3% larger than the official forest area estimates for this municipality and 15.6% larger than the official forest area estimates for 2012, while Topola's forest area obtained from CLC for 2006 is 11.5% and for 2012 is 10.8% larger than the official forest area estimates.

Type of vegetation	Kursumlija (km²)		Topola (km²)	
Year	2006	2012	2006	2012
Settlements	4.60	4.87	9.11	9.30
Green urban areas	—	—	0.82	0.78
Non-irrigated arable land	0.42	0.35	36.51	36.49
Natural grasslands	25.74	25.42	14.44	14.27
Complex cultivation patterns	78.73	79.61	154.94	155.12
Land principally occupied by agriculture, with significant areas of natural vegetation	102.25	101.81	73.17	72.91
Broad-leaved forest	620.68	619.78	55.68	55.54
Coniferous forest	3.63	3.44	0.19	0.15
Mixed forest	6.14	6.01	2.12	2.00
Pastures	24.18	24.02	1.11	1.13
Transitional woodland-shrub	75.78	77.07	0.81	1.21
Sparsely vegetated areas	0.78	0.55	—	—
Total	942.93	942.93	348.9	348.9

Table 2. Land cover in the municipalities of Kursumlija and Topola obtained from CLC for 2006 and 2012.

Municipality	Municipality total area (km²)	Official statistics for 2006	Official statistics for 2012	Calculated on the basis of CLC for 2006	Calculated on the basis of CLC for 2012
Topola	357	52.00	52.0494	57.99	57.69
Kursumlija	952	604.41	544.2856	630.45	629.23

Table 3. Forest areas according to official statistics and calculated on the basis of CLC for the years 2006 and 2012 (in km²).

	CLC—Official statistics difference (km²)		CLC—Official statistics difference (%)	
Year	2006	2012	2006	2012
Topola	5.99	5.64	11.52	10.84
Kursumlija	26.04	84.94	4.31	15.61

Table 4. Difference between forest areas calculated on the basis of CLC and according to official statistics for the years 2006 and 2012 (in km² and in %).

Municipality	Municipality total area (km²)	Official statistics for 2006	Official statistics for 2011	Official statistics for 2014	Calculated on the basis of NDVI for 2006	Calculated on the basis of NDVI for 2011	Calculated on the basis of NDVI for 2014
Topola	357	52.00	52.0494	47.52	52.14	51.24	44.34
Kursumlija	952	604.41	544.2856	546.474	600.97	530.64	507.85

Table 5. Forest areas according to official statistics and calculated on the basis of NDVI for the years 2006, 2011, 2014 (in km²).

On the other hand, when compared with official forest area estimates [68–70], the NDVI results for the Municipality of Topola's forest area show a mere −0.27% difference for 2006, −1.55% for 2011, and −6.69% difference for 2014, and for the Municipality of Kursumlija − 0.57% difference for 2006, −2.51% for 2011, and −7.07% difference for 2014 (**Table 6**). For 2006 and 2011, NDVI results completely fit within the ±5% margin of error allowed for this method [71, 72], while for 2014 (−7% difference) our NDVI results exceed ±5% margin of error. Obviously, since NFI 2006, discrepancies between official forest area updates and our NDVI results are permanently growing, which opens possibilities for further analysis.

Vegetation cover in the municipalities of Kursumlija and Topola obtained from NDVI for 2006, 2011, and 2014 is presented in **Tables 7**. Since official updates for 2011 and 2014 do not contain different (coniferous, broad-leaved, and mixed) forest areas, comparison of NDVI values with official statistics was not possible.

There are huge differences between our CLC and NDVI results for forest area for Kursumlija—even 98.59 km² of a difference for 2012 (99.1%—or 97.74 km²—of these differences belong to the broad-leaved forest area category (**Tables 8–10**).

When we finally performed the map accuracy assessment, for all of our NDVI forest spatial areas, the error did not exceed ±3%. Hence, there was an extremely high degree of conformity between NDVI results and the "ground truth" (**Tables 11**).

Finally, by using SPSS software we showed completely insignificant value of Pearson's correlation coefficient (0.106) for different altitude zones (240–280, 330–450, 450–550, 750–850, and 900–1400 m) and deviation between forest areas obtained by NDVI and by GPS, clearly showing that topography does not have any relevant impact on our NDVI results.

	NDVI—Official statistics difference (km²)			NDVI—Official statistics difference (%)		
Year	2006	2011	2014	2006	2011	2014
Topola	0.14	−0.81	−3.18	0.27%	−1.55	−6.69
Kursumlija	−3.44	−13.65	−38.62	−0.57%	−2.51	−7.07

Table 6. Difference between forest areas calculated on the basis of NDVI and according to official statistics for the years 2006, 2011 and 2014 (in km² and in %).

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Type of vegetation	Kursumlija (km²)			Topola (km²)		
Year	2006	2011	2014	2006	2011	2014
Coniferous forest	9.30	3.65	3.61	0.61	0.17	0.13
Mixed forest	12.42	4.95	4.72	2.08	2.02	1.95
Broad-leaved forest	579.25	522.04	499.52	49.45	49.05	42.26
Orchards	25.63	33.54	35.55	38.33	43.25	51.35
Vineyards	7.40	6.41	5.15	12.11	7.23	5.02
Shrub vegetation	23.33	15.42	13.24	12.22	4.20	3.86
Sparsely vegetated areas	5.2	4.12	4.01	8.65	7.55	6.24
Pastures	34.45	37.95	38.22	13.43	2.89	3.04
Other	255.02	323.92	347.98	220.12	240.64	243.15
Total	952	952	952	357	357	357

Table 7. Vegetation cover in the municipalities of Kursumlija and Topola obtained from NDVI for 2006, 2011 and 2014.

Municipality	Municipality total area (km²)	Calculated on the basis of CLC for 2006	Calculated on the basis of CLC for 2012	Calculated on the basis of NDVI for 2006	Calculated on the basis of NDVI for 2011
Topola	357	57.99	57.69	52.14	51.24
Kursumlija	952	630.45	629.23	600.97	530.64

Table 8. Forest areas calculated on the basis of NDVI and CLC for the years 2006 and 2012 (in km²).

	CLC-NDVI difference (km²)		CLC-NDVI/NDVI difference (in %)	
Year	2006	2012	2006	2012
Topola	5.85	6.45	11.22	12.59
Kursumlija	29.48	98.59	4.90	18.58

Table 9. Difference between forest areas calculated on the basis of NDVI and CLC for the years 2006 and 2012 (in km² and in %).

	Calculated on the basis of CLC				Calculated on the basis of NDVI			
Municipality	Total forest area (km²)	Coniferous forest	Broad-leaved forest	Mixed forest	Total forest area (km²)	Coniferous forest	Broad-leaved forest	Mixed forest
Topola	57.69	0.15	55.54	2.00	51.24	0.17	49.05	2.02
Kursumlija	629.2	3.44	619.78	6.01	530.64	3.65	522.04	4.95

Table 10. Forest areas calculated on the basis of NDVI and CLC for 2012(2011) (in km²).

No.	Forest area obtained by NDVI (ha)	Forest area obtained by GPS (ha)	Deviation NDVI/GPS (%)
1	0.473	0.474	99.79
2	0.345	0.345	100.00
3	0.715	0.714	100.14
4	0.763	0.762	100.13
5	0.699	0.699	100.00
6	0.545	0.545	100.00
7	0.110	0.110	100.00
8	0.112	0.112	100.00
9	0.175	0.175	100.00
10	0.049	0.050	98.00
11	0.061	0.061	100.00
12	0.058	0.059	98.30
13	0.061	0.062	98.39
14	0.071	0.072	98.61
15	0.044	0.044	100.00
16	0.041	0.042	97.62
17	0.055	0.056	98.21
18	0.055	0.055	100.00
19	0.051	0.051	100.00
20	0.032	0.032	100.00
21	0.035	0.035	100.00
22	0.031	0.030	103.33
23	0.024	0.025	96.00
24	0.021	0.021	100.00
25	0.070	0.069	101.45
26	0.451	0.452	99.78
27	0.035	0.034	102.94
28	0.033	0.032	103.125
29	0.020	0.021	95.24
30	0.022	0.022	100.00
31	3.944	3.846	102.55
32	3.625	3.623	100.05

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No.	Forest area obtained by NDVI (ha)	Forest area obtained by GPS (ha)	Deviation NDVI/GPS (%)
33	3.234	3.232	100.06
34	3.985	3.987	99.95
35	4.003	4.001	100.05
36	3.256	3.258	99.94
37	3.685	3.683	100.05
38	3.942	3.944	99.95
39	2.545	2.547	99.92
40	3.025	3.026	99.97
41	1.589	1.587	100.13
42	2.452	2.460	99.67
43	2.551	2.551	100.00
44	2.703	2.704	99.96
45	2.555	2.556	99.96
46	0.633	0.632	100.16
47	0.652	0.652	100.00
48	0.580	0.581	99.83
49	0.554	0.555	99.82
50	0.281	0.281	100.00
51	0.332	0.332	100.00
52	0.354	0.354	100.00
53	0.420	0.422	99.95
54	0.450	0.449	100.22
55	0.363	0.365	99.45
56	0.159	0.157	101.27
57	0.455	0.456	99.78
58	0.030	0.031	96.77
59	0.029	0.029	100.00
60	0.021	0.022	95.45
61	0.025	0.026	96.15
62	0.058	0.057	101.75
63	0.049	0.048	102.08
64	0.035	0.034	102.94

Table 11. Deviation between 64 forest areas/units obtained by NDVI and by GPS (for spatial units smaller than 4 ha) in municipality of Topola for 2014 (in %).

4. Discussion

Since, according to the official statistics, Kursumlija experienced a 10% (60 km^2) loss of the forest area in the 2006–2011 period, or, according to our NDVI results, 15.5% (93 km^2) loss in the 2006–2014 period, this is very clear case of alarmingly rapid process of *deforestation*, in very sharp contrast with very modest rates of deforestation in Serbia and in municipality of Topola. Numerous studies convincingly showed that this extremely quick process of *deforestation* in Kursumlija is the obvious result of illegal logging [3, 13–15, 37].

Although CLC have recently been used in Serbia for spatial planning 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; [31, 32]), CLC is actually a predominant regional database, updated rarely (every 5–10 years), whereas NDVI is available every year and (b) NDVI is much more precise than CLC.

When official statistics were compared with NDVI and CLC forest areas for the same year (2006, 2011, 2012, and 2014), NDVI was more precise than CLC. Actually, the main problem with applying CLC for Serbia is that any (for CLC) unrecognizable spatial area smaller than 4 ha is automatically added to the closest recognizable larger area. 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 0.3 ha; [3]) and it is the main cause for CLCs (up to 15.6% imprecise) larger than official forest area estimates. In short, commonly used EU CORINE land cover (CLC), which serves as a tool for fulfilling pan-European monitoring needs [49] proved not to be very suitable for local forest management in Serbia (questionable results regarding forests were also determined in Slovenia, for example, [54]). In addition, apart from the obvious CLC imprecision for studies at the local level, CLC data are not available for every year.

On the other hand, all our NDVI results for Topola and for Kursumlija for 2006 and 2011 completely fit within the ±5% margin of error, while for 2014 they are much closer (±3% difference) to the "ground truth" (checked by our multiple GPS field surveys) and better fit the forest area trajectory. These discrepancies between our NDVI results and official inventory updates are obviously permanently growing: for Kursumlija, 2006 official forest inventory shows only 3.44 km^2 more forest areas; for 2011, 13.65 km^2 more; and for 2014, 38.62 km^2 more forest areas. Since our NDVI results for forest areas proved to be very close to the "ground truth" for 2014, it clearly indicates that in case of Serbia, official forest area updates are not precise. As Foody [56] points out, although remote sensing has been used successfully in mapping a range of land covers, land cover maps are often judged to be of insufficient quality for operational applications, especially when they are evaluated against some ground or other reference data set (like official forest area updates, in our case). Disagreements between the two data sets are typically interpreted as errors in the land cover map derived from the remotely sensed data [56].

Since our NDVI results for forest areas in 2014 proved to be very close to the "ground truth", these growing discrepancies between official forest area updates and our NDVI results are obviously the result of insufficient quality of official forest area updates.

Actually, there are several reasons that official forest area updates are very imprecise:

First, private forests are inventoried via assessment methods (cadastral data are used for assessing forest area) and Serbia is well known for the lack of cadaster updating.

Second, while national forest inventory in forests includes only inventory unit areas larger than 0.5 ha, private forests (that constitute 52% of the nation's forest resources) are characterized by very small plots (average size: 0.3 ha).

Third, official inventory of illegal loggings in private forests in Serbia is notoriously imprecise. The real amount of logged wood in private forests is six time as high as the registered amount [73].

Fourth, Serbian forest authorities have limited access to this extremely sensitive Serbia-Kosovo border area (formally under Serbian forest estates Vranje, Kursumlija, Leskovac, Raska, and Leposavic).

Also, it is important to underline here that none of the number of shortcomings that are usually addressed to the NDVI use [74, 75], proved to be relevant in the case of Kursumlija. Firstly, it is very easy to locate and quantify overall amounts of timber harvested in the case of Kursumlija municipality, because illegal logging produce large canopy gaps that go/extend from the border of Kosovo to approximately 3–4 km into the Kursumlija's territory. Secondly, from the field survey (hammer marks and size/height of stumps in the field), it is obvious that it is the clear case of illegal cutting, and thirdly, since illegal logging in Kursumlija is organized by groups of individuals, with market-oriented behavior [76] which are part of organized crime and closely tied to other criminal activities such as corruption, violence, and money laundering [77], it is, of course, not any sort of concession allocation issue.

Hence, it is exactly the objectivity of remote sensing that can be of the greatest help in resolving extremely quick and forceful process of illegal logging in this very sensitive southern Serbian area [12, 13, 76, 77], by providing an reliable, up-to-date alternative data source to quantify forest cover and change (independent of often very imprecise official governmental data sources) [78].

5. Conclusions

Through this analysis of NDVI and CLC results, CLC proved not to be a very suitable tool for local forest management in Serbia: (a) CLC is an example of a top-down process of European standardization that does not properly take into account unique individual features of post-socialist countries like Serbia, which resulted in extremely high (up to 15.6%) level of results imprecision and (b) CLC data are not available for every year. On the other hand, it is evident that NDVI, especially in southern Serbian municipalities with prevalent illegal logging can provide local forest managers with much precise annual information about forest area change.

Despite certain shortcomings [18, 24, 74, 75], classification and area estimation of various land cover types based on NDVI, has obviously advanced to a point where it surpasses old wood inventory techniques, especially in the case of post-socialist countries like Serbia. Specifically,

- It is relatively cheap [17] and quick, and it can provide forest managers with precise, up-to-date, annual 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 20-year intervals (in 1961, 1979, and 2007).

The objectivity of the method can significantly help in avoiding abrupt, unrecorded illegal logging that in post-socialist countries can exceed the legal harvest by a factor of 10.

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