REMOTE SENSING AND FOREST CONSERVATION: COMPARING NDVI AND CORINE CLC AS TOOLS FOR IMPROVING NATIONAL FOREST INVENTORY UPDATES AND PREVENTING ILLEGAL LOGGING IN SERBIA

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ABSTRACT

Evidence convincingly shows that illegal and corrupt activities are the major underlying cause of deforestation – illegal logging contributes up to 30% of the global market, in excess of US $20 billion a year. Since so much deforestation is the result of illegal logging, we cannot rely on official production statistics to capture deforestation.

National forest inventories (NFIs) in Serbia have been carried out very rarely (every 20 years), while the last two official estimates of the 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).

In this article we analysed two vegetation inventory techniques (NDVI and CORINE land cover). We clearly proved that NDVI (Normalized Difference Vegetation Index) offers local policymakers in Serbia more possibilities for sound and sustainable forest management than CORINE Land Cover: calculated forest areas obtained by CORINE land cover were even 15% larger than in the official forest inventory, while NDVI gave very precise results. The main methodological cause for such a huge discrepancies in the obtained results is that CORINE land cover (no matter how good/precise the satellite images used) doesn't go below the range of 4-5 ha space-units, while NDVI easily deals with space units of 5 m2. This is of a decisive importance for Serbia, where privately owned (agricultural and) forest land usually cover much smaller areas than 4 ha. NDVI is, also, very promising in the countries that very seldom perform national forest inventories, since it can easily provide local forest managers (especially in the municipalities with highly pronounced illegal logging, like Kuršumlija), with several, very precise, up-to-date forest inventory data (per year). Also, it has scientific objectivity that (to a large extent) can help in preventing possible corruption in the sphere of forest management. In short, in order to properly manage forests in Serbia (common resources that are difficult to be produced and easy to be depleted) NDVI clearly offers policymakers very precious possibilities for better local forest management.

Keywords: Remote sensing, Forest Conservation, CORINE land cover, Illegal logging, National forest inventory, Normalized Difference Vegetation Index (NDVI), Serbia.

INTRODUCTION

The permanent clearing of forest cover was the rule in the industrial world until few decades ago. Vast areas of Europe and North America were cleared as industrial expansion and

development of infrastructure proceeded. Deforestation today occurs largely in the tropical countries of Africa, Asia, and Latin America (Chowdhury, 2006; Steininger et al., 2001). These figures are alarming.

Most of these causes of deforestation belong to the sphere of market imperfections (Jovanović, 2012). Market imperfections arise when the property cannot be clearly defined, when the property cannot be freely transferable, when the use of the goods can not exclude the others, and when the privacy rights cannot be protected (McKean and Ostrom, 2000; Tietenberg and Lewis, 2012). There is enough available evidence that convincingly shows that illegal and corrupt activities constitute a major underlying cause of forest decline (Brack 2003; Contreras-Hermosilla, 2002). The main reason for this is that Governments (and private landowners) cannot control these illegal operations. Additionally, 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. (Amacher et al., 2009; Contreras-Hermosilla, 2002).

Actually, all common goods – like forest (that are difficult to exclude but subtractable) are usually completely overlooked. However, ignoring common goods (which are difficult to produce and easy to deplete) leads to tragic results (Chakravarty et al., 2012).

The main harmful factors that need to be resolved by forest management, can be divided into three categories (Dale, 2008):

1. Factors that cannot be controlled through management measures (climate changes, air pollution, and the like);
2. Factors that can be controlled through immediate management measures (primarily the breeding measures that ensure regular development of forest ecosystems);
3. Factors that can be controlled through protection measures (primarily parasitic fungi, harmful insects, rodents and the like, that constitute harmful biotic factors, which can be kept under control through direct protection measures and anthropogenic influence such as deforestation monitoring, emergency fire service that prevents fires from spreading to larger areas, etc,).

Given the importance and complexity of the problem (de Albuquerque and Rueda, 2010; Dorman et al., 2013; Freitas et al., 2005; Gallaun, 2010; Lee, 2008; Ojea et al., 2012; Pagiola et al., 2002), we are going to evaluate here the possible use of two remote sensing techniques in local forest management.

Remote sensing has been defined as the detection, recognition, or evaluation of objects by means of distant sensing or recording devices. Historically, digital remote sensing developed quickly from the technology of aerial photography and photo-interpretation science. In forestry, information extracted visually from aerial photo images is well-understood, well-used, and integrated with field surveys.

However, although remote sensing technology has (recently) emerged to support data collection and analysis methods in forest management, it is still rarely used, since remote sensing data and methods are complex, not well understood and, also, probably not well suited by those who might best use them (Franklin, 2001).

In this paper we are going to show that remote sensing data collection and analysis methods should be implemented in local forest management in Serbia. In Serbia 30% of land is under

forest. Forest management is in a very poor condition: 50% of forests are state-owned (enterprises for state forest management are in an unsatisfactory condition - their restructuring process has only started) and 50% owned privately (with a great number of small forest holdings with small economic capacity, whose owners have been over-felling their forests for decades to meet the most urgent needs of their livelihood, characterised by a poor state and fragmented holdings, unsolved property relations, which makes forest management even more difficult) (The Republic of Serbia - Ministry of Agriculture, Forestry and Water Management - Directorate of Forests, 2006).

The basic idea of this paper is to improve the local forest management system in Serbia through the use of more precise methods for the assessment of land use changes and forest inventory.

The main purpose of this research is to analyse two vegetation inventory techniques - NDVI and CORINE (praised as very efficient tools for making precise land-use and forest inventory of vast, remote areas (Meng et al., 2009) and evaluate their suitability for local forest management in Serbia. Although both of these techniques are very effective, we are going to prove that they are not equally efficient in Serbian context.

Also, the results of this study can be easily applied to the other Balkan countries, which have similar situation in the sphere of local forest management.

MATHERIALS AND METHODS

In our study we could not make any reliable comparative analysis (between official forest inventories, NDVI and CORINE results) of time series for a longer period, since national forest inventory in Serbia has been performed very rarely (last three national forest inventories - in the 20 years range: in the years 1961, 1979 and 2003-2006).

NDVI relates the spectral absorption of the chlorophyll in the red with a reflection phenomenon in the near infrared, influenced by the leaf structure type (Jovanović M. & Milanović M., 2015).

In order to obtain forest-area data with 30 m2 precision, we used NDVI and applied necessary corrections of visible red in constellation with infrared spectrum of satellite images, using following Idrisi software procedure - GIS Analysis/Mathematical Operation/Image Calculator, and then equation:

$$NDVI = (NIR - RED)/(NIR + RED)$$

in which NIR is near infrared band/spectral channel;
and RED is red band/spectral channel from the visible part of the spectrum.

This procedure enables avoidance of mistakes and deviations in the process of combining vector and raster contents, thus allowing subsequent image photo interpretation of area to be examined (Milanović at al., 2020). It is achieved by determining beforehand the same georeferenced values: coordinate system, projection and the date, for both raster and vector elements; then raster image is imported onto vector content, and contents are overlapped using the principle of layers (Milanović M. & Filipović D., 2017).

In next tables showed are different spectral bands of images that are used in this paper.

Table 1. Spectral bands of LANDSAT 5 satellite (image processing for 2011)

LANDSAT 5	Wavelength (μm)	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
Band 6	10.40-12.50	120
Band 7	2.08-2.35	30
Band 8 PAN	0.45-0.69	15

Source: www.usgs.gov

Table 2. Spectral bands of LANDSAT 8 satellite (image processing for 2014)

LANDSAT 8	Wavelength (μm)	Resolution (m)
Band 1 Coastal	0.43-0.45	30
Band 2 Blue	0.45-0.51	30
Band 3 Green	0.53-0.59	30
Band 4 Red	0.64-0.67	30
Band 5 NIR	0.85-0.88	30
Band 6 SWIR 1	1.57-1.65	120
Band 7 SWIR 2	2.11-2.29	30
Band 8 PAN	0.50-0.68	15
Band 9 Cirrus	1.36-1.38	30
Band 10 TIRS 1	10.60-11.19	100
Band 11 TIRS 2	11.50-12.51	100

Source: www.usgs.gov

In order to more precisely distinguish sick and damaged tree areas (and their volume of timber), we applied combination of NDVI and pseudo colour composite 4,5,1, using Idrisi software (image calculator). Pseudo colour composite 4,5,1 appears in shades of reds, browns, oranges and yellows; Mid-IR (Band 5) increases sensitivity of detecting various stages of plant growth or stress; Use of TM 4 and TM 5 shows high reflectance in healthy vegetated areas.

Since official forest inventory of Topola doesn't include valid data about sick and damaged tree areas, we had to perform visual inspection (using GPS) in order to verify Idrisi results.

Hence, we compared results for two different municipality at Serbia (Topola and Kursumlija), obtained by these two different vegetation inventory techniques: a) (official EU) CORINE land cover, and b) NDVI, for year 2011 (made during spring/summer season), with c) official forest inventory for 2011 (that was performed at the end of the year). Topola municipality is located in central Serbia, Kursumlija municipality in southern Serbia, where illegal logging is very pronounced (Fig. 1).



Figure 1. Municipalities Kursumlija and Topola in Serbian and European context (author: Milanovic M, 2017)

For NDVI and, also, for creating CORINE land cover maps, we used the same LANDSAT satellite images (LANDSAT 5 and LANDSAT 8) of municipalities Kursumlija and Topola (for year 2011, made during spring/summer season, with minimum existence of clouds).

Now we are going to analyse the main methodological differences between these two vegetation inventory techniques: a) NDVI, one of the most widely used VIs (vegetation indices), and b) CORINE land cover (that is officially used in EU).

One of the main differences is that, while NDVI is related only to vegetation cover (and its status), CORINE land cover has much wider scope, and distinguishes: agricultural areas, forests and semi-natural areas, artificial surfaces (like: urban fabric, industrial, commercial and transport units), water bodies, wetlands, glaciers and perpetual snow, etc (Jensen, 2007).

NDVI, actually, is a simple graphical indicator that can be used to analyze remote sensing measurements, whether the target being 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 most well-known and used index to detect live green plant canopies in multispectral remote sensing data (Campbell and Wynne, 2011; Ne Win et al., 2012, Jovanović at al. (2018). Also, NDVI has the advantage to allow comparisons between images acquired in different times (Lillesand et al., 2004).

It belongs to the Vegetation Indices (VIs), that are related to vegetation cover and status and provide useful information on biomass productivity and health condition. Vegetation Indices have a direct correlation with leaf chlorophyll content and Leaf Area Index (LAI) and vary in relation to vegetation cycle and phenology (Montandon and Small, 2008; Vohland et al., 2007). (They are also sensitive to other external factors: contribution of the soil/background optical behaviour where the vegetation does not completely cover the ground; geometry of view due to sensor angles' acquisition and to Sun position, as well as the atmospheric effects).

NDVI, like all the vegetation indices, relates the spectral absorption of the chlorophyll in the red with a reflection phenomenon in the near infrared, influenced by the leaf structure type (Wang and Tenhunen, 2004). By using NDVI, and applying necessary corrections of visible red (in constellation with infrared) spectrum of satellite images (GIS Analysis/Mathematical Operation/Image Calculator – NDVI=(NIR-Red)/(NIR+Red), we were able to obtain forest-area data with 15 m2 precision.

Upon completion of raster image processing, importing into another software package - Global Mapper - is performed. Then vector content is added, including the borders of the municipality of Kursumlija and Topola. Vector's elements on the map contains georeferenced values that correspond to values of the imported raster image in the Idrisi software.

Basic tasks include analysis and photo interpretation of elements, occurrences and processes detected on images by the specialized GIS software (Idrisi) that is used for processing of remotely sensed images through application of normalized difference vegetation index (NDVI).

This is an extremely important factor which enables avoidance of mistakes and deviations in the process of combining vector and raster contents, thus allowing subsequent image photo interpretation of area to be examined. It is achieved by determining beforehand the same georeferenced values (coordinate system, projection and the date) for both raster and vector elements, then raster image is imported onto vector content, and contents are overlapped using the principle of layers (Hájek, 2008; Johnson and Trout, 2012).

On the other hand, CORINE (Coordination of Information on the Environment) is a European programme initiated in 1985 by the European Commission, aimed at gathering information relating to the environment on certain priority topics for the European Union (air, water, soil, land cover, coastal erosion, biotopes, etc.). The main goals of the CORINE programme are: to acquire an appropriate knowledge of the environment in order to address the community politics, assessing their effectiveness acts, and to integrate the environmental and political aspects; to unify the heterogeneous thematic cartographies of Europe produced at different levels (international, national, regional, local); to update the data at regular intervals: every 5–10 years (Bossard et al., 2000). Since 1994, the European Environment Agency (EEA) integrated CORINE in its work programme. EEA is responsible for providing objective, timely and targeted information on Europe's environment (Neumann et al., 2007).

CORINE land cover has been derived by high-resolution satellite data (SPOT-HRV, Landsat-TM), through techniques of photo-interpretation (Heymann et al., 1994; Perdigao and Annoni, 1997). While CORINE database implementation is under the responsibility of the European Agency for the Environment (EEA) and image acquisition and pre-processing is centrally organized, the land cover mapping is done by member states to benefit from local knowledge. The CORINE Land Cover map has been produced for the 27 countries of the European Union (Gomarasca, 2009).

Also, procedure implies interactive controls and constant comparisons with ancillary information. The data has been validated using local cartog¬raphy and ground surveys (Genovese et al., 2001; Heymann et al., 1994; Perdigao and Annoni, 1997). CORINE land cover has, also, NDVI module for creating maps of vegetation, but the deviations of its final results are highly pronounced (because of still highly inappropriate scale for Serbian data).

For creating CORINE land cover maps for municipalities Kursumlija and Topola, image processing and digital elevation model has been made by using municipality's boundaries and, also, colour composites (LANDSAT satellite) and pseudo colour composite with bands 4, 3, 5, and adequate contrast applied. Datasets and maps for Serbia were extracted from European Environmental Agency official web-site (mainly, IMAGE2000 and CLC2000 class), with transfer data scale 1:100,000, that resulted in a very high level of imprecision (Büttner and Kleeschulte, 2005).

Of particular interest to our research is that in the original CORINE land cover project the surface area of the smallest unit is 25 hectares, although recent approach gives more thorough results, as changes < 25 ha and > 5 ha are all mapped (EEA, 2007). Nevertheless, even this (smallest) 5 ha surface areas (that are more than highly appropriate for EU countries), do not fit land-use situation in Serbia properly, as further analysis is going to show clearly.

Also, results and discussion are going to reveal some other major differences (between these two vegetation inventory techniques) that are very important for forest management in Serbia.

RESULTS AND DISCUSSION

LANDSAT satellite images of municipalities Kursumlija and Topola (for year 2011) used for NDVI and, also, for creating CORINE land cover maps, are presented in next Figures.

The following two maps (Fig. 2 and Fig. 3) are a raster NDVI Landsat satellite images, obtained through software processing and combination of individual spectral channels in the Idrisi software package. (NDVI is formed by combining satellite images of spectral channels of visible red and near infrared part of spectrum).

Having done image processing, it was concluded (Table 3) that forest areas encompass 529.83 km^2 (or 55.7 % of the total surface) of Kursumlija municipality (which is much higher than average 30% for Serbia), and 50.73 km^2 or 14.2 % of the total surface of the municipality of Topola (which is approximatelly half of the Serbian average).

Table 3. Kursumlija's and Topola's vegetation cover for year 2011 (obtained by NDVI - Idrisi software)

	Kursumlija		**Topola**	
	Area [km^2]	**Area [%]**	**Area [km^2]**	**Area [%]**
Broad-leaved forest	521.23	54.75	48.63	13.62
Coniferous forest	3.60	0.38	0.17	0.04
Mixed forest	4.93	0.52	1.93	0.54
Pastures	38.46	4.04	-	-
Transitional woodland-shrub	60.10	6.31	-	-
Sparsely vegetated areas	14.22	1.49	-	-
Land principally occupied by agriculture, with significant areas of natural vegetation	-	-	60.19	16.85
Other	309.46	32.51	246.08	68.95
Total	**952**	**100.00**	**357**	**100.00**

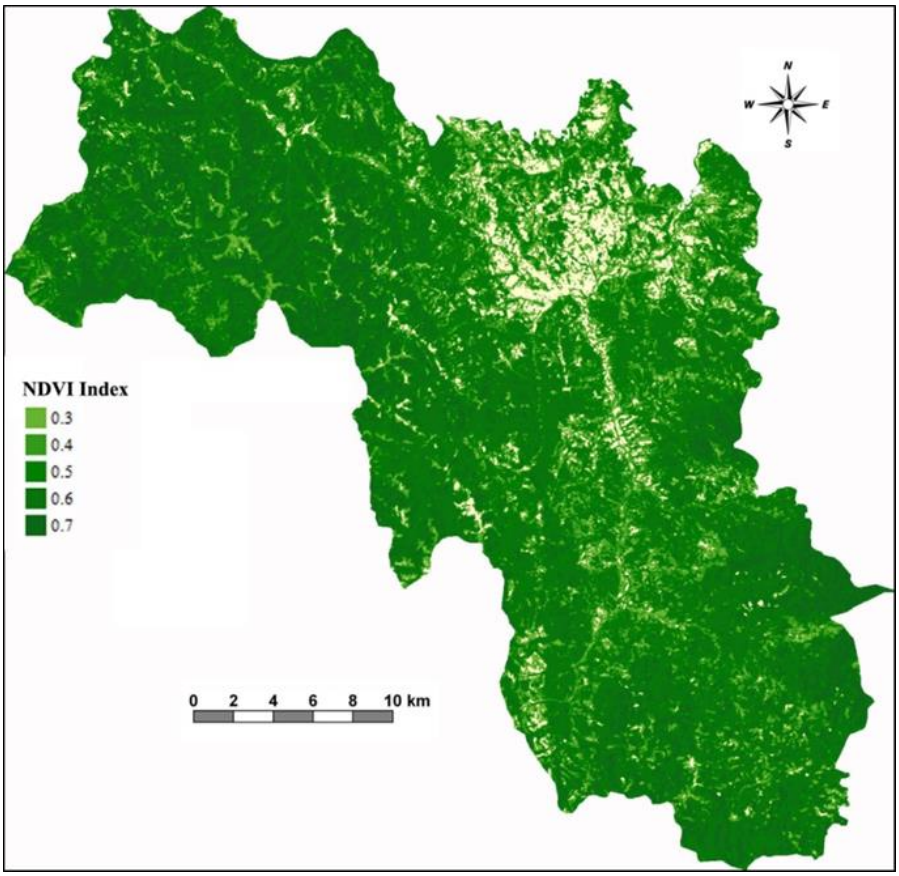

Figure 2. Kursumlija's vegetation cover for year 2011 (author: Milanovic M, 2018)

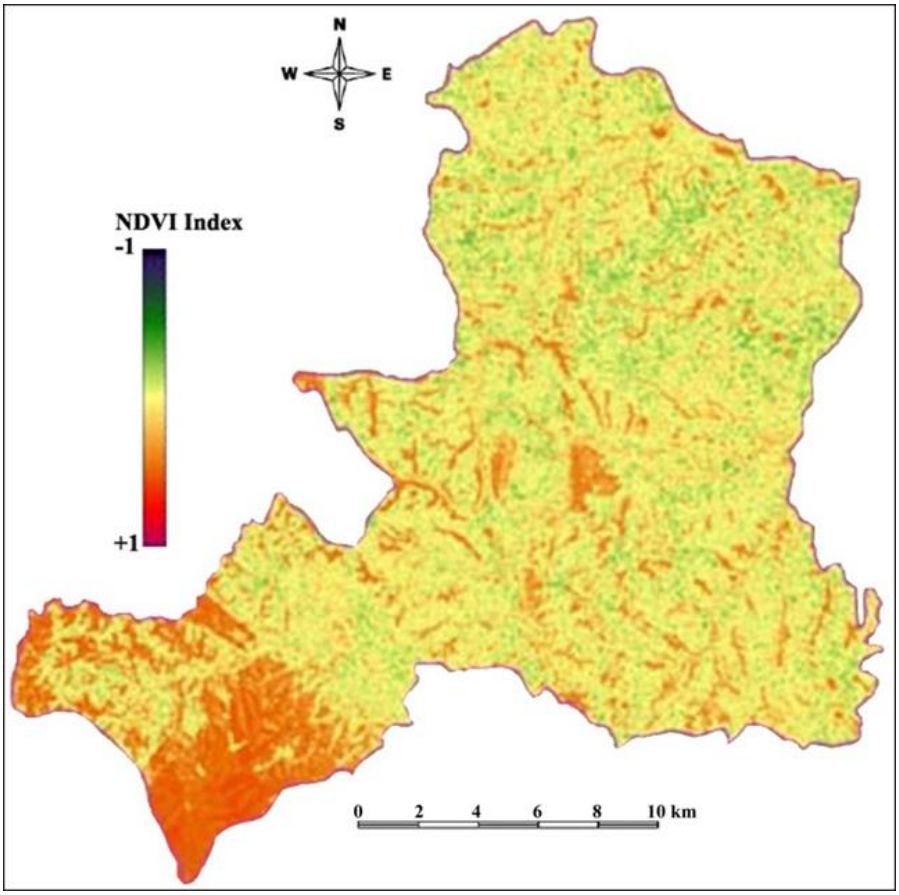

Figure 3. Topola's vegetation cover for year 2011 (author: Milanovic M, 2018)

When these NDVI results are compared with official statistical forest inventory for the same, 2011 year (SORS, 2013), there is only 1.3 km^2 of a difference for Topola's forest area, and 14.5 km^2 difference for Kursumlija (possibly because illegal logging is highly pronounced in this municipality). By CORINE land cover we obtained rather interesting results (Fig. 4 and Fig. 5).

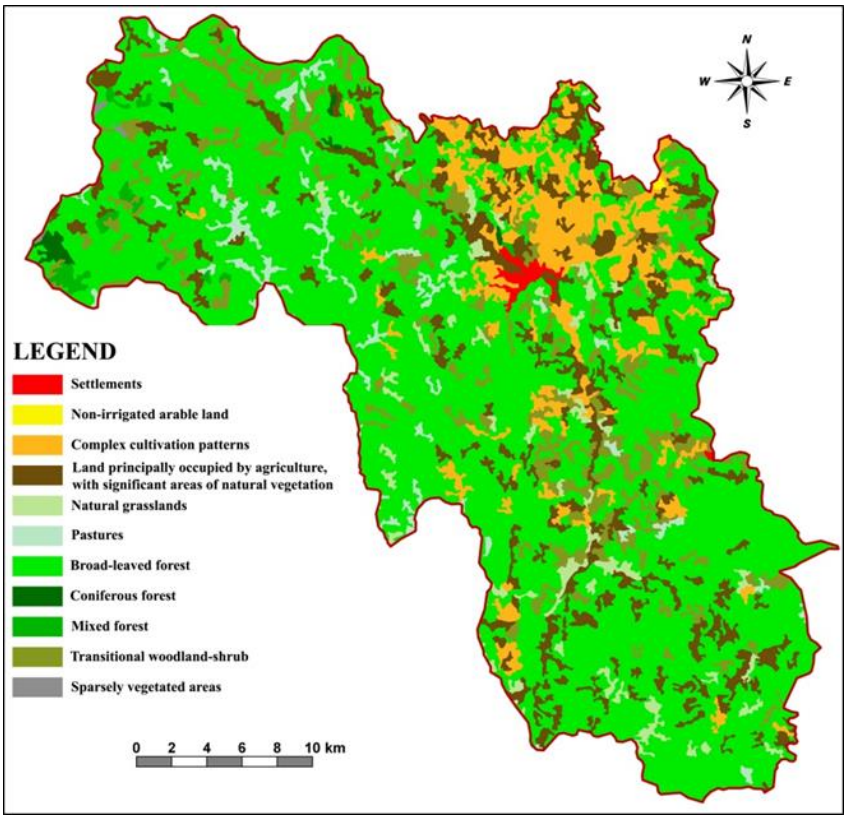

Figure 4. Kursumlija's land cover for year 2011 (author: Milanovic M, 2018)

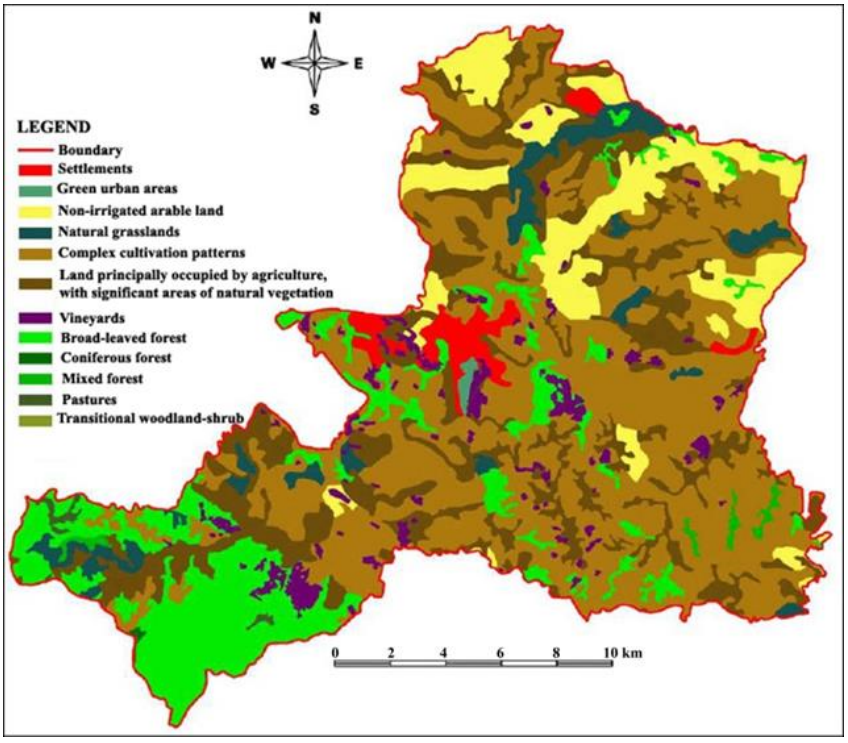

Figure 5. Topola's land cover for year 2011 (author: Milanovic M, 2018)

Table 4. Kursumlija's and Topola's land cover for year 2011 (obtained by CORINE land cover)

	Kursumlija		Topola	
	Area [km^2]	**Area [%]**	**Area [km^2]**	**Area [%]**
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**	**348.9**	**100.00**

When we compared CORINE land cover results with official statistical data and forest inventory for the year 2011 (Table 3, 4 and 5), some striking inconsistencies were apparent:

1. Kursumlija and Topola municipalities *total areas* (obtained by CORINE) were significantly (10 km^2) smaller than in official statistics (instead of 952 km^2 – 942.9 km^2 for Kursumlija, and instead 357 km^2– 348.9 km^2 for Topola:), and
2. Calculated forest areas (obtained by CORINE) were even 15% larger than in the official forest inventory. Kursumlija's forest area, obtained by CORINE (630.45 km^2) is even 86.2 km^2 larger than official forest inventory (544.3 km^2) for this municipality, while Topola's forest area, obtained by CORINE (58 km^2) is 6 km^2 larger than in official forest inventory (52 km^2).

Table 5. Forest area: by official statistics, and calculated on the basis of NDVI and CORINE Land Cover (2011)

Municipality	**Municipality-total area** [km^2]	**Forest area** [km^2]			**NDVI – Official statistics difference** [km^2]	**CORINE – Official statistics difference** [km^2]
		Official statistics [km^2][a]	**Calculated on the basis of NDVI** [km^2]	**Calculated on the basis of CORINE Land Cover** [km^2]		
Topola	357	52.0494	50.73	57.99	-1.3194	+5.94069
Kursumlija	952	544.2856	529.83	630.45	-14.4556	+86.1644

Source: Statistical Office of the Republic of Serbia (SORS) (2013) at the end of 2011

In short, through our comparative analysis of NDVI and CORINE Land Cover results, it became evident that NDVI is much more precise than CORINE Land Cover. Of the major significance for the results of this study, are some methodological/technical differences between these two vegetation inventory techniques. While NDVI easily deals with (minimum) space units of 5 m2, (no matter how good/precise the satellite images used) CORINE doesn't go below

the range of 4-5 ha. This proved to be decisive for Serbia, where privately owned forest parcels (which occupy half of the total forest area) usually cover much smaller areas than 4 ha.

Hence, CORINE Land Cover (at least, in its present state) proved not to be very suitable tool for local forest management in Serbia. Also, recent innovations, like combined use of CORINE and NDVI, can, probably, only give birth to some new, inspiring ideas (Chowdhury, 2006; Genovese et al., 2001).

At the same time, with NDVI we obtained some interesting results. Not only that these NDVI results (when compared with official statistical forest inventory data) show mere 1.3 km^2 (2.6 %) difference for Topola's forest area, and 14.5 km^2 (2.6 %) difference for Kursumlija (+-5% errors are allowed for this method), but it, also, gives us space for some further analysis and investigation.

Since NDVI aerial photos were taken during spring/summer season, while official forest inventory - at the end of the year, it would be expected that NDVI values are higher, not lower - at least for the Kursumlija municipality, notorious for its illegal logging. Actually, in Kursumlija (according to Srbija-sume - "Serbian forests" - state owned forest management company) more than 40,000 m3 of timber was illegally cut only during last 13 years. The main actors of illegal logging (in this southern Serbian municipality) come from Kosovo illegally, using secret, unsecured paths across the Serbian – Kosovo border, with professional equipment and mechanization to steal the timber from Kursumlija.

Obviously, governments often cannot efficiently control these illegal operations. Like Contreras-Hermosilla 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" (Contreras-Hermosilla, 2002).

Since our research indicate (strong) possibility that illegal logging in Kursumlija is not properly covered with current (official) forest inventory, further (NDVI) research/study of the extent of illegal logging in southern Serbian municipalities is of the utmost importance.

In short, since municipality of Kursumlija has very large territory (952 km^2), with more than 544 km^2 (or 55.7 % of its total surface) covered with forests, and NDVI can be performed very quickly, it is obvious that NDVI can provide local forest managers (in Kursumlija) with several essential up-to-date informations (per year) about forest inventory (Bellone, 2009; Chen et al., 2004; Corral-Rivas, 2010; Fensholt et al., 2009; Martinez and Gilabert, 2009). That is of a crucial importance for preventing illegal loging, which is very pronounced in this southern Serbian municipality on the very border of Kosovo.

To summarise, forest inventory technology based on remote sensing has obviously advanced to a point where it surpasses all other types of wood inventory techniques (especially in the case of Serbia):

1) It is relatively cheap, quick and provide forest managers with a lot of essential informations, and

2) It is easy to be implemented (which is of a cruical importance in Serbia, where national forest inventory has been performed very rarely (last three national forest inventories were performed in the 20 years range – in the years 1961, 1979 and 2003-2006, latest one - with a strong financial support of Norvegian government)

3) Scientific objectivity of these methods can (to a large extent) help in avoiding possible corruption (one of the main weaknesses of Serbian economic system) in forest management

4) Since these methods can be performed very quickly, they can provide local forest managers with several up-to-date informations (per year) about forest inventory, which is of a crucial importance for preventing illegal loging, that is very pronounced in southern Serbian municipalities.

CONCLUSION

Through our comparative analysis of NDVI and CORINE Land Cover results (on the example of Kursumlija and Topola municipalities), it became evident that NDVI is much more precise than CORINE Land Cover. One of the main causes for such a huge discrepancies is that CORINE land cover (no matter how good/precise the satellite images used) doesn't go below the range of 4-5 ha space-units, while NDVI easily deals with much more refine space units of 5 m2. It proved to be of a crucial importance, since individually/privately owned agricultural and forest land in Serbia usually cover much smaller areas than 4 ha (private forests in Serbia occupy approximately one half of the total forest area).

Hence, CORINE Land Cover (at least, at/in its present state) proved not to be very suitable tool for local forest management in Serbia.

It is evident that NDVI can provide local forest managers, especially in municipalities with pronounced illegal logging (like Kursumlija), with several essential up-to-date informations (per year) about forest inventory.

Also, NDVI is very promising in the countries that very seldom perform national forest inventories (like Serbia) since it is: relatively cheap, quick, provide forest managers with a lot of essential informations; easy to be implemented; and it has scientific objectivity and (to a large extent) can help in avoiding possible corruption (one of the main weaknesses of Serbian economic system) in the sphere of forest management.

In short, in order to properly manage forests in Serbia (common resources that are difficult to be produced and easy to be depleted) especially at the local level, more comprehensive account of forests through the use of normalized difference vegetation index (NDVI) - clearly offers policymakers a more sophisticated possibilities of forest management from which to derive policy options.

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