Chapter 5

Remote Sensing and Forest Conservation: Challenges of Illegal Logging in Kursumlija Municipality (Serbia)

Miomir M. Jovanović and Miško M. Milanović

Additional information is available at the end of the chapter

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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 a result of illegal logging, we cannot rely on official production statistics to capture deforestation. Given the importance and complexity of forest preservation, an attempt was made to evaluate the possible use of a normalized difference vegetation index (NDVI) in local forest management and prevention of illegal logging and corruption. We used the example of southern Serbian municipality Kursumlija that in the 2006–2011 periods experienced a 10% loss in forest area, as the obvious result of abrupt illegal logging. This process was very easy to locate and quantify (because illegal logging produced large canopy gaps that extend from the border of Kosovo to approximately 3–4 km into the Kursumlija's territory). In short, NDVI is very promising for countries like Serbia (that rarely perform forest inventories): It is relatively cheap and quick, and it can provide forest managers with essential information; it is easy to implement; the objectivity of these methods can significantly help in avoiding corruption and illegal logging.

Keywords: illegal logging, deforestation, normalized difference vegetation index (NDVI), local forest management, Serbia, Kursumlija

1. Introduction

Forests are under severe threat in many parts of the world. An average of almost 15 million hectares of forest was lost every year in 1990–2000 periods [1]. Forest decline consists of deforestation, forest degradation, and/or a combination of both. The Food and Agriculture

Organization of the United Nations defines deforestation as the sum of all transitions from natural forest classes (continuous and fragmented) to all other classes [2]. The loss of forest cover attributed to these transitions must be the reduction of tree crown cover to less than 10% of the total area for the phenomenon to qualify as deforestation [3]. While forest degradation events only partially and temporarily remove forest canopy cover, in deforestation there is near-complete removal of the original forest cover. Deforestation is an ongoing process of converting forested land to other land uses, such as pastures, agricultural fields, mining, or regional urbanization [4].

There is enough available evidence that convincingly shows that *illegal and corrupt activities* constitute a major underlying cause of forest decline worldwide [3, 5–7] and that illegal use of forests is rampant [3, 8]. Hence, illegal use of forests and deforestation is at the top of the current global policy agenda, especially understanding how to counter illegal extraction, since illegal logging contributes up to 30% of the global market, in excess of US $20 billion a year [9–13]. For some countries, such as Cambodia, Indonesia, Bolivia, indicative estimates of illegal logging even exceed 80% [14–16].

In post-socialist European countries, also, forest management changed drastically during the transition period—an increase in forest timber extraction, *including substantial illegal logging*, became common throughout the region. The illegal logging was particularly evident during the early transition years when poverty was at its peak and institutional oversight of forests was at its weakest [17]. Illegal logging is also very pronounced in southern Serbian municipalities bordering Kosovo (which is ranked as the one of the worst offenders in the world with Indonesia by Transparency International (TI) based on the percentage of illegal logging) [18].

Actually, the main problem concerning forest policies and management stems from the fact that ignoring common goods—like forests—which are difficult to produce and easy to deplete [19–21], leads to tragic results, since it is very difficult to restrict the rate at which they are consumed [22–24]. The size of many forests and the inevitable complications involved in monitoring the use of the forest and balancing one use against another, make exclusion or restrictions on access intrinsically problematic [25, 26].

Forest conservation, as a concept, has evolved from simple preservation ideas how natural resources should be used (essentially that their rate of use should not exceed the ability of the resource to replenish itself), to the very complex conservation concept that covers the equitable sharing of benefits derived from the resources, in the present and in the future (similar to the definition of sustainable development adopted by the World Commission on Environment and Development in 1987). Unfortunately, conservation managers are often faced with making decisions without access to reliable scientific information about what the potential outcomes of alternative management actions might be [27]. Such information is often lacking, partly because the scientific community has traditionally failed to address research questions of direct relevance to management practice, and partly because the scientific information that is available is often not readily accessible by conservation managers.

Chakravarty et al. point out that although it is not possible to properly manage a forest ecosystem without first understanding it, it is common that even the most basic information

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about forests is not always available … but new remote sensing technologies make it feasible and affordable to identify hotspots of deforestation [22]. Nevertheless, remote sensing (detection, recognition, or evaluation of objects by means of distant sensing or recording devices) that has recently emerged to support data collection and analysis methods in forest management [28–30] is still rarely used, not well understood, and probably not well suited by forest managers who might best use it [31].

It has been often pointed out that successful remote sensing applications in forestry were made only: (a) over an area too large or (b) otherwise difficult to survey on the ground [31]. But, there is now a pronounced shift around the globe of forest management authority from central government to municipalities (in Bolivia, Zimbabwe, Tanzania, Indonesia, Philippines, India, USA, Canada, China, etc.) [32], since forest policies are not likely to work when imposed on a country as a whole [23]. Actually, the aim of good *local* forest management is to: (1) strengthen the local rule of law, (2) improve local accountability and transparency (especially, through establishing clear mechanisms for the provision of and access to information and mechanisms and procedures for reporting grievances and misbehavior), (3) strengthen local participatory planning and decision-making, and (4) improve local governance effectiveness and efficiency through development of effective monitoring and evaluation systems at local and central levels [33]. Two of these four key dimensions of "good forest management and governance" have been taken up and pursued by many countries on national and international levels. Unfortunately, accountability and transparency, as well as governance effectiveness and efficiency, have not received equally broad recognition. Especially at the local level, which plays a crucial role in good governance, it has received comparatively little or no attention [33].

Obviously, forest conservation and management are entering a period of new challenges and greater uncertainty. Forest ecosystems supply services are crucial to human well-being, but the delivery of these services is diminishing globally. While agencies ranging from national governments to community organizations struggle to develop policies to effectively secure the conservation and sustainable management of forests resources, at the same time illegal and corrupt activities constitute a major underlying cause of forest decline worldwide.

2. Illegal logging

Most reasons for deforestation are due to market imperfections [20]. 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 [21, 24]. Evidence convincingly shows that illegal and corrupt activities are a major underlying cause of forest decline [3, 5]. 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 [3, 8].

In principle, a distinction must be made between two types of illegal logging. On the one hand, wood may be stolen by the local population due to their poverty to satisfy their living requirements. This mainly comprises firewood. *Poverty-driven illegal logging* emerges where poor people have little other choice. The harvested quantities are typically small. The greater proportion of illegal logging, however, is carried out by companies dealing with *industrial* timber which occasionally have mafia-style structures and are part of organized crime. This form of illegal logging is closely tied to other criminal activities such as corruption, violence, and money laundering [7, 34].

Since so much deforestation is a result of illegal logging, we cannot rely on official production statistics to capture deforestation.

For example, with its extremely high percentage of illegal logging, Kosovo is ranked as the one of the worst offenders in the world with Indonesia [18]. The annual *illegal* fuelwood harvesting in Kosovo represents a market of up to 21.6 million euro and is done mostly by well organized groups of individuals, with market-oriented behavior, acting rather in state forests than in private forests. To put this into perspective, the domestic market demand for fuelwood in Kosovo is estimated at more than 1.5 hm^3, while the legal supply, including imports, is slightly higher than 0.3 hm^3. Hence, illegal logging for satisfying Kosovo population fuelwood needs is therefore widespread [35]. However, the need for auto-consumed firewood resulting from the high level of poverty does not represent the major issue compared to the well spread and costly commercial illegal logging crimes. These crimes are committed by the well-off. All institutions, from the MAFRD, KFA, police to the Ministry of Justice and politicians but also the forest products industry, are responsible for the present high level of illegal logging taking place in Kosovo [18].

Also, in Serbia, illegal logging is most intense exactly in the areas adjacent to the territories of Kosovo (which are formally under Serbian forest estates Vranje, Kursumlija, Leskovac, Raska, and Leposavic) to which Serbian authorities have limited access. According to Public Enterprise for Forest Management "Srbijašume," well-organized groups of Albanians from Kosovo, which usually have several tractors and whole professional equipment and mechanization, organize large illegal loggings in Serbian municipality Kursumlija. Given extremely high percentage of illegal logging in Kosovo, it is not surprising that they extended illegal logging across the Serbia-Kosovo administrative border, approximately 3–4 km into the Kursumlija's territory.

There has been, also, considerable concern about the reliability of official forest resource statistics in Central and Eastern Europe, not only from the socialist period, but also after the breakdown of socialism [17]. Latest forest resource data from these countries often do not consider forest degradation and illegal logging. For example, 2005 World Bank study estimated that unrecorded, illegal logging in some of Central and Eastern European countries, like Albania, exceeded the legal harvest by a factor of ten [36].

The extent of illegal forest-related activities is notoriously difficult to estimate. Since deforestation and forest degradation stemming from illegal practices are inherently hard to measure, attempts to quantify illegal actions are often "guesstimates" [14].

Also, in Serbia there is no established uniform system of monitoring of illegal activities in forestry, and there are no unique records, based on which all information about illegal activities

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in forestry could be monitored. Forests inventory (national and stand inventory) is not registering stumps of illegally logged trees. The main body responsible for the control of legal regulations implementation in the field of forestry, and therefore illegal logging, is the forest inspection service. Problems that the control services have are mainly related to the lack of equipment, vehicles, fuel, etc., *as well as lack of jurisdictions* [37]. Sometimes one forest inspector covers 1.000 km^2 but has no vehicle (nor public transport) in the very poorly developed areas [36]. In spite of all these shortcomings, public forests (that represent 50% of all forest territories) are relatively well protected. Obviously theft from privately owned forests constitutes a more complex problem in Serbia, since the real amount of logged wood in private forests is six times as high as the registered amount. Private owners are not an organized group, the average area of forest plots is very small, and owners tend to live at a distance from their property, and thus, there is no security service for private forests.

Obviously, more accurate data on illegal logging could be provided if a ground inventory is undertaken combined with using remote sensing technology. Such an approach could be much cheaper, and the series of data would be quite useful for monitoring the forest cover [18]. Although forest conservation policymakers in the developing 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 [38]. These advances in conservation best practices and remotely sensed data availability have created significant new opportunities to enhance understanding of the effectiveness and efficiency of forest conservation policy. It is for these reasons that in-depth case studies, such as the ones that use remote sensing to map changes in land cover and forest patterns, in addition to using qualitative analyses, are crucial to understanding forest trends in Central and Eastern Europe.

3. Normalized difference vegetation index (NDVI) and local forest management

Remote sensing is the detection, recognition, or evaluation of objects by means of distant sensing or recording devices. Historically, digital remote sensing developed rapidly from aerial photography and photo interpretation. Information extracted visually from remote sensing is widely used in forestry [31].

According to Lu et al. [39], there are high, medium, and coarse spatial resolution images. High spatial resolution images such as IKONOS, QuickBird, and Worldview have recently become important data sources for change detection analysis at a local scale [40]. Medium spatial resolution images, especially Landsat images due to their long history of data availability and suitable spectral and spatial resolutions, have become a common data source for regional change detection [41, 42]. At a continental or global scale, coarse spatial resolution data such as AVHRR, MODIS, and SPOT VGT (VEGETATION) may be used [10, 43–46] but present challenges in developing suitable techniques to extract changed features from coarse spatial resolution data [39].

In our study, we are going to use normalized difference vegetation index (NDVI). In our previous research, we compared NDVI and Corine land cover (CLC), and NDVI proved to be much more precise than CLC [47]. Since 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 4–5 ha, NDVI easily deals with minimum space units of 25 m^2. 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; [48]). In addition, apart from the obvious CLC imprecision for studies at the local level, CLC data are not available for every year. In short, CLC proved not to be very suitable for local forest management in Serbia.

Normalized difference vegetation index (NDVI) [49] is one of the most widely used vegetation indices (VIs), which focuses on the vegetation cover and its status [50]. 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 [51]. 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 [52, 53]. NDVI also has the advantage of allowing comparisons between images acquired at different times [54]. It belongs to the VIs related to vegetation cover and its status. VIs have a direct correlation with leaf chlorophyll content and leaf area index (LAI) and vary in relation to vegetation cycle and phenology [55, 56]. 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 [31, 50, 52, 57]. 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 [58].

Given the importance and complexity of forest preservation and sustainable forest management [1, 59, 60], an attempt was made to evaluate the possible use of a normalized difference vegetation index (NDVI) [49] in local forest management and preventing illegal logging and corruption in southern Serbian municipality Kursumlija, adjacent to the territories of Kosovo.

In Serbia around 30% of land is forested (of which 48% is state-owned forests and 52% privately owned). Forest management (of both privately owned and state-owned forests) is also very poor [61].

In the study, it was not possible to make a reliable long-term comparative analysis between NDVI and official forest inventories because national forest inventories have very rarely been carried out in Serbia. Such inventories were carried out at roughly 20-year intervals: in 1961, 1979, and 2003–2006. Since 2007 until 2011, official estimates of forest areas have been made annually. The study was carried out for the municipality of Kursumlija (where illegal logging and deforestation are extremely pronounced) and also for municipality of Topola (where it is not) (**Figure 1**). The municipality of Topola is located in central Serbia, and the municipality of Kursumlija lies in southern Serbia and is adjacent to the territories of Kosovo.

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

Data obtained using NDVI for spring/summer 2006 and 2011 were analyzed and compared to official forest area estimates for 2006 and 2011 created at the end of the same year.

NDVI data for both municipalities are based on Landsat-5 Thematic Mapper (TM) satellite images for 2006 and 2011, which were created during spring/summer (August), with minimum clouds (10–20%; [62]). 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.

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 [63, 64]. 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" [31]. Because 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.

Characteristic NDVI signatures are as follows: NDVI of dense vegetation canopy tends to have positive values (0.3–0.8); clouds and snowfields are characterized by negative values of this index; bodies of water (e.g., oceans, seas, lakes, and rivers) have 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 (0.1–0.2); very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow; moderate values represent shrub and grassland (0.2–0.3); and high values (0.6–0.8) indicate temperate and tropical rainforests [65, 66]. Negative values of NDVI ranging from 0 to –0.3 are displayed in orange shades (**Figure 2**). These low negative values are detected in arable agricultural land (without vegetation) and are shown in shades of light orange. 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 up to 0.13 (shades of yellow, due to more intense reflectance of infrared radiation). Shrub vegetation has an NDVI value of 0.25 because reflectance of infrared rays decreases (light green). All forest vegetation (shades of dark green), 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 [57, 67].

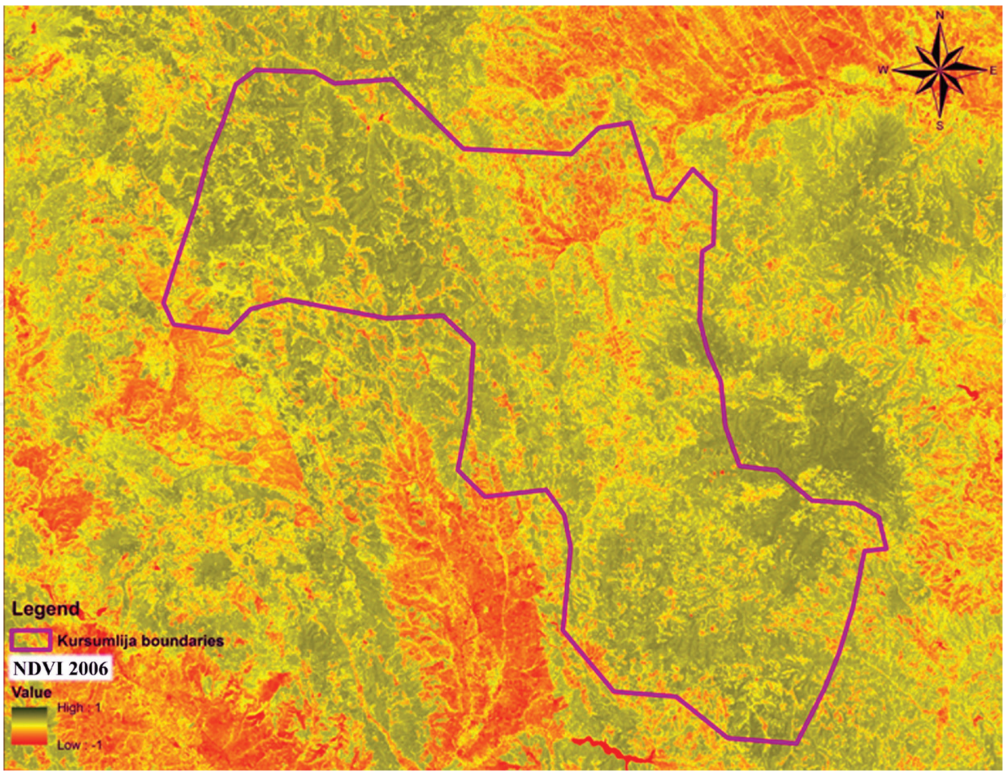

Figure 2. Vegetation cover in the municipality of Kursumlija for 2006 obtained from NDVI.

After image processing, it was determined (**Table 2**) that forest areas encompass 529.83 km^2 or 55.7% of the total area of the municipality of Kursumlija, 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.

When compared with official forest area estimates [68], the NDVI results show a mere 0.12 km^2 (0.23%) difference for the municipality of Topola's forest area and a -27.01 km^2 (-4.47%) difference for the municipality of Kursumlija (**Table 1**). Not only do these results completely fit within the ±5% margin of error allowed for this method [44, 69], 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 Kursumlija (known for its illegal logging). Moreover, because additional NDVI forest area estimates were made for 2011 (**Table 2**), it seems that even for 2006, this study's NDVI results better fit the forest area trajectory of Kursumlija for the 2006–2011 period than do the official statistics (the official forest inventory for 2006 is 604.41 km^2 [70] and NDVI results 577.4 km^2; and the official forest inventory for 2011 is 544.3 km^2 [68] and NDVI results 529.8 km^2).

The main reason that the (slightly smaller) NDVI results possibly better fit the forest area trajectory of Kursumlija than the official inventory (**Tables 3** and **4**) is that this municipality is known for illegal logging. According to the state-owned forest management company Srbijašume, Kursumlija experienced a 10% loss in forest area in the last few years alone [61, 68, 71, 72].

Municipality	**Municipality total area for 2006 (km²)**	**Forest area**		**Forest area**	
		Official statistics for 2006 (km²)	**Calculated on the basis of NDVI for 2006 (km²)**	**NDVI—official statistics difference (km²)**	**NDVI—official statistics difference (%)**
Topola	356	52.00	52.12	−0.12	0.23
Kursumlija	950	604.41	577.40	−27.01	−4.47

Table 1. Forest areas according to official statistics and calculated on the basis of NDVI for the year 2006.

Municipality	**Municipality total area for 2011 (km²)**	**Forest area**		**Forest area**	
		Official statistics for 2011	**Calculated on the basis of NDVI for 2011**	**NDVI—official statistics difference (km²)**	**NDVI—official statistics difference (%)**
Topola	357	52.0494	50.73	−1.3194	−2.53
Kursumlija	952	544.2856	529.83	−14.4556	−2.66

Table 2. Forest areas according to official statistics and calculated on the basis of NDVI for the year 2011.

Municipality	Official statistics for 2006 (km^2)	Official statistics for 2011 (km^2)	2006–2011 difference (%)
Kursumlija	604.41	544.2856	−9.95
Topola	52.00	52.05	+0.96
Serbia	19845.13	19623.35	−1.11

Table 3. Kursumlija and Topola—forest areas according to official statistics.

Municipality	Calculated on the basis of NDVI for 2006 (km^2)	Calculated on the basis of NDVI for 2011 (km^2)	2006–2011 difference (%)
Kursumlija	577.40	529.83	−8.24
Topola	52.12	50.73	−2.67

Table 4. Kursumlija and Topola—forest areas calculated on the basis of NDVI.

4. Kursumlija: challenges of illegal logging and rapid deforestation

Since, according to official statistics, Kursumlija experienced a 10% loss in forest area in the 2006–2011 period, which is 60 km^2 loss of forest cover (or 48 km^2, calculated on the basis of NDVI), and this is very clear case of alarmingly rapid process of *deforestation*, in very sharp contrast with very modest rates of deforestation in Serbia and even slight process of reforestation in municipality of Topola. This extremely quick process of *deforestation* in Kursumlija is the obvious result of illegal logging. In order to solve this problem, Public Enterprise for Forest Management "Srbijasume" regularly informed all levels of the state administration, Ministry of Interior Affairs, Army, representatives of KFOR and UNMIK, which is also well documented in various World Bank and REC studies [36, 37, 72].

Again, it seems that NDVI results possibly better fit the forest area trajectory of Kursumlija than official inventory (for 2006 official forest inventory shows 27 km^2 more forest areas, for 2011, 14 km^2 more). This is probably due to the notoriously imprecise official inventory of illegal loggings in private forests in Serbia. The real amount of logged wood in private forests is six times as high as the registered amount. This is the reason why NDVI gives more precise results than official inventory [6].

It is important to underline that the number of shortcomings that are usually addressed/related to the satellite imagery use, regarding its possibilities to truly capture illegal logging, proved to be completely irrelevant in the case of Kursumlija. For example, Khai et al. [73] state that the illegal nature of timber harvests makes it difficult to locate and quantify overall amounts of timber harvested, largely because illegal logging frequently does not produce large canopy gaps visible on satellite images. Khai et al. [73] also stress that it is very important to clearly distinguish illegal cutting from legal cutting based on hammer marks and size/height of stumps in the field. Although it can be time-consuming to estimate illegal logging from field surveys of stumps, recent forest inventories of many countries include stump measurements for carbon stock and biodiversity evaluation. Thus, such stump measurements in

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regular forest inventories can be readily used for estimating the extent of illegal logging if there is a clear difference between legally and illegally cut stumps.

Also, Lawson and Larry MacFaul [74] emphasize that, although comparing satellite imagery with official concession maps and harvesting plans could be expected to capture illegal logging more completely and precisely than existing indicators, they are still far from perfect …. First of all, because satellite images cannot easily detect whether a company harvests more trees than permitted within the area in which it is licensed to cut in a given year, the method also fails to capture illegalities regarding concession allocation.

Nevertheless, none of the above-mentioned possible shortcomings of satellite imagery proved to be relevant in the case of Kursumlija: First, it is very easy to locate and quantify overall amounts of timber harvested in the case of Kursumlija municipality, because illegal logging produces large canopy gaps that go/extend from the border of Kosovo to approximately 3–4 km into the Kursumlija's territory; second, 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 third, since illegal logging in Kursumlija is organized by groups of individuals, with market-oriented behavior [35], which is part of organized crime and closely tied to other criminal activities such as corruption, violence, and money laundering [34], it is, of course, not any sort of concession allocation issue.

Obviously, governments often cannot efficiently control these illegal operations. As Contreras-Hermosilla [3] 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."

Since this research strongly implies that illegal logging in Kursumlija 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 Kursumlija 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 Kursumlija with much essential annual information about the forest inventory [75–80]. This is of crucial importance for preventing illegal logging, which is very prevalent in this southern Serbian municipality [61, 71, 72].

Finally, we should further investigate two important issues: (a) how the remote sensing can be used as a management tool for forest management in Serbia? and (b) how it will prevent illegal logging or help the forest managers to fight this menace in Serbia?

As Potapov et al. [81] point out, information derived from satellite imagery is not equivalent to inventory data collected by forest managers. Optical remote sensing data are suitable for mapping land cover (tree canopy cover, dominant tree species composition), while national forest inventory data focus on land-use (e.g., forest land). This means that while tree canopy cover change can be readily observed with remote sensing data, it is not directly comparable to harvested timber volumes reported by the national forest statistics [81]. Remote sensing (RS) data can provide an alternative data source to quantify forest cover and change independent of official governmental data sources.

This is extremely important, since there has been considerable concern about the reliability of (very rarely performed) official forest resource inventories/statistics in the Central and Eastern Europe [17] and especially in Serbia [47, 80]. Also, deforestation and forest degradation stemming from legal practices are inherently hard to measure, and attempts to quantify illegal actions are often "guesstimates" [14]. Information system on illegal activities in forestry in Serbia has not been established yet, and within the sector, it operates several (very inefficient) internal systems for collecting data on illegal activities. Since municipality of Kursumlija experienced a 10% loss in forest area in the 2006–2011 period only (and official forest resource statistics seem to be completely unreliable since 2011), information about this very quick process of deforestation in Kursumlija (on the yearly basis, at least) is of the utmost importance.

Also, concerning (generally still rather inefficient) forest management in Serbia, 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/cycle. The emphasis is narrowly focused on timber production. The process of forest certification, extremely important for combating illegal logging, has only recently begun (although state forests have adopted the Forest Stewardship Council certification scheme, only 200,000 ha of state forests have been certified by now).

Forest management of private forests is even in a much worst condition. Private forests represent/constitute 52% of the nation's forest resources and are characterized by very small plots (average size: 0.3 ha). Interestingly enough, the (previous) forest census completed in 1979 covered only state forests and national parks and did not include private forests at all (new inventory completed in 2007, finally included private forests also). Although (at list in theory) private forests in Serbia should be managed by the private landowners according to the general plan and forest management program (i.e., financed, prepared, developed, and delivered to the private forest owners by the *municipal forest enterprise* every 10 years), since municipal forest enterprises do not financially assist the management program of private forest owners, actually only less than 10% of all private forests have any sort of management programs. Hence, no surprise that private forests suffer not only from extremely high degree of fragmentation but also from very inefficient management. Also, although no official statistics on illegal logging exist, it is clear that timber theft is greatest in private forests. The estimated value of illegally harvested wood from private forests was US$ 2.4 million (in 2003). According to UN Economic Commission for Europe (UNECE), illegal logging on public lands is 1–5% of the total harvest, while illegal practices in private forests are greater than 50% in Serbia [82].

As Verstraete and Pinty [83] point out, the use of spectral indexes is most recommended: (1) when the desired information is required as soon as possible (like in the case of forceful illegal logging in Kusumlija) or (2) when the conclusions of the study do not depend critically on the accuracy of the information (e.g., detection of significant changes—quick deforestation in Kursumlija).

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With recent progress in aerial photography, satellite imagery, and remote sensing, the possibilities of rapid analysis increase [84], which are the essential prerequisite for combating illegal logging. Also, 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.

Also, remote sensing can be extremely useful, because illegal logging in Serbia is by far most intense exactly in the Serbian municipalities adjacent to the territories of Kosovo, in the extremely sensitive Serbia-Kosovo border area (formally under Serbian forest estates Vranje, Kursumlija, Leskovac, Raska, and Leposavic) to which Serbian authorities have limited access … and where (according to Public Enterprise for Forest Management "Srbijašume"), well-organized groups of Albanians from Kosovo, organize large illegal loggings. It is illegal logging organized by groups of individuals, with market-oriented behavior [35] as part of organized crime and closely tied to other criminal activities such as corruption, violence, and money laundering [34] that simply extended illegal logging from Kosovo (ranked as the one of the worst illegal logging offenders in the world with Indonesia [18]) across the Serbia-Kosovo administrative border, approximately 3–4 km into the Kursumlija's territory.

It is exactly 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. Obviously, remote sensing (RS) data can be very efficient tool for forest management in Serbia and help the forest managers to fight illegal logging, especially in these most extreme cases of galloping deforestation and illegal logging (like in Kursumlija), by providing an reliable, alternative data source to quantify forest cover and change (independent of official governmental data sources). As Chakravarty et al. point out, it is not possible to properly manage a forest ecosystem without first understanding it [22] or to prevent illegal logging without frequently updated, objective information about deforestation and forest degradation.

5. Conclusion

Despite certain shortcomings [31, 52, 73, 74], classification and area estimation of various land-cover types based on remote sensing have 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 until 2011, 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 results for the municipalities of Kursumlija and Topola, it is evident that NDVI, especially in southern Serbian municipalities with prevalent illegal logging (like Kursumlija), 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 easily implemented, and it has objectivity that can greatly help avoid corruption and illegal logging in forest management.

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Author details

Miomir M. Jovanović* and Miško M. Milanović

*Address all correspondence to: miomir.m.jovanovic@gmail.com

Faculty of Geography, University of Belgrade, Belgrade, Serbia

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