IDENTIFYING AND UNDERSTANDING THE PATTERNS AND PROCESSES OF FOREST COVER CHANGE IN ALBANIA AND KOSOVO

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Abstract

Forests are important resources for local livelihoods and the economy. Forests regulate climate by sequestrating and storing carbon and harbor significant biodiversity. Yet, forest cover can be significantly affected by changes in institutional and political framework conditions such as induced by the collapse of socialism in Eastern Europe and the war in Kosovo. This study analyzes the patterns of changes in forest cover for a period from 1988 to 2000 and from 2000 and 2007 for Albania and Kosovo. The methodological approach applied geographically weighted regression using remote sensing forest data. Three models were developed and fitted using these forest data: one based on the environmental factors and two models associated with demographic and policy variables. The decomposition of local variation of the relationships of the forest cover change and variables was undertaken to built-up a hierarchy of determinants. Policy model included protected areas, commune forests, accessible determinants and obtained the lowest Corrected Akaike Information values, and accessible variables were the determinants explaining the patterns of forest cover changes in the study area. It is demonstrated how the results of the descriptive statistics and models can be incorporated to investigate the changes of forested landscape at country-level and village-level. Descriptive statistics demonstrated deforestation in protected areas and the modeling in the surroundings of protected areas. These results show clearly forest reforms, institutions and users contribute to the changes of forested landscape, indicating the importance of collaboration between institutions and users to monitoring of all activities in forests.

Keywords: Forest cover change, local variation, patterns, post-socialism, processes

Introduction

Timber harvesting activities such as logging, forest overuse and mismanagement may lead to forest habitat fragmentation (Lindenmayer & Fischer, 2006), which is one of the key drivers of global species loss (Fischer & Lindenmayer, 2007). The development of infrastructure e.g., roads, human settlements can encourage habitat loss and degradation (Lambin & Geist, 2006). A lack of enforcement (of law) and weak institutions contribute also to the loss of forest cover (Arun Agrawal, Chhatre, & Hardin, 2008; Taff, Müller, Kuemmerle, Ozdeneral, & Walsh, 2010).

Deforestation and forest degradation contribute up to 20% of global greenhouse gas emissions (IPCC, 2007) and are among the prime causes of global biodiversity decline due to habitat loss (Gaston, 2005; Loiselle, Graham, Goerck, & Ribeiro, 2010; Pimm & Raven, 2000; Sala et al., 2000). These consequences of forest cover change have manifold implications for ecosystem functioning and human well-being (Hooper et al., 2005; MA, 2005). Hence, understanding the patterns and processes of forest cover change may help us better comprehend the acquisition of natural resources by humans, as well as their consequences on forest-based ecosystem services.

Yet, forest cover is also expanding in many areas around the globe. Forest increases are attributed to a variety of pathways that are reactions to changes in the exogenous boundary conditions such as industrial development or state policy measures, or are caused by endogenous reactions of land users to changing forest product scarcities (Lambin & Meyfroidt, 2010; Rudel et al., 2005).

The regions of Eastern Europe and the former Soviet Union harbor significant forest resources, however, they experienced considerable illegal logging, and significant natural expansion of forests on formerly used agricultural lands (Kuemmerle, J. Kozak, V.C Radeloff, & Hostert, 2009; Müller & Munroe, 2008). However, estimations shows that political regime changes could also offer opportunities for biodiversity conservation (Radeloff et al., 2013). Therefore, it is interesting to see the forest cover changes from this perspective in the studied area.

An increase in forest cover may positively affect forest-based ecosystem services by, e.g., sequestering carbon from the atmosphere, decreasing surface runoff, and altering landscape habitats. However, the particular effects are place-specific and better knowledge of the patterns of forest increase may provide valuable inputs for the analysis of forest cover changes because these changes could be difficult to analyze with linear models. For example, the analysis of landscape change in Latvia emphasized the 'non-linearity of changes' observed after the collapse of socialism (Vanwambeke, Meyfroidt, & Nikodemus, 2012).

In this study, the GWR technique is used to explore the spatial heterogeneity using fine resolution data of forest and two distinctive datasets. The datasets were largely composed of disaggregated determinants for Albania and Kosovo. For the first time, the spatial heterogeneity of the relationships between the forest cover change and determinants are studied in two different periods from 1988 to 2000 and from 2000 to 2007 for two countries of the Southeastern Europe, filling gaps of literature on the land use change in post-socialist and post-war countries. The research questions were firstly to identify determinants that explain the strong patterns of forest cover change examining the extent to which policy factors and environmental factors explain these changes by selecting the best model using the concept of inference statistics of the parsimonious model (Burnham & Anderson, 2002; Johnson & Omland, 2004b), and secondly, exploring local variation of relationships between determinants and forest cover change, and building a hierarchy amongst determinants calculating the decomposition of the local variation of forest cover change and determinant relationship (Kamar, Partridge, & Olfert, 2007; Kmeta, 1986) using the GWR (Stewart A. Fotheringham, Brundson, & Charlton, 1998). Deductively, I assumed that minimum distance to human settlements (villages, towns) have a negative, ambiguous sign with forest cover change, and I focused my interpretation and discussion around the selected determinant and model. The analysis of generalized least squares (GLS) identified most significant determinants that had the largest value of variance of the relationships, demonstrating information about the spatial heterogeneity of relationships of forest cover change and determinants. Finally, this study provides a clear and new workflow of a GWR application focusing not simply to identify patterns of forest cover change, but also to identify determinants that explain the strong patterns of the changes of forest cover.

Methods

Study area

The study area has a total area of 39,284.9 km^2 and consists of the countries Albania and Kosovo. The two countries in the study area have been under socialist regimes from the end of the Second World War until the early 1990s. Kosovo was originally part of Yugoslavia, which split into seven countries due to conflicts and political disputes.

This resulted in Kosovo being created in 2008. In 2007, the area consisted of

Albanian forests and woodland (approximately 27 percent) and Kosovan's (40.3 percent), (Suess, 2010), (Fig. 1).

Forests and pasturelands were 100 percent state-owned in socialism in Albania. In 2005, the forests consisted of public-owned forests (98 percent) and private-owned forests (2 percent), (FAO, 2010). The change of forest ownership from the state to private and from the central government to local government started after the collapse of the socialism in 1990s in Albania. In socialism, forests were public-owned forests and private-owned forests in Kosovo. In 2003, forests consisted of public forests of 41 percent, private forests of 33 percent and unknown-ownership of 26 percent based on Kosovo Forest Inventory 2003 (MAFRD, 2007; SOK, 2008). The network of protected area consisted of 10 percent of Albania in 2006, and 8.3 percent of Kosovo in 2008. The multiple uses of oak and beech forests, and the deforestation caused by clearing land for agriculture, have caused their massive degradation, the reduction of biodiversity and severe soil erosion (FAO & Dida, 2003; Meta, 1993). The conflict in Kosovo led to high migration of population to neighboring countries such as Albania, The Former Yugoslavia Republic of Macedonia, Montenegro and Serbia (ICBL, 2000a, 2000b), to the reduction of agriculture production (Ogden, 2000) and unexploited objects and mines. The process of clearing mines started immediately after the end of the conflict of Kosovo, lasting for several years.

Forest cover data

Forest data of resolution 28.5 m derived from Landsat TM and ETM+ satellite images for ~1988, 2000 and 2007 were processed in the Geomatics Lab at the Humboldt University of Berlin with an overall accuracy of 93% and a kappa indices agreement of 0.85, and were provided by Stefan Suess (2010). The forest class consisted of forest patches greater than 7 pixels of Landsat. This class was composed of deciduous forests, coniferous forests and shrubs (with a height of greater than 3 m) and covering above the 50 percent of a Landsat pixel. The non-forest class consisted of all non-forest land cover (urban land, agriculture land, pastureland, waters), (Table 1). The sources of images were Eurimage and the Global Land Cover Facility (GLCF) of the University of Maryland. The GLCF provided large blocks of orthorectied and geodetically accurate global land data sets of the National Aeronautics and Space Administration (NASA). These data had a geodetic inaccuracy less than 15 m, (Suess, 2010). A ground truth data were collected by Suess (2010) in August and September 2008 in the study area for training and validation purpose measuring approximately 600 control points using the Global Positioning System (GPS) and photographing these spots. To validate the results of satellite images, Suess (2010) used the Quickbird images of resolution of less than 3 m, and the Google Earth. Topographic maps of the scale of 1:50 000 of the University of California were partly geo-referenced for the land cover of Albania in 1980s (Suess, 2010). He used the approach of Support Vector Machine (SVM) chain classification approach (J. Knorn et al., 2009) for the satellite images of 1988, 2000 and 2007. The SVMs represent a group of non-parametric algorithms (Huang, Davis, & Townshend, 2002), and is considered as one of the most recent developments in the field of machine learning (Janz, Linden, Waske, & Hostert, 2007). All images and vector layers were projected to UTM Zone 34 N, datum WGS84.

The masks of the analysis were the country boundary of Albania and Kosovo. This allowed the data within the country boundary to be processed. The forest and non-forest pixels were reclassified as '1' and '0', respectively. The pixels (forests, non-forests) were intersected with the village boundaries to count the number of forest pixels for each village. The number of forest pixels was multiplied by the pixel resolution (28.5m) and divided by 10,000 to give the forest cover in hectares for 1988, 2000 and 2007. The forest cover 1988 was subtracted from the forest cover 2000 presenting the forest cover change from 1988 to

2000 (in hectares). The forest cover 2000 was subtracted from the forest cover 2007 presenting the forest cover change from 2000 to 2007 (in hectares), (Fig. 2). The forest cover change had negative and positive values. The negative values of the forest cover change presented a change of land cover from forests to non-forests, a forest decrease, (designated as "deforestation" process of the forest cover change) and the positive values of the forest cover change presented a change of land cover from non-forests to forests, a forest increase, (designated as "forestation" process of the forest cover change in this study). Forestation consisted of afforestation, reforestation and the natural expansion of forests (FAO, 2000) in this study.

Biophysical, demographic and policy data

Elevation for the study area was derived from a Digital Elevation Model (DEM) of 25 m resolution for Albania and 50 m resolution for Kosovo. The data of elevation, the boundaries of Albania and Kosovo, ecological regions (Pindus Mountain Forests, Balkan Mixed Forests, Dinaric Mountains Mixed Forests and Illyrian Forests), road networks (main roads, major roads, seasonal roads, highway, first roads and secondary roads), human settlements (towns, villages and sub-urban areas), population data (1989, 2001, population estimation 1991, and projected population 2004), protected areas (strictly protected areas, national parks, natural monuments, nature resource management, landscape protection, managed resource protected area) were provided by provided by the Environmental Legislation and Planning Albania, Kosovo Ministry of Agriculture, Forestry and Rural Development, the Institute for Nature Conservation Albania, Kosovo Agency for Environmental Protection, Kosovo Statistical Office (publications). Soil data (Eutric Regosol, Calcaric Regodol, Cambic Arenosol, Eutric Cambisol, Regosol, Cambisol, Dystric Planosol, Luvisol and Ranker) were provided by the European Soil Database. The vector layer of village and commune were transformed into a layer of geographic locations of villages (X, Y) and a layer of geographic locations of communes (X, Y), respectively, by calculating the coordinates of a point that was located at the center of gravity (centroid) of villages and communes in ArcGIS.

Albania commune forests presented a new forest reform after the collapse of socialism aiming at the regeneration of degraded forests governed by the central government in the socialism (state forests). This post-socialist reform allows now the administration of forests by communes (local government) and the use of forests by villagers. In this study, I considered 364 villages consisting of villages of 1996 (14), 1997 (4), 1998 (18), 1999 (185) and 2000 (143).

The unexploded ordnance and mines (UXOM) consisted of the depleted uranium bombs and mines remained of Kosovo conflict of 1998-1999. The coordinates of approximate bombed areas and mines (point data) were geo-referenced using (UNEP, 2001), and the reports on mine clearance in cross-border Albania-Kosovo and Kosovo-Macedonia (ICBL, 2000a, 2000b), respectively.

All data used in the forest cover change modeling were aggregated to village boundaries using Zonal statistics in ArcGIS (with the aggregated pixel taking the mean value lower resolution pixels), resulting in total of 52 layers consisting of 29 layers for Albania and 23 layers for Kosovo. The total number of villages was 4,352 consisting of Albania (3,054) and Kosovo (1,298). All data were projected to UTM Zone 34 N, datum WGS84 and prepared in ArcGIS using Arcmap 9.3, (ESRI, 2009), (Appendix, Table S1, Table S2).

Descriptive statistics

The raster layers depicting elevation, slope, Euclidean distance to human settlements, Euclidean distance to roads, Euclidean distance town and commune center, Euclidean distance to major roads, Euclidean distance to protected areas, Euclidean distance to asphalted roads were transformed into a set of new layers by applying a "reclassification" operation in ArcGIS. This involved recalculating the value of a given focal cell into five quintiles (0 percent, 25 percent, 50 percent, 75 percent, 100 percent). The input raster layer of forest cover change from 1988 to 2000 (and forest cover change from 2000 to 2007) overlaid to new layers of these explanatory variables (elevation, slope, Euclidean distance to human settlements, Euclidean distance to roads, Euclidean distance town and commune center, Euclidean distance to major roads, Euclidean distance to protected areas, Euclidean distance to asphalted roads) to calculate the percent of forest cover change in five quintiles using "cell statistics" in ArcGIS. This involved recalculating the value of a given cell based on the mean value of forest cover in five quintiles (ESRI, 2009). This allowed the number of forest pixels (in a quintile) to be multiplied by the resolution of forest pixels of 28.5m and divided by the total number of forest pixels.

The vector layers depicting soil type, protected areas, and ecological zones were intersected with forest raster layers using "Zonal histogram" operation in ArcGIS. This involved forest cells intersected soil vector data generating a histogram, which was an output table consisting of a number of forest pixels for each soil type. This operation (Zonal histogram) was applied to calculate the percentage of deforestation and forestation to years of establishment of commune administration.

Models and determinants

The forest cover change models were based on information-theoretic methods, which focused on the search for a parsimonious model as the primary philosophy of statistical inference (Burnham & Anderson, 2002; Johnson & Omland, 2004a). First, I set a priori hypotheses on forest distribution that describe natural conditions required for forests to grow based on the literature of land use and forests in Albania. For example, elevation and soil type are expected to be positively correlated to the forest cover, the forests is denser in the elevated topography (Deininger & Minten, 2002; Müller & Zeller, 2002). For example beech forests grows naturally in certain soils and in elevated landscape than oak forests in Albania (Agrotec.SpA.Consortium, 2004). Hence, the variables capturing soil types are expected to be statistically significant for forest cover (changes) in some regions. But the direction of influence is a priori, because the forest cover change data does not contain information on the composition of forest species that may have allowed anticipating the effect of soil types. The geographic location of villages, measured as the centroid coordinates of a village (X, Y), serve as proxies for climatic conditions in this study. Albania has a Mediterranean climate in the west and south and a more continental climate in the east and northeast. Therefore, villages further north and villages further east tend to have a cooler (lower temperature) and a more humid climate (more rainfall) than villages further in the south and the west. For instance hotter and drier climate will result in increased risk of forest fires that negatively affect forest (cover), the forest ecosystem productivity and lead to biodiversity loss (of village forests), (IPCC, 2001; Thuiller, Lavorel, Araujo, Sykes, & Prentice, 2005).

Ecological zones are useful information to understand the changes of forests based on the natural characteristics of forests (vegetation), because ecological zone provide insights on the changes of forest resources at large-scale (region), (FAO, 2000). Forests in Albania and Kosovo are respectively subtropical dry forests rich of evergreen oak species and temperate continental forests (ecological zones) having different deciduous broadleaved forests e.g., oak, mixed oak-hornbeam and mixed lime-oak tree specie, (FAO, 2000). Therefore, more broadleaved forests are expected to grow naturally in Albania and Kosovo.

The vicinity of forests to markets, the presence of roads are all used as determinants that have an impact on deforestation (Deininger & Minten, 2002; Mertens, Forni, & Lambin, 2001; Nelson & Hellerstein, 1997). Euclidean distance to road and markets serve as a proxy for prices and transaction costs (Deininger & Minten, 2002) and access to political centers (Müller, 2003). Higher lagged population is often cited as a major factor influencing deforestation (Deininger & Minten, 2002). Forests in protected areas are better-protected from the deforestation, which means that less deforestation occurs in protected areas forests (Deininger & Minten, 2002; Geist & Lambin, 2002).

Literature tends to focus more on the selection of determinants of deforestation than to explain the causes of forest cover change. In case of forest cover change, the focus is on the selection of determinants that explain both deforestation and forestation as the processes of the changes of forest cover. Therefore, I set hypotheses of deforestation and forestation for Albania and Kosovo as follows: deforestation is caused by logging activities including illegal logging (WB, 2004, 2007), legal logging for industrial wood, firewood for heating, the grazing of forests (WB, 2011) charcoal production and open-up lands for pasture (own observations in the study area) and industrial wood. The long-term forest resources assessment database of European Forest Institute (EFI) shows the removals of forests were for firewood and industrial wood in socialism in Albania and the Former Yugoslavia (EFI, 2009) and still forests are removed for firewood and industrial wood in post-socialist Albania (FAO, 2010). The number of forest fires increased from 342 in 1996 to 1182 in 2007 in Albania (FAO, 2010). Forest fires are usually set by local people mainly for pasture improvement that could cause forestland clearing (own observations).

Both Albania and Kosovo have experienced high outmigration from rural to urban areas and abroad (Calogero, Benjamin, Stampini, & Zezza, 2006; UNDPKosovo, 2004), which could mean less pressure to forests and allow forests to grow. The post-socialism reform of agriculture in 1992 was associated with the refuse of marginalized and non-high quality agriculture land in Albania (WB, 2002). The decline of agriculture cultivation may potentially lead to the natural expansion of forests in Albania and therefore to the increase of forest cover (Müller & Munroe, 2008; Taff et al., 2010). The new reform of commune forests started in 1994 (WB, 2011). It was expected local people let forests regenerate (Arun Agrawal & Chhatre, 2006; WB, 2004, 2011). Some villages planted trees (afforestation) to protect soil from the erosion (WB, 2011). The natural regeneration of forests and afforestation in communal forests could lead to the increase of forest cover. The forests near Unexploited Objects and Mines (UXOM) sites are expected to be abandoned because they could still be dangerous to be utilized (Machlis & Hanson, 2008). The author observed land abandonment in previous mined areas of the conflict 1998-1999 in Kosovo in border with Albania (own observations).

It is also known that forests are accessed by institutions users (villagers, companies, illegal users) using the network of roads, markets, institutions and homes. The Euclidean distance to human settlements, Euclidean distance to roads, Euclidian distance to commune and city centers, Euclidean distance to forest edge were thought to be a surrogate for 'accessibility of the forests' by villages, town, communes, markets, and institutions affecting the forest cover either by increasing it (this is a case of well-managed by institutions and well-used forests by users) or by decreasing it (this is the case of mismanagement by institutions and overuse of forests by users). The remote forests (forests away from roads, markets and commune centers) and old-grown forests are likely more distributed in elevated topography and accessed because of their high quality of timber.

I split the variables for forest cover change modeling into three categories, which are labeled 'biophysical', 'demographic' and 'policy', where biophysical variables were thought to be a surrogate for forest natural growth and demographic and policy were thought to affect the forest cover changes. Demographic and policy factors were divided into category of 'demographic' and 'policy' to further understand factors that explained the observed changes of forest cover. The biophysical model consisted of layers of elevation, soil type, ecological zones, village locations, demographic model consisted of populations and model of policy determinants consisted of policy variables: roads, human settlements and mined and contaminated sites from Kosovo war and institutional: the new established post-socialist administration for communal forests and for the management of forests in protected areas and for the protection of environment and biodiversity in protected areas and environmental protection in forests. The setting-up of new post-socialist institutions (of communal forests and protected areas) is interlinked to the changes of political regime. Years of establishment of communal forest administration is an institutional variable, which also implies a political decision to give forests from central to local government and local people to manage and use forests, respectively. Protected areas entails the institution that are established to plan, design, establish and manage existing and new protected areas and it also implies the political decision for planning, management and the expansion of protected areas. The policy and institutional variables is designated as 'policy' model in this paper.

Tests for variables were conducted to remove those that were highly correlated (Pearson correlation test >0.7).

Forest cover change model were created using Geographically Weighted Regression (GWR) technique (Stewart A. Fotheringham et al., 1998) to identify and understand the patterns of the relationships of forest cover change and explanatory variables, and how these relationships varied across space (e.g., spatial heterogeneity between environment and vegetation (Kupfer & Farris, 2007), socioeconomic and vegetation (Ogneva-Himmelberger, Pearsall, & Rakshit, 2009), access to infrastructure and forests (Deininger & Minten, 2002). The forest cover change from 1988 to 2000 and forest cover change from 2000 to 2007 were the dependent variables, and the independent variables were made up of combinations of either biophysical, demographic or policy variables. An adaptive kernel (Gaussian function) was used because of non-uniformly dispersed data selecting 30 neighbors (villages), (S. A. Fotheringham, Brunsdon, & Charlton, 2002), after many tries of GWR using different number of neighbors (30, 60, 90, 150 and 350). Model selection was undertaken using the Corrected Akaike's Information (AICc) (Burnham & Anderson, 2002; Kupfer & Farris, 2007) and Moran' I of residuals, local R^2, standardized residuals, the significance of local coefficients using Monte Carlo test (Moran, 1948) and the variance of local coefficients using a cut-off of 0.50 as Kamar et al. (2007). A variance of local coefficient was considerable above 0.50, high at 0.60, considerably high at more than 0.70, and non- considerable under 0.50. Generalized least squares (GLS) is used to calculate the spatial relationships of observations and examine the variance structure function of relationships between determinants and forest cover change, (Zuur, Ieno, Walker, Anatoly A., & Smith, 2009). All GWR models were fitted using R (version 2.9.0) (RDCT, 2009).

Results

The patterns of forest cover changes

Albania shows more absolute changes of forest cover from the first to the second period compared to Kosovo. Deforestation dominates in the first period and forestation in the second period in both countries. Forest distribution of observed disturbed forests (forest increase and forest decrease) in the study area is shown in the Fig. 1. The patterns of forest cover change altered from north to south and from east to west of the study area. The forests have massively been reduced in the first period (1988-2000). The forests have increased mostly in southern and north-central area of Albania and southwest of Kosovo in the second period (2000-2007). Over the same period, forests have been decreased in the northern and western Albania and in northern and central Kosovo, (Fig. 2).

Descriptive statistics of forest cover change

This analysis enabled us to distinguish differences and similarities of the forest cover changes in Albania and Kosovo from 1988 to 2007. Firstly, the forest covers have changed from the first period (1988-2000) to the second period (2000-2007) in the study area. Secondly, the patterns of forest cover change in Kosovo differed from Albania. For example, deforestation is stronger and more spread in higher elevations, steep slopes, and long-distance accessibility areas or in remote forested lands (away from roads and/or human settlements and commune and town centers). Forestation is higher in low elevations, gentle slope areas, and close to roads, markets and human settlements in Albania, (Fig. 3a). In Kosovo, deforestation is encountered in high elevations, steep slopes, and far from roads, protected areas, communes, UXOM sites and in remote areas. Deforestation is encountered in the first quintiles of the nearest distance to protected areas, commune centers, and human settlements from 1988-2000. Forestation occurs in low elevations, gentle slopes, is accessible from roads, close to protected areas, and close to populated areas and commune centers, (Fig. 3b).

Models for forest cover change

The policy models of forest cover change were the one with the lowest AICc values for Albania and Kosovo, the lowest values of Moran' I of residuals, (Table 2), statistically significant values of Monte Carlo test of GWR coefficients, and considerable high values of the variance of GWR coefficient (>50 percent), (Table 3), and low values of standard errors of GWR coefficients (0.0; 0.03), (Fig. 5, Fig. S1). The values of model-fit local R^2 of these policy models ranged up to 0.72 in the first period and 0.80 for the second period, (Fig. 4) indicating the presence of the high local variation of the relationships between policy variables and the forest cover change in the study area in both periods. Top-hierarchy determinant of Euclidean distance to human settlements explained the strong patterns of forest cover change. The patterns of Euclidean distance to human settlement (in average per village) were positively correlated with forest increase in Albania in the second period. In Kosovo, the negative patterns (negative values of the GWR coefficients of Euclidean distance to human settlement) were correlated with forest decrease and positive patterns (positive values of the GWR coefficients of Euclidean distance to human settlement) with forest increase (in the same period). The distinct patterns of the estimated GWR coefficients of the Euclidean distance to human settlements and forest cover change relationships were concentrated in northern, southern and western Albania, and in northern and southern Kosovo (Fig. 5). Forest increased closer to human settlements and tended to decline more in remote areas in Albania and Kosovo. Despite forest increase nearer human settlements, the pressure for wood collection concentrated towards stable forests in remote areas (forests were more abundant, well-grown and old-grown) from the first period to the second period.

Discussion

This study showed a workflow starting with the descriptive analysis of the forest cover change, applying the GWR combined with the decomposition of local variation and the information theoretic using two unique datasets to explain the patterns and processes of the changes of forest cover. This study examined forest cover change in two post-socialist countries of Southeastern Europe for two periods of 1988-2000 and 2000-2007. It was the first country-wide study for Albania and Kosovo that investigated the influence and the spatial variation of the determinants of forest cover change at the village level by applying GWR. The statistical modeling allowed both to draw comparisons across the two countries and over time. The results demonstrated the substantial differences in the patterns of determinants of forest cover change for distinct areas in both countries. Three models of biophysical, policy and demographic determinants, respectively, were estimated and the most parsimonious model was selected for the interpretation of the results. The variable selection in all models was based on the academic work on land use change, forests in Albania and data availability to conduct this research. The decision criterion for the most parsimonious model was the Corrected Akaike's Information Criterion. GWR was used to estimate patterns and processes and therefore to reveal the information at the local level for the relationships of forest cover change and determinants. GWR allowed the calculation of the decomposition of local variation of the relationships, which defined the importance of the influence of GWR coefficients of determinants obtained by GWR to the response variable. GLS further allowed calculating the spatial relationships of observations and hence to investigate the variance structure function of relationships between determinants and forest cover change (Table S3). The calculation of the variance of local coefficients and of the spatial relationship of observations was apparently two steps frequently neglected in GWR studies.

The determinants of forest cover change in Albania and Kosovo

This study demonstrated interesting results on the determinants of forest cover change, namely Euclidean distance to human settlements, Euclidean distance to war-sites, protected areas, commune forests and climate. Firstly, one of these results was the decrease of forest cover inside of protected areas and their surroundings, indicating these forested areas were utilized for their resources. This also indicated responsible institutions of forestry, environmental protection and nature conservation institutions for the management and protection of forests were unable to survey, monitor and control any forest activities inside of protected areas and their surrounding areas. Protected area could ensure better forest protection, but they cannot guarantee a full protection and halt entirely the deforestation within these areas (Deininger & Minten, 2002). In case of Romania, the high logging rates were likely trigged by rapid changes in institutions and ownership resulting in the reduction of the forest cover, and causing an increasing fragmentation of forest cover in protected areas (Jan Knorn et al., 2012). Secondly, forests close to war-site spots have not been used by people in the first period of 1988-2000, indicating these forests were not safe. These forests were utilized by people in the second period indicating these forests were harmless. Thirdly, the policy variable of Euclidean distance human settlements had clear effects to forest cover changes. It was estimated deforestation was more spread in Albania compared to Kosovo (occurred in more quintiles of Euclidean distance human settlements). This shows that forests accessed by human settlements tended to be used more in Albania compared to Kosovo. The observations of forest cover derived from the satellite images and the descriptive analysis of forest cover change demonstrated clearly forests have been reduced in the first period (particularly Albania), indicating firewood collection and logging have been intensive near roads and human settlements. Over the same period, the institutions entailed for forest management and environmental protection were unable to halt the spread of forest cutting activities. During the second period, forest loss was encountered in the highest quintiles of the Euclidean distance to human settlement telling us that forests grown in elevated topography and away from the populated areas were under pressure for firewood and industrial wood. Euclidean distance to human settlements was very much associated with deforestation at high quintiles in Kosovo, indicating the collection of woods for heating of houses was still important for rural areas. Fourthly, the descriptive analysis showed a slight increase of forest cover change in 364 communal forests. Forest cover increased from the first period (-3,013 ha) to the second period (5,350 ha), demonstrating commune forests increased unevenly in communes, (Table 5). However, deforestation was present in commune forests indicating these forests were unsustainably used in these communes jeopardizing the forest reform. Fifthly, the location of village and therefore the condition of climate had clear effects to the forest cover changes in Albania and Kosovo, demonstrating influence varied over space on forests, (Table 6).

The drivers of forest cover change in Albania and Kosovo

This study demonstrated clearly that forests differed spatially and temporarily in the study area because of the extraction of woods and regeneration of forests. The principal finding of the current study was the accessibility of well-grown and old-grown forests likely spurred a larger extraction of wood for firewood and export, the production of charcoal and the grazing of livestock including pasture open-up areas and war in Kosovo. It is highlighted that forest clearing in Albania was mainly driven by the subsistence necessities around populated areas in the years after the collapse of socialism, while more commercial clearing patterns dominated in later stages of the post-socialist period, indicated by the changing influences of the determinants of accessibility cf. (Müller & Munroe, 2008). Also, forest cover decreases and increases were higher at medium and high elevation terciles while closed forests persisted at higher altitudes cf. (Müller & Sikor, 2006; Taff et al., 2010). For example, forests tended to decrease in remote areas, in protected areas and commune forests due to these drivers in the second period, indicating institutions were unable to control logging and land-use activities (pasture) contributing to the loss of forest cover in northern Albania and in northern and southern Kosovo.

Conclusion

This study demonstrated that the change of regime in two countries was associated with massive changes of forest cover after the collapse of socialism in Albania and war in Kosovo. It was estimated that most of pressure would be on stable remote and protected forests in distinct local patterns of forests, indicating that present day management and use of forests had strong implications on the protection and conservation of forests.

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Support information

Appendix Table S1 Dataset of Albania at village level
Appendix Table S2 Dataset of Kosovo at village level
Appendix Table S3 The summary of GLS results and model selection estimators
Appendix Fig S1 Standard errors of coefficients of the Euclidean distance to human settlements of the policy model 1988-2000

Appendix Table S1 Dataset of Albania at village level

Variables	Unit	MEAN	STD	MIN	MAX
Forest cover change 1988-2000	hectare	-5.6	69.38	-901.11	467.78
Forest cover change 2000-2007	hectare	18.12	56.1	-562.48	397.35
Pindus Mountain Forests	percentage	41.38	48.56	0.00	100.00
Cambisols	percentage	26.19	40.78	0.00	100.00
Regosols	percentage	28.90	43.01	0.00	100.00
Protected areas	percentage	3.44	15.35	0.00	100.00
Population 2001	number of inhabitants	1137.9	3867.7	2.00	98792.00
Population 1989	number of inhabitants	1166	3492.4	15.00	82719.00
Eutric regosols	percentage	28.8	43.01	0.00	100.00
Calcaric regosols	percentage	0.09	1.88	0.00	80.29
Eutric cambisols	percentage	17.74	35.88	0.00	100.00
Cambic arenosols	percentage	0.99	8.62	0.00	100.00
Elevation mean	meters	520.2	432.05	0.74	2024.76
Balkan Mixed Forests	percentage	2.36	15.17	0.00	100.00
Dinaric Mountain Forests	percentage	3.44	18.22	0.00	100.00
Years of establishment of communal forest administration	percentage	11.91	32.4	0.00	100.00
Strict nature reserve	percentage	0.29	4.19	0.00	100.00
National parks	percentage	2	12.39	0.00	100.00
Natural monuments	percentage	0.18	3.2	0.00	99.65
Habitat/species management area	percentage	0.98	7.7	0.00	100.00
Protected landscape/seascape area	percentage	2.69	15.29	0.00	100.00
Managed resource protection area	percentage	0.54	5.94	0.00	100.00
Distance to nearest roads	meter	612.64	544.12	69.65	5214.46
Distance to nearest major roads	meter	1400.2	1326.9	92.14	9969.53
Distance to nearest asphalted road	meter	2371.4	2262.1	119.67	16357.20
Distance to nearest human settlements	meter	1070.8	539.52	318.12	5714.65
Distance to nearest city and commune centre	meter	3442.3	1494.8	369.52	10995.20
Distance to nearest forest edge 1988	meter	220.79	254.6	3.37	3602.54
Distance to nearest forest edge 2000	meter	185.76	201.95	3.80	2074.16

Appendix Table S2 Dataset of Kosovo at village level

Variables	Unit	Mean	STD	Min	Max
Forest cover change 1988-2000	hectare	-0.42	36.03	-358.77	218.41
Forest cover change 2000-2007	hectare	9.12	32.51	-176.91	323.27
Population estimation 1991	number of inhabitants	1471.26	6400.38	0.00	155499.00
Population projection 2004	number of inhabitants	1621.41	7489.05	0.00	188776.00
Luvisols	percentage	3.17	15.93	0.00	100.00
Rankers	percentage	8.01	25.62	0.00	100.00
Cambisols	percentage	54.43	46.30	0.00	100.00
Dystric Planosols	percentage	1.81	12.06	0.00	100.00
Elevation mean	meters	703.49	276.04	308.09	2234.79
Pindus Mountain Forests	percentage	1.60	11.82	0.00	100.00
Balkan Mixed Forests	percentage	97.28	14.31	0.00	100.00
Dinaric Mountain Forests	percentage	1.11	8.14	0.00	100.00
National parks	percentage	1.12	7.86	0.00	99.00
Proposed national parks	percentage	2.29	13.53	0.00	100.00
Protected landscape/seascape area	percentage	0.02	0.50	0.00	13.00
Distance to nearest roads	meter	556.05	496.79	54.73	7461.87
Distance to nearest major roads	meter	2899.8	2448.95	90.44	16833.2
Distance to nearest highway	meter	5013.71	4242.58	223.1	30095.8
Distance to nearest UXOM	meter	7942.44	6811.32	183.81	45737.3

Distance to nearest city and commune centre	meter	7636.47	3375.58	742.08	21782
Distance to nearest human settlements	meter	1011.4	444.8	271.36	5146.68
Distance to nearest forest edge 1988	meter	141.22	181.25	2.163	1927.26
Distance to nearest forest edge 2000	meter	114.24	122.72	2.46	1138.42

Appendix Table S3 The summary of GLS results and model selection estimators:
Corrected Akaike's Information Criterion (AICc), variance structure, likelihood ratio, df, p-value. Levels of significance for p-value is 1 percent, 5 percent and 10 percent

Model, Albania 1988-2000	GWR AICc	GLS AIC	Weights	Likelihood ratio	df	p-value	Determinant significance at p-value <.0001
Biophysical	33320	33109	Elevation constant power structure variance	91.70	2	<.0001	Elevation, Pindus Mountain Forests, Cambisols
Demographic	33926	34498	Population exponential structure variance		1		
Political-institutional	33176	32574	Euclidean distance to forest edge 1988 power structure variance	1970.84	1	<.0001	Distance to nearest: asphalted roads, roads, forest edge 1988
2000-2007							
Biophysical	31886	31926	Elevation constant power structure variance	79.00	2	<.0001	Elevation, Cambisols or Cambisols, Regsols
Demographic	32250	33200	Population exponential structure variance		1		
Political-institutional	31650	31774	Euclidean distance to human settlement power structure variance	1487.96	1	<.0001	Landscape protected areas and Managed resource protected areas; distance to nearest: roads, asphalted roads, human settlements, city and commune center, forest edge 2000, protected areas

Model, Kosovo 1988-2000	GWR AICc	GLS AIC	Weights	Likelihood ratio	df	p	Determinant significance at p <.0001
Biophysical	12474	12393	Elevation constant power structure variance	23.85	2	<.0001	Elevation, Pindus mountain forests, Dinaric mountain forests, Luvisosl
Demographic	12655	13003	Population exponential structure variance				

Political-institutional	12358	12397	Euclidean distance to human settlement power structure variance	208.80	1	<.0001	Euclidean distance to highway, Euclidean distance to nearest roads, distance to nearest protected areas
2000-2007							
Biophysical	12395	12641	Elevation fixed structure variance function				Elevation, Pindus mountain forests; Rankers
Demographic	12440	12700	Population exponential structure variance				
Political-institutional	12317	12523	Euclidean distance to human settlement power structure variance	70.75	1	<.0001	Euclidean distance to nearest city and commune center, distance to nearest protected areas

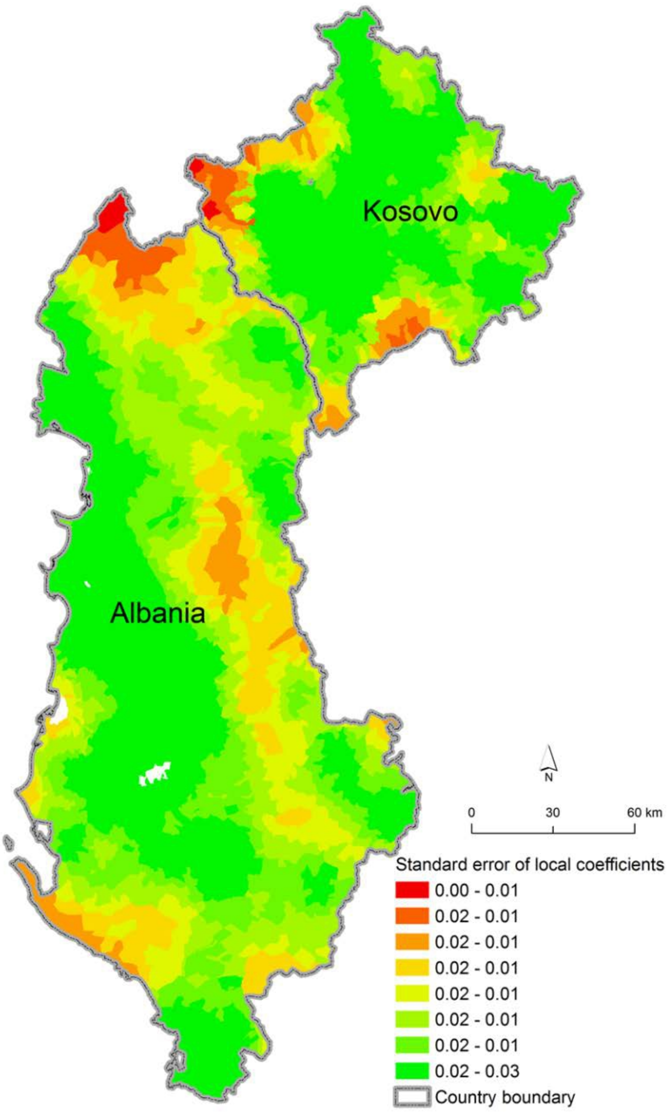

Figure S1

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Table 1 Description of land cover classes

Class name	Description
Forest	(Semi-) natural terrestrial vegetation (broadleaved evergreen forest, broadleaved deciduous forest, coniferous forest and mixed forest), cultivated terrestrial (broadleaved arboriculture, fruit trees, orchards, groves, nurseries, vineyards) and shrub forest
Non-forest	All others: built up areas, urban and industrial areas, artificial and natural perennial water bodies, aquatic vegetation, beaches, bare rocks/soils, sparse trees and shrubs; rock outcrops, (herbaceous) crops, vegetated urban areas, grassland

Source: (Suess, 2010)

Table 2 Percentage of forest cover change by protection status

Forest cover change	Protected landscape	Habitat management	Proposed national park	National park	Strict protected areas
Albania	-0.5	0.3	-	0.8	-0.7
Kosovo	0.03	-	-0.02	-0.02	0

Table note: Habitat management category of protected areas is only in Albania and proposed national park category is only in Kosovo.

Table 3 The summary of the best biophysical, demographic and policy GWR models for forest cover change and model selection estimator: Corrected Akaike Information (AICc), Moran'I of the residuals

Model 1988-2000	AICc	AICc	Moran's I of the residuals	
Albania	OLS	GWR	OLS	GWR
Biophysical	34298	33320	0.38	0.18
Biophysical including climate determinants	34285	33209	0.38	0.15
Demographic	34566	33926	0.44	0.26
Policy	34462	33176	0.48	0.14
Kosovo	OLS	GWR	OLS	GWR
Biophysical	12894	12474	0.39	0.06
Biophysical including climate determinants	12826	12456	0.31	0.03
Demographic	12991	12655	0.41	0.16
Policy	12908	12358	0.36	0.0004
Model 2000-2007	AICc	AICc	Moran's I of the residuals	
Albania	OLS	GWR	OLS	GWR
Biophysical	33121	31886	0.48	0.20
Biophysical including climate determinants	33046	31748	0.46	0.15
Demographic	33259	32250	0.50	0.26
Political-institutional	33178	31650	0.48	0.13
Kosovo	OLS	GWR	OLS	GWR
Biophysical	12694	12395	0.30	0.08
Biophysical including proxy climate determinants	12687	12370	0.29	0.046
Demographic	12720	12440	0.33	0.16
Policy	12722	12317	0.32	0.03

Table 4 The summary of the best biophysical, demographic and policy GWR models for forest cover change. For each model the variance of GWR coefficients is shown along with their statistically significance of Monte Carlo test

Model, Albania	Determinant	1988-2000		2000-2007	
		Variance of local coefficient	Monte Carlo test p-value	Variance of local coefficient	Monte Carlo test p-value
Biophysical					
	Elevation	0.69	0.0	0.66	< 0.01
	Pindus Mountain Forests	0.60	0.0	0.61	< 0.01
	Balkan Mixed Forests	0.49	0.0	0.45	< 0.01
	Cambisol soil type	0.56	0.0	0.56	< 0.01
	Regosol soil type	0.58	0.0	0.56	< 0.01
	Cambic Arenosols soil type	0.50	0.1	0.50	< 0.01
Demographic					
	Population 2001			0.47	0.06
	Population 1989	0.53	0.02		
Policy					
	Years of establishment of communal forest administration	0.53	0.0	0.52	0.0
	Strict Nature Reserve	0.47	0.6		
	National parks	0.50	0.0		
	Natural monuments	0.48	0.5	0.51	0.0
	Habitat or Species Management Area	0.50	0.0		
	Protected Landscape or Seascape	0.51	0.0	0.48	0.0
	Managed Resource Protected Area	0.50	0.0		
	Distance to nearest road			0.69	0.2
	Distance to nearest major road	0.67	0.0	0.68	0.0
	Distance to nearest asphalt road	0.67	0.0		
	Distance to nearest human settlement	0.79	0.0	0.83	0.0
	Distance to nearest city and commune center	0.86	0.9	0.80	0.9
	Distance to nearest forest edge in the beginning of the period	0.60	0.0	0.58	0.0
	Distance to nearest protected areas	0.74	0.0	0.74	0.0

Model, Kosovo	Determinant	1988-2000		2000-2007	
		Variance of GWR coefficient	Monte Carlo test p-value	Variance of GWR coefficient	Monte Carlo test p-value
Biophysical					
	Elevation	0.89	<0.01	0.87	<0.01
	Pindus Mountain Forests	0.49	<0.01	0.47	<0.01
	Dystric Planosol soil type	0.49	<0.01	0.44	0.06
	Luvisol soil type	0.51	0.04		
	Ranker soil type	0.48	<0.01	0.52	<0.01
	Dinaric Mountain Forests	0.50	<0.01		
Demographic					

	Population estimation 1991	0.51	0.99		
	Population projection 2004			0.40	0.92
Policy					
	Protected areas	0.49	0.01	0.51	<0.01
	Distance to nearest road	0.67	0.36	0.69	<0.01
	Distance to nearest highway	0.70	0.00	0.71	<0.01
	Distance to nearest human settlement	0.86	0.02	0.86	<0.01
	Distance to nearest protected areas	0.75	0.00	0.73	<0.01
	Distance to nearest UXOM	0.70	0.00	0.70	<0.01

Table note: Levels of significance for Monte Carlo test p-value: 1 percent; 5 percent; 10 percent; high local variation is above the cut-off value of 0.5 for variance of local coefficient. Variance of local coefficient (the decomposition of local variation of the relationship between forest cover change and determinant) is calculated to build-up a hierarchy of determinants. The Euclidean distance to human settlements have statistically significant values of Monte Carlo test and the highest value of the variance of local coefficients (in bold).

Table 5 Forest cover change by Albanian commune forests

Forest cover change in percent	Year 1996	Year 1997	Year 1998	Year 1999	Year 2000
1988-2000	3.57	-0.2	-2.11	4.37	-31.08
2000-2007	1.38	0.14	0.08	6.38	-0.06

Table 6 Sign of village location

Village location	Sign of village location, median, Albania	Sign of village location, median, Kosovo	Period
x	negative	negative	1988-2000
y	positive	positive	
x	positive	positive	2000-2007
y	positive	negative	

Figures

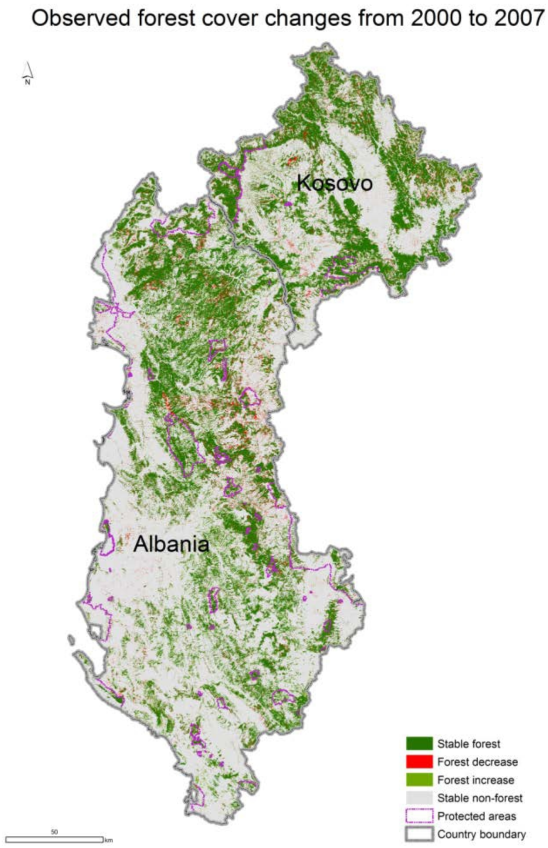
Fig. 1 Observed stable and disturbed forests in Albania and Kosovo from 2000-2007

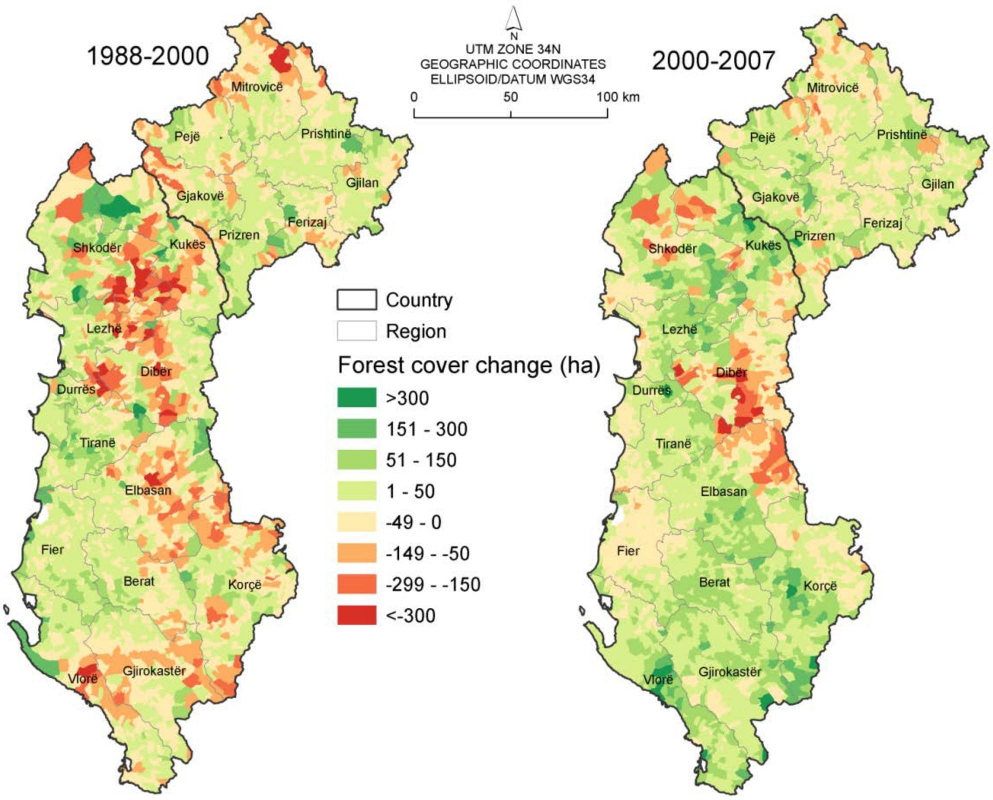
Fig. 2 Forest cover change a) in thousand hectares, b) at village level

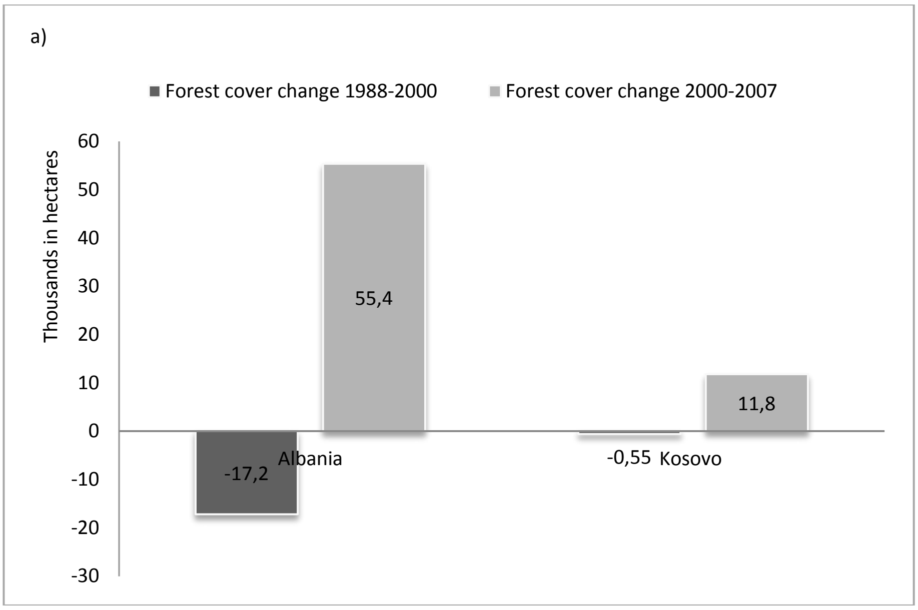
Fig 3 Forest cover change in percentage in determinants quintiles a) Albania, b) Kosovo

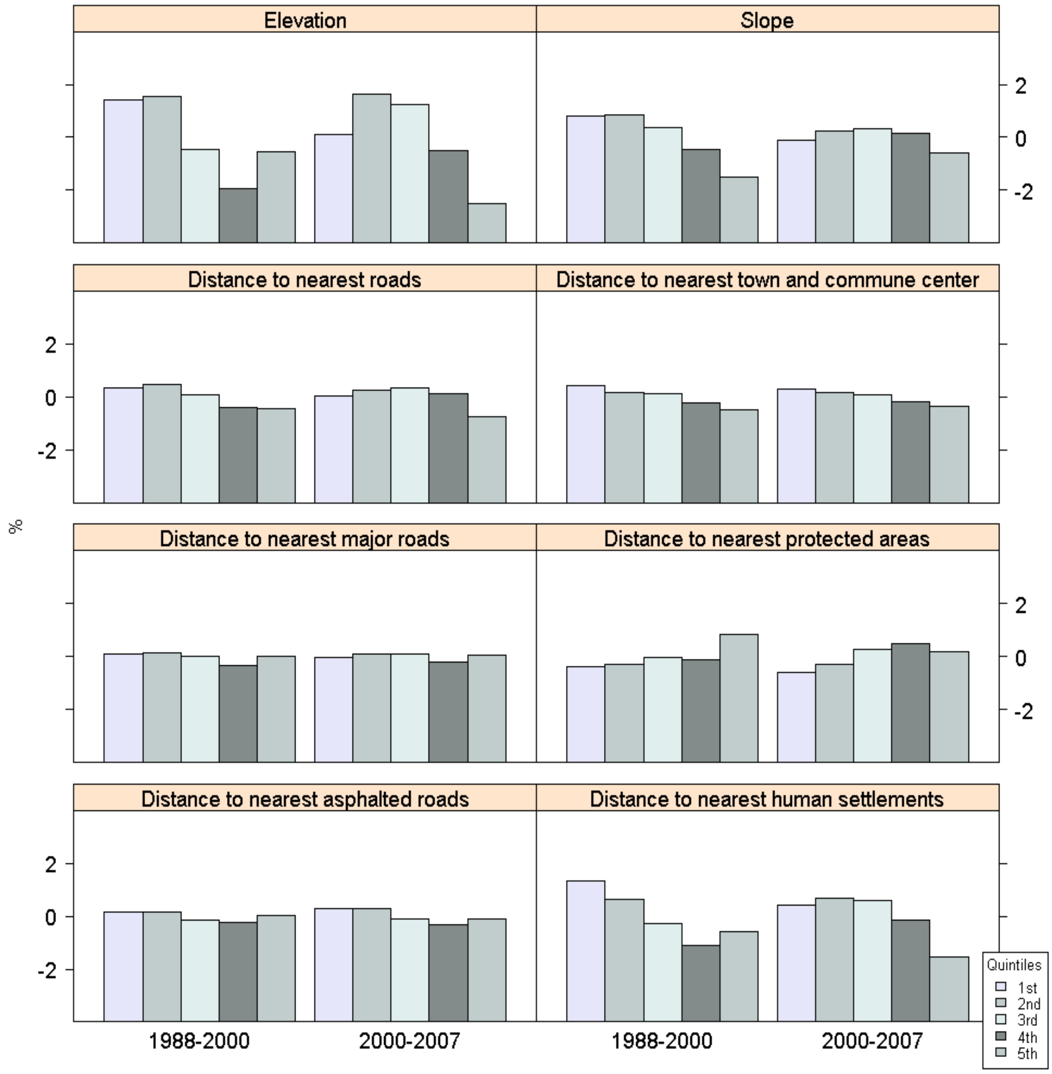
Fig 4 Local R^2 of policy models a) 1988-2000, b) 2000-2007

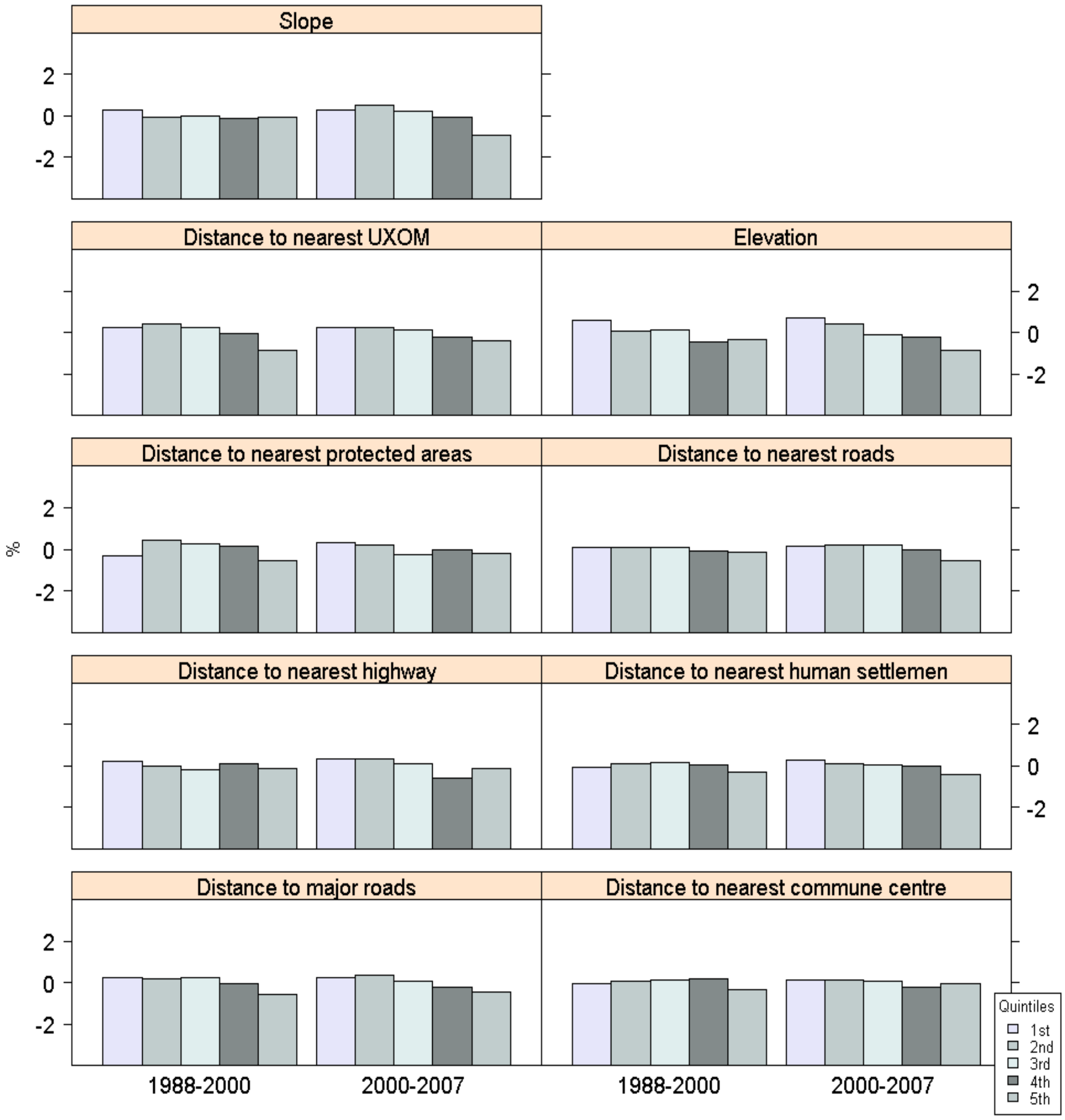
Fig 5 Spatial distribution of estimated local coefficient of Euclidean distance to human settlement for the period of 2000-2007


Observed forest cover changes from 2000 to 2007
Kosovo
Albania
Stable forest
Forest decrease
Forest increase
Stable non-forest
Protected areas
Country boundary

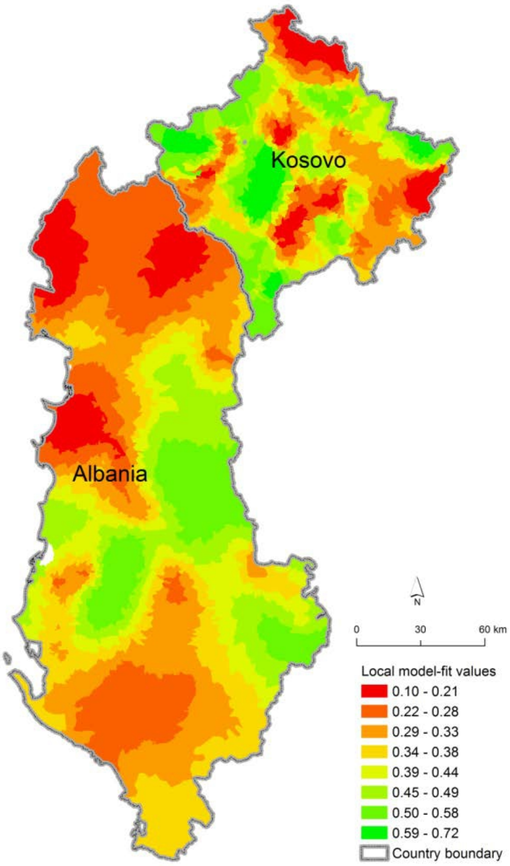

1988-2000
2000-2007
UTM ZONE 34N
GEOGRAPHIC COORDINATES
ELLIPSOID/DATUM WGS34
0 50 100 km
Mitrovicë
Pejë
Prishtinë
Gjilan
Gjakovë
Prizren
Ferizaj
Shkodër
Kukës
Lezhë
Dibër
Durrës
Tiranë
Elbasan
Fier
Berat
Korçë
Vlorë
Gjirokastër
Country
Region
Forest cover change (ha)
>300
151 - 300
51 - 150
1 - 50
-49 - 0
-149 - -50
-299 - -150
<-300


a)
Forest cover change 1988-2000
Forest cover change 2000-2007
Thousands in hectares
60
50
40
30
20
10
0
-10
-20
-30
55,4
-17,2
Albania
11,8
-0,55
Kosovo


Elevation
Slope
Distance to nearest roads
Distance to nearest town and commune center
Distance to nearest major roads
Distance to nearest protected areas
Distance to nearest asphalted roads
Distance to nearest human settlements
%
2
0
-2
1988-2000
2000-2007
Quintiles
1st
2nd
3rd
4th
5th


Slope
Distance to nearest UXOM
Elevation
Distance to nearest protected areas
Distance to nearest roads
Distance to nearest highway
Distance to nearest human settlemen
Distance to major roads
Distance to nearest commune centre
%
2
0
-2
1988-2000
2000-2007
Quintiles
1st
2nd
3rd
4th
5th

a)


Kosovo
Albania
N
0
30
60 km
Local model-fit values
0.10 - 0.21
0.22 - 0.28
0.29 - 0.33
0.34 - 0.38
0.39 - 0.44
0.45 - 0.49
0.50 - 0.58
0.59 - 0.72
Country boundary

b)

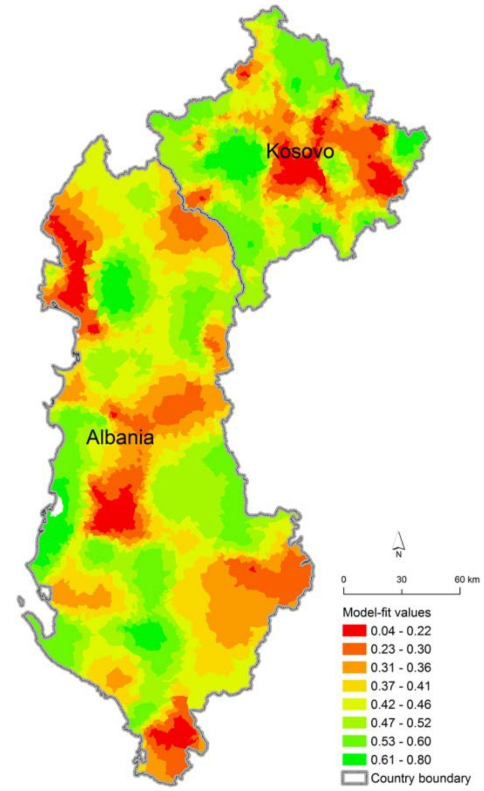

Kosovo
Albania
N
0
30
60 km
Model-fit values
0.04 - 0.22
0.23 - 0.30
0.31 - 0.36
0.37 - 0.41
0.42 - 0.46
0.47 - 0.52
0.53 - 0.60
0.61 - 0.80
Country boundary

Figure 4

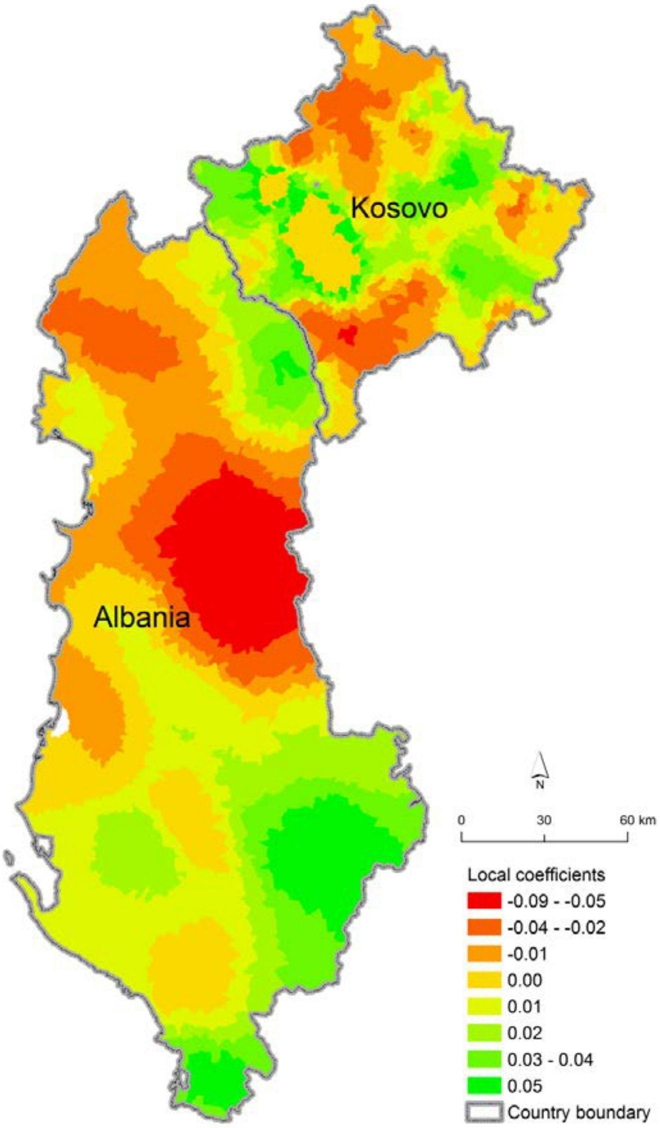

Kosovo
Albania
N
0
30
60 km
Local coefficients
-0.09 - -0.05
-0.04 - -0.02
-0.01
0.00
0.01
0.02
0.03 - 0.04
0.05
Country boundary

Figure 5