AEgean Journal of Environmental Sciences (AEJES),
Vol.2 (2016), pp. 1-10

Change detection of forests and semi-natural areas in Greece for the period 1990-2010

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A B S T R A C T

Changes in composition and spatial distribution of forests affect directly and indirectly fundamental ecosystem functions. The direct and underlying factors of changes are numerous and interact at various scales. Thus, spatial information of forest cover and its associated changes are essential. Modern tools like geoinformatics and remote sensing allow the systematic monitoring and evaluation of forested areas. Spatially explicit information is considered an important first step in order to achieve sustainable management, protection and restoration. In this study, we detect the changes in forest cover of Greece for the period 1990 to 2010. Additionally, we test the efficiency of comparing data with overarching differences. Overall, results show a slight - approximately by 2% - decrease in dense forests while sparse forests and shrublands increase - approximately by 7% - in the same period.

K E Y W O R D S (in alphabetical order): *Change detection; CORINE; forests and semi-natural areas; Greece; moving window filter; sustainable management*

1 Introduction

Forests provide a wide range of ecosystem services that can range from an ecological, socio-economic and aesthetic point of view. In brief, forest ecosystems sustain all levels of biodiversity serving as habitat for terrestrial animal and plant species (Costanza et al. 1997), while at the same time maintain soil quality by sediment retention, accumulation of organic material and nutrient cycle (Schoenholtz et al. 2000). Additionally, forest ecosystems influence climate through carbon sequestration (Bonan 2008; Canadell and Raupach 2008) and surface albedo regulation (Sagan et al. 1979). They also directly affect the hydrologic cycling through evapotranspiration, infiltration and surface runoff (Bosch and Hewlett 1982). Besides these ecosystem services, forests have been perpetually exploited by humans as they constitute a vital source of food, materials and energy supply (Vos and Meekes 1999).

Nevertheless, the substantial increase of human domination resulted in substantial changes of the Earth's land cover, altering the continuity and structure of the natural reserves and degrading environmental conditions (Vitousek et al. 1997). These changes, which are amplified by economic driven mismanagement, pose serious threats to the Earth's capacity for sustainability (Foley et al. 2005). This complex interaction system has attracted the attention of the scientific community during the last decades (Turner et al. 2007). Numerous research projects, organizations, conservation initiatives, legislative interventions and conventions have focused on measures to reduce the negative and irreversible environmental impacts and to confront further deterioration of the land (Turner et al. 1994).

Earth observation through satellite remote sensing has proven to be an effective way to provide accurate and timely information on the distribution and characteristics of forests. In addition, change detection (Coppin et al. 2004) of forest cover can act as a reliable and consistent pool of evidence in order to reveal underlying and proximate causal factor synergies (Geist and Lambin 2002). Recent technological and methodological advancements allowed several geospatial data sets representing Earth's forest cover (or land cover in general) and/or its associated changes, to be produced. The majority of them consists of case studies at a local scale, mostly focusing on the determination of local processes that are often case specific and may not be identifiable at broader scales (Verburg et al. 2004). An integrated analysis of the phenomenon requires a multi-scale (from local to national or even regional to global) assessment. A number of high resolution global datasets exist today (e.g. Hansen et al. 2013; Kim et al. 2014; Potapov et al. 2008), at various temporal scales of analysis. In Europe, the most frequently used land cover (LC) database is the Coordinate Information on the Environment (CORINE), a pan-European LC map for the years 1990, 2000 and 2006, provided by the European Environmental Agency (EEA). Although these research efforts are important to numerous applications at coarser scales, there still exist limitations that need to be addressed (Giri et al. 2013). Regarding forest land cover mapping, the major source of disagreement is the inconsistency and the incomparability between the datasets due to differences in the definition of forests (Hansen et al. 2013).

Nowadays, research on LC has turned into a frequently discussed topic for environmental and social scientists, a fact that increased the construction and distribution of spatial digital data. However, most studies focus on the local or the regional scale and thus, producing case specific datasets. On the other hand, the pan-European's CORINE LC latest update for Greece was for the year 2000. Given the importance of such a complex phenomenon to be addressed at various scales, we conducted a national scale change detection study of forested and semi-natural areas for Greece. We employed existing available datasets of land cover for the year 1990; 2000 and 2010. The main objectives were: a) to map and quantify the changes occurred in the forests and semi-natural areas of Greece between 1990-2010 and b) to test the effectiveness of inter-comparison between different resolution and minimum mapping unit datasets (CORINE and Landsat derived).

2 Methodology

2.1 Study area

Greece, a Mediterranean Balkan country occupies an area of approximately 132,000 km^2 with a coastline stretching for 15,000 km. Geomorphologically, the Greek territory is complex and heterogeneous, consisting of about 40% mountainous or hilly landscape (land that exceeds 500m in altitude). Extensive agricultural plains are primarily located in Thessaly, Central Macedonia and the Thrace regions. The climate is typical Mediterranean, with hot and dry summers and relatively mild and wet winters. Dominant vegetation types are broadleaved and coniferous forests, sclerophyllous maquis and garrigue (Arianoutsou et al. 1997).

The inhabitants of Greece have a long history of land-based economic activities and to this day forests still constitute a source of income for the rural residents (Papanastasis et al. 2009). The majority of the Greek forests are public and administered by the Hellenic Forest Service, while a large part is owned by Municipalities, charitable foundations and monasteries. Finally, a total area of approximately 200,000 ha is private land and while its land use is determined through legislation frameworks a number of unresolved issues still to be addressed (Vogiatzis 2008). Although formulated regional and national policies regarding sustainability and protection of the natural reserves have been promoted over the last decades (Vokou et al. 2014), forested ecosystems have notably been degraded and fragmented in several areas (Gounaridis et al 2014; Minetos and Polyzos 2010). Arbitrary land tenure arrangements, market induced mismanagement or passive management, lack of public awareness (Minetos and Polyzos 2010) as well as an increasing number of devastating wildland fires (Koutsias et al. 2013) have been identified as the main direct and underlying causes of natural reserves degradation.

2.2. Data and processing

We employed the CORINE land cover datasets for the years 1990 and 2000 produced by the European Environment Agency. The datasets are freely available under the creative commons licensing regime, with a nomenclature that comprises 44 LC classes, organized hierarchically in 3 levels of detail. The first level indicates the major categories of LC e.g. forests and semi-natural areas. The second level indicates more specific types of LC e.g. forests, while the third level narrows down to more specific characterizations e.g. coniferous forest. The minimum mapping unit is 25 ha (Bossard et al. 2000).

For the year 2010, we used a newly produced dataset of LC for Greece (Gounaridis et al. 2015). Primary data for this dataset were the 2010 Landsat GLS imagery (Gutman et al. 2013), spanning paths: 180 to 186 and rows: 31 to 36. The LC information was derived by implementing the random forests classification algorithm (Breiman 2001). The algorithm was trained semi-automatically, extracting information from the CORINE 2000 LC polygon centroids. The result underwent a series of post processing techniques including the single pixels elimination using the mode of their neighborhood pixels, defined by a 3x3 window. The nomenclature adopted was identical to the CORINE land cover at level 2.

The 2010 dataset, derived from Landsat imagery, was resampled to 100m using the nearest neighborhood method, to allow for comparison with the other two datasets. To deal with the difference in the minimum mapping unit, we re-applied a 5x5 moving window targeting isolated patches of less than 25 ha, using the mode of their neighbors. Next, the datasets were reclassified into four categories focusing on forests and semi-natural areas in order to better distinguish them from the other classes. The final four categories were: forests; shrub and/or herbaceous vegetation associations; open spaces with little or no vegetation; all other types (see Figure 1).

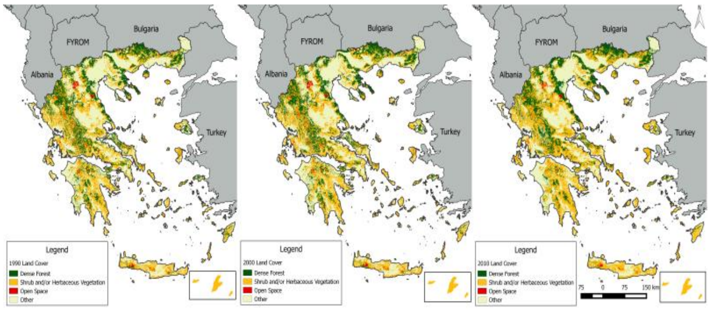

Figure 1: *The final (after pre processing and reclassification) three land cover datasets used for the change detection*

The final stage was the accuracy assessment of the LC classes regarding forests and semi-natural areas. A total of 37,000 randomly distributed points -independent from the original dataset- were photo-interpreted utilizing very high resolution satellite imagery provided by OpenLayers plugin in QGIS (Quantum GIS Development Team, 2013). Visual interpretation analysis is a complex and demanding task, completely based on the interpreter's personal judgment. To efficiently estimate LC, a general assessment of the surroundings is necessary to be taken into consideration. Thus a buffer of 50m diameter was applied to every point. The length of 50m was chosen in order to achieve a compatible minimum mapping unit with the

CORINE data to avoid discrepancies during the change detection stage. The objective to define LC for every single location, considering the wider surroundings, increased the complexity. For such a complex and long duration process, the user agreement, in other words a predefined common sense of the team members, was crucial. Therefore, several exploratory interpretations were conducted. The results of the team members for different parts where switched and the matching entries rate was computed. This procedure continued until an acceptable rate (90%) was reached. Only the points that were commonly assigned by the members were kept. The photo-interpretation performed regarding the current LC taking place in every randomly distributed point's location. Each of the buffer polygons attribute, was labeled a value according to the interpreter's opinion, indicating a land cover class at the CORINE's level 1. Subsequently, we focused on quantifying cover changes of the forests and the semi- natural areas and mapping their spatial distribution. Firstly, the statistics of percent cover of each of the four classes were calculated. Secondly, post-classification (PC) comparison in the form of cross-classification (Lu et al. 2004) was employed, because of its pixel-by-pixel nature and more specifically the 'from-to' change class information provision.

3 Results

From the initial 37,000 points, 20,552 were labeled as forests and semi-natural areas and were chosen to be compared against the 2010 reclassified dataset, resulting in a total accuracy of 92%. The percentages of LC changes that occurred between the years 1990 and 2010 are summarized in Figure 2. A decrease in forested areas (dense forests) is observed (approximately a 2% reduction of the original coverage) between 1990 and 2010. Comparatively, the area of sparse forests and shrubs increased approximately 7% at the same period, while open spaces appear slightly reduced at about 0.4% from their original area. In addition, a small percentage of 1% of sparse forests/shrubs appears to have been converted to dense forests.

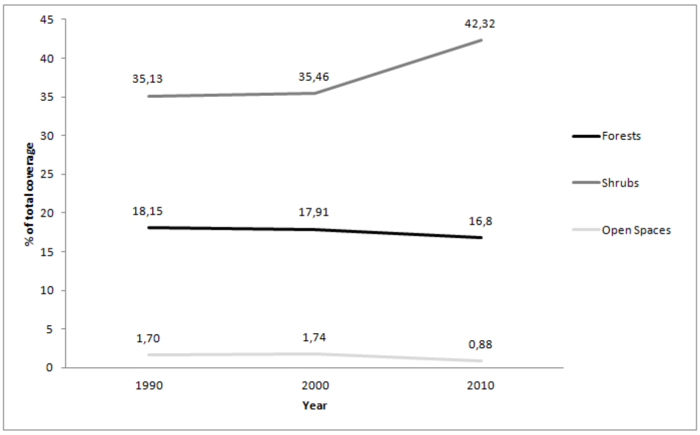

Figure 2: *Percentages of total land occupied by each of the forests and semi-natural areas land cover classes for the three datasets*.

The spatial patterns of changes in LC are illustrated in Figure 3 with a categorization of changes into four classes. The first two categories present the two different forest types that remained unchanged (dense and sparse/shrubs including the slight gain), followed by the changes (loses) of any type of forest to some other artificial LC type. The fourth category is that of the remaining LC types, aggregated into one category for easier visualization. The results presented focus on the changes that occurred to forests including the percentage lost and the percentage unchanged.

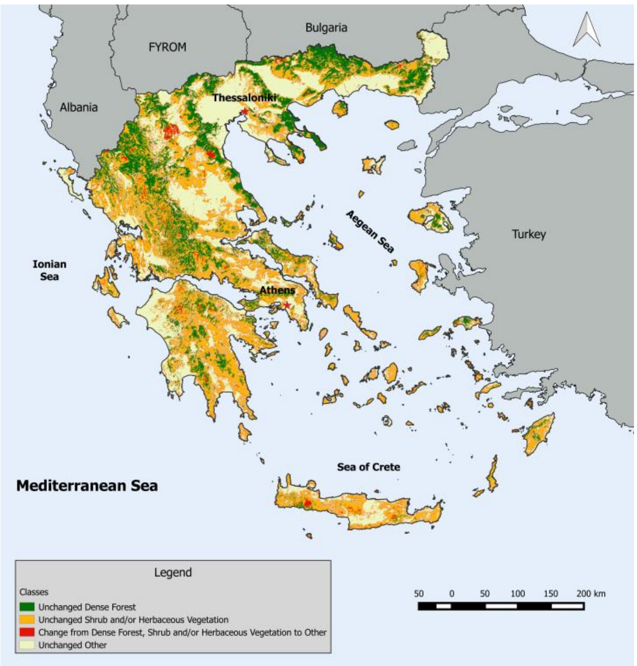

Figure 3: *The spatial patterns of changes in forests and semi-natural areas land cover as revealed by the cross classification methodology*

4 Discussion

The changes in forest cover which are the main focus of this study can be explained by a series of facts. Firstly, Greece has been suffering from extensive forest fires for many years, leading to a significant loss of forested areas (Koutsias et al. 2013). This also leads to a partial explanation regarding the increase appearing in sparse forests and shrubs as it can be seen in Figure 2. Mediterranean ecosystems have very effective mechanisms of coping with fire if left undisturbed after a fire incident (Arianoutsou 1999; Calvo et al. 2002; Le Houerou 1974). Thus, post-fire regeneration (natural or artificial), leads to younger and sparser forests. The increase of shrublands can also be attributed to rural land abandonment (Antrop 2004; MacDonald et al. 2000). During the last decades in Greece, triggered by socio-economic changes and gradual urbanization, remote rural areas have been abandoned and, in many cases, they are gradually transformed into shrubland and or sparse forests (Kasimis et al. 2003; Zomeni et al. 2008)

An issue with this study that should be discussed is that some of the observed changes seem to appear due to the difference in resolution between the datasets used. Both CORINE 1990 and 2000 datasets were acquired at 100m resolution (originally based on the digitization of remote sensing imagery) while the newly developed 2010 dataset was created at 30m resolution through a machine learning classification process (Gounaridis et al. 2015). Despite our efforts to make datasets as comparable as possible (resampling to 100 m and moving window filter for areas <25 ha), differences were not entirely eliminated, thus affecting the accuracy of the results. The majority of the erroneously classified as change pixels can be traced close to the borders (edges) of different land cover patches and it can lead to inaccuracies in LC change detection. The reason for such a result can be traced to the different way edges are represented in the datasets employed for the comparison. This study demonstrates that change detection between datasets with different resolution and minimum mapping unit should be conducted with caution. Additionally, it is clear that accurate finer resolution datasets are important in LC change detection, a fact that raises challenges for future research.

5 Conclusions

In this study we focused on changes that occurred in forest and semi-natural areas cover during the period between 1990 and 2010 in Greece. The main change observed is the reduction of forest cover by approximately 2% and its substitution by other forms of LC. Sparse forests and shrubs showed a 7% increase in the past 20 years, open spaces were reduced by 4% and finally 1% of sparse forests has changed category to that of dense forests. A series of matters regarding the protection and sustainability of forests arise along with issues regarding land abandonment and the expansion of urban areas lacking proper planning. The issue of forest fires and its implications to the state of forests in Greece is well documented and the resulting loss of forest cover is evident in various areas of the country.

In the context of planning a sustainable forest policy, and at the same time assessing the effectiveness of past activities, spatio-temporal information of land cover and its associated changes, is essential, making it obvious that spatial data construction should be prioritized. Accurate high resolution LC datasets are a key priority for further research, environmental monitoring and land use planning. Additionally, appropriate attention should be given to the compatibility and interoperability between the produced and existing datasets. Dataset construction initiatives require the adoption of new, robust and low cost methodologies.

Acknowledgements: The authors wish to thank the two reviewers and Iosif Botetzagias (on behalf of the Editors of AEJES), for their constructive comments on earlier drafts of this manuscript. Bika Konstantina, Kontou Danai, Moustos Petros and Riga Maria, were under summer internship placement at SAGISRS lab

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