European Journal of Geography

Volume 11, Issue 4, pp. 093 - 109

Article Info:
Accepted: 16/12/2020
Corresponding Author: *stavroskolios@yahoo.gr
https://doi.org/10.48088/ejg.s.kol.11.4.93.109

Special Issue: *"Selected Papers from 12th International Conference of the Hellenic Geographical Society (ICHGS): Innovative Geographies II, 2019"*

Spatial changes of forests in a coastal and a remote mountainous area of Greece over a 65-year period

Stavros **KOLIOS**[1*], George **NTOGAS**[2], Efthimios **ZERVAS**[2]

[1] *University of Ioannina, Greece*
[2] *Hellenic Open University, Greece*

Keywords:
ICHGS-2019,
forest changes,
spatial analysis,
image classification,
GIS

Abstract

The scope of the study is to detect spatial changes in the forested areas over six decades (1945 - 2010) of two completely different landscapes in Greece (pilot areas). The first pilot area is Kastoria which is a relatively remote and mountainous area located north-western on the Greek peninsula, while the second one is Propontida which is a coastal area in the Chalkidiki peninsula (central Macedonia, Greece). High resolution orthorectified aerial images are used to detect the general types (classes) of land use/land cover (LULC) in these pilot areas. The results reveal that during the examined period, a notable spatial growth and thickening of the forest areas was found (10,51%) in the pilot area of Kastoria. The spatial homogeneity of the forested areas in Kastoria decreased only by 2,11%. Regarding Propontida, the forested areas decreased in total about 13,02% while the agricultural and arable land has increased by 12,10%.

The publication of the European Journal of Geography (EJG) is based on the European Association of Geographers' goal to make European Geography a worldwide reference and standard. Thus, the scope of the EJG is to publish original and innovative papers that will substantially improve, in a theoretical, conceptual or empirical way the quality of research, learning, teaching and applying geography, as well as in promoting the significance of geography as a discipline. Submissions are encouraged to have a European dimension. The European Journal of Geography is a peer-reviewed open access journal and is published quarterly.

1. INTRODUCTION

The land use /land cover (LULC) changes are the long-term result of socioeconomic changes as well as natural disasters (e.g. fires, landslides, urbanization, intense agricultural production) and they are of great importance because are strictly connected with the environmental changes of an area.

Numerous studies from various disciplines have already proven that LULC changes are a key-component to many different applications such as agriculture, environment, geology, ecology, forestry, and hydrology (e.g. Weng 2001). These applications concerned the loss of crops, land degradation, urban sprawl, changing water quality etc. Additionally, in recent decades, an important issue to study land use change has emerged from the efforts to understand the forces leading to LULC changes. These efforts have stimulated the interest of researchers to apply various techniques to identify and model environmental dynamics at different spatiotemporal levels (Paegelow et al., 2008).

Among the most important LULC changes are included the spatial changes in the forested areas. More specifically, the forested areas neighboring with cities are usually under pressure because of the urban sprawl and the increase of the population demands (e.g. food, transportation, infrastructures, heating) as well as the expansion of the local agricultural sector (e.g. Se Bin and Alousavath, 2016; Vidal-Macua et al., 2017; Imai et al., 2018; Halder, 2018; Singha et al., 2019). Moreover, it is noteworthy pointing out that the sustainability of the forests is affected by the drought and population growth, which are global issues. As a result, such issues must be thoroughly studied, especially in the most vulnerable in climate change regions, like the Mediterranean countries (IPCC, 2014). Also, changing forest cover, is an important local driver of climate change worldwide, as it affects albedo and evapotranspiration (Prevedello et al., 2019). Considering that the increased population growth will intensify the pressure on the forested areas with the potential escalation of forest degradation (FAO, 2018) studies that focus on local changes can efficiently highlight the forest changes and their possible causes, in order to adapt policies for a sustainable forested management (e.g., Keenan, 2015; Jandl et al., 2019; Kolios et al., 2018).

Indeed, forests represent nearly one-third of the world's area (FAO, 2018) and their changes have strong influence on conserving biodiversity, protecting the soil from erosion, reducing floods by regulating runoff, improving the quality of water produced, wind protection, noise protection and the improvement of climate and air quality, acting as a storehouse of carbon dioxide (e.g. Foley et al., 2005; Hansen et al., 2013). Moreover, the forests operate as a place of recreation, aesthetic pleasure and has a positive effect on human health (Leontaraki, 2017). Therefore, studies about changes in forested areas at local scales using data of high accuracy can be considered extremely useful for supporting detection and monitoring of the changes in carbon fluxes, carbon stock, and ecosystem services by scientists and managers (Qin et al., 2017). However, considerable uncertainties still exist in the spatial distribution of forest cover and deforestation (Qin et al., 2016). Though, studies at local scales can improve the existing knowledge of forest extent and changes and provide a better understanding of the consequences of forest cover change, supporting scientific and sustainable management of forests (Chen et al., 2016).

In a more general aspect, the environmental protection and the economic development are commonalities in any modern society. The three dimensions of sustainable development, which are the environment, economy, and social cohesion, need to coexist through balanced ways, based on the common assumption that the environment is expendable (UN, 2019). As the global population is continuously increasing in urban centers and its needs increase it leads to the misuse of natural resources to meet their needs causing irreparable damage to the environment. The forest is an important part of the environment that has been burdened. Different approaches have been used to improve LULC classification methods and spatial analysis accuracy (e.g. Lu and Weng, 2004). These approaches include the integration of geospatial datasets, census data, attribute characteristics, environmental information and point measurements from different types of ground-based instrumentation (e.g. Gong and Howarth, 1990; Harris and Ventura, 1995; Mesev, 1998; Myint, 2001; Shaban and Dikshit, 2001; Stuckens et al., 2002).

Remote sensing and Geographic Information Systems (GIS) are nowadays the most common approaches of quantifying, mapping and detecting LULC patterns due to their precise georeferencing procedures, digital format suitable for computer processing and repetitive data acquisition (Lu et al. 2004; Chen et al. 2005 ; Nuñez et al. 2008; Rahman et al. 2011).More specifically, the modern spatial analysis techniques and spatial analysis software, in combination with the availability of high-resolution multispectral remote sensing imagery, are extensively being used in order to accurately detect LULC changes at many different spatial scales. The Landsat imagery is one of the most used freely available image data for LULC analyses in regional scales (e.g. Mahmoodzadeh et al., 2007; Guo et al., 2009; Kolios and Stylios, 2013; Mokarram et al., 2016; Zormpas et al., 2017; Kolios et al., 2018), but there are numerous other different datasets, like remote sensing imagery coming from the satellites SPOT and Sentinel, for such studies (e.g. Desclee et al., 2007; Mitchell et al. 2017; Alam et al., 2019). Moreover, the aerial imagery is extremely useful in studying LULC changes, especially in local scales, due to its high-resolution (e.g. Wundler and Franklin, 2003; Nyamgeroh et al., 2018).

The detection of spatiotemporal changes in forested areas is an essential type of applications regarding the LULC analyses. As above mentioned, such studies are of specific interest because the forested areas are under pressure worldwide, due to human-induced activities and climate change (e.g. Jiménez-Muñoz et al., 2013; Rosa etal., 2017; Lossou etal., 2017; Tejada etal., 2019). More specifically, Greece, as part of the Mediterranean region, is projected to be among the most vulnerable countries to climate change (e.g. Giorgi, 2006; Galassi and Spada, 2014; Adloff etal., 2015). Therefore, is very important to study the forest changes with a scope to enable the conservation of healthy and productive forests and to enhance biodiversity.

The scope of the study is to detect the long-term spatial changes in the forested areas over six decades (1947 - 2010) over two completely different landscapes in Greece (pilot areas) in order to further highlight the potential factors that affect the changes of forest areas. The one study pilot area is Kastoria (Fig. 1b), which is a relatively remote and mountainous area, located in the northwestern part of Greece, while the other one is Propontida, which is a coastal area in the Chalkidiki peninsula (central Macedonia, Greece, Fig. 1c).

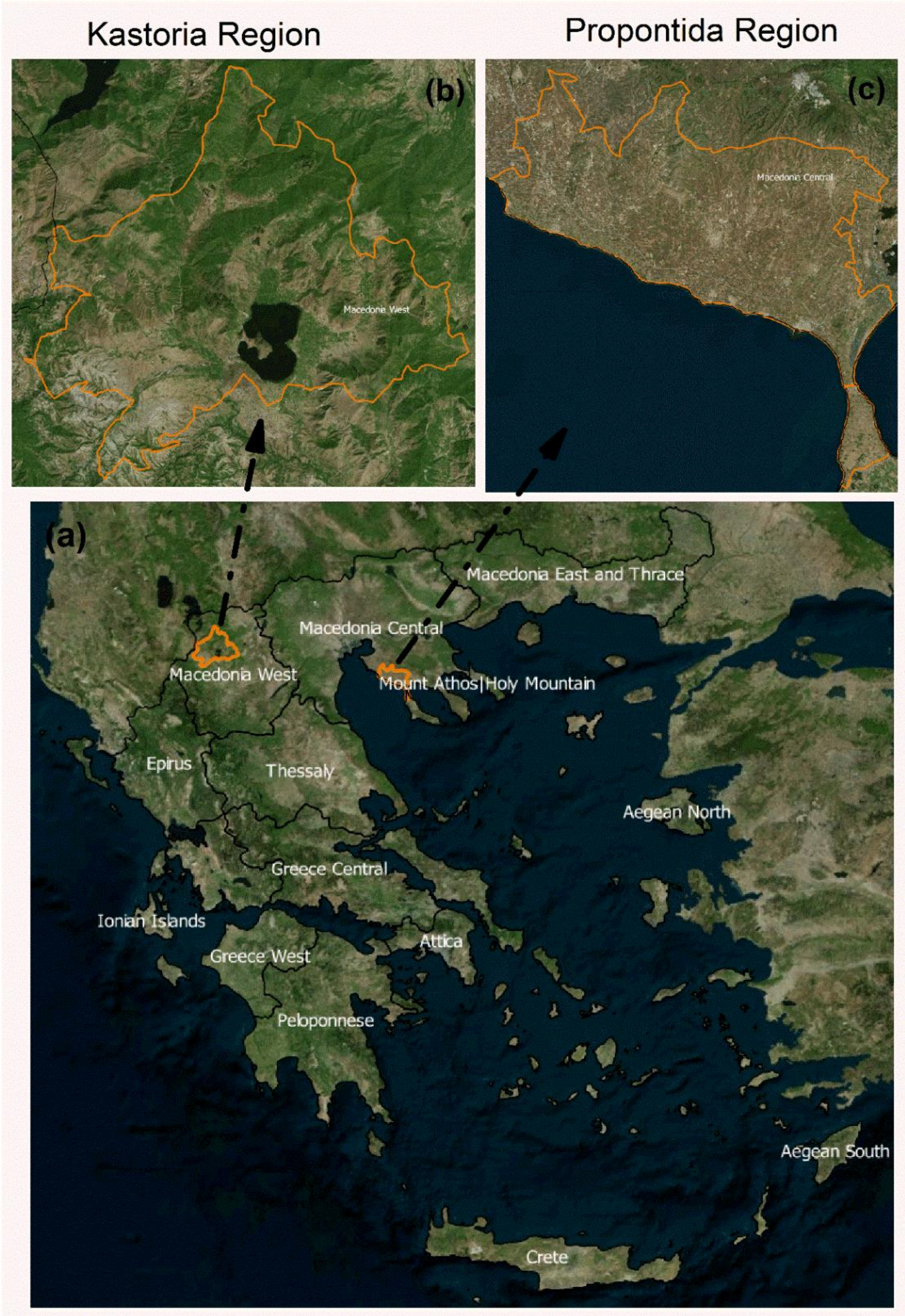

Figure 1. a) The greek periphery as provided by the "Bing" Maps API service, b) the first pilot area (Kastoria) and c) the second pilot area (Propontida).

2. DATA AND METHODS

A series of different spatial datasets and widely used methodologies were used to create final forest maps (for the years 1945 and 2010) and extract the spatial changes in major LULC classes, focusing on forested areas. The Fig. 2 represents schematically, the flowchart of all the procedures were implemented in the study.

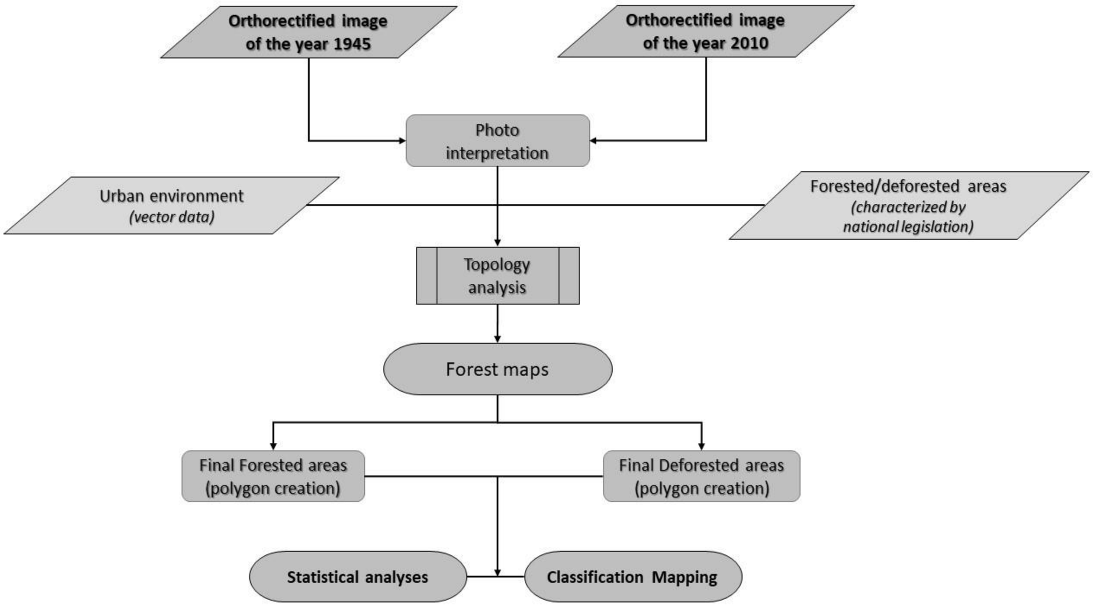

Figure 2. Flowchart of the procedures are followed, and the data used in the study.

As can be seen in the Fig. 2, the orthorectified images of two different years (1945 and 2010) were analyzed through a thorough photointerpretation (detection of the basic classes which are provided in Table 1). Additionally, spatial data regarding the urban environment and the forested/deforested areas as characterized by the national legislation, were used. This spatial information is needed to improve the characterization of the polygons following the national legislation and the official data regarding the limits of the urban environment and the forested areas. All the different polygons were merged (spatial "union" procedure) and the topology analysis of all these data was used to fix possible gaps and overlays among the polygons. Finally, relative forest maps, were created. More specifically, the final forested and deforested areas (polygons) were extracted along with their relative class changes (Table 2), and their statistical analyses were performed along with the final classification maps (Fig. 5 and Fig. 6).More specifically, the initial data used in this study are highly accurate orthorectified images (orthophotos) of 0,5 m spatial resolution (Fig. 3 and Fig. 4), coming from the National Cadastre and mapping Agency (http://gis.ktimanet.gr/wms/ktbasemap/default.aspx). These image data were used to detect different categories of land cover types (classes) and to define relative polygons about these classes. In following, digital files containing spatial information in polygons regarding the official limits of many characterized areas, such as Municipality limits and urban fabric limits, were collected from the database of the Hellenic Mapping and Cadastral Organization (http://geodata.gov.gr). This type of spatial information in the form of vector spatial representation is very accurate and widely used in such types of spatial analyses (e.g. Burrough et al., 1998; Chang, 2016).

In a third step, the different LULC classes of interest were constructed by digitizing different polygons for each of the classes via the thorough visual examination of the orthophoto images (Table 1). It should be mentioned that the classes (Table 1) as well as the class changes (Table 2) were based on the relative Greek legislation regarding the definition of LULC types regarding the characterization forested areas (Law 2373/Β'/12-07-2017, Law 998/79; Law 248/1976). Additionally, the classes were chosen in a way to comply with the general principles of a land use classification system (Anderson et al., 1976). These general principles require (a) The classification system has to be applicable to extended areas, (b) categorization should allow vegetation and other types of land cover to be used as substitutes for the activity, (c) The classification system must be suitable for the use of remotely sensed data obtained at different times, and (d) Comparison with future land cover data should be feasible. Finally, a topology analysis was conducted to eliminate possible geometric errors and fix possible overlapping and/or gaps among different polygons, as suggested by Oosterom et al. 2002 and Zlatanova et al. 2003.

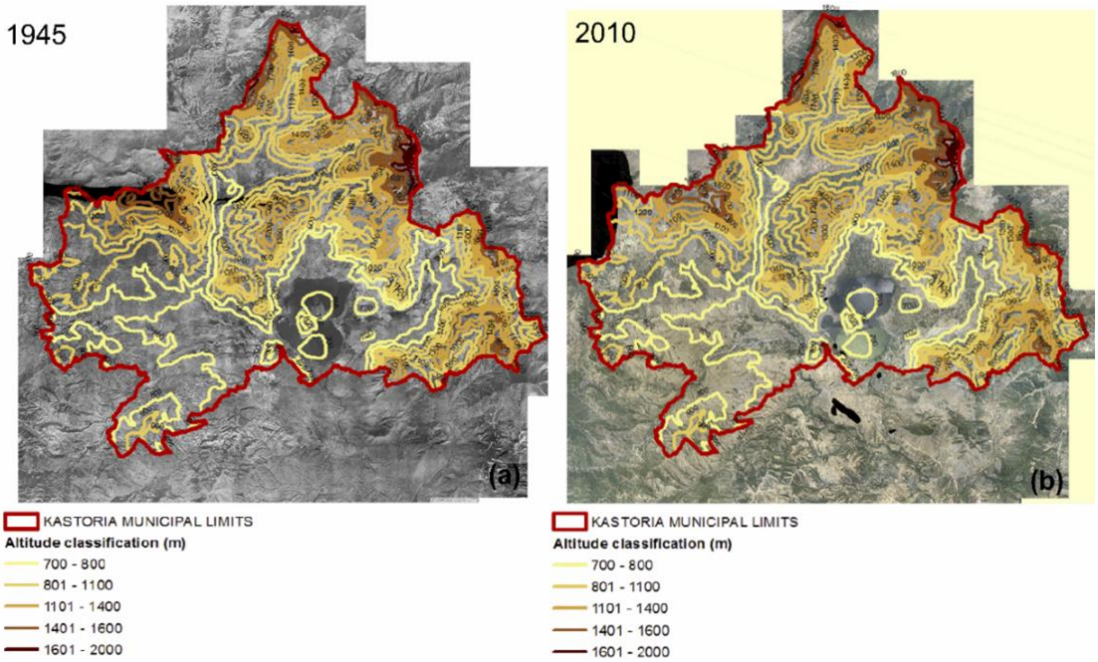

Figure 3. Orthophoto images with the overlay of altitude per 100 m (iso-heights) for the Kastoria in a) the year 1945, b) the year 2010.

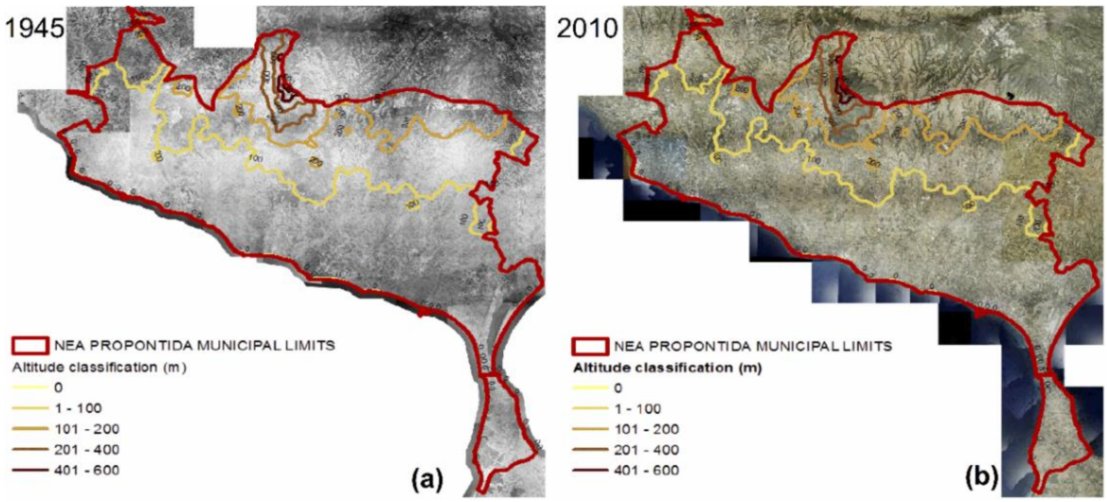

Figure 4. Orthophoto images with the overlay of altitude per 100 m (iso-heights) for the Propontida in a) the year 1945, b) the year 2010.

Table 1. Different LULC classes in the study areas.

No.	Class Name	Class Description
1	Forests ("F")	Homogenous forested areas
2	Grassland/Rocky ("GR")	Areas that represent grassland and/or rocky areas, according to the Greek legislation (Law 998/79)
3	Urban fabric ("U")	Urban areas inside the as they defined by the Greek legislation (Law 3889/2010)
4	Other ("O")	Other types of land use that like mixed areas, agricultural areas and any other land cover types that do not belong the above-mentioned ones.
5	Water Surface ("W")	Water surfaces (sea or lake)

Table 2. Different LULC changes in the classes of interest in the study areas.

No.	Category of class changes	Description	Group of class
1	F-F	Forested areas in 1945 that remain forested until 2010	Forested
2	O-F	Areas characterized as "O" in 1945 that converted to forested ones ("F") until 2010	
3	F-O	Forested areas ("F") in 1945 that converted to other types ("O") until 2010	
4	O-O	Areas characterized as "O" in 1945 that remain in the same class until 2010	No forested
5	O-GR	Areas characterized as "O" in 1945 that converted to the grassland class ("GR") until 2010	Grassland/ Rocky areas
6	GR-O	Areas characterized as "GR" in 1945 that converted to the other types ("O") until 2010	
7	GR-GR	Areas characterized as grassland "GR" in 1945 that remain in the same class ("GR") until 2010	
8	W	The water surface	Water surface
9	U-U	Urban fabric area ("U") in 1945 that remain in the same class ("U") until 2010	Urban fabric
10	Re-F	Areas that defined as re-forested by the Greek government after trespass or forest fires	Re-forested areas

3. RESULTS AND DISCUSSION

Several statistics (Table 4-6), regarding the spatial changes of every examined land cover type (class) as well as relative Figs. (Fig. 5 and Fig. 6) representing maps of all detected spatial changes during the examined period, are used to support the findings and the conclusions of this study.

3.1 First pilot area (Kastoria)

In Fig. 5 it is provided the spatial distribution of the defined classes regarding Kastoria pilot area. At this point, it should be noted that the whole study area of Kastoria has areal extent of 786.453 x 10^3 m^2. The spatial changes between the two examined periods are also shown (Table 2, Fig. 6c). Tables 1, 2 and Fig. 6 clearly show that there is a significant increase of the forested areas (10.51%) during the 1945-2010 period in the whole area of Kastoria. The increase is especially evident in the northern and the eastern parts of this study area, which is the most mountainous and the less populated. Also, it is noteworthy to be mentioned that there are important parts of the forests that were characterized as re-forested areas by the Greek Government (Fig. 5c). This finding, highlights that although the intrusions and the changes in the forested areas (e.g. fires, over-grazing, illegal agricultural use), this forested environment significantly expanded.

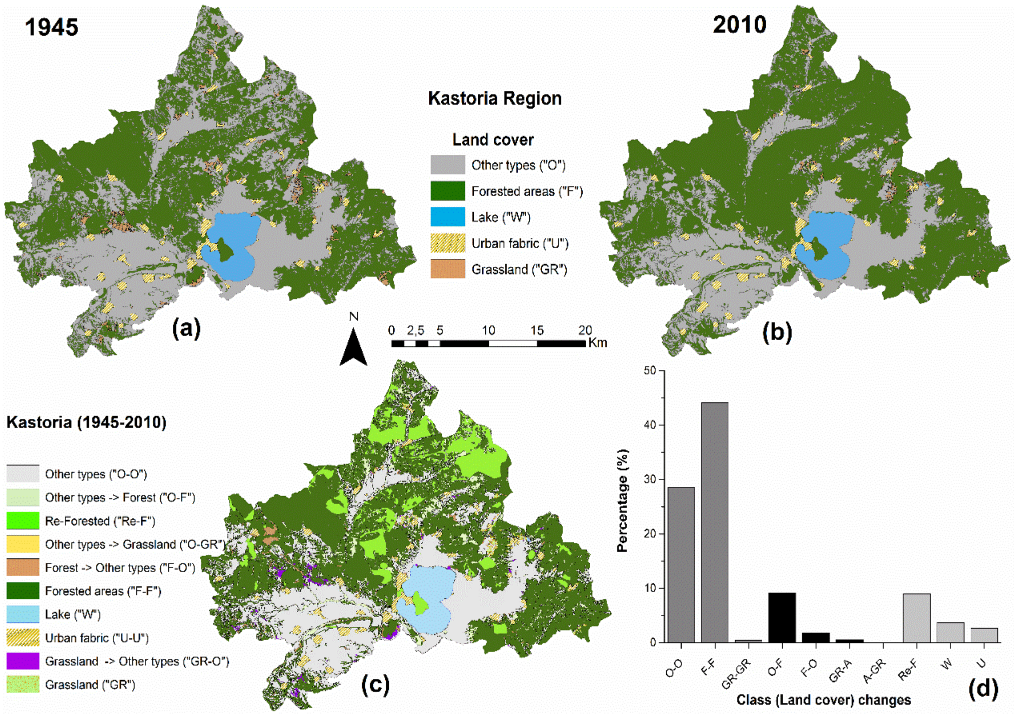

Figure 5. Kastoria region land cover types in the year 1945 (a), the year 2010 (b), land cover spatial changes during the examined period (c) while in (d) is provided quantitatively, the percentages of these spatial changes.

Significant decrease (-9,3%, according to the Table 3) was occurred in the class "other types", that includes mainly the agricultural land. This decrease highlights the gradual abandonment of the agricultural sector and the immigration of the population from the remote mountainous areas to the main city of the study area, Kastoria city. This population move increased the population of Kastoria by 68.75% over 60 years, i.e. from 10.049 inhabitants in 1951 to 16.958 inhabitants in 2011. A small increase in population (3,78%) is also observed in the neighbor villages, while a significant population decrease of 54% in average is observed in the mountainous villages of Vitsi, Korestia, Kleisoura and Agioi Anargyroi (Hellenic Statistical Authority 2011).

Table 3. Spatial changes of the examined LULC class regarding Kastoria region.

Kastoria						
Land cover type (label)	**Year 1945**		**Year 2010**		**Class difference ($x 10^3 m^2$)**	**Class difference (%)**
	Area ($x 10^3 m^2$)	**%**	**Area ($x 10^3 m^2$)**	**%**		
O	321.081,50	40,83	247.927,78	31,52%	-73.153,72	-9,30%
F	401.699,86	51,08	484.323,87	61,58%	82.624,01	10,51%
O	29.410,47	3,74%	29.626,39	3,77%	215,92	0,03%
W	20.774,28	2,64%	20.788,92	2,64%	14,64	0,002%
GR	13.487,84	1,72%	3.786,98	0,48%	-9.700,86	-1,23%
TOTAL	**786.453,94**	**100 %**	**786.453,94**	**100 %**		

The entire region of Kastoria has in total a population increase of 27,45%, from 28.147 inhabitants in 1951 to 35.874 in 2011). Fig. 5c represents the spatial changes of the different classes, where it can be clearly seen the significant increase of the forested areas, especially considering the re-forested areas (9.02% of the whole area). Fig. 5d provides the percentage of change regarding the total area of the different classes shown in Fig. 5c.

Another parameter that is important to calculate for the accurate evaluation of the spatial changes of the forested areas, is their spatial homogeneity. This parameter is calculated in this study by measuring the number of the different polygons of the forested areas. The large number of different polygons indicates a high spatial fragmentation of the forested areas, leading to a decrease of spatial homogeneity. In contradiction, a small number of different polygons in the same total areal extent of the forests indicates highly uniform forested areas, leading to an increase of the spatial homogeneity. Table 3 and 4 show the total number of polygons of each class, as well as their changes, using as reference period the oldest date (the change of each class corresponds to the fraction of the absolute difference in the number of polygons divided by the number of the polygons of the reference date). According to Tables 3 and 4, the class "O" not only decreased spatially, but its homogeneity is significantly increased, as a decrease of 21,02% in the class change is observed. This is probably due to the gradual development of agricultural sector in well-organized forms near the irrigation network of the area, as well as the increase of building infrastructure and the expansion of the road network, which led to the increase of its spatial homogeneity. The forested areas increased in surface during the examined period and, in parallel, lost their homogeneity only by 2,11%. This loss can be considered small, not only because of the spatial expansion of this class, but also because of the population concentration in the main city of Kastoria, that contributed to the sprawl of the forested areas and not to their fragmentation. It is also noteworthy pointing out that the class "GR" although has only a small decrease (Table 3), a high increase of 30% of its spatial homogeneity is observed (Table 4), which is a result of the decrease of cultivated areas and livestock.

3.2 Second pilot area (Propontida)

A completely different situation is observed in Propontida, which is a coastal area very close to the second largest city of Greece, Thessaloniki, and is located in one of the most touristic areas in Greece, Chalkidiki peninsula. The study area of Propontida has areal extent of 371.271 x 10^3 m^2. In this area, a significant increase of the class "Other types", including mainly the agricultural sector, occurred. This increase is 12.10 % during the examined period (Table 5) and can be attributed to the increase of the agricultural production in this area. Consequently, the surface of the forested areas of this region is significantly decreased (by 13.02%, Table 5) during the examined period under the pressure of the increase of the agricultural sector. Another important factor led to this high decrease of the total areal extent of the forested areas, is the development of the touristic product. This factor increases the needs in food and residences as well as the development of other relative infrastructure, resulting to the gradual degradation of the forested areas leading finally to their decrease.

Although the limits of the urban fabric in the whole area were increased by only 0,91 % (Table 5), the number of small residences outside the strict spatial limits of the main urban fabric that belong to the class "other types", was significantly increased and this is one of the most important factors of the total population increase by 98,63% during the examined period (from 18,376 inhabitants in 1951 to 36,500 inhabitants in 2011). Moreover, it should be mentioned that in the most touristic parts, which are located in the southeastern and the western parts of this region (Moudania and Kallikrateia, respectively) the population was increases by 121% between the years 1951 and 2011 (years of national census). The spatial changes between 1945 and 2010 can be seen in Fig. 6c, where the significant decrease of the forested areas can be observed. This Fig. also shows that many villages expanded spatially very close to the forested areas, as well as many forested areas close to these villages converted to agricultural areas (class change “F-O”). Fig. 6d provides the percentage of spatial changes among the different classes as they spatially depicted in Fig. 6c.

Table 4. Number of polygons defining each of the examined land cover classes in the Kastoria region.

Kastoria						
Land cover type (label)	**Number of polygons (1945)**		**Number of polygons (2010)**		**Class difference**	**Class change (%)**
	Number	**%**	**Number**	**%**		
O	4444	85,00	3510	82,43%	- 934	-21,02
F	569	10,88	581	13,64%	12	2,11
W	1	0,02	1	0,05	1	0,00
U	54	1,03	53	1,24	- 1	-1,85
GR	160	3,07	112	2,64	- 48	-30,00
TOTAL	**5228**	**100**	**4258**	**100**		

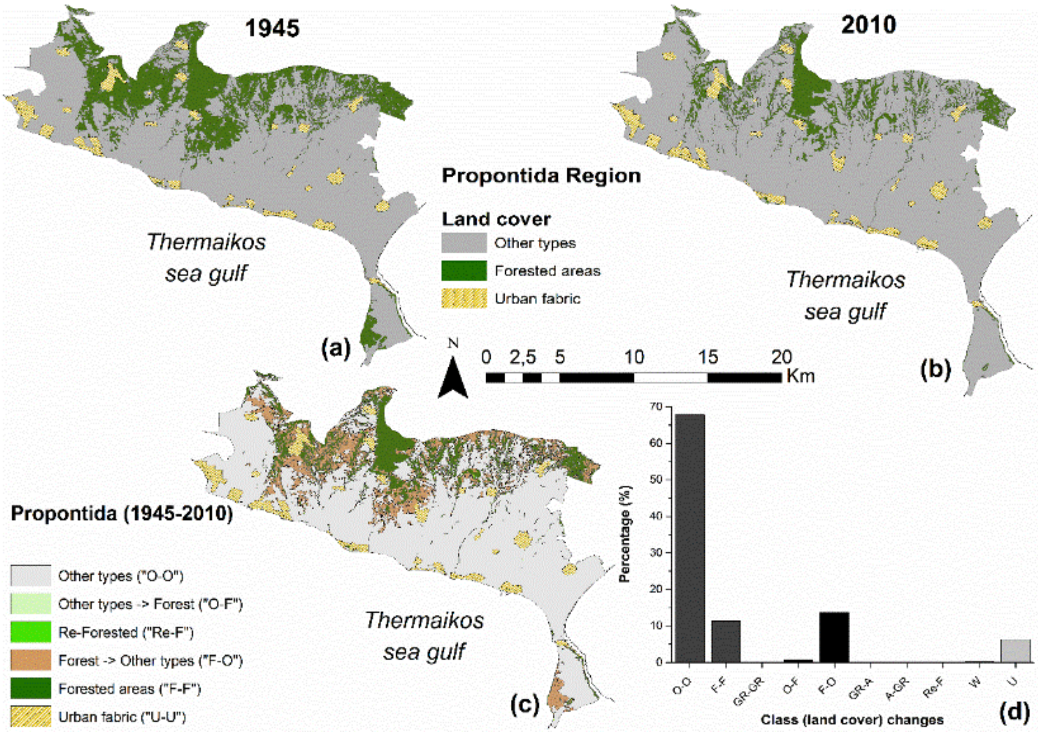

Figure 6. Propontida region land cover types in a) 1945 b) 2010, in c) the land cover spatial changes, are depicted and in d) it is provided quantitatively the percentages of these spatial land cover changes.

The spatial homogeneity of the Propontida which is based on the number of the different polygons consisting the total area of each class, was also examined as in the case of Kastoria. More specifically, the class "O" increased spatially as a total (Table 5) but, in parallel, increased inhomogeneity, as a decrease of 53,58% in the number of polygons was found. This finding indicates the significant areal changes during the 65-year period in this class, which is mainly due to the concentration of the population in the coastal part of the region. That concentration was the reason for the spatial changes in the land use and the land cover of human activities, the agricultural sector, and the livestock. Nevertheless, the most important finding concerns the areal changes of the forested areas. The forested areas not only decreased (13.02%, according to Table 5), but also lost their homogeneity at about 99,12% during the examined 65-year period (Table 6). This finding highlights the significant spatial changes of the landscape in the Propontida, which gradually led to the deforestation and the decrease of the spatial homogeneity of the remaining forested areas. Moreover, it should be noted that the class representing the main urban fabric remained almost unchanged. This result indicates that the touristic growth of this region has led to the construction of small residences scattered along the greater coastline without being into a main urban fabric. This is a common phenomenon all over Greece. This phenomenon contributes to the degradation of the natural environment, including forests, in long-term scale, changing in parallel the microclimate of the coastal areas.

Table 5. Spatial changes of the examined LULC classes of Propontida.

Propontida						
Land cover type (label)	Year 1945		Year 2010		Class difference (x 10^3 m^2)	Class difference (%)
	Area (x 10^3 m^2)	%	Area (x 10^3 m^2)	%		
U	257.976,09	69,47	302.910,90	81,59	44.934,81	12.10
F	93.261,91	25,12%	44.905,38	12,10	-48.356,53	-13.02
O	-	0,00	-	0,00	-	0.00
U	20.088,94	5,41	23.455,11	6,32	3.366,17	0.91
GR	-	0,00	-	0,00	-	0.00
TOTAL	**371.326,94**	**100**	**371.271,38**	**100**		

Table 6. Number of polygons that define each of the examined land cover classes in the Propontida region.

Propontida						
Land cover type (label)	Number of polygons (1945)		Number of polygons (2010)		Class difference	Class change (%)
	Number	%	Number	%		
O	851	63,98	395	29,86	-456	-53,58
F	452	33,98	900	68,03	448	99,12
W	-	0.00	0	0,00	-	-
U	27	2,03	28	2,12	1	3,70
GR	-	0,00	0	0,00	-	-
TOTAL	**1330**	**100**	**1323**	**100**		

Additionally, the areal changes of the forests are overlaid in the population changes per municipality unit of the two pilot areas (Fig. 7). The spatial comparison was chosen because the population changes are strictly related with land use dynamics (e.g. Halder, 2018). The results of this mapping representation highlight that the largest increase of the forested areas in the examined period in Kastoria region is spatially correlated with the largest decrease of the population (northwestern parts of the examined study area), while in Propontida region, the largest the forest decrease the largest is the population increase.

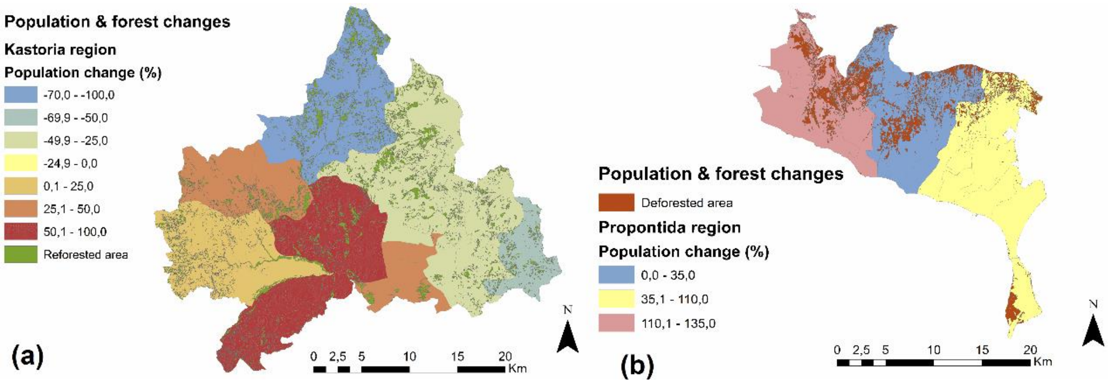

Figure 7. Population and forest changes during the examined period (1945-2010) over the areas of a) Kastoria and b) Propontida.

4. CONCLUSIONS

Forests are playing a key role in the life on the planet Earth a vital component of the natural environment because they stabilize climate, regulate the water cycle, and provide habitat to thousands of life forms. On the other hand, forests and forest ecosystems are fragile and vulnerable because endanger various factors, some of which are forest fires, especially in hot and dry climates, and human activities, mainly illegal logging and deforestation in order to turn them into agricultural land. Climate change also has serious negative consequences for forests, the effects of which have already been seen with prolonged periods of drought, frequent and intense storms, floods and fires, increased heat days, etc. Considering the vital importance to study the forests and their changes, the study is focused on the detection of the spatial changes in the forested areas during six decades (1945-2010) over two completely different landscapes (pilot areas) in order to examine the potential factors that affect the forest areas. The one study domain is the remote mountainous region of Kastoria (Fig. 1b and Fig. 2) and the other one is the coastal region of Propontida (Fig. 1c and Fig. 3). It was concluded that regarding Kastoria, the analytical study of the forested spatial changes during the examined period, depicted a significant increase (10,51%) especially across the most mountainous and remote parts of this region. Also, the forested areas in Kastoria have lost their spatial homogeneity only by 2,11%. This seems to be owed to the decrease of the population and consequently the decrease of the agricultural sector and the livestock, which are the main human activities in the whole area. Contrariwise, in Propontida the forested areas were significantly shrunk (13,02%) but the total population was doubled during the examined period. The forested areas not only decreased (13,02%, according to the statistics of Table 5) but also lose their spatial homogeneity at about 99,12% (Table 6) during the whole examined period. This fact along with the important increase of the tourism sector in this region, seem to contribute to the decrease of the forest areas and its environmental degradation, overall. The population increase in urban and suburban coastal areas with high tourist activity can lead to a reduction of the forested areas. The large number of polygons with small size is another clear indicator that near the coastal areas (such as Propontida), the forested areas gradually lose their spatial homogeneity (spatial fragmentation) because of the continuous expansion of the road network and the increased human activities and touristic demands (hotels and relative infrastructures). Characteristic also, is that in the two study domains that examined in this study (Kastoria and Propontida), the major decrease of the forested areas, is mainly found around urban and sub-urban areas with altitude less than 800 m while in mountainous areas the forested areas remain stable or increase.

Conclusively, it was achieved to detect the spatial changes in a coastal (Propontida) and a remote mountainous area (Kastoria) using spatial data of high accuracy and following common rules and widely used methodological steps (considering the relative national legislation). The examination of the forested areas changes of the in these two pilot areas (Kastoria and Propontida) can operate as a guide in order to assess the spatial forest changes that can be caused in other regions with similar topography and general characteristics. Such analyses can further help to improve or implement strategic plans and relative legislation, according to the specific needs of an area in order to protect and ensure the sustainability of the forested areas without affecting the population changes, the tourism and the agricultural production which seem to be major contributors in the forest changes in Greece. In a more general approach, the specific study illustrates the abrupt and random spatial changes in the forested areas that underline the need for long-term spatial planning and sustainable forest management in local to regional levels.

Future steps include the extension of this in many other areas with different landscapes, the use of remotely sensed data and products such as vegetation indices and the examination of sophisticated methodological approaches in the classification procedures such as decision trees and supervised classification schemes.

REFERENCES

Adloff, F., Somot, S., Sevault, F., Jorda, G., Aznar, R., Deque, M., Herrmann, M., Marcos, M., Dubois, C., Padorno, E., Alvarez-Fanjul, E., Gomis, D. (2015). Mediterranean Sea response to climate change in an ensemble of twenty first century scenarios. *Climate Dynamics*, 45 (9-10), 2775-2802

Alam, A., Bhat, M. S., Maheen, M. (2019). Using Landsat satellite data for assessing the land use and land cover change in Kashmir valley. *GeoJournal*, 1-15. /doi.org/10.1007/s10708-019-10037-x

Anderson, J. R., Hardy, E. E., Roach, J. T., and Witmer, R. E. (1976). A land use and land cover classification system for use with remote sensor data, U.S. Geol. Survey Prof. Paper 964, DOI: 10.3133/pp964Burrough, P. A., & MacDonnell, R. A., Lloyd C. D. (1998). Principles of geographical information systems, 2nd Edition. *Oxford Univ. Press*, ISBN: 0198742843

Chang, K-T. (2016). Introduction to geographic information systems, 8th Edition. Boston, MA: *McGraw-Hill*, ISBN: 0078095131

Chen, B. Q., Li, X. P., Xiao, X. M., Zhao, B., Dong, J. W., Kou, W. L., Qin, Y. W., Yang, C., Wu, Z. X., Sun, R. (2016). Mapping tropical forests and deciduous rubber plantations in hainan island, china by integrating palsar 25-m and multi-temporal landsat images. *International Journal of Applied Earth Observation & Geoinformation*, 50, 117–130

Desclee, B., Defourny, P., Bogaert, P. (2007). Identifying Forest Dynamics for Change Detection Using Multitemporal SPOT Imagery. International Workshop on the Analysis of Multi-temporal Remote Sensing Images, IEE, 18-20 July 2007, doi: 10.1109/MULTITEMP.2007.4293055

FAO, (2018). State of Mediterranean Forests 2018. Food and Agriculture Organization (FAO) of the United Nations, Rome and Plan Bleu, Marseille. *ISBN FAO*: 978-92-5-131047-2

Foley, J., DeFries, R., Asner, G., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K. (2005). Global consequences of land use. *Science*, 309, 570–574.

Galassi, G., Spada, G. (2014). Sea-level rise in the Mediterranean Sea by 2050: Roles of terrestrial ice melt, steric effects and glacial isostatic adjustment. *Global and Planetary Change*, 123, Part A, 55-66

Giorgi, F. (2006). Climate changes hot-spots. *Geophysical Research Letters*, 33(8), https://doi.org/10.1029/2006GL025734

Gong, P., Howarth, P. J. (1990). The use of structure information for improving land-cover classification accuracies at the rural-urban fringe. *Photogrammetric Engineering & Remote Sensing*, 56, 67–73.

Guo, L., Wang, D., Qiu, J., Wang, L., Liu, Y. (2009). Spatio-temporal patterns of land use change along the Bohai Rim in China during 1985-2005. *Journal of Geographical Sciences*, 19, 568-576.

Halder, J. C. (2018). Population change and land use dynamics: A case study of Paschim Medinipur, West Benga, India. *European Journal of Geography*, 9(3), 23-44.

Hansen, M.; Potapov, P., Moore, R., Hancher, M., Turubanova, S., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R. (2013). High-resolution global maps of 21st-century forest cover change. *Science*, 342, 850–853.

Harris, P. M., Ventura, S. J. (1995). The integration of geographic data with remotely sensed imagery to improve classification in an urban area. *Photogrammetric Engineering & Remote Sensing*, 61:993–998.

Imai, N., Furukawa, T., Tsujino, R., Kitamura, S., Yumoto, T. (2018). Factors affecting forest area change in Southeast Asia during 1980-2010. *PLOS*, doi.org/10.1371/journal.pone.0197391

IPCC, (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the *Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Geneva, Switzerland, ISBN 978-92-9169-143-2

Jandl, R., Spathelf, P., Bolte, A., Prescott C. E. (2019). Forest adaptation to climate change—is non-management an option? *Annals of Forest Science*, 76:48, doi.org/10.1007/s1359

Jiménez-Muñoz, J., Sobrino, J., Mattar, C., Malhi, Y. (2013). Spatial and temporal patterns of the recent warming of the Amazon forest. *JGR Atmospheres*, 118(11): 5204-5215, https://doi.org/10.1002/jgrd.50456

Keenan, R. J. (2015). Climate change impacts and adaptation in forest management: a review. *Annals of Forest Science*, 72(2), 145–167.

Kolios, S. Mitrakos, S., Stylios, C. (2018). Detection of areas susceptible for land degradation in Cyprus using remote sensed data and environmental quality indices. *Land Degradation & Development*. https://doi.org/10.1002/ldr.3024

Kolios, S., Stylios, C. (2013). Identification of land cover/land use changes in the greater area of the Preveza peninsula in Greece using Landsat satellite data. *Applied Geography*, 40, 150-160

Lossou, E., Owusu-Prempeh, N., Agyemang, G. (2019). Monitoring Land Cover changes in the tropical high forests using multi-temporal remote sensing and spatial analysis techniques. *Remote Sensing Applications: Society and Environment*, 16: 100264, https://doi.org/10.1016/j.rsase.2019.100264

Lu, D. S., Weng, Q. H. (2004). Spectral mixture analysis of the urban landscape in Indianapolis with landsat ETM plus imagery. *Photogrammetric Engineering and Remote Sensing*, 70, September 2004, 1053-1062

Mahmoodzadeh, H. (2007). Digital change detection using remotely sensed data for monitoring green space destruction of Tabriz. *International Journal of Environmental Research*, 1, 35-41

Mesev, V. (1998). The use of census data in urban image classification. *Photogrammetric Engineering & Remote Sensing*, 64: 431–438.

Mitchell, A., Rosenqvist, A., Mora, B. (2017). Current remote sensing approaches to monitoring forest degradation in support of countries measurement, reporting and verification (MRV) systems for REDD+. *Carbon Balance and Management*. DOI 10.1186/s13021-017-0078-9

Mokarram, M., Bolooorani, A. D., Hojati M. (2016). Relatioship between land cover and vegetation indices. Case study: Eghlid plain, Fars Province. Iran. *European Journal of Geography*, 7(2), 48-60.

Myint, S. W. (2001). A robust texture analysis and classification approach for urban land-use and land-cover feature discrimination, *Geocarto International*, 16:27–38.

Nyamgeroh, B. B., Groen, T. A., Weir, M. J. C., Dimov, P., Zlatanov, T. (2018). Detection of forest canopy gaps from very high-resolution aerial images. *Ecological Indicators*, 95(1), 629-636, doi.org/10.1016/j.ecolind.2018.08.011

Oosterom, P., Van Stoter, J. E., Quak, C. W., & Zlatanova, S. (2002). The Balance Between Geometry and Topology. In: Advances in Spatial Data Handling, 10th International Symposium on Spatial Data Handling, Dianne Richardson and Peter van Oosterom (eds.), ISBN 3-540-43802-5, *Springer-Verlag*, Berlinpages 209-224.

Paegelow, M., Olmedo, C., Teresa M. (2008). Modelling environmental dynamics. *Advances in Geomatic Solutions*, *Springer*, ISBN 978-3-540-68489-3

Prevedello, J. A., Winck, G. R., Marcelo, M., Weber, M. M., Nichols, E., Sinervo, B. (2019). Impacts of forestation and deforestation on local temperature across the globe. *PLOS One*, doi.org/10.1371/journal.pone.0213368

Qin, Y., Xiao, X., Dong, J., Zhou, Y., Wang, J., Doughty, R. B., Chen, Y., Zou, Z,. Moore, B. (2017). Annual dynamics of forest areas in south america during 2007–2010 at 50-m spatial resolution. *Remote Sensing of Environment*, 201, 73–87

Qin, Y., Xiao, X., Wang, J., Dong, J., Ewing, K., Hoagland, B., Hough, D., Fagin, T., Zou, Z., Geissler, G. (2016). Mapping annual forest cover in sub-humid and semi-arid regions through analysis of landsat and palsar imagery. *Remote Sensing*, 8, 933

Rosa, I., Gabriel, C., Carreiras, J. (2017). Spatial and temporal dimensions of landscape fragmentation across the Brazilian Amazon. *Regional Environmental Change*, 17(6), 1687-1699.

Shaban, M. A., Dikshit, O. (2001). Improvement of classification in urban areas by the use of textural features: The case study of Lucknow city, Uttar Pradesh, *International Journal of Remote Sensing*, 22, 565–593.

Se Bin, K., Alounsavath, O. (2016). Factors influencing the increase of forest cover in Luang Prabang Province, Northern Laos. *Forest Science and Technology*, 12(2), 98-103, doi.org/10.1080/21580103.2015.1075437

Singha, K., Sahariah, D., Saikia, A. (2019). Shrinking forest and contested frontiers: A case of changing human-forest interface along the protected areas of Nafaon district, Assam, India. *European Journal of Geography*, 10 (3), 120-136

Stuckens, J., Coppin, P. R., Bauer, M. E. (2000). Integrating contextual information with per-pixel classification for improved land cover classification. *Remote Sensing of Environment*, 71:282–296

Tejada, G., Bastos Görgens, E., Del Bon Espírito-Santo, F., Roberta Zecchini Cantinho, R., Ometto, J-P. (2019). Evaluating spatial coverage of data on the aboveground biomass in undisturbed forests in the Brazilian Amazon. *Carbon Balance and Management*, 14(11): https://doi.org/10.1186/s13021-019-0126-8

UN (United Nations). (2019). Mainstreaming of the three dimensions of sustainable development throughout the United Nations system. Technical Report. A/74/72–E/2019/13

Vidal-Macua, J. J., Ninyerola, M., Zabala, A., Domingo-Marimon, C., Pons, X. (2017). Factors affecting forest dynamics in the Iberian Peninsula from 1987 to 2012. The role of topography and drought. *Forest and Ecology Management*, 406, 290-306, doi.org/10.1016/j.foreco.2017.10.011

Weng, Q. (2001). A remote sensing-GIS evaluation of urban expansion and its impacts on temperature in the Zhujang Delta, China. *International Journal of Remote Sensing*, 22(10), 1999–2014

Wundler, M. A., Franklin, S. E. (2003). Remote Sensing of Forest Environments Concepts and Case Studies. *Springer*, ISBN: 978-1-4613-5014-9, doi.org/10.1007/978-1-4615-0306-4

Zlatanova, S., Tijssen, T. P. M., van Oosterom, P. J. M., Quak, C. W. (2003). Research on usability of Oracle Spatial within the RWS organization. *AGI-GAG-2003-21*, ISBN: 90-77029-07-9. (Available at: http://www.gdmc.nl/publications/reports/GISt21.pdf)

Zormpas, K., Vasilakos, C., Athanasis, N., Soulakelis, N., Kalabokidis, K. (2017). Dead fuel moisture content estimation using remote sensing. *European Journal of Geography*, 8(5), 17-32.