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Land Cover Changes in Evrytania Prefecture (Greece)

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Abstract: To record land cover changes over time, geographic information systems software was used for selecting and studying sampling surfaces in ortho-aerial photographs. In particular, ortho-aerial photographs of the years 1945 and 2015 were used to record changes in land cover. A total of 103 test surfaces were obtained, which consisted of 25 cells each. The results showed that the area and density of forest cover have increased significantly during the study period. Changes in land cover, and in particular forest cover, are mainly attributed to (a) the gradual decline of the population, and therefore to the decline in man-made interventions such as crops, nomadic herd grazing, and logging, and to (b) natural species competition. Moreover, the effect of climatic change and the reduction in human presence on fir treelines was examined. Based on the results, no clear evidence about treeline changes was found. Also, the effect of soil and topographic factors on land cover changes, as well as the prediction capability of land cover changes, were examined using an artificial neural network. Promising results came out that could provide substantial explanations for land cover changes and quantify the effect of environmental factors on vegetation evolution.

Keywords: land cover changes; climate change; geographic information systems; remote sensing; neural networks

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1. Introduction

The factors that affect the vegetation composition of a certain area usually act continuously and affect the changes in its evolution. In addition to the effect of biophysical factors, the land cover changes also reflect the impact of humans on the environment [1]. The investigation of land cover changes is a key parameter in the science of Ecology and land management [2]. The inventory of land cover changes can provide important information about the ecology and past economic and social life of local societies. Moreover, it provides information about the dynamics of vegetation species and the effect of various environmental factors on land cover evolution. This information leads to more accurate assessments and safer decisions concerning the rational and sustainable management of natural resources [3].

The Mediterranean basin is a region with significant changes over time [4] because it is an area in which humans have been active for thousands of years. Forest ecosystems are a major environmental component in Greece in terms of their area and ecological significance, especially in the study area, and for this reason forest cover changes are analyzed in this study to a greater extent than other cover types that are less extensive. During the last few decades, there have been indications that forest area as well as forest density have been increasing in the mountainous zone of Greece. These indications are also confirmed by the gradual posting and updating of forest maps, although there are a limited number of publications that quantify these types of changes over time [5,6]. Changes in socio-economic conditions affect the intensity with which humans intervene in forest ecosystems, as well as the ways in which they intervene. These ways constitute a fact that is significant for the natural succession of forest vegetation [5]. The study of the socio-economic changes that led to the evolution of traditional methods of land management, as well as the study of the impact of environmental factors on ecosystems combined with photointerpretation data concerning land cover changes, could lead to useful findings about the driving forces that affect land cover changes.

Forest species in the treeline are sensitive to species antagonism and environmental conditions, such as climate and human intervention, usually in the form of grazing. Due to the ecological validity of species in the treeline concerning the forest ecosystem's status and its sensitivity to environmental and managerial changes, much research has been carried out in recent years in this field [7–14]. Species composition and land cover changes, especially forest land cover changes, are related to environmental risks such as wildfires and floods. In this notion, the knowledge of future land cover changes is useful for scientific, managerial, and policy decision-making purposes.

The purpose of this research is (a) to investigate land cover changes over time for the period between the years of 1945 and 2015, (b) to assess the impact of environmental factors on land cover changes in the territory of Evrytania and find out if it is possible to predict these changes using neural networks, and (c) to find out if there are any treeline changes in the upper forest limits as a result of the reduction in human intervention and climate change.

To carry out this research, geographic information systems, remote sensing, and artificial neural networks were used to investigate land cover changes and the impact of environmental and anthropogenic factors on land cover changes over time.

2. Materials and Methods

2.1. Study Area

Evrytania prefecture is located in the center of the mainland of Greece and is part of the southern Pindos massif with an area of about 1868 km^2 (Figure 1). The climate of the region is characterized as rough, with long heavy winters and short summers with sporadic rain [15]. The dry and hot season lasts for about 3 months, from the middle of June up to the middle of September, and is characterized by low intensity in terms of the size and frequency of high temperatures and the duration of droughts. From a geotectonic point of view, the study area belongs to the Olonos–Pindos zone. It is characterized by pelagic phase sediments and, in places, by clastic materials derived from adjacent submarine ridges. The main geological formations of the area are flysch, which occupies the largest part of the study area, limestone, radiolarites, chert, and sandstone [16]. As far as the forest management in the study area, the high forests are under conventional management by the forest service, mainly for wood production and secondarily for other forest services such as grazing and recreation. In terms of vegetation, the most common vegetation types [17] are the following:

1. At low altitudes, evergreen broadleaf shrublands, with a predominance of kermes oak;
2. At medium and high altitudes, a few deciduous broadleaf forests (with species such as *Quercus frainetto*, *Castanea sativa*) but mainly fir forests (*Abies borisii-regis*, *A. cephalonica*);
3. At very high altitudes, subalpine grasslands and chasmophytic vegetation on calcareous rocky slopes and screes.

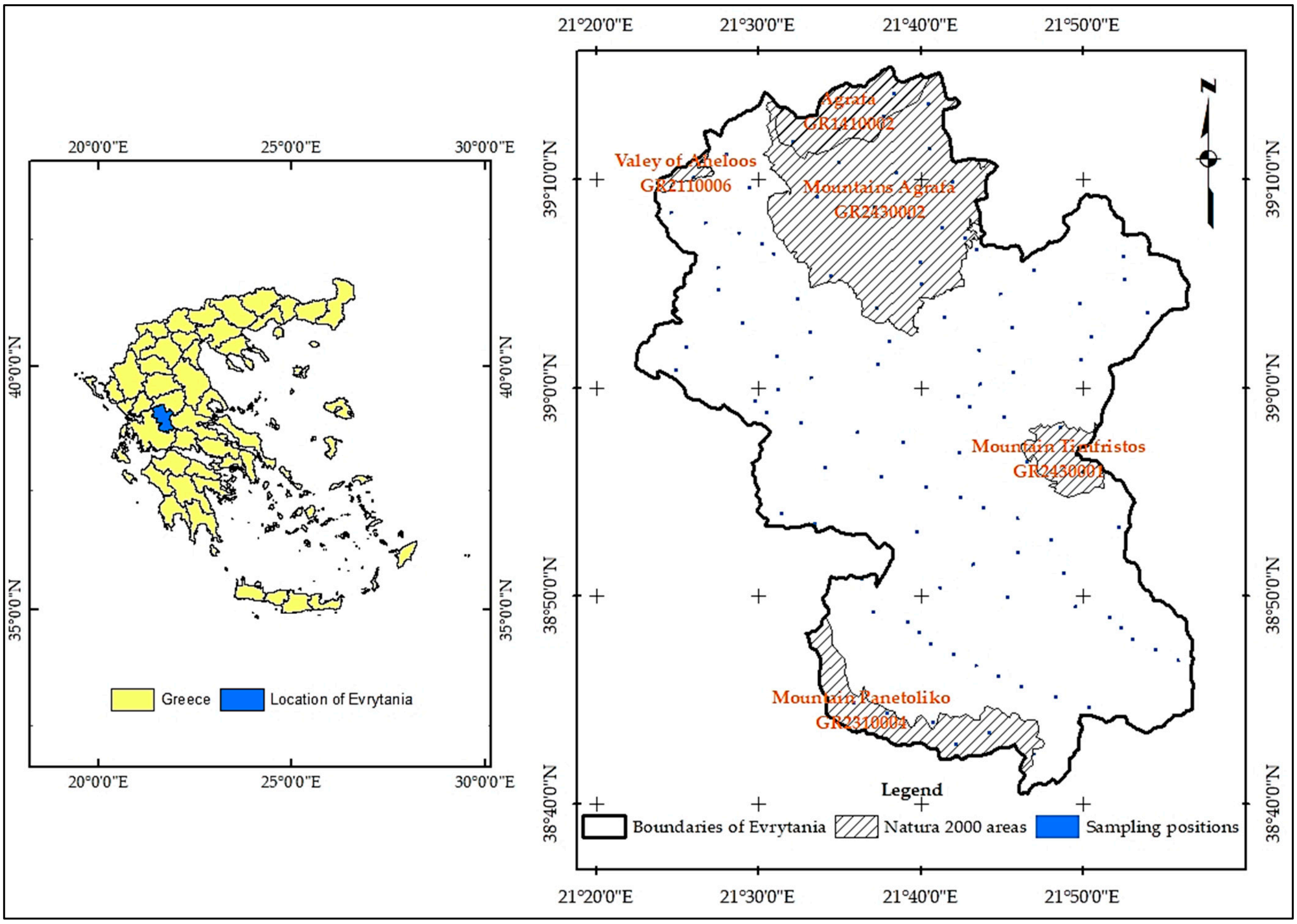


Figure 1. Orientation map of the study area.

In Evrytania, the following protected areas have been designated (Figure 1) within the framework of the Natura 2000 network in accordance with Directive 92/43/EEC: the Agrafa mountains (GR1410002), Mount Timfristos (GR 2430001), and three more that also partially fall in neighboring prefectures, namely Agrafa (GR2430002), Mount Panetoliko (GR 2310004), and the Aheloos valley (GR 2110006) [18].

According to the Hellenic Statistical Authority, the population of Evrytania in 1940 was 53,780 inhabitants, but according to the 2011 census, the population declined to 29.080 inhabitants [19,20]. The cultivable agricultural land according to the 1950 census amounted to 17,361 hectares. Livestock during the 1950 census was 29,532 goats and 29,036 sheep. In the year 2015, according to data from the Department of Veterinary Medicine of the Region of Evrytania, 34,011 goats and 43,011 sheep were registered. Nomadic animal husbandry was gradually reduced and is nowadays applied by about 35% of livestock breeders [21].

2.2. Methodology

This research work is based on the available orthophoto maps of Evrytania prefecture from the years 1945 (with a pixel size of 1 m and produced by the Greek Geographical Military Service) and 2015 (with a cell size of 0.25 m and produced the by Greek Land Registry). Many other related studies have used aerial photographs to examine land cover changes through various periods [5,8–10,22–24]. Based on the above data, it was possible to study the land cover changes over a period of 70 years.

Thematic digital maps were also used to aid photointerpretation and/or analysis of land cover changes in the following areas: (a) the boundaries of Evrytania prefecture, (b) the elevation curves, (c) the streams, and (d) the urban areas.

To investigate further the influence of environmental factors on the succession of land cover, especially vegetation cover, the following environmental factors that affect land use and land cover were derived from digital soil maps [25,26] provided by the Forest Maps, Cadaster, Inventory, and Thematic Support for Public Rights of the Ministry of Environment and Energy.

1. Ecological areas: Areas that represent the four main vegetation zones that occur successively across Greece from sea level to upper altitudes, specifically (a) evergreen broadleaf shrublands with an altitudinal distribution range of 0–600 m, (b) deciduous broadleaf oak forests with a range of 300–1300 m, (c) fir forests with a range of 700–1600 m, and (d) subalpine zones with of an altitude over 1600 m.
2. Landforms: Areas determined by petrography (parent material of the soil) and physiography. Landforms are characteristic units of the earth's surface with a specific origin of material and a distinct shape. In the classification of lands, landforms are distinguished according to their geometric shape (physiography), which is linked to the petrography of the area. The 20 categories of petrography or soil parent material have been distinguished in total for the entire country. In relation to their physiography, the landforms are distinguished into the following 10 classes: flat surfaces, steep peaks, steep slopes, rounded peaks and ridges, the upper parts of slopes, the middle parts of slopes, elevations, the lower parts of slopes, open valleys, and closed valleys.
3. Soil depth: For the classification of soil depth, three classes were used:
    - Rocky soil (<5 cm depth);
    - Shallow soil (5–30 cm depth);
    - Deep soil (>30 cm depth).

Combinations of the above classes were used, creating a total of 9 soil depth classes to describe the diversity of soil depth in larger areas. These combinations [18] are as follows:

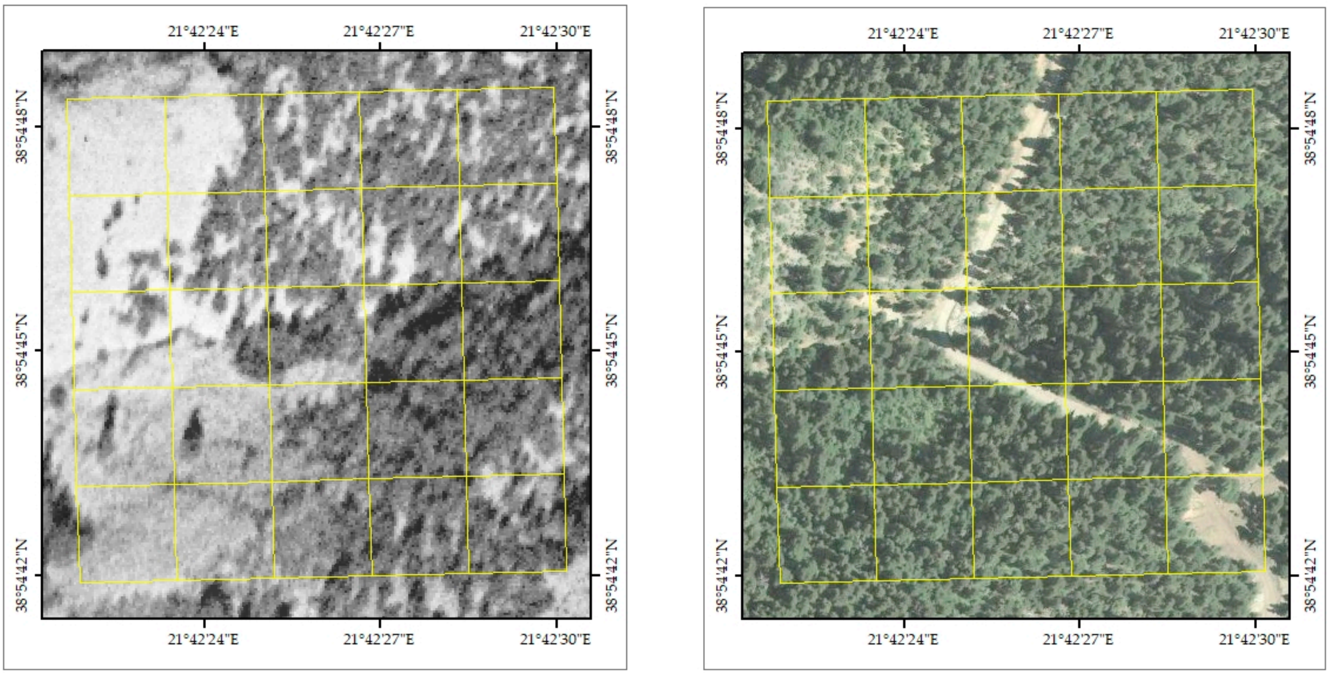
- "Deep";
- "Deep and shallow";
- "Deep and rocky";
- "Shallow and deep";
- "Shallow";
- "Shallow and rocky";
- "Rocky and deep";
- "Rocky and shallow";
- "Rocky".

4. Ground slope: This parameter was classified into five classes: 0%–6%, 6%–18%, 18%–40%, 40%–70%, and >70%. However, for the characterization of the slope of the ground surface of the cartographic units, the three gentlest classes of slopes were taken as one (0%–40%) and characterized as slight. Slopes from 40%–70% were characterized as moderate and those above 70% as steep. The slope classes were combined to describe larger areas, creating a total of 9 slope classes.
5. Exposure (to the horizon): Exposure was classified into 4 classes: North, South, Various, and Flat positions. The combinations of the above four classes lead to 12 classes of exposure.

For the coding of land cover and forest vegetation density, we used the encoding applied by the forest administration of Greece (National Special Secretariat for Forests). Specifically, the following land cover types were identified in the study area: abandoned agricultural fields (Ab. agr. fields), agricultural fields (Agr. fields), bare land (Bare), bushes, fir forest (Fir), meadows, lakes, other, broadleaved species forest (Broadleaved), and urban. In the following, these names refer to land use types.

The recording of land cover changes was carried out using sample areas (Figures 1 and 2) selected through the systematic sampling process in three (3) phases:

(a) In the first phase, a grid was created within the study area with cells measuring 1000 × 1000 m, and, with systematic sampling, 111 cells were then selected from this canvas.
(b) In the second phase, a new grid of 200 × 200 m was created. For each 1000 × 1000 m cell selected in the first phase, the 200 × 200 m cell located in its center was selected as a sampling surface. The sampling areas that were partially outside the boundaries of Evrytania prefecture were rejected from the study. Finally, 103 sampling areas with dimensions of 200 × 200 m were obtained.
(c) In the third phase, the 200 × 200 m sampling areas were divided into smaller cells with dimensions of 40 × 40 m, which resulted in a total of 2575 cells (Figure 2).



(**a**) (**b**)

Figure 2. Instances of a sampling area with corresponding orthophotographs for (**a**) 1945 and (**b**) 2015.

Problems from the presence of intensive shadows that hide a part of the land cover, cloudy locations, and problems from the quality of orthophotos led us to remove 71 cells because it was impossible to come to a reliable photointerpretation. Of the above 71 cells, 29 are related to the year 2015 and 47 cells to the year 1945, while there were 5 common cells for both 1945 and 2015. After discarding the cells in which it was not possible to identify land cover, 2504 cells remained for analysis of the results.

The land cover type was determined by direct observation of ortho-aerial photographs and was complemented, in some of the sampling areas, by on-site observation for assurance of classification accuracy. Assignment of cover type per cell was based on the following classification:

(a) For the presence of forest in a cell, we applied the classification considering the most significant coverage with the following descending order: fir, broadleaved, and bushes. The same order applied in the case of the coexistence of forest and non-forest coverage types in a cell. Following the above order of significance, if the land coverage of the more significant vegetation was more than 10% of a cell then it was assigned the more significant type.
(b) For the non-forest coverage types, the greater coverage method was used to classify a cell.

For estimation of the percentage of forest cover type per cell (density), the following procedure was applied: A grid with 8 × 8 m dimensions was created; thus, each 40 × 40 m cell was assigned 25 points (points in the center of the 8 × 8 m cells). The type of forest type cover was calculated next by counting the points that coincided with only the forest type that was determined in the classification stage [5]. Coverage was codified according to the administration of Greece (National Special Secretariat for Forests) as follows: (a) "Open" coverage (10%–40%) code 1, (b) "Almost dense" coverage (40%–70%) code 2, (c) "Dense" (70%–100%) code 3.

To examine the capability of future prediction of land cover in the study area, the artificial neural network of IBM's SPSS 25 software was employed. For reasons of completeness, a short description of neural networks is presented in this study, as well as the factors that were used for the prediction of land cover in the year 2015.

Artificial neural networks, or simply neural networks, are computer programs inspired by biological neural networks. All living organisms of the animal kingdom, from the simplest to humans, have a nervous system that is responsible for multiple specialized processes, such as contact with the outside world, learning, memory, etc. The nervous system of organisms consists of several different neural networks which are dedicated to specialized processes. Each neural network consists of many units, called neurons. The neuron is the smallest independent unit of the network. Neurons are constantly processing information by receiving and sending electrical signals to other neurons.

An artificial neural network (ANN) consists of a set of artificial neurons or nodes, with each one connected to other nodes. The way the nodes are interconnected determines the topology/architecture of the ANN. One of the most common ANNs is the Multi-Layer Perceptron (MLP) feedforward neural network. An MLP neural network consists of at least three layers [27] (see Figure 3):

- The input layer: The input layer consists of several nodes and is responsible for the input of the initial data into the system for further processing by the first hidden layer.
- The hidden layer(s): An ANN contains one or more hidden layers. The first hidden layer is connected with the input layer and the last is connected with the output layer.
- The output layer: Each MLP contains one output layer consisting of one or more nodes. The output layer receives as input the outputs of the last hidden layer. The output layer stores the result of the computational procedure of the hidden layers.

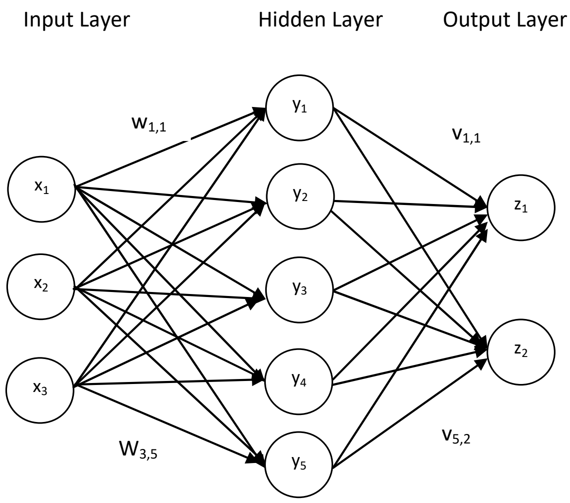


Figure 3. An example of an MLP neural network.

$$S_j = b_i + \sum_{i=1}^{3} x_i w_{j,i} \ : j = 1, .., 5$$
$$y_j = f_1(S_j)$$
$$S_k = b_k + \sum_{j=1}^{5} y_j v_{j,k} \ : \ k = 1, 2$$
$$z_k = f_2(S_k)$$

where: f_1 and f_2 are the corresponding activation functions. The role of the corresponding activation function is to calculate the value that a specific node will receive as input.

b_i and b_k represent the corresponding bias, and

$w_{j,i}, v_{j,k}$ the corresponding weights.

The training of a neural network is performed through a training algorithm that uses a set of training data. A set of training data for an ANN consists of a set of vectors of the form [$x_{1,p}$, $x_{2,p}$, … $x_{n,p}$],y_p] where $x_{1,p}$, $x_{2,p}$, … $x_{n,p}$ are the input data corresponding to the pattern y_p where p = 1 … m (number of different patterns).

In this study, the training set of the ANN contains 9 fields (Table 1). The first 8 fields are the input values, and the 9th concerns the pattern (the output).

Table 1. The structure of the dataset.

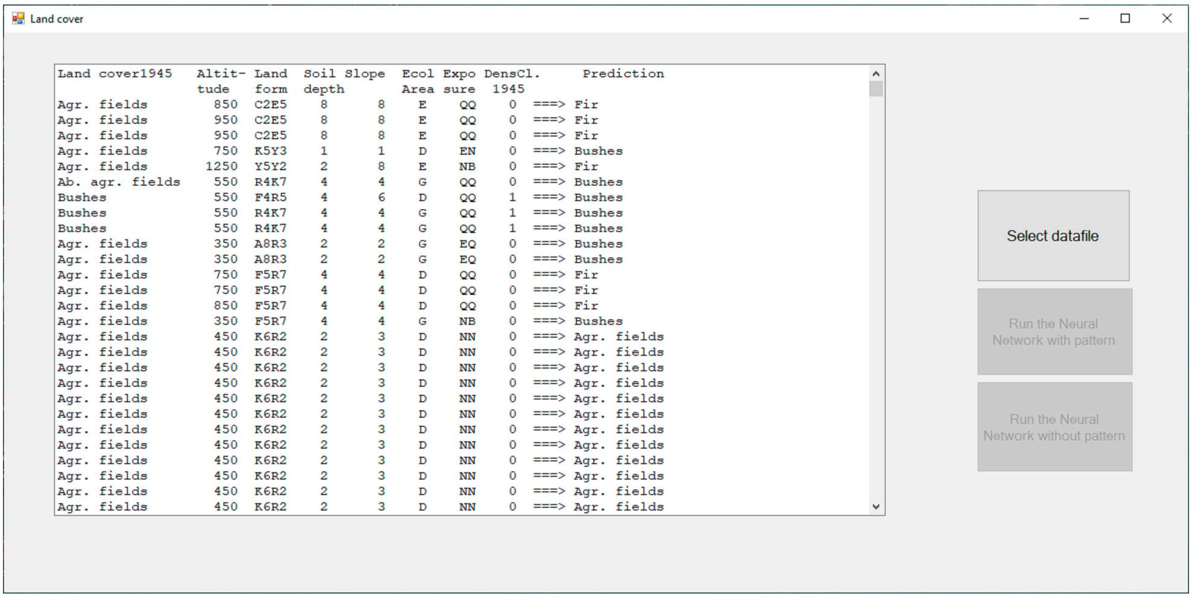
Numbering	Field
1	Land cover in 1945
2	Altitude
3	Landform
4	Soil depth
5	Slope
6	Ecological area
7	Exposure
8	Density class in 1945
9	Land cover in 2015

Because the dataset contained nominal values, the actual number of nodes for the input and output layers was as presented in the table below (Table 2).

Table 2. Structure of the ANN.

Layers	Number of Nodes	Activation Function
Input layer	138	
Hidden layer	10	Hyperbolic tangent
Output layer	9	Softmax

The developed artificial neural network has two running modes. The first is used mainly for evaluation purposes when the pattern (the land cover) is known. The second is used to make predictions of land cover in the future (Figure 4). The results of the ANN run are displayed on the screen and are also stored in a storage device as a text file.



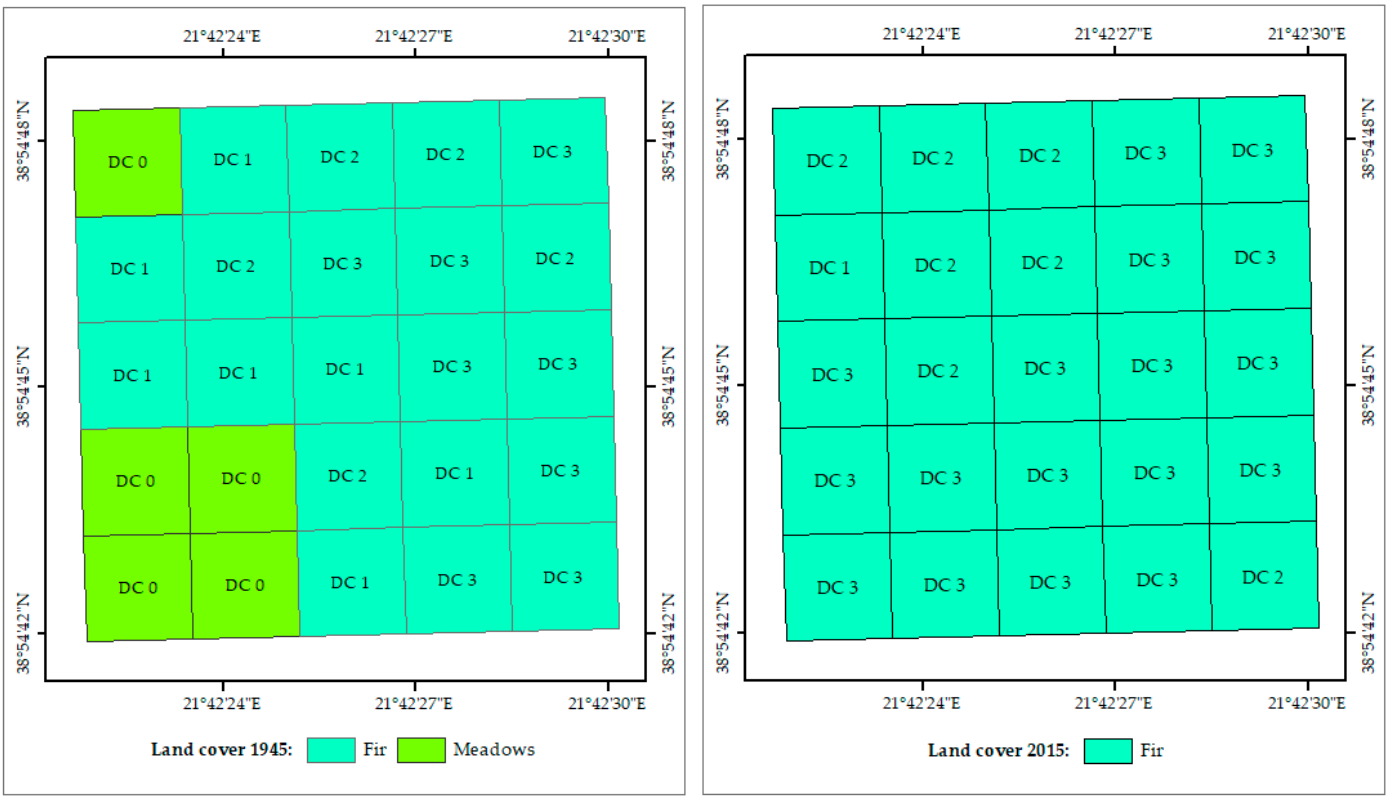
Land cover1945	Altit- tude	Land form	Soil depth	Slope	Ecol Area	Expo sure	DensCl. 1945		Prediction
Agr. fields	850	C2E5	8	8	E	QQ	0	===>	Fir
Agr. fields	950	C2E5	8	8	E	QQ	0	===>	Fir
Agr. fields	950	C2E5	8	8	E	QQ	0	===>	Fir
Agr. fields	750	K5Y3	1	1	D	EN	0	===>	Bushes
Agr. fields	1250	Y5Y2	2	8	E	NB	0	===>	Fir
Ab. agr. fields	550	R4K7	4	4	G	QQ	0	===>	Bushes
Bushes	550	F4R5	4	6	D	QQ	1	===>	Bushes
Bushes	550	R4K7	4	4	G	QQ	1	===>	Bushes
Bushes	550	R4K7	4	4	G	QQ	1	===>	Bushes
Agr. fields	350	A8R3	2	2	G	EQ	0	===>	Bushes
Agr. fields	350	A8R3	2	2	G	EQ	0	===>	Bushes
Agr. fields	750	F5R7	4	4	D	QQ	0	===>	Fir
Agr. fields	750	F5R7	4	4	D	QQ	0	===>	Fir
Agr. fields	850	F5R7	4	4	D	QQ	0	===>	Fir
Agr. fields	350	F5R7	4	4	G	NB	0	===>	Bushes
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields
Agr. fields	450	K6R2	2	3	D	NN	0	===>	Agr. fields

Figure 4. The ANN making predictions of future land cover.

3. Results

3.1. Total Land Cover Changes

The classification results of the sampling area depicted in Figure 2 are given in Figure 5 to present the classification methodology that applied to all sampling areas. In the next section, the results of the classification are presented in the form of tables and charts.



(**a**) (**b**)

Figure 5. Results of the classification of orthophotographs from (**a**) 1945 and (**b**) 2015 ("DC" stands for density class).

The study area is mostly covered by forest and secondarily by meadows and agricultural fields (Table 3). The general trend is an increase in fir and broadleaved forests. On the contrary, there is a decrease in agricultural cultivation, bushy vegetation, and meadows (Table 3). More specifically, the changes in the land cover present an increased amount of land covered by fir (increase of 13.70%) and broadleaved species (increase of 6.43%), as well as a reduction in bushy areas (8.43% reduction), in meadows areas (4.33% reduction), and in agricultural fields (9.39% reduction).

The increase in forest cover is due to the greatly reduced human population and the consequent reduction in the number of nomadic animals grazing [21] and abandonment of agricultural fields and meadows. The expansion of forest vegetation and the shaping of its composition is a combined result of reduced human activity and natural competition between species, as well the effect of the remaining livestock grazing, agricultural, and other activities recorded in the study area.

The domination of fir is undisputed and is carried out at the expense, mainly, of bushlands and abandoned lands (agricultural and meadows). Bushlands have a wide coverage that is decreasing, which can be attributed to their conversion to fir forest and the fact that a small percentage was covered by water due to the creation of the artificial lake of Kremasta. Another important finding concerns meadows, which in 2015 occupied 7.34% of land while in the year 1945 occupied 11.67%. This is an interesting change since it is due to a reduction in the number of animal herds grazing and the occupation of these areas by tall forests or bushes.

Table 3. Land cover changes in Evrytania prefecture during the study period.

Land Cover	Ab. Agr. Fields	Agr. Fields	Bare	Broadleaved	Bushes	Fir	Lake	Meadows	Other	Urban	Total 1945
Ab. Agr. fields	0.04	0.00	0.00	0.32	0.12	0.44	0.68	0.00	0.00	0.00	1.60
Agr. fields	0.16	0.94	0.04	1.52	1.80	4.23	0.40	0.24	0.00	1.00	10.33
Bare	0.00	0.00	1.96	0.24	0.44	0.16	0.64	0.12	0.08	0.00	3.64
Broadleaved	0.00	0.00	0.00	3.55	0.03	0.15	0.14	0.00	0.00	0.00	3.87
Bushes	0.08	0.00	0.40	3.83	19.21	7.23	1.40	0.68	0.00	0.00	32.83
Fir	0.00	0.00	0.16	0.20	1.08	33.91	0.00	0.15	0.00	0.00	35.50
Meadows	0.00	0.00	0.16	0.56	1.72	3.08	0.00	6.15	0.00	0.00	11.67
Other	0.00	0.00	0.00	0.08	0.00	0.00	0.48	0.00	0.00	0.00	0.56
Total 2015	0.28	0.94	2.72	10.30	24.40	49.20	3.74	7.34	0.08	1.00	100.00

3.2. Changes in Cell Vegetation Density

In the following section, the changes in forest coverage density are examined. The comparison is based on the total number of sampling cells. The percentage of forest coverage in the three density classes (sparse, 10%–40%; medium, 40%–70%; high density, 70%–100%) is recorded in Table 4. The decrease in bush coverage is significant in the sparse density category and the moderate density category. This decrease is related to the corresponding increase in the presence of fir, which tends to occupy thin bushy areas and meadows that neighbor fir forests. These data show that fir and broadleaf tree species present an increase in all density classes of forest cover. In contrast, land covered by bushes decreased in the sparse and medium forest cover density categories, though an increase was observed in the dense forest cover class where it was difficult for other species to invade.

Table 4. Forest land cover changes (%) by coverage density class for the period of 1945 to 2015.

Land Cover Type	Land Cover Density Class	Year 2015	Year 1945	Change from 1945 to 2015
Fir forest	1	22.04	16.97	5.07
	2	19.77	12.46	7.31
	3	7.39	6.07	1.32
Subtotal		49.20	35.50	13.70
Broadleaf forest	1	5.39	2.55	2.84
	2	3.71	1.20	2.51
	3	1.20	0.12	1.08
Subtotal		10.30	3.87	6.43
Bushes	1	6.03	11.98	−5,95
	2	6.31	10.91	−4.60
	3	12.06	9.94	2.12
Subtotal		24.40	32.83	−8.43

3.3. Land Cover Changes inside Protected Areas

Fir forests had a particular increase throughout Evrytania prefecture, and this increase was also significant (12.44%) within the protected areas of the Natura 2000 network; the increase outside these protected areas was 14.93% (Figure 6). The justification for these differences in fir land cover inside and outside protected areas can be given by the following:

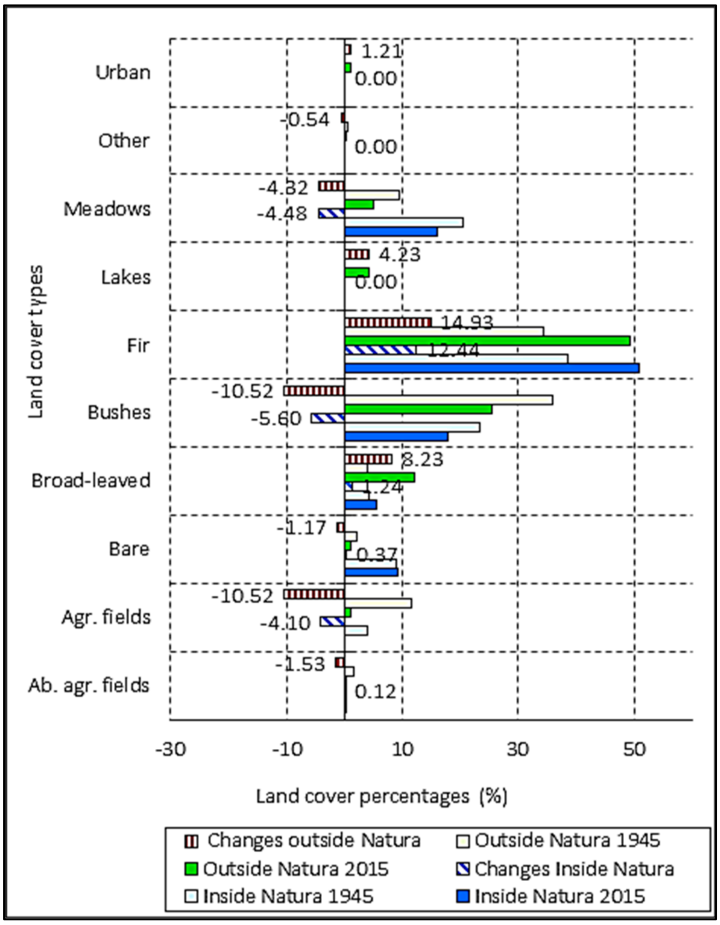


Figure 6. Land cover changes inside and outside Natura 2000 areas.

(a) The initial land cover of fir outside the network was less than in the Natura 2000 network areas; therefore, there was a larger area for it to spread there.
(b) A greater percentage of cultivated land inside the non-protected areas was abandoned, and then the abandoned land was mostly covered with fir. Fir was able to expand at the expense of bushlands (−10.52% vs. −5.60%).

Broadleaf coverage increased by 1.24% and 8.23% in network and non-network areas, respectively. The interpretation of changes in the land cover of broadleaved species is like that of fir.

3.4. Land Cover Changes per Altitude Zone

At all altitudes, the ground cover of fir increased during the study period. The greatest increase is observed at altitudes between 850 and 1450 m, which is the most favorable altitude zone in the area in terms of fir distribution (Figure 7). A significant increase in the ground cover of fir also occurred at an altitude of 550 m, which was mainly occupied by bushes and agricultural fields. The spread of fir in general, as shown by the data, took place mainly at the expense of bushes though also at the expense of meadows and agricultural land. Bushes have more than 50% coverage at altitudes of 350 to 650 m. The largest percentage (53.57%) was recorded in the 550 m zone. This is to be expected as they are the main vegetation of mainly semi-mountainous areas. It is characteristic that bush coverage was higher in 1945 than in 2015, as grazing did not allow for the growth of forest trees.

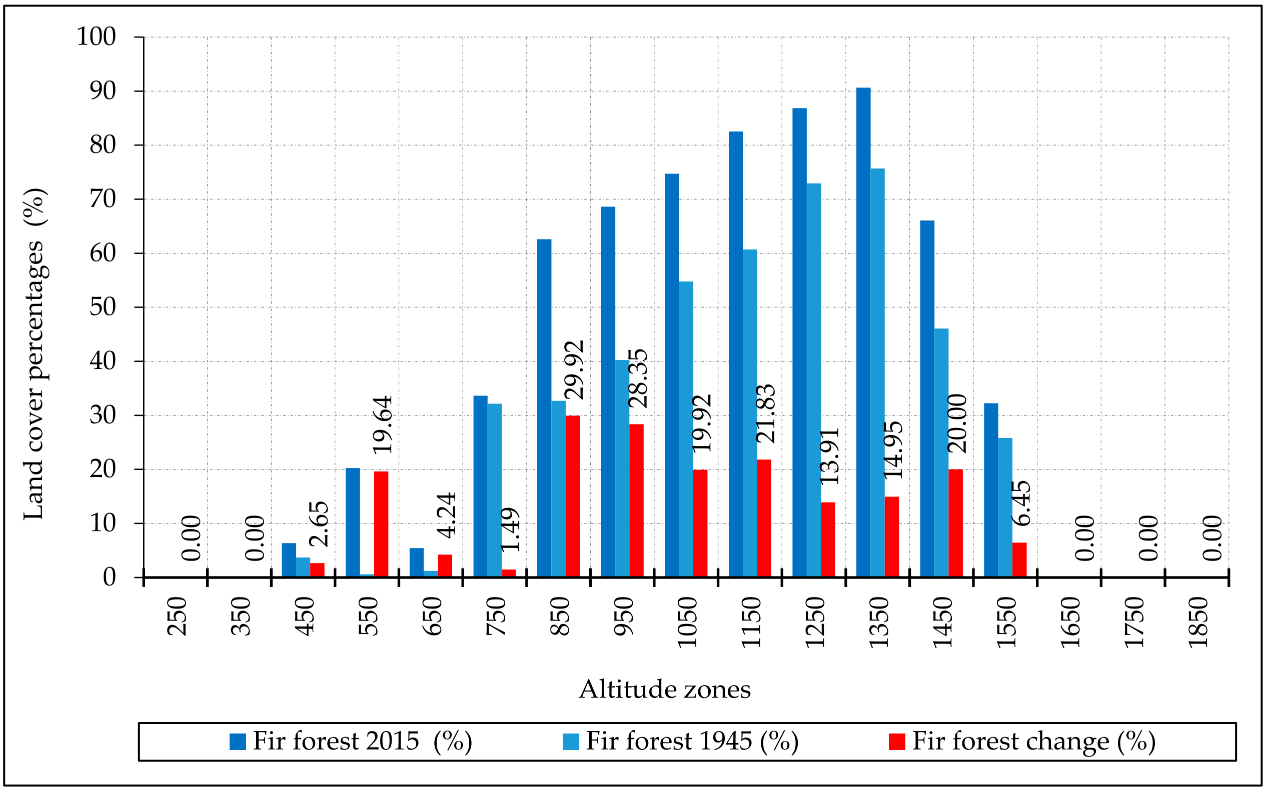


Figure 7. Fir forest changes in percentages per altitude zone.

The growth of broadleaf vegetation is located at altitudes from 350 m, and their presence is recorded up to an altitude of 1250 m. The altitude zone of 850 m is the transitional zone of connectivity between broadleaves and conifers, and in recent decades the expansion of fir towards broadleaf forests has taken place in these zones, leading to the creation of mixed forestsThe recorded changes in land cover are mainly due to the reduction of human activities, especially the reduction of nomadic grazing of livestock herds. Grassland vegetation is mainly located at higher altitudes (from 1450 m and above) as it part of the meadow areas of the subalpine zone. The interpretation of these changes also considers the general bioclimatic conditions of the area, which favor grassland vegetation compared to other more demanding forms of vegetation. The crops were being applied in extended areas in 1945, especially in low-altitude zones, while up to 2015 gradually their extent was significantly reduced. A significant reduction in crops occurred for almost all altitude zones due to difficult cultivation conditions and population migration.

3.5. Prediction of Land Cover Changes

To investigate the ability to predict future land cover changes and the impact of environmental factors on vegetation succession through time we employed the neural network multi-layer perceptron component of IBM's SPSS software to analyze the data.

In Figure 8, the impact of each factor is given as both absolute and normalized importance. From this analysis, it is shown that the most important factor is the initial land cover type, while the least important factor is shown to be land cover percentage. Between the two of them, the topographic and ecological factors are placed.

Moreover, the analysis of land cover changes and vegetation succession obtained via the neural network provided a satisfactory explanation of the majority of the variability in vegetation succession in the study area (Table 1). Specifically, predictions for broadleaved forests, bushes, and fir forests were correct 78.1%, 85.9%, and 93.7% of the time with the training mode and 76.0%, 81.3%, and 94.5% of the time with the testing mode. The overall prediction capacity of the analysis is 88.9% for the training mode and 86.2% for the testing mode (Table 5). In this analysis, the impact of human intervention was not directly taken into account; thus, the accumulated impact on land cover changes is due to environmental factors, including the initial cover type, as well as the gradual reduction in human interventions. The results of this analysis provide an explanation of more than 85% of the total land cover changes, with the rest of the variability attributable to other factors such as climate change, which was not considered in this study.

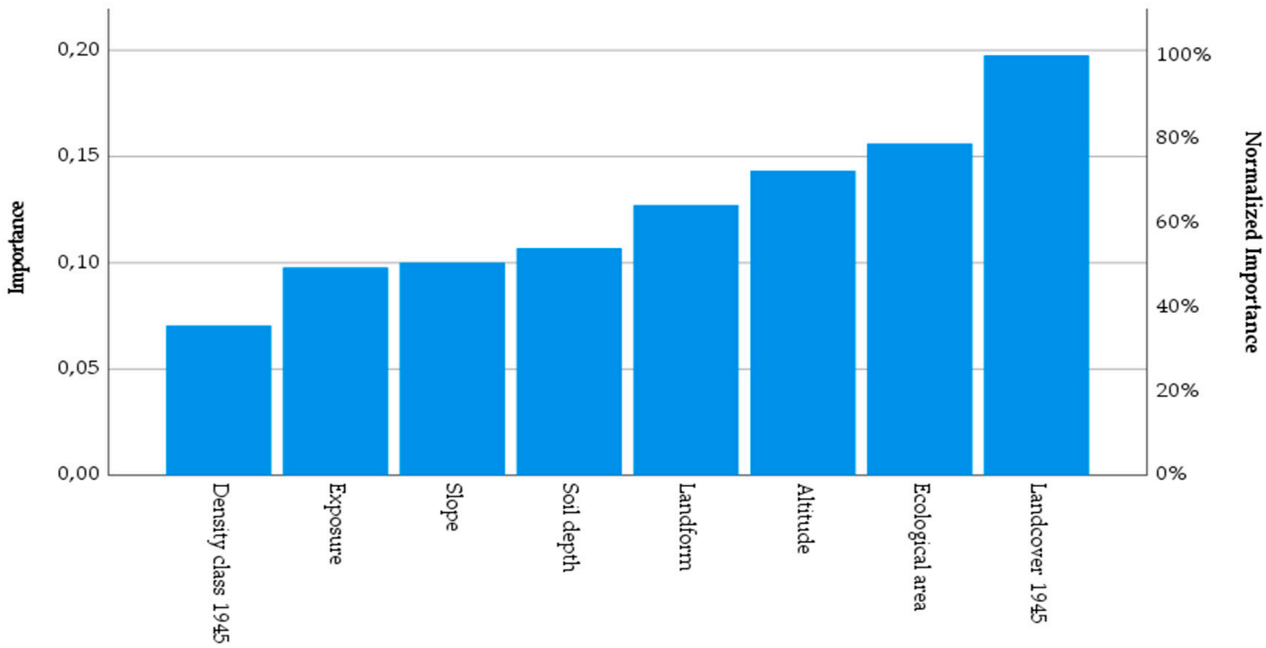


Figure 8. Impact of initial land cover and environmental factors on future land cover changes.

Table 5. Prediction accuracy of the neural network during the training and testing phases.

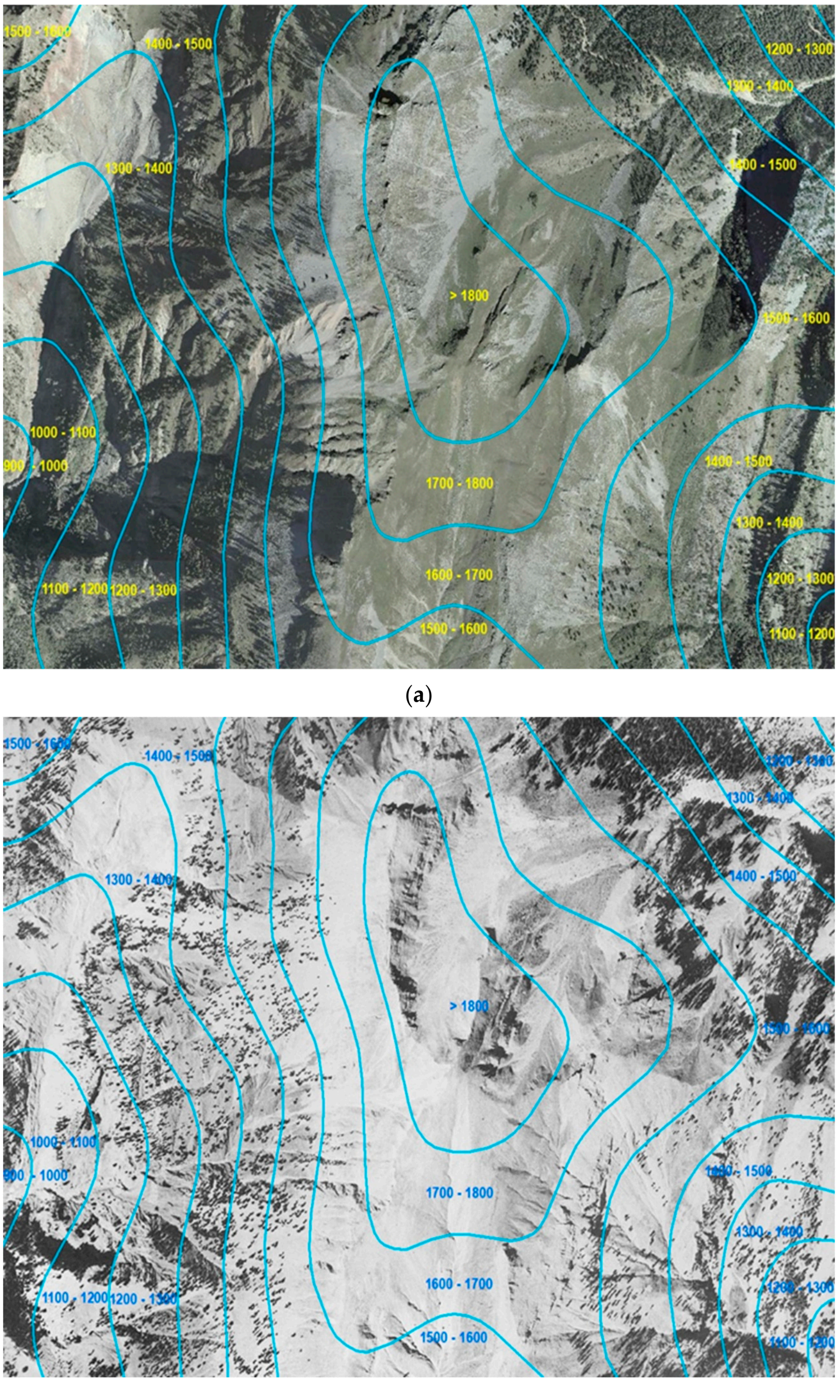
Sample	Observed	Predicted									
		Ab. agr. Fields	Agr. Fields	Bare	Broadleaved	Bushes	Fir	Meadows	Other	Urban	Percent Correct
Training	Ab. agr. fields	2	0	0	0	1	4	0	0	0	28.6%
	Agr. fields	0	17	0	0	1	0	0	0	0	94.4%
	Bare	0	0	54	1	2	5	3	0	0	83.1%
	Broadleaved	2	1	1	196	30	21	0	0	0	78.1%
	Bushes	0	0	4	25	489	50	1	0	0	85.9%
	Fir	0	0	0	13	56	1092	5	0	0	93.7%
	Meadows	0	0	3	5	4	15	159	0	0	85.5%
	Other	0	0	1	0	0	0	0	0	0	0.0%
	Urban	0	0	0	0	0	0	0	0	22	100.0%
	Overall Percentage	0.2%	0.8%	2.8%	10.5%	25.5%	51.9%	7.4%	0.0%	1.0%	88.9%
Testing	Ab. agr. fields	0	0	0	0	1	1	0	0	0	0.0%
	Agr. fields	0	8	0	2	0	0	0	0	0	80.0%
	Bare	0	0	15	2	3	3	2	0	0	60.0%
	Broadleaved	1	0	0	95	22	7	0	0	0	76.0%
	Bushes	0	0	3	18	204	26	0	0	0	81.3%
	Fir	0	0	0	3	24	501	2	0	0	94.5%
	Meadows	0	0	2	7	2	8	55	0	0	74.3%
	Other	0	0	2	0	0	0	0	0	0	0.0%
	Urban	0	0	0	0	0	0	0	0	5	100.0%
	Overall Percentage	0.1%	0.8%	2.1%	12.4%	25.0%	53.3%	5.8%	0.0%	0.5%	86.2%

Dependent variable: Land cover in 2015.

4. Discussion

The upper forest boundaries are determined by the ability of a species to endure the climatic conditions, the natural competition of the species, and human intervention, which usually in the form of nomadic animal grazing. Taking into account (a) that the fir in the study area does not face natural competition from other species in its upper limits and (b) the reduction in the nomadic animal grazing of herds [21], we reached the conclusion that the intensity and type of climatic changes have so far not affected the spread of fir over the initial (1945) forest treeline in the study area (Figure 9). Also, bushes did not expand during the study period above the initial heights of their expansion (Figure 9). Instead of this, the fir forest became denser in most cases in the upper limits of their expansion, as also happened at lower altitudes.

For fir forest, it should be mentioned that it is difficult for these forests to climb above their upper boundaries due to the sensitivity of seedlings and saplings to sun radiation during the spring and summer. For bush species, the above constraint does not apply. In a few cases, pioneer species expanded their coverage at the treeline, though this could be assigned to the reduction in grazing rather than to climate change effects. As can be concluded from the data, fir forests and bushes have not yet climbed to higher altitudes due to climatic changes. This does not necessarily mean that climatic change is not present but suggests that climate change intensity has not yet been great enough to drive forest species to climb to higher altitudes. Moreover, the extreme weather phenomena attributed to climatic change [12], in combination with the prevalent and persistent low temperatures at these heights during the winter, may prevent the expansion of fir forests and bushes upwards [28]. Our findings are like the results of other studies that have found no shift in treelines [24] in Samaria National Park in Creta, Greece. In contrast, an upwards shift in the treeline is referred to by Devi et al. [11] for Siberian larch, by Zindros et al. [23] on Mount Olympus in Greece, and by Trem and Chuman [29] on the Sudetes Mountains in Central Europe. In the Northern Hemisphere, most of the studies show an increase in the treeline and others show no change [12,13], though a few studies have shown a marginal decline [30,31]. In addition, several studies showed no climate effects on vegetation composition and species shift [32,33]. Although climate change is expected to shift the treeline up, microclimatic and topographic conditions, tree species characteristics, and human intervention, mostly in the form of grazing, may have more of an effect on vegetation variability than global climate change [34,35]. The impact of extreme weather conditions on tree species' ability to regenerate in un-protected areas, from maternal trees, should be studied further to better understand the effects of climate change on forest dynamics. [13,36,37].



(**a**)

(**b**)

Figure 9. Examble area of forest evolution on the upper limits, during the study period, with altitudinal zones: (**a**) land cover snapshot of the year 2015; (**b**) land cover snapshot of the year 1945. *Numbers like (1700–1800) stand for: Altitude zone height (1700 to 1800 m).*

5. Conclusions

The mountainous area of Evrytania, the dense hydrographic network, and the geophysical terrain have created conditions for the expansion of forest cover and the regeneration of forests and woodlands, as recorded in the comparative study of aerial photographs from 1945 and 2015. The particularly intense abandonment of mountainous agricultural land, which was the result of both the tendency of populations to migrate abroad to find work and their tendency to move to urban centers of Greece, has resulted in the following changes:

(a) An increase in the area and density of forest cover since 1945, both in terms of the main forest species of the study area, which is fir (increase of 13.7%), and the broadleaved forest species (increase of 6.43%).
(b) A significant reduction in agricultural fields (9.39% reduction) and bush areas (8.43% reduction).
(c) An increase in dense forests (70%–100% coverage) in terms of area, particularly fir forests (1.32% increase), broadleaved species (1.08% increase), and bush species (2.12% increase).
(d) An increase in forest cover in Natura 2000 protected areas, specifically for fir (12.44% increase) and broadleaved species (1.24% increase), which is considered significant but smaller than that found in non-protected areas.

This differentiation is probably because the protected areas were already more forested by the year 1945 than the other off-network areas. Accordingly, the smaller reduction in bush species within the protected areas (5.6%) compared to the areas outside these areas (10.52%) can be partially attributed to the fact that the initial land coverage of bush species within the protected areas was smaller (23.38%) compared to that of non-protected areas (36.02%).

Based on the results of this study, it is confirmed that forest vegetation will be able to expand to free areas in a predictable way if the pressure of human intervention is reduced. This could aid forest managers in more effective long-term forest management planning.

Up to now, there is no clear evidence that climate change has altered the upper forest treeline in the study area. To better understand the impact of climate change on forests and their expansion over their upper limits, as well as the effect of climatic and other factors, further and more detailed study is needed.

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