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Mapping and Understanding the Dynamics of Landscape Changes on Heterogeneous Mediterranean Islands with the Use of OBIA: The Case of Ionian Region, Greece

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Abstract: Mediterranean islands contain heterogeneous landscapes, resulting from the complex interactions between natural and anthropogenic processes, and have significant ecological and conservation importance. They are vulnerable systems to global change and the monitoring of changes, induced by the interacting environmental drivers, is of particular importance for applying a sustainable management regime. The aim of this study was to detect and analyze the landscape dynamics and changes in landscape composition over a 30-year period on the Ionian Islands of Western Greece. State-of-the-art object-oriented image analysis on freely available remote sensing data such as Landsat images was employed achieving final mapping products with high spatial and thematic accuracy (over than 85%), and a transferable classification scheme. The main drivers of environmental change are tourism and associated activities, wildfires and livestock breeding which act in different ways and intensities within and between the islands. The repopulation of those islands, after a period of significant depopulation from the 1940s to the 1980s, and the boom of tourism since the mid-1970s prevented further land abandonment and the recultivation of abandoned land which indicates that tourism and agriculture can be complementary rather than competing economic sectors. Despite the significant increase of tourism, a general trend was observed towards increasing cover of high-density vegetation formations, such as shrublands and forests. At the same time, wildfires, which are in some cases associated with livestock breeding, continue to be an important vegetation degradation factor preventing further ecosystem recovery on the study islands.

Keywords: Mediterranean ecosystems; land use/cover changes; object-oriented image analysis; insular landscapes

1. Introduction

The Mediterranean landscape is a mosaic of land use/cover types (LULC) created by the interaction between anthropogenic and natural processes over time [1]. Agricultural and pastoral activities, practiced for millennia, wood cutting for fuel and timber along with human induced wildfires formed the main activities playing a significant role in determining landscape structure and composition [2–4]. On the other hand, the complex geological history and topography of the Mediterranean basin, climatic changes, before and after the establishment of the Mediterranean climate, and the patchwork of ecological niches and habitats have all resulted in a very rich biodiversity, including many endemic species [5,6]. Since the second half of the 20th century, significant socioeconomic changes have occurred, which in turn affected the use of land and the spatial distribution of human activities. Uplands and marginal agricultural lands have been gradually abandoned while agriculture in lowlands and more productive areas has been intensified [5,7,8]. At the same time, significant tourism development has occurred, changing the primary drivers of shaping the Mediterranean landscape.

The localized intensification of human activities, coupled with an increase in the frequency and intensity of natural disasters, and especially wildfires, has resulted in changes in LULC, affecting the ecological integrity and status of ecosystems [9,10]. Furthermore, rapid changes in LULC strongly alter the local climatic conditions [11] with cascade effects on biodiversity [12,13] and the provision of important ecosystem services [14,15]. Likewise, another fundamental result is land degradation and desertification, which is intense in the Mediterranean region [16]. Subsequently, monitoring and understanding LULC changes and trends is essential to guide sustainable habitat and ecosystem management [17] and to meet the European and Global conservation objectives, including the prevention of further biodiversity loss and the implementation of the Streamlining European Biodiversity Indicators 2020 [18].

While several studies have focused on monitoring LULC changes and landscape dynamics in Mediterranean regions [9,19–22], islands and island complexes are rather underrepresented in the literature, with only few studies focusing on such environments [2,23,24]. While the underlying process determining the landscape structure and composition, and the provided services, may be similar between continental areas and islands, their effect may defer significantly. Islands exhibit important peculiarities as a result of their limited size, available resources and geographic remoteness, hindering the ability to extrapolate results achieved in continental areas [2].

Remote sensing provides efficient, low-cost solutions for long-term monitoring, the mapping of LULC and the observation of processes occurring on the surface of the earth, over large geographic regions [25]. Mapping of LULC using remote sensing data has significantly improved spatial and thematic accuracy over recent decades, primarily as a result of the development of new and sophisticated analysis and algorithms [14,15] and the provision of good quality data. Traditional approaches depending on in situ observations and/or visual interpretation of high-resolution images or aerial photographs have a high cost as well as a high degree of subjectivity. One of the new approaches is "Object-Oriented Image Analysis" (OBIA) which was found to outperform traditional approaches, such as "Pixel-Based Classification" [12,26]. One of the main advantages of OBIA is that it allows the identification of geographic features not only based on their spectral characteristics but also on properties related to shape, texture and other topological characteristics [12,27,28]. Recent studies [19,29–32] investigating the potential of OBIA to accurately classify natural Mediterranean ecosystems show promising results. Galidaki and Gitas [30], who employed and compared pixel- and object-based classification approaches to identify forest species, found that, in more uniform landscapes, the classic pixel-based classification achieved better results than object-based classification, while, in more complicated landscapes, OBIA resulted in a much higher classification accuracy. Another fundamental advantage of remote sensing is the ability to collect and analyze time series images [33] for change detection. Digital change detection is a process of determining and quantifying change based on multi-temporal remote sensing data [34]. Generally, there are two change detection approaches: (a) the pre-classification approach comparing and analyzing the spectral features or products (vegetation indices) of images; and (b) the post-classification approach where two thematic land use/cover maps are compared and analyzed [34]. Despite the significant advances in remote sensing data availability and techniques, to be operational, they have to rely on transferable classification rules and datasets that are widely available and at a reasonable cost.

In this context, the current study aimed to investigate the landscape dynamics and LULC changes over a period of 30 years using remote sensing data on insular Mediterranean landscapes in western Greece. The specific objectives of the study were: (a) to develop and test an OBIA approach for the identification of LULC types that is transferable to other areas; (b) to identify the LULC changes in the study area; and c) to understand the underlying processes which result in the observed land use/cover changes.

2. Materials and Methods

2.1. Study Area

The study was carried out in the Ionian Region which consists of four main islands or island complexes, located in the Ionian Sea in Western Greece (Figure 1). Kefalonia and Ithaca is the largest complex with an area of 786.58 km^2, followed by Corfu and Paxoi (585.30 km^2), Zakynthos (405.55 km^2) and Lefkada (359 km^2). The study area constitutes a typical heterogeneous Mediterranean landscape, where stands of natural vegetation are intermixed with cultivations, primarily olive orchards [35–37]. The climate is Mediterranean, with mild and wet winters and hot and dry summers. Temperatures vary slightly between the islands, with the highest occurring in the south (Zakynthos) and the lowest in the north (Corfu) [38]. Natural and human pressures, such as frequent forest fires [39] and intense seasonal tourism activities [40], are particularly significant on the study area.

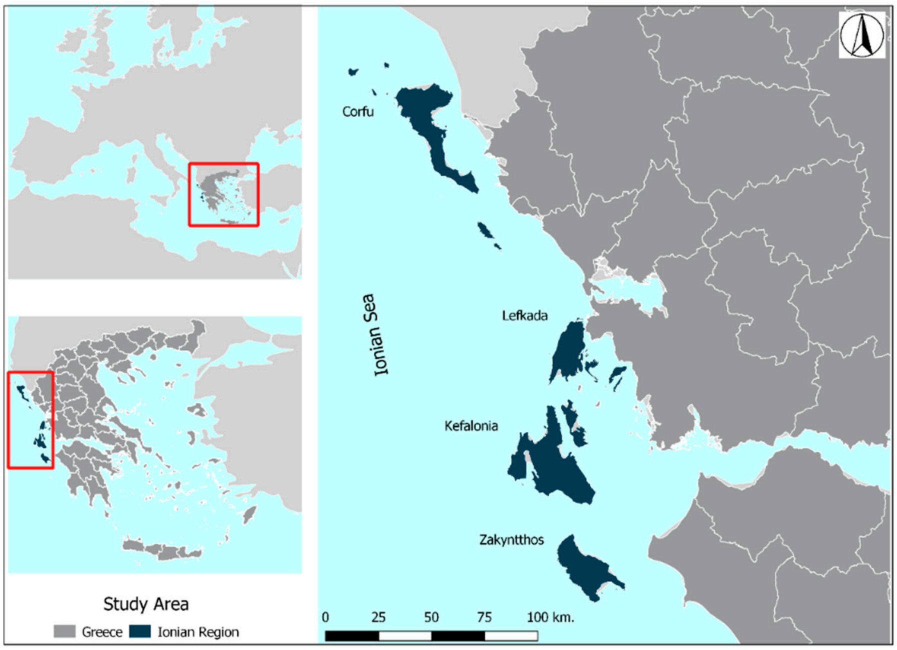

Figure 1. Study Area.

The Ionian Islands comprise some of the most important protected areas in the Eastern Mediterranean. Zakynthos has three Natura 2000 sites, which are under the protection of the National Marine Park of Zakynthos (NMPZ), that constitute an essential habitat for *Caretta caretta*, *Manachus monachus* and endemic plant species [35]. In Kefalonia, mount Ainos, the highest of the Ionian islands (1600 m), is part of the Natura 2000 network and constitutes a National Park due to its floristic composition and especially the presence of *Abies cephalonica* and *Pinus nigra*, while it has two other Natura 2000 sites. Finally, Lefkada has two and Corfu five protected areas which are included in the Natura 2000 network of protected areas.

2.2. Object-Oriented Classification for LULC Change Analysis

Landsat 5 TM images acquired in 1985 and Landsat 8 OLI acquired in 2015 were analyzed to identify the LULC described in Table 2 and detect changes within the study period of 30 years. The 30-year study period correspond to the period where high quality Landsat data exist, ensuring the transferability of the developed methods to other areas and time slots. Furthermore, although tourism appeared in the region since the 1970s it was during the 1980s and 1990s where it actually boomed [12]. In each time slot, two images were acquired for spring (April) and summer (August) to detect phenological differences in the various LULC and especially the most dynamic ones such as meadows, phrygana and arable land. When using multi-temporal images, calibration and georeferencing are necessary prior to classification and change detection [41]. In our case, we used images that were pre-processed at Level 1 (geometric corrections in UTM WGS84 projection), and we applied an absolute atmospheric correction using Dark Object Subtraction algorithm (DOS) in ENVI 5.5 software.

The first step of an object-oriented image analysis is to segment the image into objects by applying an appropriate segmentation algorithm. Several image segmentation algorithms have been developed, from very simple (e.g., chessboard segmentation) to highly sophisticated (e.g., multiresolution segmentation) [12]. Multi-resolution segmentation was adopted in the current study which segments the image into numerous objects of varying size and shape. The size and shape of the objects depend primarily on the selected scale parameter (which determines the degree of homogeneity in the resulted objects) as well as by the shape and compactness criterion. After repetitive segmentations and visual inspection of the results, the value 5 was used for scale parameter, and the values of 0.1 and 0.8 for the shape and compactness, respectively, and were employed for all classification levels and LULC classes. Given the spatial resolution of Landsat images (30 m), the scale of the resulting products is approximately 1:75,000.

While the aim of the study was the analysis of the dynamics in LULC in the study area, the first objective was to develop a classification algorithm that is transferable to other areas with similar landscape structure and composition. For this reason, the classification was based solely on crisp or fuzzy rules using the vegetation index values (Table 1), avoiding the direct integration of training areas in the classifier. The classification was applied using a "top-down" approach which starts from general and proceeds into more specific and complicated classes.

Table 1. Vegetation indices.

Vegetation Index	Equation	Index Range
Modified Soil-Adjusted Vegetation Index [42]	$\text{MSAVI} = \frac{(\text{NIR}-\text{RED})(1+\text{L})}{\text{NIR}+\text{RED}+\text{L}}$	−1 to 1
Normalized Difference Moisture Index [43]	$\text{NDMI} = \frac{(\text{NIR}-\text{SWIR}_1)}{(\text{NIR}+\text{SWIR}_1)}$	−1 to 1
Normalized Difference Vegetation Index [44]	$\text{NDVI} = \frac{(\text{NIR}-\text{RED})}{(\text{NIR}+\text{RED})}$	−1 to 1
Modified Normalized Difference Water Index [43]	$\text{MNDWI} = \frac{(\text{GREEN}-\text{SWIR}_1)}{(\text{GREEN}+\text{SWIR}_1)}$	−1 to 1
Normalized Burned Ratio [45]	$\text{NBR} = \frac{(\text{NIR}-\text{SWIR}_2)}{(\text{NIR}+\text{SWIR}_2)}$	−1 to 1
Disturbance Index	$\text{DI} = \text{TC}_{\text{BR}} - (\text{TC}_{\text{GR}} + \text{TC}_{\text{WET}})$	No range

Note: NIR, Near Infrared Band; SWIR_1, First Sort Wave Infrared Band (Landsat 5 TM Band 5 and Landsat 8 OLI Band 6); SWIR_2, Second Sort Wave Infrared Band (Landsat 5 TM Band 7 and Landsat 8 OLI Band 7); TC_{BR}, Tasseled Cup Brightness Band; TC_{GR}, Tasseled Cup Greenness Band; TC_{WET}, Tasseled Cup Wetness Band.

The classification scheme consisted of four classification levels (Table 2 and Figure 2) where at the first level (Level 1) the water mass and terrestrial area were identified, using the Modified Normalized Difference Water Index (MNDWI) where higher values indicate the existence of water. At the second level (Level 2), the settlements and the agricultural zone were identified using a vector file of settlements that was generated by digitizing orthophoto maps (1984 and 2015) and the vector file of Land Identification Parcel System (LPIS)—provided by the Hellenic Agricultural Payments Organisation (OPEKEPE). The remaining area was classified as high-, medium- or low-density vegetation and non-vegetation using the Normalized Difference Moisture Index (NDMI) and the Normalized Difference Vegetation Index (NDVI) where higher values indicate denser vegetation.

Table 2. Land use/cover classes.

Level 1	**Level 2**		**Level 3**	**Level 4**	**Class Description**	**Aggregated class**
Land	Natural Vegetation Zone	High-Density Vegetation	Forest		Areas dominated by dense tree vegetation	High-Density Vegetation
			Shrublands		Areas dominated by shrubs or maquis species.	
		Medium-Density Vegetation	Transitional		Areas with floristic elements from both phrygana and shrublands	Medium-Density Vegetation
		Low-Density Vegetation	Phrygana		Areas covered by dense phryganic vegetation	Low-Density Vegetation and Open—Rocky areas
			Sparse Phrygana		Areas covered by sparse phryganic vegetation	
			Meadow		Areas covered by natural grass	
		No Vegetated	Open Areas/Rocks		Open and rocky areas	
			Burned		Land surface areas previously burnt	Burned
	No-Natural Vegetation Zone	Croplands	Olive Orchards	Medium-Density Olive Orchards	Medium-density olives	Medium-Density Olive Orchards
				Low-Density Olive Orchards	Low-density olives	
				High-Density Olive Orchards with Natural Vegetation	High-density olives with natural vegetation patches	High-Density Olive Orchards
			Other Crops	Vineyards	Vineyards	Cultivations
				Arable land	Arable land used for annual crops (mainly cereals and seasonal vegetables)	
				Mixed Cultures	Mosaic of vineyards and arable land where the former prevails	
				Other Cultures	Mosaic of vineyards and arable land where the latter prevails	
				Permanent Cultures	Tree crops other than olive orchards	
		Settlements	Urban		Settlements, builds- up	Settlements
Sea		Water	Sea		Sea or inland water (saline)	

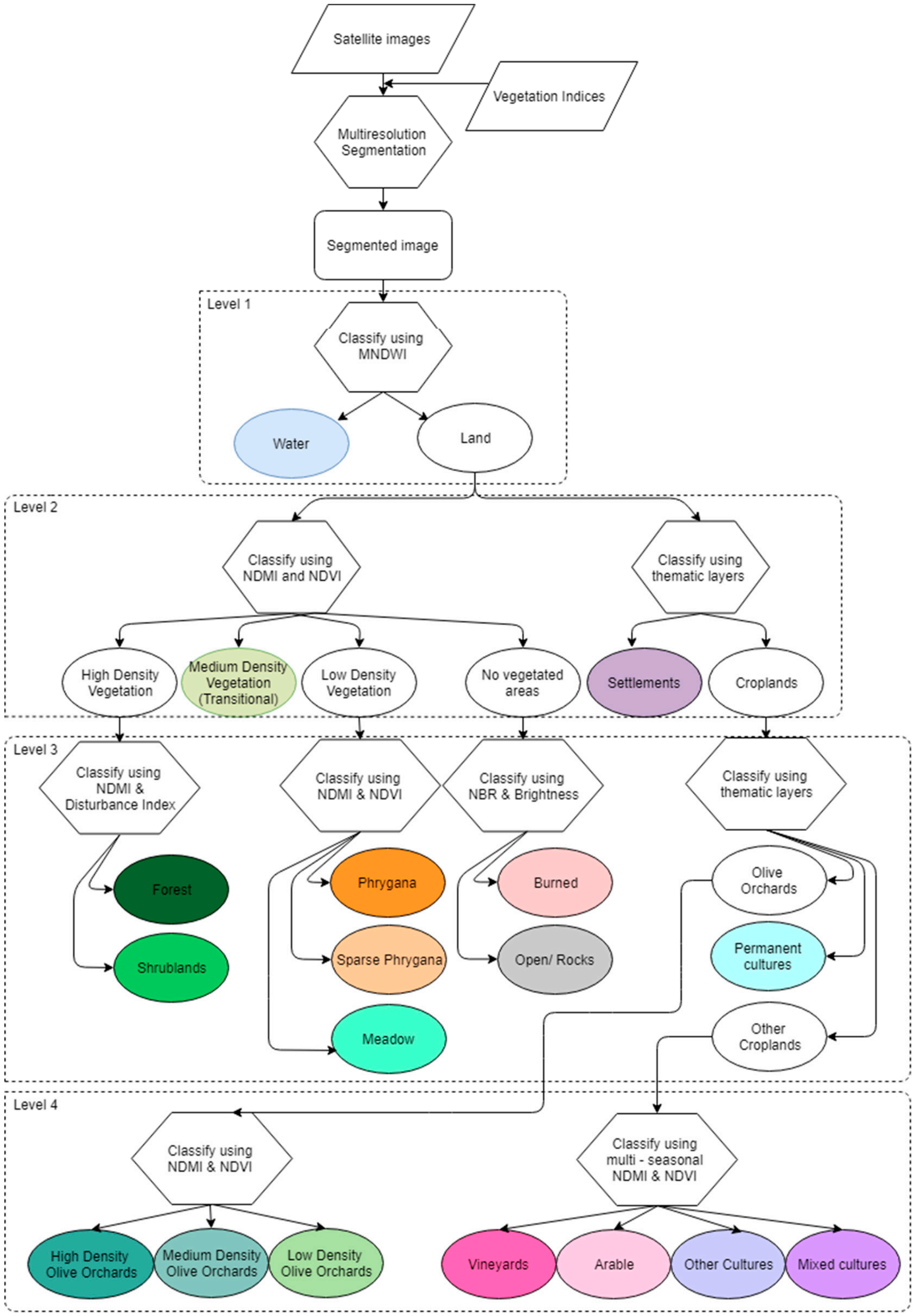

Figure 2. Hierarchical scheme of classification (filled ellipses are the final result of each of 18 classes).

At the third level (Level 3), the croplands (agricultural zone) were further divided into olive orchards, permanent (tree crops) and other crops according to the cultivation type given by the LPIS shapefiles. The areas with dense vegetation were classified into forests and shrublands using the NDMI and Disturbance index (where lower values indicate denser vegetation). The class of forest corresponds to vegetation formations where *Pinus halepensis* is the dominant species while occasionally *Abies cephalonica* prevails. Shrublands, on the other hand correspond to a formation where shrubs and maquis species prevail, including *Quercus coccifera*, *Pistacea* sp. and *Arbutus unedo*. For sparse vegetation, three main vegetation types were identified, where the classification of phrygana and sparse phrygana was based on the values of the NDMI and NDVI, while meadows were identified using the difference between the summer and spring values of NDVI where greater values indicate phryganic vegetation and lower values indicate meadow. In the two phryganic vegetation types, the dominant species are *Calicotome villosa, Cistus creticus* and *Sarcopoterium spinosum* while meadows are occupied natural grasslands. Finally, the non-vegetation areas were divided in two classes, where the burnt areas were identified using the Normalized Burned Ratio (NBR), and the rocky and open areas using the brightness index of a tasseled cup transformation. In the fourth classification level (Level 4), we further separated the olive orchards and other crops. Specifically, the category of olive orchards was classified into three density classes: high-density olive orchards with patches of natural vegetation, medium-density olive orchards and low-density olive orchards, using NDVI and NDMI. The other cultivations were reclassified as vineyards, arable land, mixed and other cultures and permanent crops using the difference between the summer and spring NDVI and NDMI values.

2.3. Accuracy Assessment

The classification accuracy was assessed using ground-truth data collected by visual interpretation of Very-High-Resolution (VHR) aerial photographs from 1984 and VHR images from Google Earth for 2015 and in situ verification. The method proposed by Congalton [46] was applied for the calculation of the minimum sample size. Ground-truth samples were selected based on randomized layered sampling. The number of samples was not equally distributed among the identified LULC classes but it was adjusted according to LULC complexity which refers to the ambiguity during the classification process due to spectral overlapping. The LULC classes were divided into three groups depending on the degree of their complexity estimated during the classification process (Table 3), where LULC classes with a higher degree of complexity had more samples than areas with less complexity. Confusion matrices were created to estimate statistical measures such as Kappa index (K) agreement [47], Overall accuracy (OA), User's accuracy and Producer's accuracy (UP and PU), for assessing the accuracy of classifications.

Table 3. Accuracy assessment samples categories.

Low "Complexity"	Medium "Complexity"	High "Complexity"
Arable	Vineyards	High-Density Olive Orchards
Permanent Cultures	Mixed Cultures	Forest
Low-Density Olive Orchards	Other Cultures	Shrublands
Open Areas/ Rocks	Medium-Density Olive Orchards	Transitional
	Sparse Phrygana	Phrygana
	Meadow	

2.4. Change Detection

Change detection was conducted using the post-classification approach on the final mapping products of the two time slots. The analysis was made on aggregate classes, resulted by merging the identified detailed classes into broader categories, as shown in Table 2 (aggregated classes column), and are presented in separate transition matrices for each island or island complex. The three aggregated classes of the natural vegetation zone represent different successional stages in the process of secondary succession. The low-density vegetation class represent early successional stages where phrygana vegetation is intermixed with bare ground, resulting primarily by fire, deforestation or intensive grazing. The medium-density vegetation is characterized by the encroachment of shrubs and trees into the previous vegetation class which progressively and in the absence of additional disturbance is transformed to the high-density vegetation class where shrubs and trees prevail and the formed ecosystems are characterized by high cover. The two aggregate classes of olive orchards represent differences in their management regime. The high-density olives are rather old fields which have been abandoned for years allowing the olive trees to grow in both directions and also shrubs and trees to encroach leading to the development of dense vegetation (natural or olive trees). The medium-density olives, on the other hand, are managed or newly created orchards which are used for production of oil and to a lesser degree table olives.

3. Results

3.1. Land Use/Cover Mapping

After developing the OBIA classification scheme for the Island of Zakynthos, it was then possible to transfer it to the other islands with only minor adjustments to the applied thresholds in the crisp and fuzzy rules. The classification achieved a high overall accuracy, reaching or exceeding 84% for all islands, while the Kappa Statistic, which exceeds 0.82 in all cases, indicates an excellent classifier performance (Table 4 and Appendix A). The dominant LULC type for all islands is olive orchards (summary of the three density classes) covering approximately 42% of Corfu, 30% of Lefkada and Zakynthos and 19% of Kefalonia. For the natural zone, forested areas had greater extent on Corfu (19%) and Kefalonia (18%) followed by Lefkada and Zakynthos (12% and 6%, respectively). Areas covered by sparse vegetation (phrygana, sparse phrygana and meadow) was less extensive on Corfu (5–8%), while on others islands ranges from 20% to 10% during the study period (Figure 3 and Tables 5 and 6). Spatially, in Zakynthos Island there was a separation of agricultural and natural vegetation zones, as the cultivation occupied the eastern-flat part of the island while the natural vegetation the west-mountainous part. On the other islands, the landscape consisted of a mosaic of natural vegetation mixed with croplands (Figures 4 and 5).

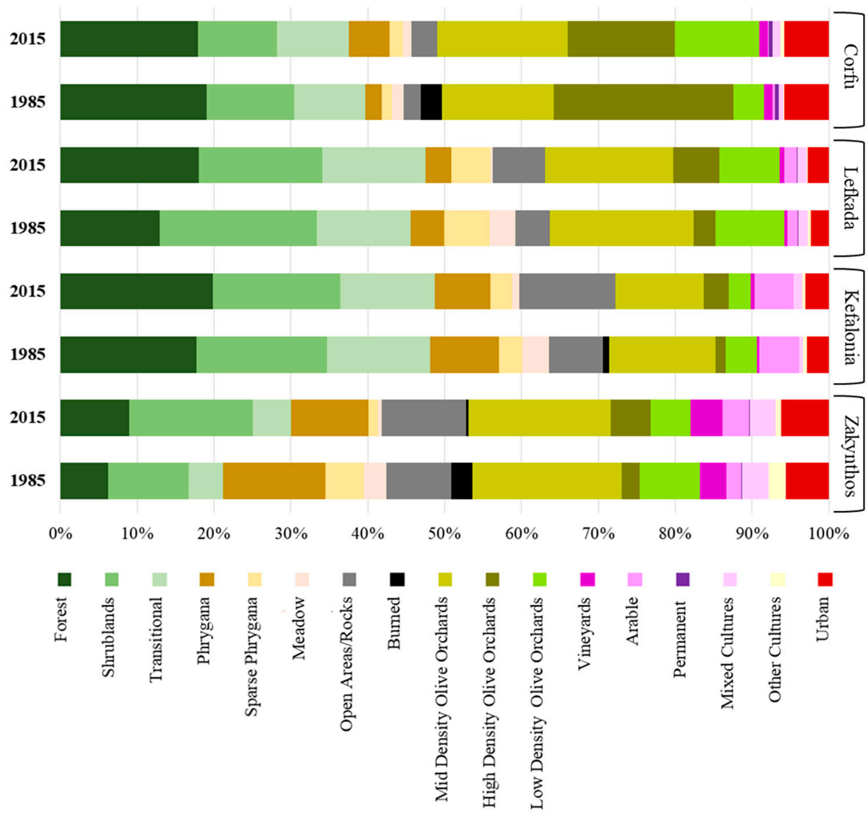

Figure 3. Land cover/use presence of Ionian Islands during the period 1985–2015.

Table 4. Overall accuracy and Kappa statistic.

	Overall Accuracy (%)		Kappa Statistic	
Prefecture	1985	2015	1985	2015
Corfu	87	86	0.86	0.85
Lefkada	85	86	0.84	0.85
Kefalonia	84	84	0.82	0.82
Zakynthos	86	85	0.84	0.83

Table 5. Corfu and Lefkada land cover/use.

LULC Class	Corfu				Lefkada			
	1985		2015		1985		2015	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Forest	11,666	19.3	10,903	18.0	4479	12.6	6306	18.1
Shrublands	6843	11.3	5598	9.3	7102	20.3	5625	16.1
Transitional	5557	9.2	6059	10.1	4299	12.3	4751	13.6
Phrygana	1309	2.1	3550	5.3	1592	4.4	1201	3.4
Sparse Phrygana	792	1.3	1096	1.8	2116	5.9	1816	5.1
Meadow	1040	1.7	632	1.1	1171	3.4	82	0.2
Open Area/Rocks	798	1.4	1951	3.2	1261	3.6	2324	6.7
Burned	1692	2.8	0	0.0	—-	—-	—-	—-
Medium-Density Olive Orchards	8924	14.5	10,492	17.0	6712	18.7	5906	16.7
High-Density Olive Orchards	14,375	23.4	8499	14.0	996	2.8	2134	6.0
Low-Density Olive Orchards	2422	4.0	6706	10.9	3240	9.0	2757	7.8
Vineyards	660	1.1	754	1.2	137	0.4	206	0.6
Arable	185	0.3	60	0.1	471	1.3	570	1.6
Permanent	311	0.5	310	0.5	16	0.1	16	0.1
Mixed Cultures	408	0.6	230	1.0	461	1.3	438	1.2
Other Cultures	66	0.1	193	0.5	138	0.4	18	0.1
Urban	3544	5.9	3817	6.3	793	2.3	964	2.8

Table 6. Kefalonia and Zakynthos land cover/use.

LULC Class	Kefalonia				Zakynthos			
	1985		2015		1985		2015	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Forest	15,737	18.1	17,989	20.7	2527	6.1	3615	9.0
Shrublands	14,766	16.9	13,904	16.0	4253	10.6	6466	17.0
Transitional	11,294	12.9	10,580	12.2	1824	4.5	2029	5.0
Phrygana	8154	9.0	6646	7.3	5419	13.3	4156	10.1
Sparse Phrygana	2731	3.0	2549	2.8	2024	5.0	498	1.2
Meadow	3096	3.5	694	0.8	1160	2.9	124	0.3
Open Area/Rocks	5202	6.0	10,703	12.3	3159	7.9	4368	10.8
Burned	683	0.8	47	0.0	1115	2.8	114	0.3
Medium-Density Olive Orchards	12,396	13.8	10,514	11.5	7894	19.4	7554	18.5
High-Density Olive Orchards	1229	1.4	3599	3.3	975	2.4	2134	5.2
Low-Density Olive Orchards	3664	4.0	2600	2.8	3176	7.8	2109	5.2
Vineyards	792	0.3	298	0.5	1401	3.5	1689	4.2
Arable	4596	5.2	4676	5.1	790	1.9	1365	3.4
Permanent	—-	—-	—-	—-	28	0.1	28	0.1
Mixed Cultures	397	0.5	986	1.1	1418	3.5	1388	3.4
Other Cultures	458	0.5	358	0.4	902	2.2	277	0.7
Urban	2599	2.9	2816	3.1	2240	5.6	2476	6.3

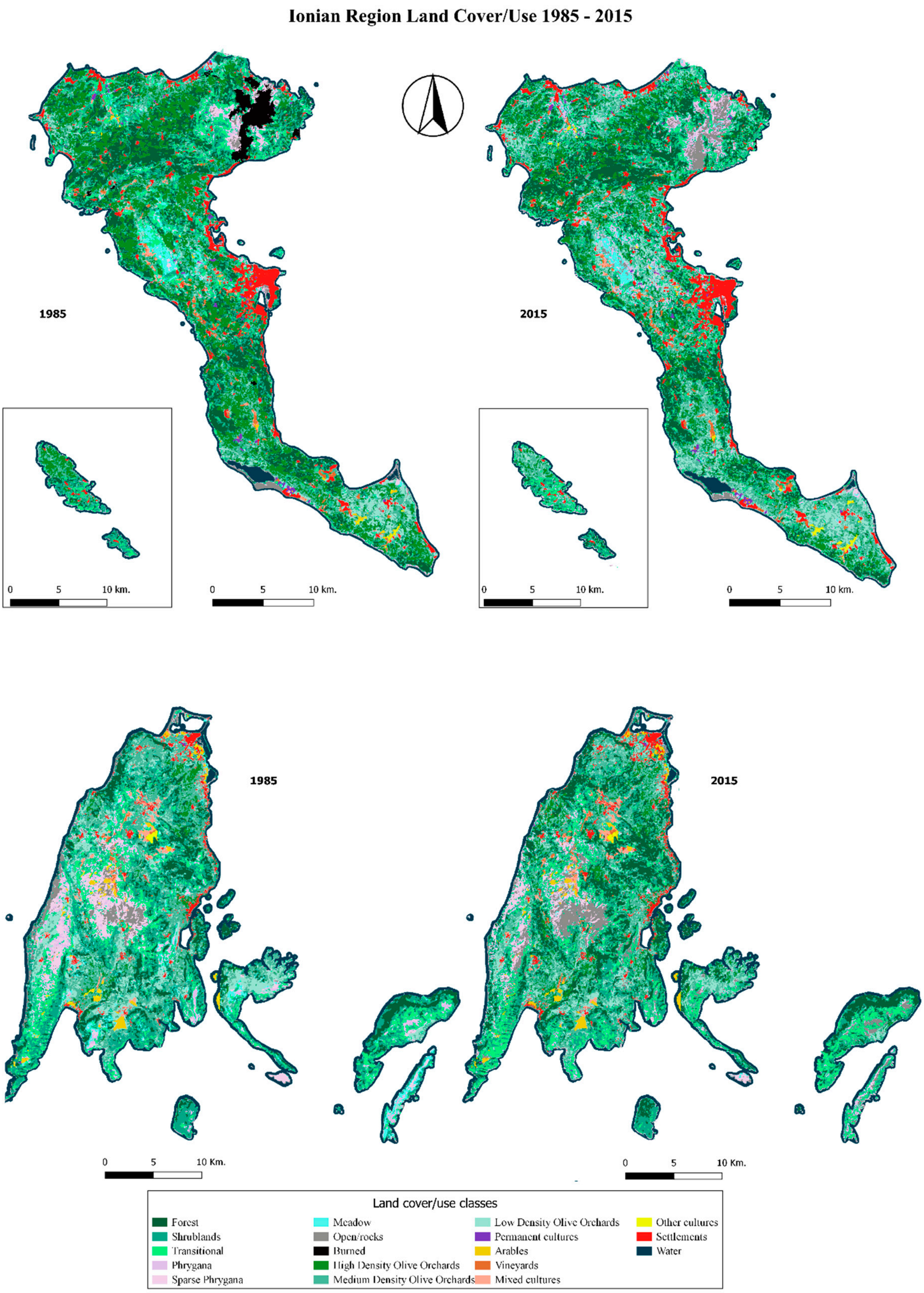

Figure 4. Land cover/use in 1985 and 2015 on: Corfu (**top**); and Lefkada (**bottom**).

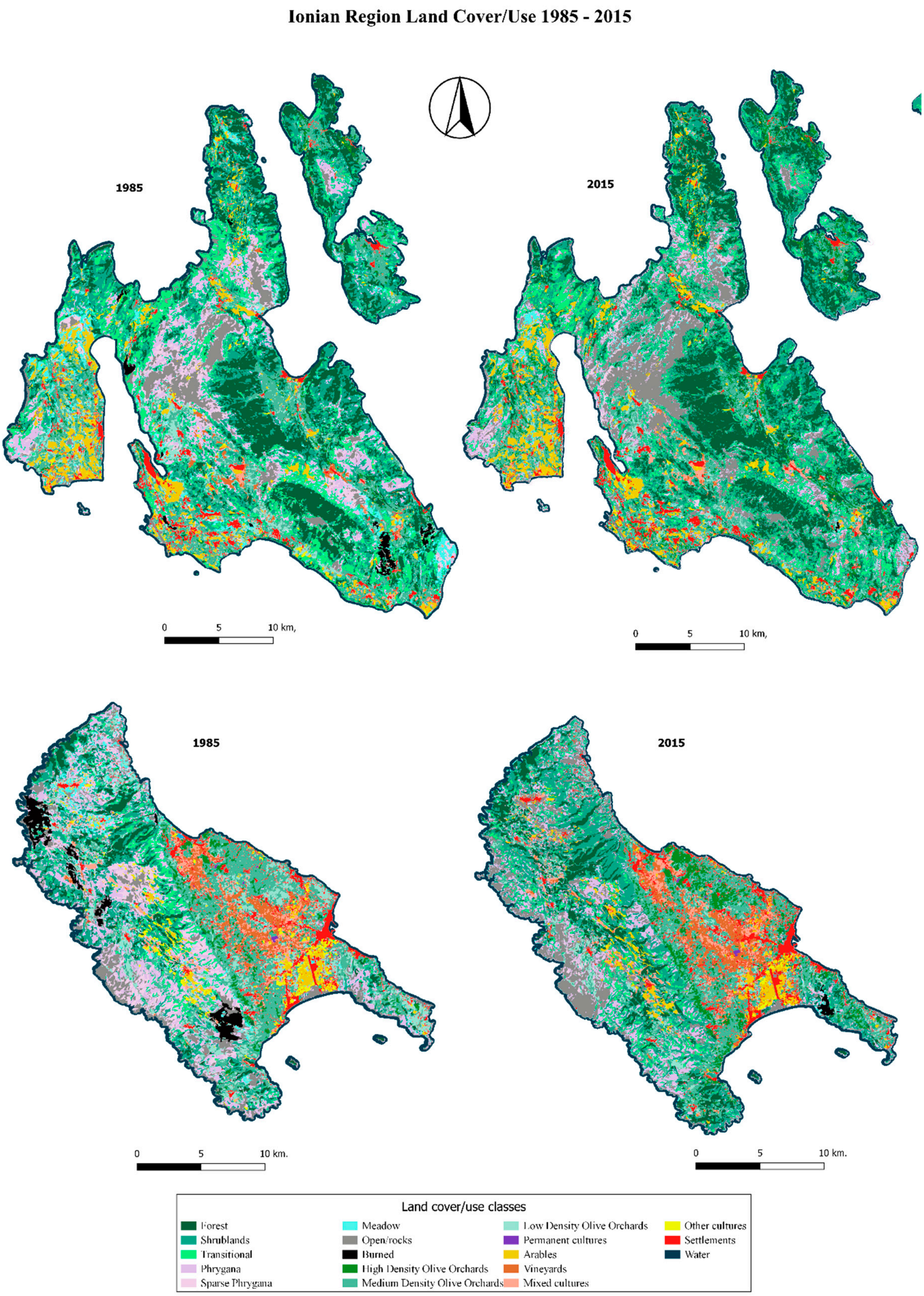

Figure 5. Land cover/use in 1985 and 2015 on: Kefalonia (**top**); and Zakynthos (**bottom**).

3.2. Change Detection Analysis

Change detection analysis for the period 1985–2015 (Tables 6–10 and Figure 6) showed that both the magnitude and the direction of changes differ between the four island complexes, while complex patterns of change are also observed within each of the studied islands. On Corfu, 33.4% of its area has changed land cover within the 30 years of study. During this period, almost 25% of its high-density ecosystems were lost, primarily to medium- and, to a lesser extent, to low-density ecosystems. The partial transition, however, of medium- and low-density ecosystems to high-density and the restoration of burned areas partially compensated the previous loss restricting the total reduction of high-density vegetation to 3.32% or approximately 2000 ha. An interesting observation is the high persistence of the most degraded vegetation types of low-density/no vegetation during the thirty years of study and their further increase, which was caused primarily by the degradation of the medium-density vegetation types. Despite this increase, however, the percentage cover of the low-density vegetation types is the lowest observed among the four islands. Medium-density vegetation types are apparently the most dynamic, retaining only one third of their area occupied in 1985, while the rest is converted to almost equal rates to either high- or low-density vegetation types. Another noticeable change was the transitions between the two density classes of olive orchards, with the medium-density being the ones increased. Finally, urban areas increase slightly by 0.45%. The observed mutual transition between the various LULC types indicate a dynamic landscape despite the relatively small changes in their relevant proportions of land cover during the study period.

On Lefkada, a high persistence of high-density vegetation types was observed, retaining more than 80% of their area occupied in 1985. At the same time, the partial transition of medium- and low-density vegetation types to high-density ones leads to a slight net increase of 1.2%. Medium-density vegetation types appear again to be the most dynamic, retaining only 43% of their original cover with the rest converted by 35% to high and by 20% to low-density vegetation. Low-density vegetation was reduced during the study period, indicating a process of ecosystem recovery, since it was converted primarily to medium- and to a lesser extent high-density vegetation types. Unlike Corfu, medium-density olive orchards were reduced in favor of the high-density ones. However, it is worth mentioning that high-density olive orchards in 1985 covered a small part of the island in relation to the medium-density ones. Urban areas increased only slightly by 0.49%

Kefalonia is another case where high-density vegetation formations showed high persistence and an increasing trend, occupying in 2015 more than 36% of the island. Medium-density vegetation types were again the most dynamic ones, with equal trends of transition to high- and low-density vegetation formations. The latter covered a significant part of the island with high persistence and an increasing trend, indicating the continuous action of a degradation factor in these areas. The pattern of change regarding olive orchards and urban area was similar to Lefkada with an increase of high-density orchards and a slight increase of urban areas.

Zakynthos exhibits some important peculiarities compared to the other islands and island complexes. High-density vegetation formations covered 16.66% in 1985 as is the lowest observed among all studied islands. At the same time, they had the lowest persistence during the 30 years of study, losing almost 30% of their area, primarily to low-density vegetation types. Despite the low initial cover and the significant losses, high-density vegetation types increased by 9.3% during the study period, reaching almost 26% in 2015. This is due to the observed transition of medium- and low-density vegetation types to high-density ones. Low-density vegetation types were the most abundant within the natural vegetation zone in 1985 and despite their significant losses during the 30 years they remained high in 2015. This pattern indicates a recovering process of the natural vegetation types while at the same time an active degradation factor seems to be present in the area preventing further ecosystem recovery. Olive orchards and urban areas changed in the same way as the previous two islands of Lefkada and Kefalonia with a minor increase of high-density olive orchards and urban areas.

The minor contribution or complete absence of burned areas in the landscape composition was observed in almost all islands at both time points; however, the above does not indicate an insignificance of fire in shaping these insular landscapes. Our approach is only able to detect burned areas soon after the event. As time progresses, burned areas appear first as open areas and then, as secondary succession proceeds, a transition to medium- and high-density vegetation formations occurs. Thus, the role of fire should not be underestimated based on the results, as discussed below.

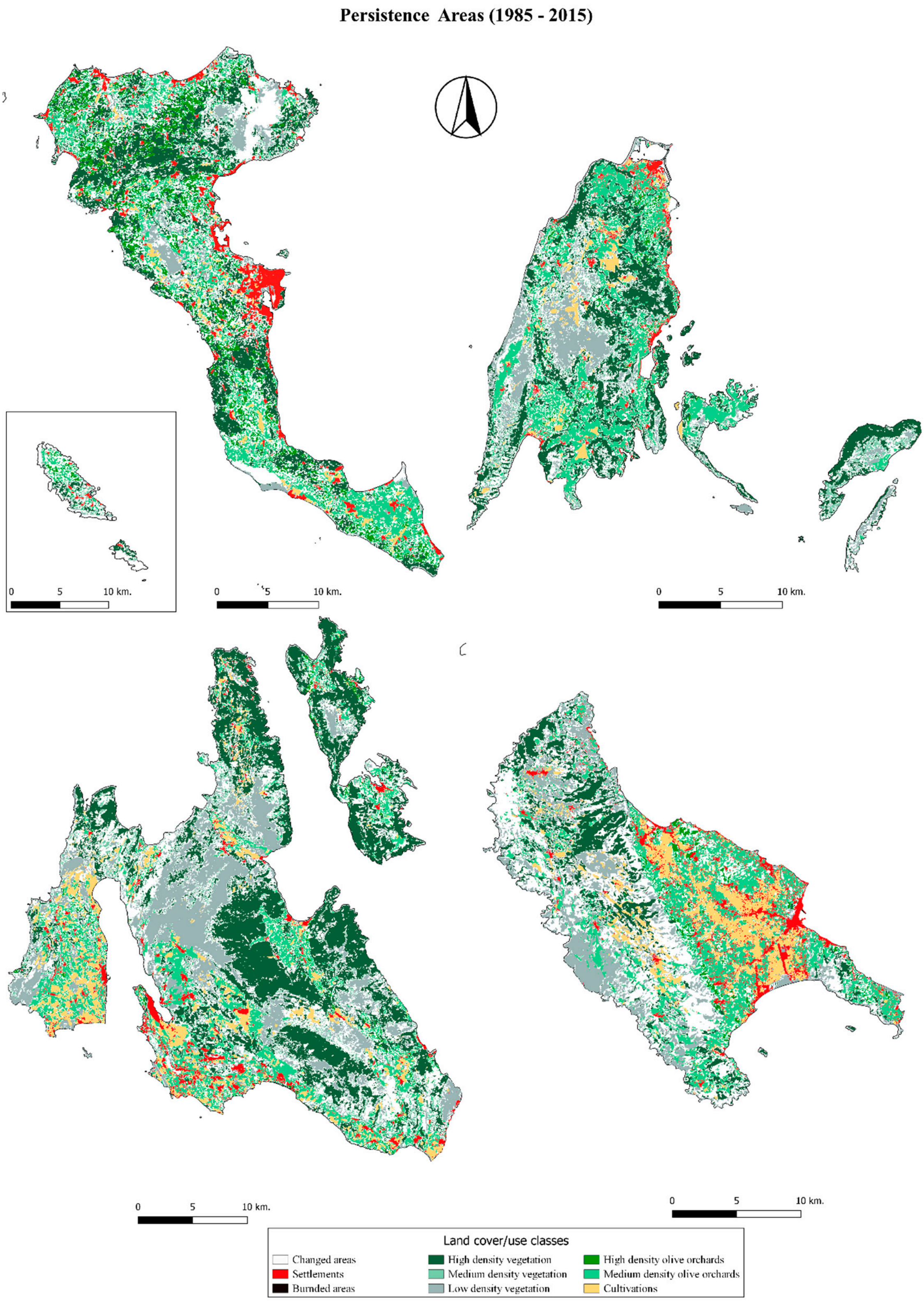

Figure 6. Persistence and changed areas at Ionian region (uncolored regions refer to changed areas).

Table 7. Corfu's transition matrix.

		Initial State 1985 (Hectare and Percent Dif. of Classes): Corfu and Paxoi									
		High-Density Vegetation	**Medium-Density Vegetation**	**Low-Density/No Vegetation**	**Medium-Density Olive Orchards**	**High-Density Olive Orchards**	**Burned**	**Cultivations**	**Settlements**	**Sum 2015 Percent of Total Area**	**Dif.**
Final State 2015	**High-Density Vegetation**	14,028 *75.79*	1700 *30.59*	261 *6.92*	75 *0.66*	222 *1.54*	176 *10.40*	10 *0.61*	29 *0.82*	16,501 *27.26*	−2008 *−3.32*
	Medium-Density Vegetation	3086 *16.67*	1946 *35.02*	564 *14.96*	86 *0.76*	66 *0.46*	259 *15.31*	12 *0.73*	40 *1.13*	6059 *10.08*	502 *0.9*
	Low-Density/No Vegetation	936 *5.06*	1739 *31.29*	2830 *75.09*	75 *0.66*	19 *0.13*	1170 *69.15*	19 *1.16*	40 *1.13*	6828 *11.28*	3059 *4.99*
	Medium-Density Olive Orchards	216 *1.17*	105 *1.89*	40 *1.06*	9622 *84.66*	7082 *49.13*	48 *2.84*	100 *6.12*	24 *0.68*	17,237 *28.48*	5871 *9.7*
	High-Density Olive Orchards	181 *0.98*	14 *0.25*	2 *0.05*	1315 *11.57*	6973 *48.37*	19 *1.12*	14 *0.86*	2 *0.06*	8520 *14.08*	−5896 *−9.74*
	Burned	0 *0.00*	0 *0.00*	0 *0.00*	0 *0.00*	0 *0.00*	0 *0.00*	0 *0.00*	0 *0.00*	0 *0*	−1692 *−2.79*
	Cultivations	18 *0.10*	16 *0.29*	7 *0.19*	17 *0.15*	6 *0.04*	8 *0.47*	1450 *88.74*	3 *0.08*	1525 *2.52*	−109 *−0.18*
	Settlements	44 *0.24*	37 *0.67*	65 *1.72*	176 *1.55*	48 *0.33*	12 *0.71*	29 *1.77*	3406 *96.11*	3817 *6.31*	273 *0.45*
	Sum 1985 **Percent of total area**	18,509 *30.58*	5557 *9.18*	3769 *6.29*	11,366 *18.78*	14,416 *23.82*	1692 *2.79*	1634 *2.70*	3544 *5.86*		

Table 8. Lefkada's transition matrix.

		Initial State 1985 (Hectare and Percent Dif. of Classes): Lefkada									
		High-Density Vegetation	**Medium-Density Vegetation**	**Low-Density/No Vegetation**	**Medium-Density Olive Orchards**	**High-Density Olive Orchards**	**Burned**	**Cultivations**	**Settlements**	**Sum 2015 Percent of total area**	**Dif.**
Final State 2015	**High-Density Vegetation**	9313 *80.42*	1511 *35.15*	787 *12.99*	246 *2.47*	36 *3.61*	–	22 *1.79*	16 *2.02*	11,931 *34.17*	350 *1.20*
	Medium-Density Vegetation	1491 *12.87*	1866 *43.41*	1295 *21.37*	70 *0.70*	1 *0.10*	–	19 *1.55*	9 *1.13*	4751 *13.61*	452 *1.29*
	Low-Density/No Vegetation	444 *3.83*	835 *19.42*	3816 *62.98*	59 *0.59*	1 *0.10*	–	33 *2.69*	21 *2.65*	5209 *14.93*	−850 *−2.42*
	Medium-Density Olive Orchards	180 *1.55*	54 *1.26*	83 *1.37*	7826 *78.57*	408 *40.96*	–	19 *1.55*	100 *12.61*	8670 *24.83*	−1290 *−3.7*
	High-Density Olive Orchards	87 *0.75*	4 *0.09*	5 *0.08*	1490 *14.96*	534 *53.61*	–	3 *0.24*	10 *1.26*	2133 *6.11*	1137 *3.26*
	Burned	–	–	–	–	–	–	–	–	–	–
	Cultivations	22 *0.19*	18 *0.42*	35 *0.58*	56 *0.56*	2 *0.20*	–	1110 *90.54*	13 *1.64*	1256 *3.59*	30 *0.08*
	Settlements	44 *0.38*	11 *0.26*	38 *0.63*	213 *2.14*	14 *1.41*	–	20 *1.63*	624 *78.69*	964 *2.76*	171 *0.49*
	Sum 1985 Percent of total area	11,581 *32.97*	4299 *12.32*	6059 *17.35*	9960 *28.53*	996 *2.85*	–	1226 *3.51*	793 *2.27*		

Table 9. Kefalonia's transition matrix.

		Initial State 1985 (Hectare and Percent Dif. of Classes): Kefalonia									
		High-Density Vegetation	**Medium-Density Vegetation**	**Low-Density/No Vegetation**	**Medium-Density Olive Orchards**	**High-Density Olive Orchards**	**Burned**	**Cultivations**	**Settlements**	**Sum 2015 Percent of total area**	**Dif.**
Final State 2015	**High-Density Vegetation**	25,434 *83.38*	3871 *34.27*	1816 *9.76*	373 *2.32*	85 *6.92*	147 *21.52*	140 *2.24*	27 *1.04*	31,893 *36.63*	1390 *1.63*
	Medium-Density Vegetation	3279 *10.75*	3535 *31.30*	3301 *17.74*	170 *1.06*	9 *0.73*	176 *25.77*	87 *1.39*	23 *0.89*	10,580 *12.15*	−714 *−0.75*
	Low-Density/No Vegetation	1499 *4.91*	3681 *32.59*	13,154 *70.71*	237 *1.47*	7 *0.57*	257 *37.63*	150 *2.40*	16 *0.62*	19,001 *21.86*	397 *0.57*
	Medium-Density Olive Orchards	109 *0.36*	76 *0.67*	101 *0.54*	11,980 *74.49*	372 *30.29*	57 *8.35*	147 *2.35*	261 *10.08*	13,103 *15.05*	−2979 *−3.42*
	High-Density Olive Orchards	109 *0.36*	76 *0.67*	88 *0.47*	2686 *16.70*	733 *59.69*	57 *8.35*	147 *2.35*	261 *10.08*	3768 *4.13*	2540 *2.72*
	Burned	3 *0.01*	1 *0.01*	9 *0.05*	1 *0.01*	0 *0.00*	4 *0.59*	0 *0.00*	29 *1.12*	47 *0.02*	−636 *−0.77*
	Cultivations	49 *0.16*	30 *0.27*	83 *0.45*	408 *2.54*	16 *1.30*	20 *2.93*	5640 *90.27*	69 *2.66*	6315 *7.25*	67 *0.07*
	Settlements	21 *0.07*	24 *0.21*	52 *0.28*	227 *1.41*	6 *0.49*	1 *0.15*	67 *1.07*	2127 *82.12*	2816 *3.14*	226 *0.16*
	Sum 1985 Percent of total area	30,503 *35*	11,294 *12.9*	18,604 *21.29*	16,082 *18.47*	1228 *1.41*	683 *0.79*	6248 *7.18*	2590 *2.98*		

Table 10. Zakyntho's transition matrix.

		Initial State 1985 (Hectare and Percent Dif. of Classes): Zakynthos									
		High-Density Vegetation	**Medium-Density Vegetation**	**Low-Density/No Vegetation**	**Medium-Density Olive Orchards**	**High-Density Olive Orchards**	**Burned**	**Cultivations**	**Settlements**	**Sum 2015 Percent of total area**	**Dif.**
Final State 2015	**High-Density Vegetation**	4814 *71.00*	1129 *62.41*	3641 *31.08*	66 *0.60*	3 *0.31*	405 *36.32*	21 *0.46*	2 *0.09*	10,081 *25.96*	3301 *9.30*
	Medium-Density Vegetation	443 *6.53*	144 *7.96*	1245 *10.63*	17 *0.15*	0 *0.00*	173 *15.52*	5 *0.11*	1 *0.04*	2028 *5.04*	219 *0.55*
	Low-Density/No Vegetation	1451 *21.40*	504 *27.86*	6480 *55.31*	86 *0.78*	0 *0.00*	422 *37.85*	37 *0.81*	24 *1.07*	9004 *22.35*	−2711 *−6.74*
	Medium-Density Olive Orchards	36 *0.53*	12 *0.66*	117 *1.00*	8872 *80.01*	361 *37.06*	105 *9.42*	28 *0.62*	145 *6.47*	9679 *24.02*	−1409 *−3.5*
	High-Density Olive Orchards	8 *0.12*	2 *0.11*	4 *0.03*	1559 *14.06*	549 *56.37*	1 *0.09*	2 *0.04*	11 *0.49*	2136 *5.3*	1162 *2.88*
	Burned	9 *0.13*	3 *0.17*	102 *0.87*	0 *0.00*	0 *0.00*	0 *0.00*	0 *0.00*	0 *0.00*	114 *0.29*	−1001 *−2.48*
	Cultivations	9 *0.13*	6 *0.33*	49 *0.42*	239 *2.16*	50 *5.13*	8 *0.72*	4323 *95.09*	68 *3.04*	4752 *11.8*	206 *0.51*
	Settlements	10 *0.15*	9 *0.50*	77 *0.66*	249 *2.25*	11 *1.13*	1 *0.09*	130 *2.86*	1989 *88.79*	2476 *6.31*	236 *0.75*
	Sum 1985 Percent of total area	6780 *16.66*	1809 *4.49*	11,715 *29.09*	11,088 *27.52*	974 *2.42*	1115 *2.77*	4546 *11.29*	2240 *5.56*		

4. Discussion

The use of object-oriented image analysis and mid-resolution images provides a useful and accurate tool for land cover mapping of Mediterranean landscapes, as demonstrated by the high thematic and spatial accuracy of the resulted products. The Mediterranean landscape is characterized by high degree of complexity and, as suggested by Galidaki and Gitas [30], OBIA performs much better than pixel-based methods for image analysis and classification. As set by Anderson et al. [48] and Thomlinson et al. [49], minimum overall accuracy for performing a change detection analysis based on mapping products must be higher than 85%, which is achieved in all cases in the current study. The classification approach developed in this study offers a suitable monitoring tool since it relies exclusively on the use of crisp and fuzzy rules mainly applicable to vegetation indices from images available for free (such as Landsat). The rules created were directly transferable between the islands for the dynamic land cover/use mapping and it can be transferred in regions with similar ecosystems and similar remote sensing data. Furthermore, the launch of Sentinel 2 by ESA under the program Copernicus (formerly known as GMES) [50], which is a constellation of two polar-orbiting satellites, opens a new era in the provision of high resolution data at no cost. Sentinel 2 delivers multispectral data at spatial resolution of up to 10 m in the visual and near infrared bands and great thematic resolution (20 and 60 m spatial resolution), providing better opportunities for thematically and spatially accurate mapping when used in an OBIA approach.

Islands located at the northeast Mediterranean basin constitute heterogeneous and dynamic landscapes driven primarily by natural factors and processes and the long term presence of human and their related activities [6,51]. Wood cutting for energy and construction, livestock breeding, agriculture and wildfires, which are again affected by the topographic conditions and remoteness, formed traditionally the main drivers of shaping those landscapes. Although the current study was confined to a 30-year period since 1985, most Mediterranean islands experienced severe socioeconomic changes during the entire second half of the 20th century, including severe depopulation and land abandonment, which in turn resulted in noticeable changes in the landscape composition and structure [52,53]. The increase of tourism from the 1970s, on the other hand, again changed the economic conditions and activities and generated conditions of complex patterns of landscape change, with important effects on the character of those environments [2]. Great variations in the pattern of change between the islands and within the islands were observed in the current study, which indicates that there is not a prevailing driver which leads the pattern of change into a particular trajectory. On the contrary the various environmental drivers act in different ways and intensities and cause different patterns of change between and within the islands, as discussed below.

Corfu is the most densely populated island and at the same time the one with the highest touristic development, constituting today a hotspot of tourism. The island experienced severe depopulation from 1941 to 1971 followed by a period of population recovery, approaching today the numbers reported for the mid-20th century (Table 11). The increase in tourism, which started during the 1970s, is the only reason for this population recovery, as documented by the high number of available beds for accommodation in 1996 which continued to increase until 2015 and possibly still today (Table 12). Although one would expect a significant increase of urban area, as observed on other Mediterranean islands [2], this has not occurred on any of the studied islands, possibly due to the improvement of accommodation facilities within the existing urban zones rather than by their expansion in rural areas of an agricultural or natural origin. During the study period livestock density decreased dramatically by 35% (Table 13), remaining however the highest among the studied islands. With this reduction one would expect a significant transition of medium- and low-density vegetation to high and the significant increase of the latter. However, the changes between those three formations are mutual and in fact high-density is decreasing and fire is possibly responsible for this pattern. During the study period, 13,359 ha were burned, which correspond to 22.1% of the area. However, a high number of those fires occurred at the same places affecting eventually only 5228 ha or 8.64% of the area, and they are mainly concentrated in the semi-mountainous northern part of the island (Figure A1). The pattern of repeated fires in the same places is usually observed in areas with active livestock breeding to improve the grazing conditions [54]. Subsequently, it seems that the reduction of livestock on the island allowed a significant part of the low- and medium-density vegetation to recover but the remaining high livestock density, practiced in the less touristically developed parts, has prevented further vegetation recovery and caused the decrease of high-density vegetation cover. High-density olive orchards occupied almost 24% of the area in 1985, exceeding the cover of medium-density. This is the result of depopulation and abandonment of olive cultivations in the years before 1985. However, during the study period, and possibly before that, the population recovery and tourism development resulted in a significant proportion of the abandoned olive orchards to be re-cultivated, shifting the balance between the two. Given that land abandonment can result in the loss of significant cultural elements from the insular landscapes, such as the characteristic terraces observed in many Aegean Islands [2], the example of Corfu demonstrate that tourism can be successfully combined with the production of local agricultural products, such as olive oil and table olive, and prevent such loss.

Table 11. Population density during the period 1941–2011 [55].

Population Density								
Prefecture	1941	1951	1961	1971	1981	1991	2001	2011
Corfu	184.42	174.23	168.25	153.64	164.70	177.88	185.12	174.07
Lefkada	51.36	50.39	47.91	40.64	35.88	34.90	37.21	38.05
Kefalonia	110.51	90.34	76.57	60.74	51.50	53.69	65.28	62.65
Zakynthos	68.06	62.93	58.71	49.91	49.37	53.82	64.50	67.38

Table 12. Beds density of the period 1996–2015 [56,57].

Beds Density (No of beds/km^2)			
Prefecture	1996	2015	% dif.
Corfu	59.05	74.43	*+26%*
Lefkada	4.80	9.13	*+90%*
Kefalonia	9.68	17.44	*+80%*
Zakynthos	28.33	50.36	*+78%*

Table 13. Livestock density during the period 1981–2011 [55].

Livestock Density (Animal Units/km^2)			
Prefecture	1981	2011	% dif.
Corfu	603.51	393.37	*−35%*
Lefkada	176.12	129.72	*−26%*
Kefalonia	344.76	358.32	*+4%*
Zakynthos	260.62	262.26	*+1%*

Lefkada and Kefalonia are the two islands with the sharpest relief and the highest proportion of semi-mountainous areas above 500 m a.s.l., which in both cases exceeds 20%. This explains the higher proportions of high-density vegetation which exceeds 34% and with a slightly increasing trend. Lefkada has the lowest population density and density of available beds and the lowest livestock density among all islands with a decrease of 26% over the study period. At the same time, fires are almost absent from Lefkada, affecting only 2.1% of its area, possibly due to the sensitivity of locals to avoid accidental or intentional forest fires. This phenomenon may be explained by the high dispersal of settlements across the island, as well as the degree of mixing between forests and olive orchards. It is these differences in the main drivers of environmental change which explain the fact that, in Kefalonia, the low-density vegetation formations occupy a higher proportion and with an increasing trend while in Lefkada this proportion is much smaller and with a decreasing trend. In Kefalonia, fire affected 15.5% of the area over the study period and these areas are the ones exhibiting the highest change dynamics (Figures 6 and A1).

Zakynthos is the island exhibiting the strongest change dynamics. While it has the lowest persistence rate in high-density vegetation formations, they are increasing more than on any other island, by 9.3%, reaching in 2015 a percentage similar to Corfu with which it has similar relief characteristics with areas below 500 m exceeding 90%. The areas with the lowest persistence are concentrated in the western part of the island (Figure 6) which is less developed and where most fires occur (Figure A1). Fires occur more on Zakynthos than on any other island affecting 33% of the area and with many of them occurring in the same places. Despite the frequent occurrence of fire and the maintenance of the same livestock density during the study period, the low-density vegetation is decreasing significantly allowing vegetation to recover. This can be attributed to the fact that fires occur mostly in isolated areas where human presence is less intense. As a result, restoration is more likely to be affected by the dynamic nature of vegetation recovery and secondary succession and not by the pressures from grazing or other human activities.

5. Conclusions

Mediterranean islands exhibit a complex history of interactions between natural and anthropogenic processes which resulted in high biodiversity and high aesthetic and cultural values [2,6]. They are vulnerable to environmental changes since climate change and the projected increase of aridity, coupled with sea-level rise and changes in traditional human practices, are likely to affect many ecosystems and plant communities which are associated with high plant and animal biodiversity [50]. Thus, monitoring the magnitude and nature of changes is important to ensure sustainable management and balance among the acting environmental drivers. The methodology proposed in the current study, which combines freely available remote sensing data and a state-of-the-art analysis approach, offer a useful tool towards establishing an operational monitoring scheme.

The observed changes in the area in combination with an analysis of the main drivers of this change indicate that human induced processes, including livestock breeding, wild fires, and provision of tourism services, can affect the insular landscapes in varying ways. Natural vegetation types appear to be favored in most cases by the action of environmental drivers over the last 30 years. Furthermore, the development of tourism did not result in the deterioration of landscapes; in fact, it seems to have helped to prevent the loss of important cultural elements by re-establishing traditional land use practices and maintaining in those isolated areas flourishing human populations. This positive role of tourism in relation to the preservation of cultural landscapes observed in this study has not been observed in other studies conducted in the Aegean Islands. Petanidou et al. [52], for instance, pointed out the need for actions on preserving important cultural elements such as the cultivation terraces which are threatened by land abandonment and the increase in animal husbandry, despite the parallel increase of tourism over the recent decades in Aegean Islands.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Corfu 1985 accuracy assessment.

Classes	Ara.	For.	Phry.	Mea.	M. Cul.	Oli.	Oli. HD	Oli.LD	OR	O.Cult.	Per.	Shru.	Sp. Phry.	Tra.	Vin.	Total	UA
Ara.	29	0	0	2	2	0	0	0	1	4	0	0	0	0	2	40	0.73
For.	0	43	0	0	0	0	3	0	0	0	0	3	0	0	0	49	0.88
Phry.	0	0	43	1	0	0	0	0	0	0	0	0	1	4	0	49	0.88
Mea.	0	0	0	34	0	0	0	0	0	2	0	0	0	0	0	36	0.94
M. Cul	0	0	0	0	33	0	0	0	0	0	0	0	0	0	2	35	0.94
Oli.	0	1	0	0	0	36	3	5	0	0	0	0	0	0	2	45	0.80
Oli. HD	0	3	0	0	0	3	44	0	0	0	0	0	0	0	0	52	0.85
Oli.LD	0	0	0	0	0	1	0	28	0	0	0	0	0	0	0	29	0.97
OR	0	0	2	3	0	0	0	2	31	0	0	0	0	0	0	42	0.74
O. Cul	3	0	0	0	0	0	0	0	0	32	0	0	04	0	0	35	0.91
Per.	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0	35	1.00
Shru.	0	3	0	0	0	0	0	0	0	0	0	46	0	2	0	51	0.90
Sp. Phry.	0	0	3	0	0	0	0	0	3	0	0	0	35	0	0	41	0.85
Tra.	0	0	2	0	0	0	0	0	0	0	0	1	0	44	0	47	0.94
Vin.	3	0	0	0	5	0	0	0	0	2	0	0	0	0	34	47	0.77
Total	35	50	50	40	40	40	50	35	35	40	35	50	40	50	40	OA	0.87
PA	0.83	0.86	0.86	0.85	0.83	0.90	0.88	0.80	0.89	0.80	1.00	0.92	0.88	0.88	0.85	K	0.86

Table A2. Corfu 2015 accuracy assessment.

Classes	Ara.	For.	Phry.	Mea.	M. Cul.	Oli.	Oli. HD	Oli.LD	OR	O.Cult.	Per.	Shru.	Sp. Phry.	Tra.	Vin.	Total	UA
Ara.	28	0	0	1	1	0	0	0	1	5	0	0	0	0	2	38	0.74
For.	0	42	0	0	0	0	2	0	0	0	0	3	0	0	0	47	0.89
Phry.	0	0	41	1	0	0	0	0	1	0	0	0	0	3	0	46	0.89
Mea.	0	0	0	36	0	0	0	0	0	3	0	0	0	0	0	39	0.92
M. Cul	0	0	0	0	33	0	0	0	0	0	0	0	0	0	2	35	0.94
Oli.	0	1	0	0	0	34	4	6	0	0	0	0	0	0	0	45	0.76
Oli. HD	0	3	0	0	0	3	44	0	0	0	0	0	0	0	2	52	0.85
Oli.LD	0	0	0	0	0	2	0	26	0	0	0	0	0	0	0	28	0.93
OR	0	0	3	2	0	0	0	3	29	0	0	0	3	0	0	40	0.73
O. Cul	2	0	0	0	0	0	0	0	0	30	0	0	0	0	0	32	0.94
Per.	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0	35	1.00
Shru.	0	4	0	0	0	1	0	0	0	0	0	44	0	1	0	50	0.88
Sp. Phry.	0	0	4	0	0	0	0	0	4	0	0	0	37	0	0	45	0.82
Tra.	0	0	2	0	0	0	0	0	0	0	0	3	0	46	0	51	0.90
Vin.	5	0	0	0	6	0	0	0	0	2	0	0	0	0	34	47	0.72
Total	35	50	50	40	40	40	50	35	35	40	35	50	40	50	40	OA	0.86
PA	0.80	0.84	0.82	0.90	0.83	0.85	0.88	0.74	0.83	0.75	1.00	0.88	0.93	0.92	0.85	K	0.85

Table A3. Lefkada 1985 accuracy assessment.

Classes	Ara.	For.	Phry.	Mea.	M. Cul.	Oli.	Oli. HD	Oli.LD	OR	O.Cult.	Shru.	Sp. Phry.	Tra.	Vin.	Total	UA
Ara.	21	0	0	1	3	0	0	0	0	2	0	1	0	0	28	0.75
For.	0	40	0	0	0	0	3	0	0	0	2	0	0	0	45	0.89
Phry.	0	0	38	1	0	0	0	1	0	0	0	3	2	0	45	0.84
Mea.	0	0	1	31	1	0	0	0	0	0	0	1	0	0	34	0.91
M. Cul	0	0	0	0	24	0	0	0	0	0	0	0	0	5	29	0.83
Oli.	0	0	0	0	0	30	2	0	0	2	0	0	0	0	34	0.88
Oli. HD	0	0	0	0	0	0	39	0	0	0	0	0	0	0	39	1.00
Oli.LD	0	0	0	0	0	2	0	19	0	0	0	0	0	0	21	0.90
OR	0	0	0	1	0	0	0	2	22	0	0	0	0	0	25	0.88
O. Cul	2	0	0	0	0	0	0	0	0	23	0	0	0	0	25	0.92
Shru.	0	4	0	0	0	3	0	0	0	0	37	0	4	0	48	0.77
Sp. Phry.	0	0	2	0	0	0	0	0	2	0	0	30	0	0	34	0.88
Tra.	1	0	3	1	0	0	0	3	1	3	3	0	38	1	54	0.70
Vin.	0	0	0	0	3	0	0	0	0	0	0	0	0	29	32	0.91
Total	2	44	44	35	31	35	44	25	25	30	42	35	44	35	OA	0.85
PA	0.88	0.91	0.86	0.89	0.77	0.86	0.89	0.76	0.88	0.77	0.88	0.86	0.86	0.83	K	0.84

Table A4. Lefkada 2015 accuracy assessment.

Classes	Ara.	For.	Phry.	Mea.	M. Cul.	Oli.	Oli. HD	Oli.LD	OR	O.Cult.	Shru.	Sp. Phry.	Tra.	Vin.	Total	UA
Ara.	21	0	0	0	1	0	0	2	0	1	0	0	0	1	26	0.81
For.	0	41	0	0	0	0	1	0	0	0	3	0	0	0	45	0.91
Phry.	0	0	38	2	0	0	0	0	1	0	1	2	0	0	44	0.86
Mea.	0	0	1	30	3	0	0	0	0	1	0	1	0	0	36	0.83
M. Cul	0	0	0	0	27	0	0	0	0	0	0	0	0	2	29	0.93
Oli.	1	0	1	0	0	32	3	2	0	0	0	0	0	3	42	0.76
Oli. HD	0	0	0	0	0	2	40	0	0	0	0	0	0	0	42	0.95
Oli.LD	0	0	0	0	2	1	0	21	0	0	0	0	0	1	25	0.84
OR	0	0	0	0	0	0	0	0	21	0	0	0	0	0	21	1.00
O. Cul	2	0	0	0	1	0	0	0	0	30	0	0	0	0	33	0.91
Shru.	0	3	0	1	0	0	0	0	0	2	38	0	2	3	49	0.78
Sp. Phry.	0	0	2	0	0	0	0	0	3	0	0	31	0	0	36	0.86
Tra.	0	0	2	2	0	0	0	0	0	1	2	1	42	2	52	0.81
Vin.	1	0	0	0	1	0	0	0	0	0	0	0	0	23	25	0.92
Total	25	44	44	35	35	35	44	25	25	35	44	35	44	35	OA	0.86
PA	0.84	0.93	0.86	0.86	0.77	0.91	0.91	0.84	0.84	0.86	0.86	0.89	0.95	0.99	K	0.85

Table A5. Kefalonia 1985 accuracy assessment.

Classes	Ara.	For.	Phry.	Mea.	M. Cul.	Oli.	Oli. HD	Oli.LD	OR	O.Cult.	Shru.	Sp. Phry.	Tra.	Vin.	TOTAL	UA
Ara.	25	0	0	1	6	0	1	0	0	5	0	0	0	3	41	0.61
For.	0	56	0	0	0	0	4	0	0	0	5	0	0	0	65	0.86
Phry.	0	0	52	3	0	0	0	1	2	0	0	3	4	0	65	0.80
Mea.	0	0	1	37	1	0	0	0	0	0	0	0	0	0	39	0.95
M. Cul	0	0	0	0	34	0	0	0	0	0	0	0	0	4	38	0.89
Oli.	0	0	0	0	0	36	4	1	0	0	1	0	0	0	42	0.86
Oli. HD	0	0	0	0	0	2	49	0	0	0	0	0	0	0	51	0.96
Oli.LD	1	0	0	0	0	5	0	27	0	2	0	0	2	0	34	0.71
OR	0	0	2	3	0	0	0	4	26	0	0	4	0	0	39	0.67
O. Cul	3	0	0	0	2	0	0	0	0	38	0	0	0	0	43	0.88
Shru.	0	3	00	0	0	2	2	0	0	0	48	0	3	0	58	0.83
Sp. Phry.	0	0	2	0	0	0	0	0	2	0	0	38	0	0	42	0.90
Tra.	0	1	3	1	0	0	0	0	0	0	6	0	51	0	62	0.82
Vin.	0	0	0	0	2	0	0	0	0	0	0	0	0	38	41	0.93
Total	30	60	60	45	45	45	60	30	30	45	60	45	60	45	OA	0.84
PA	0.83	0.93	0.87	0.82	0.76	0.80	0.82	0.80	0.87	0.84	0.80	0.84	0.85	0.84	K	0.82

Table A6. Kefalonia 2015 accuracy assessment.

Classes	Ara.	For.	Phry.	Mea.	M. Cul.	Oli.	Oli. HD	Oli.LD	OR	O.Cult.	Shru.	Sp. Phry.	Tra.	Vin.	Total	UA
Ara.	24	0	0	2	7	0	0	0	0	7	0	0	0	3	43	0.56
For.	0	55	0	0	0	0	2	0	0	0	05	0	0	0	62	0.89
Phry.	0	0	53	3	0	0	0	1	2	0	0	3	4	0	66	0.80
Mea.	0	0	1	36	2	0	0	0	0	0	0	0	0	0	39	0.92
M. Cul	0	0	0	0	32	0	0	0	0	0	0	0	0	4	36	0.89
Oli.	0	0	0	0	0	37	3	2	0	0	1	0	0	0	43	0.86
Oli. HD	0	1	0	0	0	1	54	0	0	0	0	0	0	0	56	0.96
Oli.LD	0	0	0	0	0	5	0	23	0	2	0	0	2	0	32	0.72
OR	0	0	2	3	0	0	0	4	26	0	0	3	0	0	38	0.68
O. Cul	4	0	0	1	2	0	0	0	0	36	0	0	0	0	43	0.84
Shru.	0	3	0	0	0	2	1	0	0	0	48	0	3	0	57	0.84
Sp. Phry.	0	0	2	0	0	0	0	0	2	0	0	39	0	0	43	0.91
Tra.	0	1	2	0	0	0	0	0	0	0	6	0	51	0	60	0.85
Vin.	2	0	0	0	2	0	0	0	0	0	0	0	0	38	42	0.90
Total	30	60	60	45	45	45	60	30	30	45	60	45	60	45	OA	0.84
PA	0.80	0.92	0.88	0.80	0.71	0.82	0.90	0.77	0.87	0.80	0.80	0.87	0.85	0.84	K	0.82

Table A7. Zakynthos 1985 accuracy assessment.

Classes	Ara.	For.	Phry.	Mea.	M. Cul.	Oli.	Oli. HD	Oli.LD	OR	O.Cult.	Per.	Shru.	Sp. Phry.	Tra.	Vin.	Total	UA
Ara.	27	0	0	0	0	0	0	0	0	3	0	0	0	0	0	30	0.90
For.	0	46	0	0	0	0	0	0	0	0	0	5	0	1	0	52	0.88
Phry.	1	0	45	3	0	0	0	0	0	0	0	0	0	3	0	52	0.87
Mea.	2	0	1	32	0	0	0	2	1	0	0	0	0	3	0	41	0.78
M. Cul	2	0	0	0	32	0	0	0	0	0	0	0	0	2	4	40	0.80
Oli.	1	2	0	0	0	36	3	1	0	0	0	0	0	0	0	43	0.84
Oli. HD	0	1	0	0	0	3	46	0	0	0	0	0	0	0	2	52	0.88
Oli.LD	2	0	0	0	0	1	0	25	2	0	0	0	0	0	0	30	0.83
OR	0	0	2	1	0	0	0	0	24	0	0	2	2	1	0	32	0.75
O. Cul	3	0	0	0	0	0	0	2	0	32	0	1	0	0	2	40	0.80
Per.	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	7	1.00
Shru.	0	4	1	0	0	0	0	0	0	0	0	44	0	3	0	52	0.85
Sp. Phry.	0	0	0	0	0	0	0	0	0	0	0	0	38	0	0	38	1.00
Tra.	0	2	1	0	0	0	0	0	1	0	0	3	0	45	0	52	0.87
Vin.	0	0	0	0	4	1	0	0	0	0	0	0	0	0	35	40	0.88
Total	38	55	50	36	36	41	49	30	28	35	7	55	40	58	43	OA	0.86
PA	0.71	0.84	0.90	0.89	0.89	0.88	0.94	0.83	0.86	0.91	1.00	0.80	0.95	0.78	0.81	K	0.84

Table A8. Zakynthos 2015 accuracy assessment.

Classes	Ara.	For.	Phry.	Mea.	M. Cul.	Oli.	Oli. HD	Oli.LD	OR	O.Cult.	Per.	Shru.	Sp. Phry.	Tra.	Vin.	Total	UA
Ara.	23	1	0	3	1	0	0	0	0	1	0	0	0	0	1	30	0.77
For.	0	48	0	0	0	0	0	0	0	0	0	4	0	0	0	52	0.92
Phry.	0	2	45	0	0	0	0	0	0	0	0	0	2	3	0	52	0.87
Mea.	1	0	3	35	0	0	0	0	0	0	0	0	0	1	0	40	0.88
M. Cul	0	0	0	5	31	0	0	0	0	1	0	0	0	0	2	39	0.79
Oli.	0	1	0	0	1	35	0	3	0	0	0	0	0	0	0	40	0.88
Oli. HD	0	0	0	0	0	8	44	0	0	0	0	0	0	0	0	52	0.85
Oli.LD	0	0	0	1	1	0	0	24	0	0	0	0	0	1	0	27	0.89
OR	0	0	3	0	0	0	0	0	26	0	0	0	3	0	0	32	0.81
O. Cul	2	1	0	1	2	1	0	0	0	33	0	0	0	0	0	40	0.83
Per.	0	0	0	0	0	6	0	0	0	0	1	0	0	0	0	7	0.14
Shru.	0	10	0	0	0	0	0	0	0	0	0	42	0	0	0	52	0.81
Sp. Phry.	0	0	3	0	0	0	0	0	1	0	0	0	35	1	0	40	0.88
Tra.	0	3	0	0	0	0	0	0	0	0	0	3	0	45	0	51	0.88
Vin.	0	0	0	0	3	1	0	0	0	0	0	0	0	0	36	40	0.90
Total	26	66	54	45	39	51	44	27	27	35	1	49	40	51	39	OA	0.85
PA	0.88	0.73	0.83	0.78	0.79	0.69	1	0.89	0.96	0.94	1	0.86	0.86	0.88	0.92	K	0.83

Appendix B

Table A9. Burned areas (Ha) during the period 1985–2015 (source: Laboratory of Environmental Management and Ecology, Technological Education Institute of Ionian Islands).

Year	Corfu	Lefkada	Kefalonia	Zakynthos	Year	Corfu	Lefkada	Kefalonia	Zakynthos
1985	1253	–	1065	2139	2000	954	–	680	100
1986	332	–	1137	664	2001	60	–	56	188
1987	1204	–	1572	254	2002	8	–	30	64
1988	2982	40	5297	124	2003	42	–	109	64
1989	126	–	351	333	2004	–	2	228	150
1990	378	259	289	1618	2005	143	–	137	296
1991	19	–	242	–	2006	0	–	260	933
1992	702	45	1569	2146	2007	129	–	2214	1095
1993	321	39	51	40	2008	14	18	156	908
1994	1171	10	400	96	2009	3	–	52	2128
1995	–	–	478	202	2010	149	167	223	232
1996	1393	135	121	63	2011	1027	–	245	2003
1997	704	26	597	412	2012	–	–	166	1053
1998	–	–	1803	1312	2013	–	–	124	29
1999	233	–	12	56	2014	–	–	46	31
					2015	12	–	38	125

Figure A1. Fire events during the period 1985–2015.

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