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Mapping change in the agricultural landscape of Lemnos

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ABSTRACT

The agricultural landscape of Mediterranean islands has transformed radically over the last 60 years. The results differ, due to the interplay of macro, national, and local factors for each setting. In this study, some of these trajectories of change are examined for the island of Lemnos in Greece, using remote sensing and oral history techniques. The first aim is to present the changes in and of the agricultural landscape of Lemnos, applying quantitative and qualitative methods, in order to capture different aspects of those changes. The second aim is to identify the socio-economic factors that underlie landscape changes or lack of, using local knowledge and perception of the landscape. Land cover maps were produced by aerial photographs using additional texture features, for 1960, 1980, and 2002, through object-oriented image analysis (OBIA). Interviews and a workshop with local actors were used to validate and understand different change trajectories, and to identify the factors behind these changes. Results show that although grasslands have increased, revealing a process of extensification of agriculture in the study area, change has affected a small proportion of the landscape. This process is backed by information revealed through qualitative methods, as migration of labor power in the 1960s and mechanization of the agricultural sector in the late 1970s and early 1980s have been the main factors of the transformation of the agricultural sector in Lemnos, resulting in bigger mixed crop-livestock farms and the abandonment of marginal areas. The results of these processes are discussed in the context of agricultural change in the Mediterranean.

1. Introduction

The study of landscape change provides a tool to understand land use and landscape dynamics. Landscapes reflect the dynamic relation between humans and the environment over time in a specific geographic setting. Land uses and management systems leave their own imprint and specific elements on the landscape. Especially in the Mediterranean, the landscape has been shaped by the interaction of human agency and the natural environment for thousands of years. This dynamic interaction is expressed in many elements of the traditional Mediterranean landscape, such as field systems, enclosures, and stone terraces (Detsis, Ntasiopoulou, Chalkias, & Efthimiou, 2010; Grove & Rackham, 2001; Turner, Bolòs, & Kinnaird, 2018; Tzanopoulos, Mitchley, & Pantis, 2007).

Change is an inherent characteristic of landscapes (Bürgi, Hersperger, & Schneeberger, 2004), happening at different rates and depending on many factors. In the Mediterranean, landscape has been radically transformed over the last 60 years (Jepsen et al., 2015). The results differ due to the interplay of macro, national, and local factors for each setting (Malek & Verburg, 2017). Plieninger et al. (2016) report that the most important landscape change processes in the Mediterranean include land abandonment and extensification. It has been acknowledged that some of these changes are linked with severe environmental problems, such as soil erosion, desertification, and biodiversity loss, along with the loss of cultural practices (Karamesouti et al., 2015; Lasanta, Nadal-Romero, & Arnáez, 2015), especially on islands. The Mediterranean islands are typically characterized by limited biodiversity, a higher degree of endemism, and more fragile ecosystems (Blondel, Aronson, Bodiou, & Boeuf, 2015). The islands of the Aegean are typical cases of limited potential for intensive agricultural production due to their rather poor soils and limited water resources (Spilanis & Kizos, 2015), while they have been both open and isolated (Royle, 2014) in terms of land use systems.

Landscape change has recently been linked to processes and drivers of change (for an overview of the different conceptualizations see Kizos et al., 2018a). Currently, there are five major types of landscape change drivers used in the literature (Brandt, Primdahl, & Reenberg, 1999; Plieninger et al., 2016): socioeconomic, political, technological, natural, and cultural, while different temporal and spatial scales have been identified as important for their study (Bürgi et al., 2004). The process of change in agricultural landscapes mainly concerns land-use change (such as deforestation or urbanization) and intensity of land uses, although the difference between the two is not always very clear (van Vliet, de Groot, Rietveld, & Verburg, 2015). In land system science, these processes are interlinked with their underlying drivers, in an effort to comprehend their dynamics and eventually construct models that will be able to provide more sustainable solutions (Meyfroidt et al., 2018).

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In this human-environment system, the decisions and actions of people (often called actors or agents) are the main actual forces that result in landscape change at a local level. Most studies in landscape change involve quantitative methods, especially remote sensing techniques to conduct Land Cover – Land Use (LCLU) analysis alongside socioeconomic data and official statistics to access drivers, usually with the help of experts (Plieninger et al., 2016). However, these cases do not explicitly address the role of actors but try to explain the effects of drivers directly on land. In more complex models where actors are considered important in modeling landscape change, qualitative methods are required, such as surveys or face to-face interviews, to gain information on their actions (Hersperger, Gennaio, Verburg, & Bürgi, 2010).

Moreover, Bürgi, Östlund, and Mladenoff (2017) stress the matter of landscape perception as a component that needs to be incorporated in an integrated approach. Recording perceptions of landscape change and drivers of change directly from the actors' recollection can provide a cultural framework for these changes. In this direction, the combination of quantitative information from LCLU change detection with the use of remote sensing, and qualitative information from social sciences has been proposed in order to gain a comprehensive understanding of landscape change (Bürgi et al., 2017; Rindfuss, Walsh, Turner, Fox, & Mishra, 2004; Yaeger & Steiger, 2013).

Many studies on agricultural landscape change focus on marginal areas, such as mountains or islands, as they are considered hotspots of change (van Vliet et al., 2015; Verburg & Overmars, 2009). In this paper the history and drivers of landscape change on a Mediterranean Island, Lemnos, are presented having a twofold scope: The first aim is to identify and quantify change and persistence in and of the landscape and the second to explore and understand the processes and the socio-economic drivers behind these changes – or the lack of them. Our intention is to go beyond a broad landscape persistence/change analysis and attempt to focus on a specific time period of a locality where major changes on other Aegean islands have been reported (e.g. Spilanis & Kizos, 2015; Tzanopoulos & Vogiatzakis, 2011; Schaich, Kizos, Schneider, & Plieninger, 2015; Tzanopoulos et al., 2007; Petanidou, Kizos, & Soulakellis, 2008b) and discuss the reasons why such radical changes did not take place in the particular case study area. We also aim for a methodological "plurality" advocated by Kizos et al. (2018a) in bringing in the views and attitudes of local actors to verify findings and explain the local context of change/persistence.

2. Methodology, data, processing and analysis

2.1. Study area

Lemnos is a Greek island (478 km^2, 260 km coastline), partly volcanic, consisting of trachytes, phonolites, and volcanic tuffs, while tertiary sediments of marly clay and loess loam can be found mainly in the lowlands (Biel, 2002). Its relief, in contrast to most of the Greek islands, is mostly flat with rolling hills in the western part. Vegetation on the island is mainly phrygana and low maquis along with extensive areas of arable fields and vineyards. The climate is Mediterranean semi-arid, with mild winters and hot dry summers, strong winds, and annual precipitation of 500 mm (Panitsa, Snogerup, Snogerup, & Tzanoudakis, 2003).

Fakos study area is located at the southwest part of Lemnos, covers 54,50 km^2 and includes the communities of Kontias, Tsimandria, and Portianou (Fig. 1). The landscape is mixed with hilly areas in the western part, succeeded by the fertile irrigated plain of Kontias and Tsimandria, where fodder and cereals are mainly cultivated. The uninhabited peninsula of Fakos in the south has always been used primarily for grazing. The number of farms has declined by 70% in the period 1961–2000 (from 578 to 179 farms), but the Utilized Agricultural Area (UAA) has increased by 20%, marking a rise in the average size of farms and a rapid decline in the number of plots per farm. Stockbreeding has intensified as the number of sheep per farm increased from 30 to 100 (all data retrieved from the Official Census of Agriculture in 1961 and 2000). At the same period, according to the Population Census data, the population of the three villages declined by 42% (from 2,188 in 1961 to 1,248 people in 2001, almost all of which took place from 1961 to 1971). These trends follow the overall trends of most Aegean Islands: population decline until the 1970s, stabilization until the 1990s, and partial growth with ageing thereafter (Spilanis & Kizos, 2015). Migration to the mainland and abroad, mainly Australia, during the decade of 1960 played a major part in rural depopulation of the area (Bakalis, 2007).

2.2. Materials and methods

Following Bürgi et al. (2017), a mixed-method approach that combines remote sensing and qualitative methods (interview, workshop) was used in order to not only document and monitor landscape changes but also explore the human-environment system dynamics.

The methodology can be divided into 3 separate phases (see Fig. 2):

First, published literature and statistical information were used to create a basic timeline of historical changes in order to explore the broader time frame of changes and guide further analysis. This information was cross-checked through an open interview with two key informants of the Regional Department of Agricultural Economy in Lemnos. The questions focused primarily on historical changes of agricultural history which brought changes in production, practices, and characteristics of agricultural holdings, aiming to build a narrative of events and factors that might have affected the landscape. Two periods were selected after this step to assess changes, covering 20 years each, from 1960 to 1980 and from 1980 to 2002.

Land cover change analysis followed. Object-based image analysis (OBIA) on panchromatic ortho-photos was used to get information on land cover from aerial imagery on the selected dates. The selection of classes in the classification process was based on ground truth data obtained through a published survey conducted in 2018, which focused on recording agricultural practices (Dimopoulos, Dimitropoulos, & Georgiadis, 2018), as well as on data from vegetation maps of 1996 from the Ministry of Agriculture, resulting in seven classes. A fundamental difference was between cultivated and grazing (grasslands and frygana) land. Crops included cereals, cotton, legumes, other fodder crops and vegetables. In grazing lands herbaceous and phryganic formations (mainly *Sarcopoterium spinosum*) were included. The remaining categories – urban, shrublands, inland water bodies, bare soil and coastal wetlands – complement the rest of the classification.

Post classification comparison followed, providing changes that occurred between these periods, and cross tabulation was used to assess land conversions. Overarching trends were selected to highlight the change and persistence processes as presented in Table 1: intensification, extensification, urbanization, and abandonment of farm land (Bürgi et al., 2017). Other patterns of land use change include the construction of the water dam in the location of Kontias and flooding. Relationships between findings and topography (slope, altitude) were also investigated (Detsis et al., 2010).

Finally, a focus group workshop targeting local elder farmers (over 50 years old) was held to validate changes derived in the previous step. The workshop took place on 10th July 2019 in one of the villages of the area, Portianou. The nine participants were over 60 years old, all still active farmers with mixed farms, covering a range of farm sizes. Making use of the results from remote sensing, a participatory mapping approach was performed, as farmers were asked to point on maps what land use changes they had witnessed, with the help of place names and other landmarks such as *mandras* (livestock pens). Results were grouped into categories that correspond to the selected processes of change and persistence. Other explanatory information was also recorded in order to understand the processes behind those land use conversions. With the use of questionnaires (see supplementary material) factors that

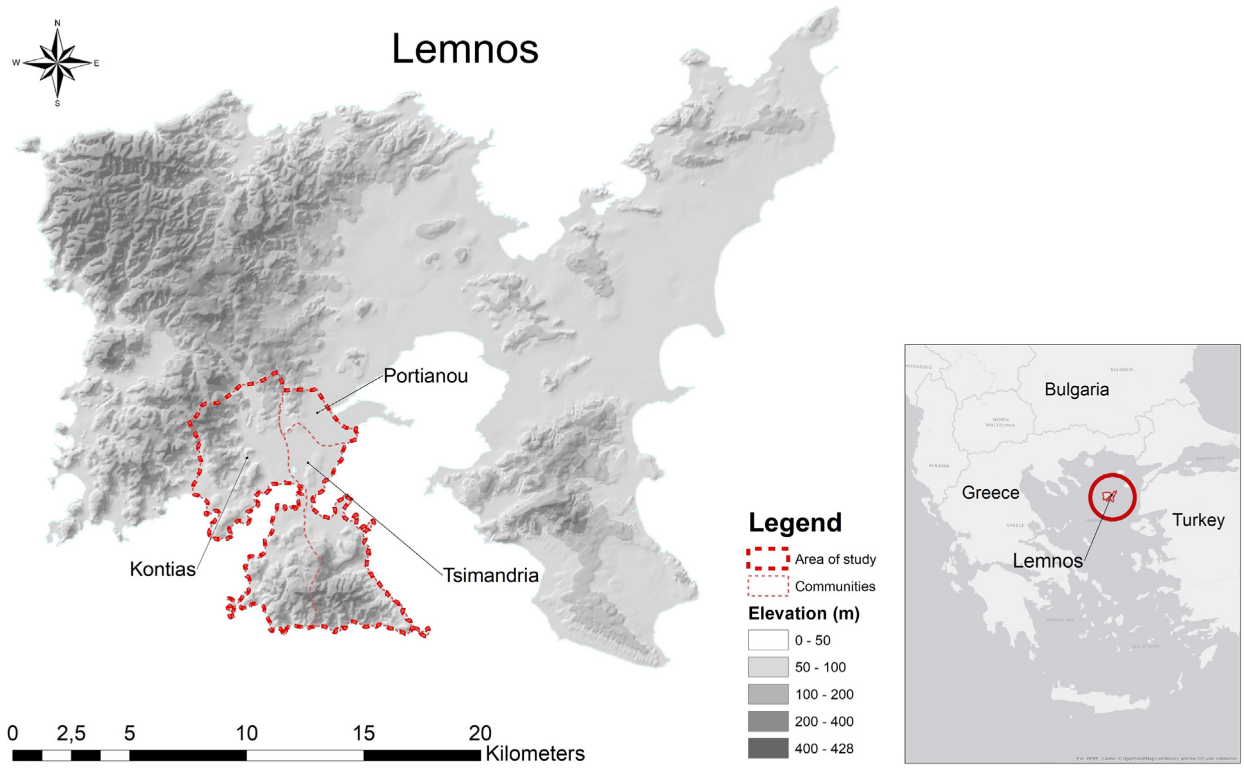

Fig. 1. . Lemnos island and position of case study area.

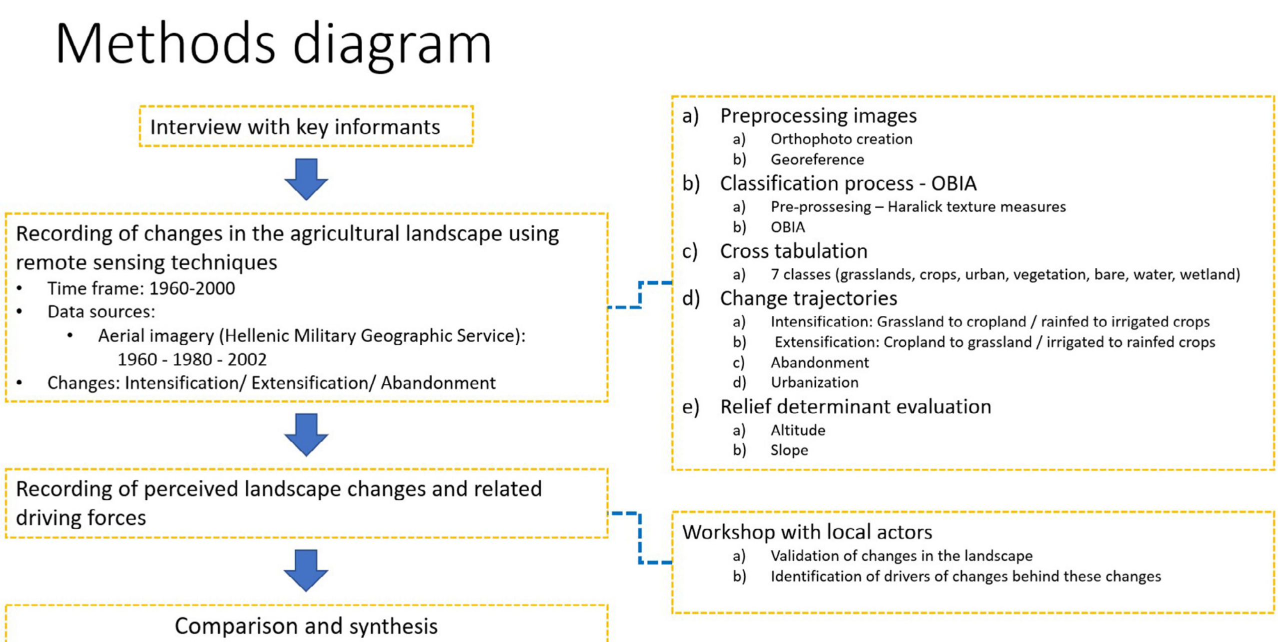

Fig. 2. . Methodology diagram followed in this study.

contributed to the changes were also recorded. Answers by the farmers were gathered and then were qualitatively regrouped into drivers of change. A clear connection between the spotted changes and drivers of change was not possible in all cases, as farmers tended to cite factors that refer to the wider context of the whole island.

2.3. Data sets, data processing, and analysis

2.3.1. Preprocessing images

Black and white panchromatic aerial photographs were obtained for the years 1960 (1:30,000), 1980 (1:35,000), and 2002 (1:40,000), and a time series of three photo-mosaics for each study site was developed using structure for motion algorithm from AgisoftPhotoscan software, producing photo-mosaics that covered 97% of the area. Prior to the analysis, the photo mosaics were georeferenced and rectified to EGSA87

Table 1
. Land cover conversion and acknowledged processes.

	Grasslands	Crops	Urban	Shrubland	Bare	Waterbodies	Wetlands
Grasslands	–	Intensification	Urbanization	Abandonment	Abandonment	Water dam	Other / Flooding
Crops	Extensification	–	Urbanization	Abandonment	Abandonment	Water dam	Other / Flooding
Urban	–	–	–	–	–	–	–
Shrubland	Other	Intensification	Urbanization	–	Other	Water dam	Other / Flooding
Bare	Other	Intensification	Urbanization	Other	–	Water dam	Other / Flooding
Waterbodies	Intensification	Intensification	Urbanization	Other	Other	–	Other
Wetlands	Intensification	Intensification	Urbanization	Other	Other	Water dam	–

Greek Grid projection with the same resolution of 1 m pixel size in order to make comparison between images possible (see Table 1 of Supplementary material).

Additional texture features were used to enlarge signature space and provide information on the pixel level for the segmentation process. Haralick, Shanmugan, and Dinstein (1973) has provided the most accredited and well-known texture measures based on the Grey Level Co-occurrence Matrix (GLCM). Caridade, Marçal, and Mendonça (2008) have tested the Haralick features in pixel-based classification, suggesting that the method has proven useful with good results. Halounova (2004) uses GLCM in OBIA in order to find solutions for classification of black and white aerial orthophotographs. From a variety of GLCM textures, contrast and homogeneity were used (see Table 2 of Supplementary material).

Following our conversation with key informants, slope was also selected to contribute to OBIA analysis and especially in the segmentation process, as it seems to be an important parameter in distinguishing crops from grasslands.

2.3.2. Object-based image analysis – OBIA

Object Based Image Analysis uses pixel neighboring values to analyze images in segments through various segmentation methods. Then the image objects created from the segmentation process can be classified through known classification methods.

In this study, multiresolution segmentation was used in a 3 levels procedure (Fig. 3). This was done in order to overcome the problem of under-segmentation as pointed out by Liu and Xia (2010). The scene is segmented at a scale of 400, classified, then specific classes (crops, grassland and wetlands) are segmented again at a scale of 200, reclassified, and then crop class is segmented again at a scale of 75, when a final classification is applied. This procedure has the advantage of refining the results in order to get more precise classification and more meaningful features, avoiding under-segmentation. In every step an evaluation of the classification and manual correction of some results was necessary in order to avoid the replication of errors in lower levels.

After the multiresolution segmentation, supervised classification based on nearest neighbor classification was applied (Cover & Hart, 1967). Sample selection for each class was selected through interpretation of the photomosaics as no ground information was available on those dates. Texture, homogeneity of brightness, asymmetry, and scale of shapes, were among the characteristics used to define the samples (Table 3 of Supplementary material).

2.3.3. Accuracy assessment

The commonly used accuracy assessment elements in pixel-based change detection include overall accuracy, producer's accuracy, user's accuracy and the kappa coefficient (Lu, Mausel, Brondízio, & Moran, 2004). However, a basic difference with object oriented based analysis is that study units can be either pixels or image objects. Biging et al. (1999) argued that pixel-based accuracy assessments tend to underestimate object-based map accuracy. In this study, a polygon-wise validation is used with an error matrix that was provided from E-Cognition software based on image objects.

To produce the error matrix with a Training and Test Area mask in E-cognition two scenes were used. Classification as produced from the classifier and a revised version where misclassification errors were corrected based on interpretation of the ortho-photos as other validation data was not available for these dates. From this comparison three accuracy measures were produced: Producer's, User's, and Overall Accuracy. Producer's accuracy indicates how well training set image objects of the given cover type are classified (Table 2). User's accuracy indicates the probability that an image object classified into a given category represents that category on the ground (Rahman & Saha, 2008). Kappa statistics indicate how much the classifier omits errors, compared to a randomly assigned classification.

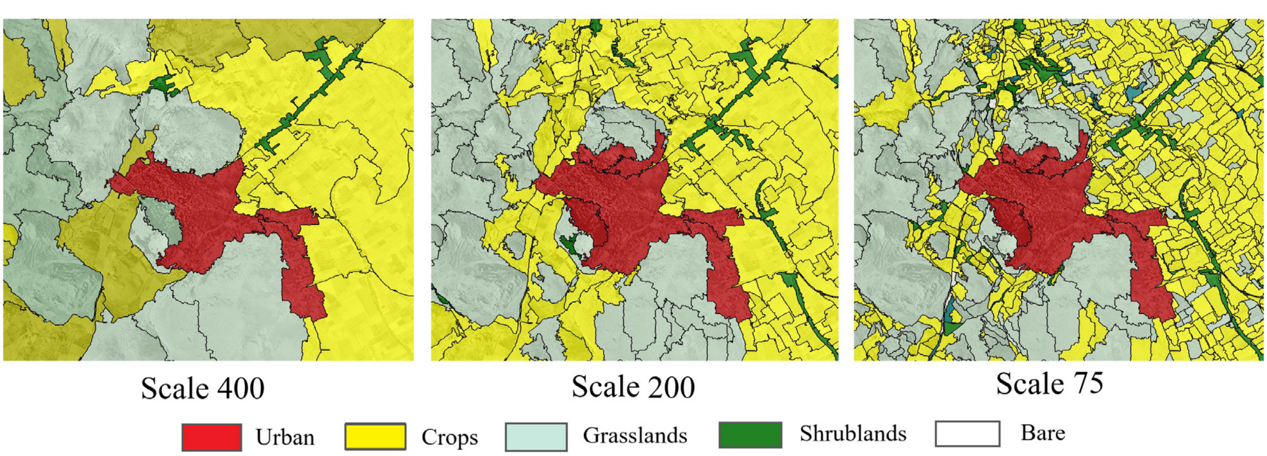

Fig. 3. Different segmentation scale results.

Table 2
. Classification accuracy for each year.

Error matrix 1960

	Grasslands	Crops	urban	Shrublands	Bare	Waterbodies	Wetlands
Producer's Accuracy	0.8846	0.8736	1	0.7112	0.8712	–	0.6924
User's Accuracy	0.8848	0.8822	0.982	0.8082	0.5827	–	0.7775
Kappa Index Per Class	0.7876	0.7638	1	0.7057	0.8682	–	0.688
Overall Accuracy 0.875							
Kappa Index Overall 0.781							

Error matrix 1980

	Grasslands	Crops	Urban	Shrublands	Bare	Waterbodies	Wetlands
Producer's Accuracy	0.9374	0.9695	0.823	0.699	0.468	1	0.2586
User's Accuracy	0.9707	0.8727	1	0.9792	1	1	0.8917
Kappa Index Per Class	0.879	0.944	0.8198	0.695	0.4611	1	0.256
Overall Accuracy: 0.9235							
Kappa Index Overall: 0.866							

Error matrix 2002

	Grasslands	Crops	Urban	Shrublands	Bare	Waterbodies	Wetlands
Producer's Accuracy	0.9966	0.9718	0.8791	0.6343	0.4926	1	0.7952
User's Accuracy	0.8233	0.8637	0.9846	0.7857	1	1	0.6228
Kappa Index Per Class	0.9965	0.9407	0.8	0.63	0.484	1	0.7915
Overall Accuracy: 0.9085							
Kappa Index Overall: 0.8417							

3. Results

3.1. Remote sensing

3.1.1. Land cover

Grasslands are the dominant land cover throughout the 40-year period (Table 3), followed by crops, cumulatively covering over 90% of land. In 1960, grasslands accounted for 50% and crops for 40%, while in 1980 grasslands increased to 60% and crops decreased to 32% of the total land area. In 2002, grasslands decreased to 55% and crops increased to 37%. The other land cover classes are marginal, as only bare land has a presence near 4% and all others account for less than 2%.

Crops, as expected, are prominent in lowlands whereas the higher altitudinal zones are occupied by grasslands. Altitudinal zones from 100 to 200 m have a significant presence of crops in 1960 that later decreases. This indicates that cultivation in the 1960s was present in more marginal areas such as hill slopes, with 20% of all crops located between 50 and 200 m altitude. Bare land can be found mainly in Fakos, as the peninsula has steeper slopes. The appearance of waterbodies in 1980 and in 2002 is a result of the construction of the Agios Dimitrios irrigation dam.

Shrubland vegetation has been identified in ravines and linear features such as tree lines alongside main roads. Moreover, in some cases plots were occupied by trees at a visible scale and were classified as shrubland, but this doesn't mean that those were tree crops, as different tree structures were classified under this class label. Presence of sparse shrubland vegetation among cropland was recorded in 1960 but not in consecutive years.

Table 3
. Land cover per year and changes in cover between the two periods. Differences in total area are due to difference of area cover of the photomosaics.

	1960		1980		2002		1960-1980	1980-2002	1960-2002
	Km²	Percentage	Km²	Percentage	Km²	Percentage	Percentage	Percentage	Percentage
Grassland	26,86	50,13%	33,09	60,32%	30,50	55,48%	23,21%	-7,83%	13,56%
Crops	21,84	40,77%	17,54	31,97%	20,11	36,59%	-19,71%	14,66%	-7,94%
Urban	0,61	1,14%	0,61	1,12%	0,62	1,12%	0,79%	0,73%	1,52%
Shrubland	0,87	1,63%	0,63	1,15%	0,46	0,84%	-27,46%	-26,66%	-46,80%
Bare	2,48	4,63%	1,84	3,35%	2,22	4,05%	-25,83%	20,94%	-10,30%
Waterbodies			0,30	0,55%	0,23	0,42%	100%	-23,07%	100%
Wetlands	0,52	0,97%	0,43	0,79%	0,48	0,88%	-16,50%	11,27%	-7,09%
Unclassified	0,40	0,74%	0,41	0,75%	0,34	0,62%	3,20%	-16,82%	-14,15%
Total	53,58	100%	54,85	100%	54,96	100%			

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Urban areas occupy the edge of the main plains at the feet of hills overlooking the plain and are evenly dispersed. There are two areas that appear constantly as coastal wetlands north and south of Diapori, as well as two smaller areas east and west of Nevgatis which appear in the classification of 1960 and 2002, but not in 1980.

3.1.2. Changes and conversions

When comparing the classifications of 1960 and 2002 it seems that the landscape has not changed significantly, as 75.6% of land is classified under the same class. The examination of the two intermediate periods reveals that in 1960–1980 classification changes comprise 25.4% of the total land area, while in 1980–2002 up to 20.8%. Cumulatively, 65.76% of the total land cover has not been transformed at all in both periods.

Another 22.2% has undergone some kind of transformation once in the period of 40 years, while 12.1% is in constant transformation. These areas under change are not evenly distributed geographically as the peninsula of Fakos has undergone more changes than the mainland.

The most important change seems to be the interchange of land between the two dominant classes, with cropland turning to grasslands being the major trend between 1960 and 1980, while in the period 1980–2002 the opposite trend is recorded (Table 4). Although these changes happen simultaneously, it seems that cultivated land is continuously abandoned in higher altitudes and steeper slopes, whereas it is regained in the period of 1980–2002 in lowlands with mild to steep slopes (Figs. 4 and 5).

The small area size of other classes can lead to erroneous conclusions as spectral and resolution differences may cause unexpected changes due to false classification. Under this prism, change from urban areas to other uses has been ignored as it is highly unlikely for such a transformation to take place. Bare land was in some cases misclassified under grasslands and thus presented an intense fluctuation, from −25.83% in 1960–1980 to +20.94% in the next period, presenting an overall loss of 10.30%. Shrubland presents a steady decrease trend between 1960 and 2002, shrinking to almost half of its initial surface. Wetlands presented an overall loss of 7.09% with fluctuation between −16.50% and 11.27%. This fluctuation should be attributed to their seasonal appearance rather than a transformation into another class.

3.1.3. Land use trajectories – processes of change

Land use trajectories reveal that extensification and intensification processes coexist, the first being prominent overall, as the basic trend seems to be that of cropland transforming to grasslands (Table 5). Intensification is also a basic trend as different land uses are turned to agricultural land and grasslands are converted to crops. Abandonment, which represents a variety of transformations from agricultural land to bare land, shrubland vegetation and wetlands, stands for 12.45% of total land transformations in the period 1960–2002. Looking at the two periods separately a distinct pattern can be observed. Extensification seems to be the main process of change from 1960 to 1980, whereas intensification is the main trend for the following 20 years.

3.2. Workshop results

3.2.1. Processes

Recalling actual memories of past changes, participants stated their own perception of changes in the landscape (Fig. 6). Reference units used in this oral procedure were less exact, as they varied from the whole plain of Kontias, a place name, or a *mandra* unit. Results from questions regarding changes and processes of change were focused on 5 main narratives:

Cotton to cereals: The rise and fall of cotton cultivation on the island and the subsequent change from cotton crops to cereal crops. This process is characterized as extensification, as it involves a change between intensively managed irrigated crops to more extensive rain-fed crops.

Cropland to grassland: This process of extensification was directly connected with the use of machinery and access to roads, as participants commented on the need to convert from croplands for areas which were not accessible with machinery.

Abandonment: In the case of the southeastern Fakos peninsula participants described the area as abandoned, i.e. neither cropland nor grasslands. This process was directly related to abandoned holdings (*mandras)* as people either migrated or failed to ensure succession in their farms.

Intensification: participants identified an area of grasslands that was converted into cropland after 1980.

Persistent areas: When it came to define what remained unchanged, participants tended to refer to specific holdings (*mandras)* where land is

Table 4
Cross tabulation of classes between the two periods.

CLASS 1960/CLASS 1980	Grassland	Crops	Urban	Shrubland	Bare	Water	Wetlands
Grassland	89,24%	8,78%	0,05%	0,64%	1,24%	0,01%	0,05%
Crops	30,79%	63,50%	0,53%	1,37%	2,34%	1,16%	0,32%
Urban	12,03%	8,85%	78,26%	0,46%	0,40%	0,00%	0,00%
Shrubland	34,25%	43,88%	1,01%	16,11%	2,02%	1,91%	0,82%
Bare	45,86%	23,28%	0,21%	0,67%	28,31%	1,10%	0,57%
Wetlands	4,49%	24,00%	0,00%	0,26%	7,27%	0,00%	63,97%
CLASS 1980/CLASS 2002	**Grassland**	**Crops**	**Urban**	**Shrubland**	**Bare**	**Water**	**Wetlands**
Grassland	81,71%	16,11%	0,06%	0,30%	1,73%	0,00%	0,08%
Crops	15,03%	79,15%	0,78%	0,90%	3,48%	0,00%	0,67%
Urban	6,23%	15,57%	70,69%	0,22%	7,28%	0,00%	0,00%
Shrubland	23,06%	43,57%	0,34%	28,21%	4,64%	0,00%	0,18%
Bare	26,17%	23,55%	0,94%	0,85%	46,95%	0,00%	1,54%
Water	4,41%	9,45%	0,00%	0,29%	8,16%	69,26%	8,43%
Wetlands	2,43%	19,26%	0,07%	2,85%	9,63%	0,00%	65,76%
CLASS 1960/CLASS 2002	**Grassland**	**Crops**	**Urban**	**Shrubland**	**Bare**	**Water**	**Wetlands**
Grassland	85,93%	11,90%	0,08%	0,29%	1,73%	0,01%	0,06%
Crops	22,63%	71,12%	0,63%	1,09%	3,40%	0,78%	0,36%
Urban	12,05%	6,20%	73,13%	2,15%	6,46%	0,00%	0,00%
Shrubland	30,05%	51,25%	0,81%	12,11%	3,92%	1,50%	0,35%
Bare	45,39%	23,12%	0,19%	0,45%	28,16%	0,90%	1,79%
Wetlands	1,71%	21,94%	0,04%	1,31%	8,84%	0,00%	66,16%

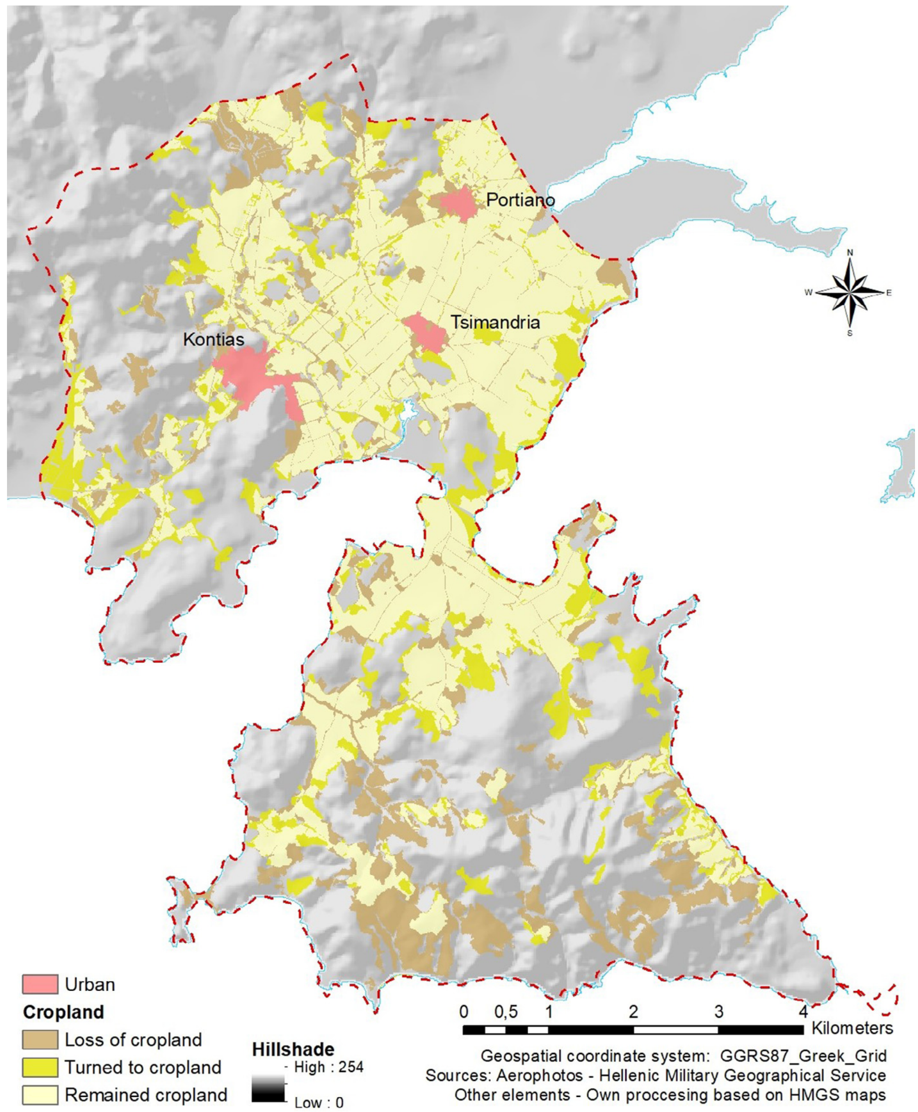

Fig. 4. Cropland conversions between 1960 and 2002.

still cultivated, even if those were located in areas where some kind of change was recorded, usually extensification or abandonment.

3.2.2. Drivers of change

The results of the questionnaire on drivers indicate out-migration as the most prominent factor, as everybody recognized that it had a great impact on the island's agricultural sector, resulting in major changes (see Table 4 of Supplementary material). A second factor that seems to be of great importance is the mechanization of agriculture which has affected the way people work the land. Economic drivers were also recorded, as subsidies, production costs, and market prices have a direct impact on decisions made by farmers. Irrigation works and the construction of the dam in the 1970s were mentioned only by two farmers, although they had a great impact on the landscape. Crop disease was considered a factor in the abandonment of cotton crops and the transition to cereals in the lowlands. Change from using home seeds from their own production to purchasing commercial seeds was also considered a contributing factor. The change in the relationship between "kechagias" (farmer/shepherd who used to rent land) and landowner was also mentioned, practically describing the change in ownership status and function of a holding.

All these results were not linked to specific changes in the landscape but were mentioned as drivers that led to major changes in agricultural practices, contributing to decisions that ultimately led to landscape changes. The drivers that were related more to specific changes were technological. Irrigation works were connected to the cultivation of clover in Kontias and Tsimandria plain, and introduction of machinery was related to change from cropland to grassland in marginal areas (i.e. where machinery cannot be used for ploughing) and to the cultivation of some mild-sloped areas that were previously grasslands, as is mentioned above. What was also important was that people recognized the effect of mechanization of agriculture in both periods. Crop disease was also directly connected to cotton production decline and a change towards cereal production, which is a process of extensification. Out-migration seems to have affected more than one process, related to both a decline in cotton production and the shift from crops to grasslands.

3.3. Timeline of landscape changes

A holistic narrative of change combined remote sensing results and farmers and key informants' knowledge. As Fig. 7 illustrates, the end of the 1950s, the golden "cotton decade" according to farmers' views, was followed by rural depopulation due to out-migration. One factor for this according to key informants was that less manual labour was needed to cultivate cereals compared to cotton. At the same time, upland fields were turned into grasslands. In the 1970s the construction of the dam of

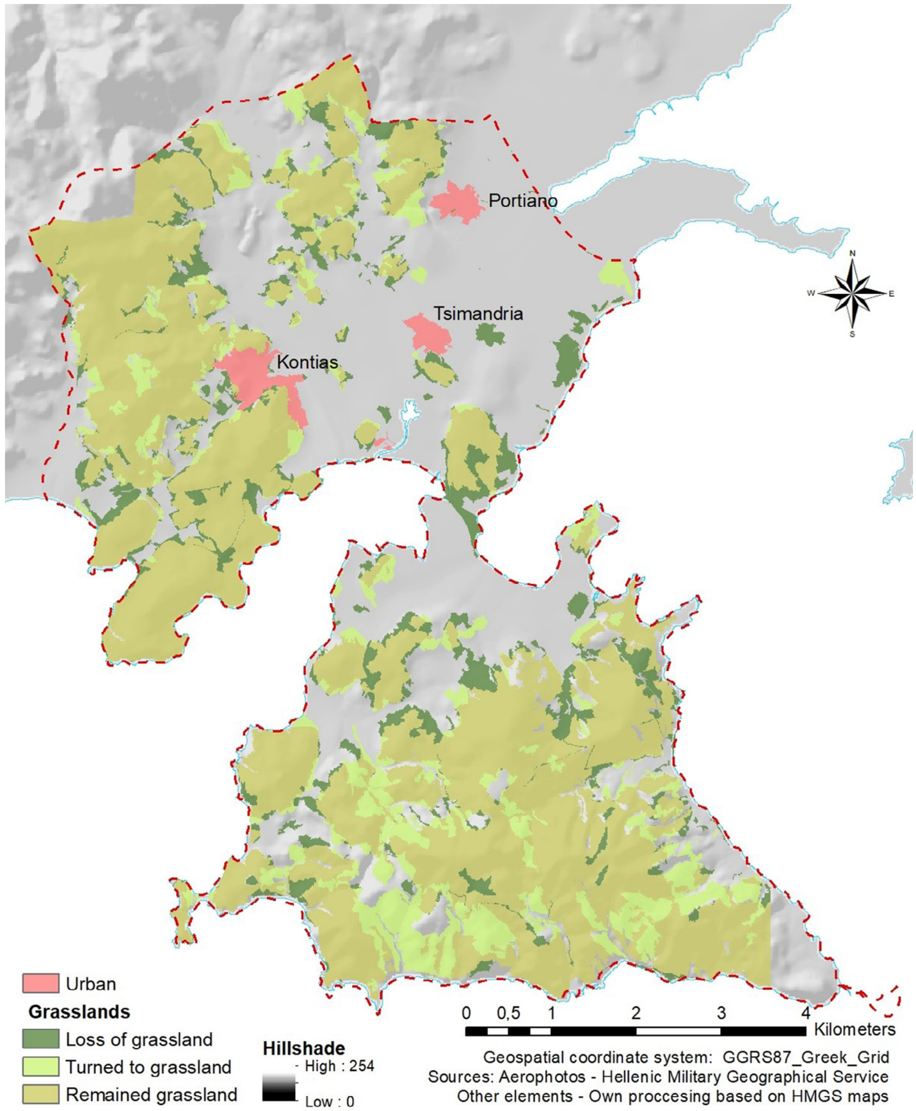

Fig. 5. Grassland conversions between 1960 and 2002.

Table 5
. Processes of change between the two periods.

	1960-1980		1980-2002		1960-2002	
	km2	Percentage	km2	Percentage	km2	Percentage
Extensification	6,71	50,09%	2,63	23,28%	4,94	38.74%
Intensification	3,41	25,45%	6,13	54,17%	4,30	33.72%
Urbanization	0,14	1,06%	0,18	1,55%	0,17	1.35%
Waterdam	0,30	2,23%			0,21	1.62%
Other	1,44	10,78%	0,82	7,31%	1,52	11.90%
Abandonment	1,39	10,39%	1,58	13,98%	1,61	12.66%
Change	13,39	100%	11,34	100%	12,75	100%

Aghios Dimitrios on the Chandrias stream at the upland part of Kontias and of an extensive irrigation network in the lowlands were an effort to reduce depopulation, according to key informants' view. This resulted in a redistribution of land and bigger parcels, new roads, and a loss of riparian vegetation along the old canals in the lowland plains.

In the 1980s a new period began with the implementation of the EU's Common Agricultural Policy (CAP) and further mechanization of agriculture. Machinery was widely used for threshing and ploughing, branding this era as "productivism". The new agricultural machinery and CAP subsidies expanded the cultivation of crops to the edges of lowlands, regaining some of the cropland that was converted to grasslands in the previous period, a finding from remote sensing that was partially confirmed by farmers. At the same time, uplands and areas inaccessible to machinery switched to grasslands. Small patches of

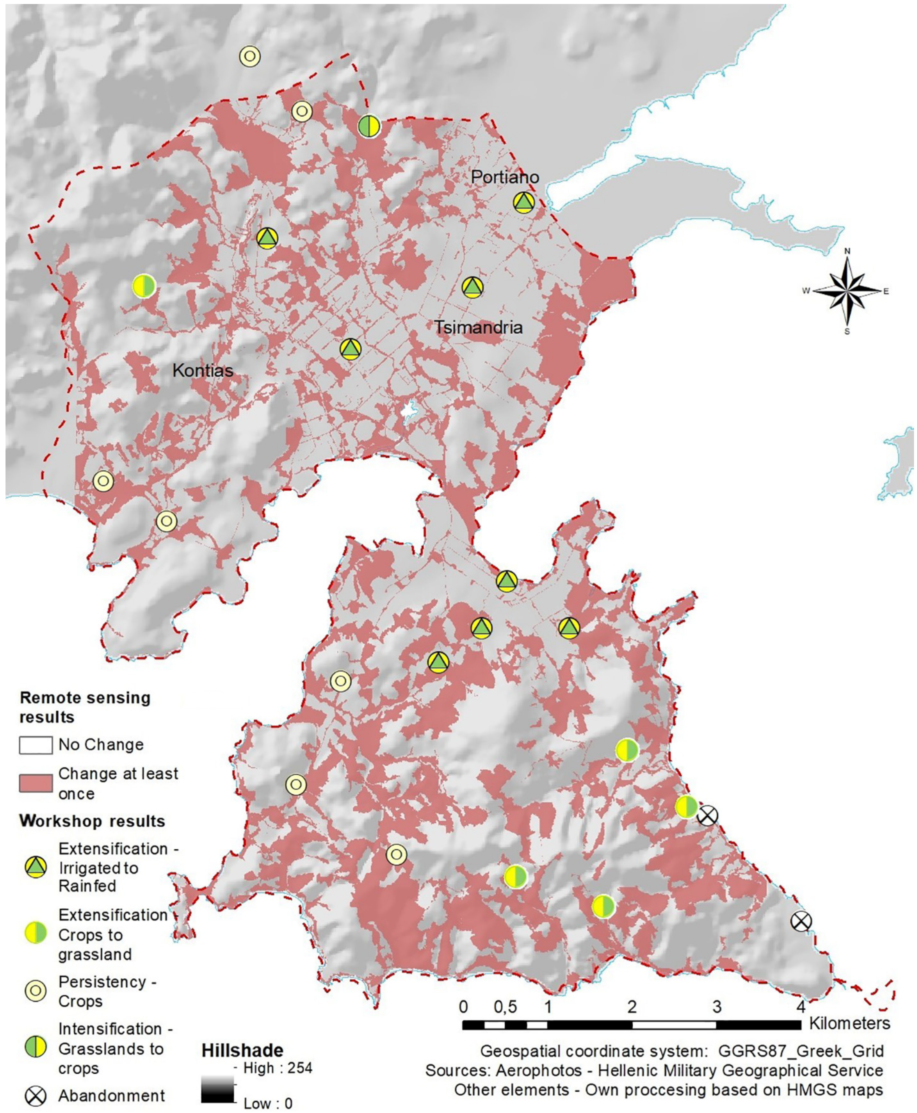

Fig. 6. Perception of changes in the landscape by farmers compared to remote sensing results.

cropland that persist are attributed to the few *mandras* that still operate in the area, as stated by the farmers. It seems that livestock production preserves *mandras* and crops in the uplands of Fakos. Accessibility seems to be a significant factor, as the furthest point of the peninsula is gradually being abandoned and used only to let goats graze free.

4. Discussion

4.1. Landscape change and persistence

Results on landscape change in this study indicate two main findings:

a) Landscape persistence, as despite some crop changes, the overall landscape structure, the appearance of the land and many landscape features have remained the same over a period of profound changes on most of Mediterranean coastal areas (Fig. 8).
b) Different processes of change, namely less land abandonment compared to most Aegean and Mediterranean islands (Blondel et al., 2015; Spilanis & Kizos, 2015). Historical analyses of landscape change in Greek islands name land abandonment, extensification of agriculture, and tourism development as the most important processes (Detsis et al., 2010; Petanidou, Kallimanis, Tzanopoulos, Sgardelis, & Pantis, 2008a, 2008b; Tzanopoulos & Vogiatzakis, 2011). For the Mediterranean, similar processes of land abandonment and extensification in mountain areas have been widely reported (Lasanta et al., 2017; Wolpert, Quintas-Soriano, & Plieninger, 2020), while level and coastal areas are affected by intensification and urbanization processes (Debolini et al., 2018; Kuemmerle et al., 2016). On Lemnos, even if the number of farms decreased and many former farmers moved out of the area, the landscape impacts were not those other similar areas experienced. The presence of a commercial crop seems to be a factor in this, along with irrigation infrastructure and mechanization.

Moreover, complex spatial and temporal patterns emerge from these change processes: Extensification/abandonment in the hilly uplands, as more remote and marginal areas are being converted from crops into grasslands, and intensification in level areas, as mechanized agriculture in bigger and irrigated fields replaces more extensive land uses and traditional landscape elements such as tree hedges – a pattern of processes described as polarization between extensive and intensive use of land (Plieninger et al., 2016). Such synchronic processes have been reported across the islands of the Mediterranean (Tzanopoulos and Vogiatzakis, 2011), presenting a duality between large islands (such as Crete, Sicily and Sardinia), where irrigation - drainage investments

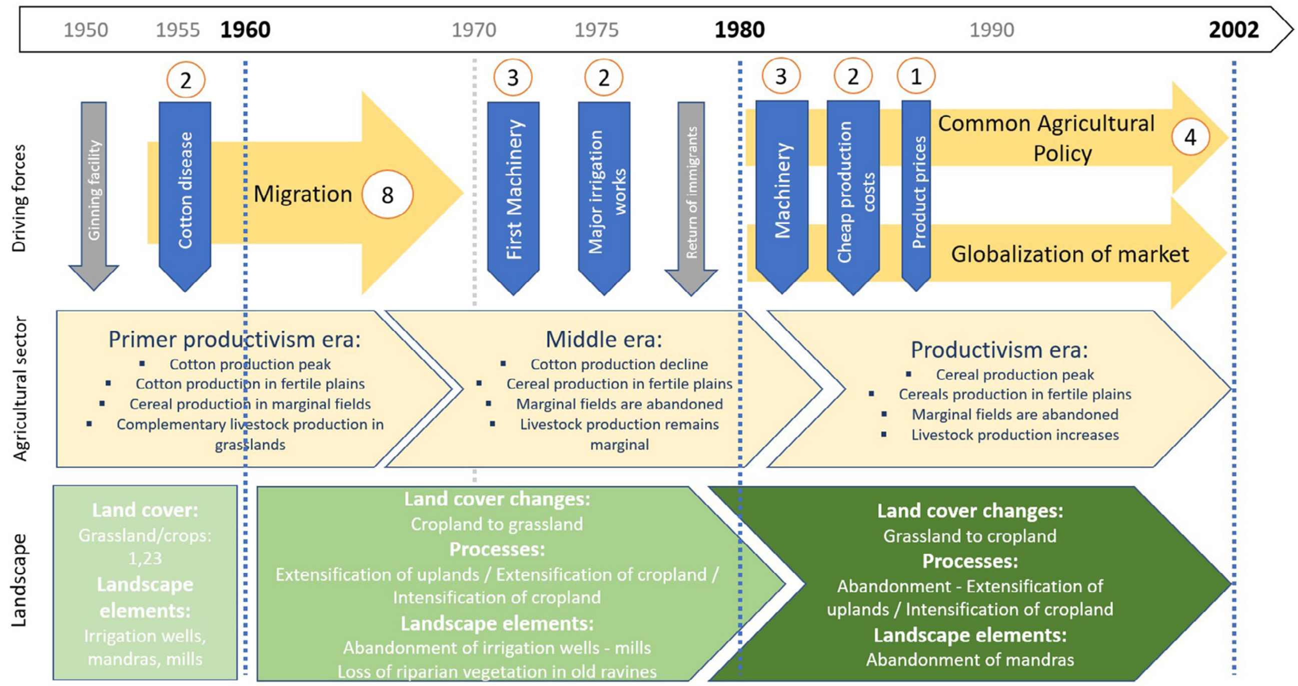

Fig. 7. Basic timeline of historical changes in agricultural history of Lemnos and evolution of the landscape. The circles represent the number of farmers identifying drivers.

made intensive agriculture possible and small islands where decline in total cultivated land and abandonment of traditional agricultural practices prevail (Tzanopoulos and Vogiatzakis, 2011; Petanidou et al., 2008a). In our study area, infrastructure construction assisted intensification, as according to our informants, the plains of Kontias and Tsimandria were irrigated by wells for cotton cultivation before the 1960s, then changed to rain-fed cereal crops – a process of extensification – and after the construction of the dam and the irrigation network in the mid-1970s into clover – a process of intensification. Processes of extensification of land uses from cropland to grasslands that take place in the uplands, have been observed in other Aegean islands, like Lesvos (Kizos, Plieninger, & Schaich, 2013) and Samothraki (Löw, 2017), but also in other Mediterranean locations alongside intensification of land use management from complementary grazing to overgrazing and soil degradation (Lasanta et al., 2017).

Overall, from irrigated cotton fields in the lowlands and cereal production in terraced fields in the uplands in the 1960s to clover and cereal production in the lowlands and grazing land in the uplands in the 2000s, the constant use of agricultural land reveals a general process of diversification of production in response to changing driving forces, as farmers try to make the best out of their land. Of great importance in this diversification strategy is complementarity between crop and livestock production which has been present all along this period, until today. As the majority of farms in Lemnos are mixed (in 2000 about 90.5% of total holdings was mixed, comparing to 61.4% in the North Aegean and to the national 42.6% average, according to the Hellenic Statistical Authority) agricultural land is still managed and the polarization process described above does not lead to abandonment as has been observed in other cases.

4.2. Drivers of landscape change

One of the factors that seem to have played a major role in agricultural change over the last 60 years in Europe is the mechanization of agriculture which favors lowlands and productive plains and marginalizes less productive areas (Antrop & Van Eetvelde, 2017; Jepsen et al., 2015; Petanidou et al., 2008a). The CAP, another significant driver of change for countries of the European Union, has also impacted landscape dynamics on many Mediterranean islands in a different way than mainland areas (Tzanopoulos et al., 2007; Vogiatzakis et al., 2008). Out-migration and agricultural sector change in the islands are intertwined, as the complex agricultural systems that characterized insular landscapes were labor intensive (Kizos et al., 2013). More than one study is citing migration as a driver (Fetzel, Petridis, Noll, Singh, & Fischer-Kowalski, 2018; Petanidou et al., 2008b), which was a major trend for most islands in the period from 1950 to 1980 (Spilanis and Kizos, 2015). This trend concerns marginal areas of the Mediterranean in general (Debolini et al., 2018).

Lemnos was affected by these pressures but with some options for a more competitive agricultural sector. Bakalis (2007) describes a chain of events that led to the big out-migration flows of the 1950s–1960s in Lemnos, attributing the failure of further growth of cotton production as one of the major causes of out-migration in search for work. On the other hand, the presence of a dynamic cultivation such as that of cotton, although in decline, appears to be a factor that partially sustained the population on the island.

State intervention by means of irrigation infrastructure and land reforms provided a shift towards productive agriculture in our study, but it is the agricultural system's own characteristics that sustained the agricultural economy between the cotton peak of the 1950s and the cereal peak of the 1980s and 1990s. The complementarity of this mixed crop - livestock system as described in Bakalis (2007) provided an alternative during the cotton production decline and a relief from rural depopulation pressures. The concurrent presence of active *mandras* and crop cultivation in the uplands found during this study, indicates that where *mandras* were active, the crop-livestock system preserved a diversified landscape. *Mandras* were abandoned later, from 1980 and onwards, in areas that are only grasslands in 2002, and are being described as abandoned by both farmers and key informants (i.e. Kastria and the southeastern part of "wild" Fakos). We also found revealing that perceptions towards landscape change seem to be driven mostly by people and landscape features of this system (*mandra* buildings or fields of *mandras*). This is indicative of the importance of the particular land use system for the area and we also believe that it is linked to landscape

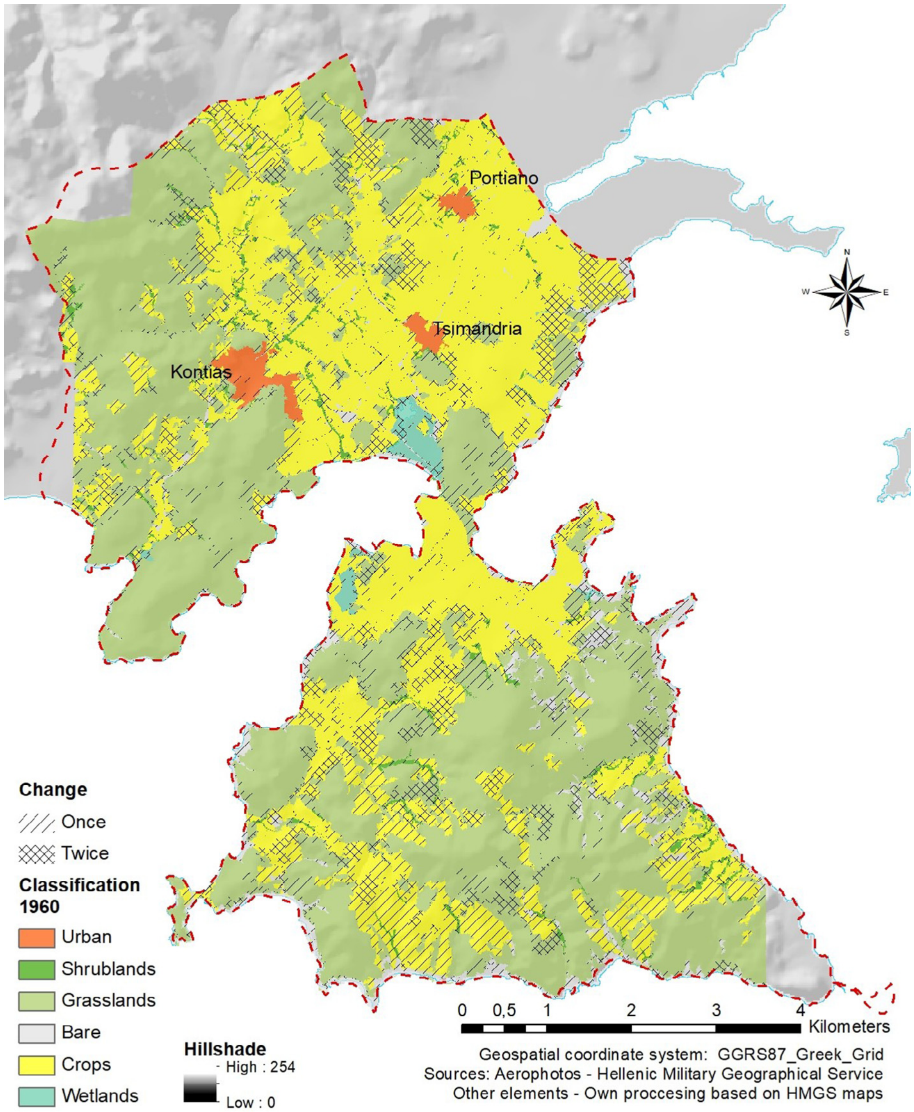

Fig. 8. Areas of change 1960–2002 over land cover in 1960.

persistence (for a similar discussion see Kizos et al., 2018b).

The Common Agricultural Policy in the case of Lemnos is related to the productivism era of 1980–2000 and the cereal production peak. Livestock production was complementary and started growing as an economic activity after 2000, according to key informants. Therefore, the effect CAP had on agriculture seems to have contributed to the upland / lowland polarization.

4.3. Quantitative and qualitative methods

The analysis made clear that finer detail changes cannot be assessed through land cover change analysis only and should be complemented by qualitative data. An example is land abandonment that could not be addressed only by remote sensing of aerial photographs. The conversion from irrigated to rain-fed crops was another type of conversion that required qualitative input by farmers.

This combination of techniques has produced both narratives and quantitative data. Rindfuss et al. (2004) discuss how the integration of such diverse processes can generate problems such as matching spatial and temporal data or assessing the accuracy of land-change models. One of the difficulties encountered in this study was that the reference unit used at the workshop by the farmers did not always match the spatial units produced through remote sensing. Elements of reference during the workshop were wider areas, such as a particular site or place names, but also specific landscape elements such as *mandras*. This affirms the need to build narratives as a means to understand changes through combination of information from LULC change and oral history techniques as suggested by Bürgi et al. (2017).

What also came out of the workshop was information on how landscape change is perceived and remembered. The perception of the role of *mandras* in the organization of agricultural life on the islands emerged as significant in order to understand change and specifically abandonment. This information fuels the conservation effort that has started recently with the Terra Lemnia project, contributing to the establishment of *mandras* as a feature of cultural value for Lemnos.

5. Conclusion

Our case study highlights three issues related to mapping and understanding landscape change:

(a) The use of a methodological "plurality": mixed qualitative and quantitative approaches can provide a holistic narrative of landscape change and persistence. Historical events, along with LULC change analysis as interpreted through information retrieved from local actors, can enhance our knowledge on how and why farmers and land managers in general adapt to external pressures and drivers of change, and how much land cover patterns and landscape structures change (or not). Intertwining this complex procedure in a historic timeline provides a tool that links not only pixels and people but driving forces, actors, and change. With this approach we attempted to go beyond a persistence/change analysis and map different trajectories of change over the same area in consequent decades. The period in question was a time of profound changes around the Mediterranean and particularly in small islands. Unlike other areas and what we expected, abandonment and urbanization appeared to be less important for Lemnos.

(b) The importance of context on how similar driving forces can bring forward different types of change, but also persistence in similar landscapes. While landscape research seeks to generalize from case studies, it is important not to forget that different case studies may not always add up in expected ways.

(c) Understanding change processes can provide useful insights on policy-making in specific socio-economic and socio-ecological contexts by pinpointing the characteristics of a land use system that are fundamental for resilience and sustainability, as well as the impacts on landscape level. Our case study demonstrates how change and persistence can be components of the landscape history of an area in a period of major socioeconomic change. We believe that this type of approach combining quantitative and qualitative data, recording both process and change, has provided such an understanding.

CRediT authorship contribution statement

Efthymios Dimopoulos: Methodology, Formal analysis, Data curation, Visualization, Writing - original draft. **Thanasis Kizos:** Conceptualization, Methodology, Writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2020.103894.

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