Χαρτογράφηση των μεταβολών του αγροτικού τοπίου στη Λήμνο και αξιολόγηση τους από τοπικούς δρώντες

Mapping change in agricultural landscapes of Limnos

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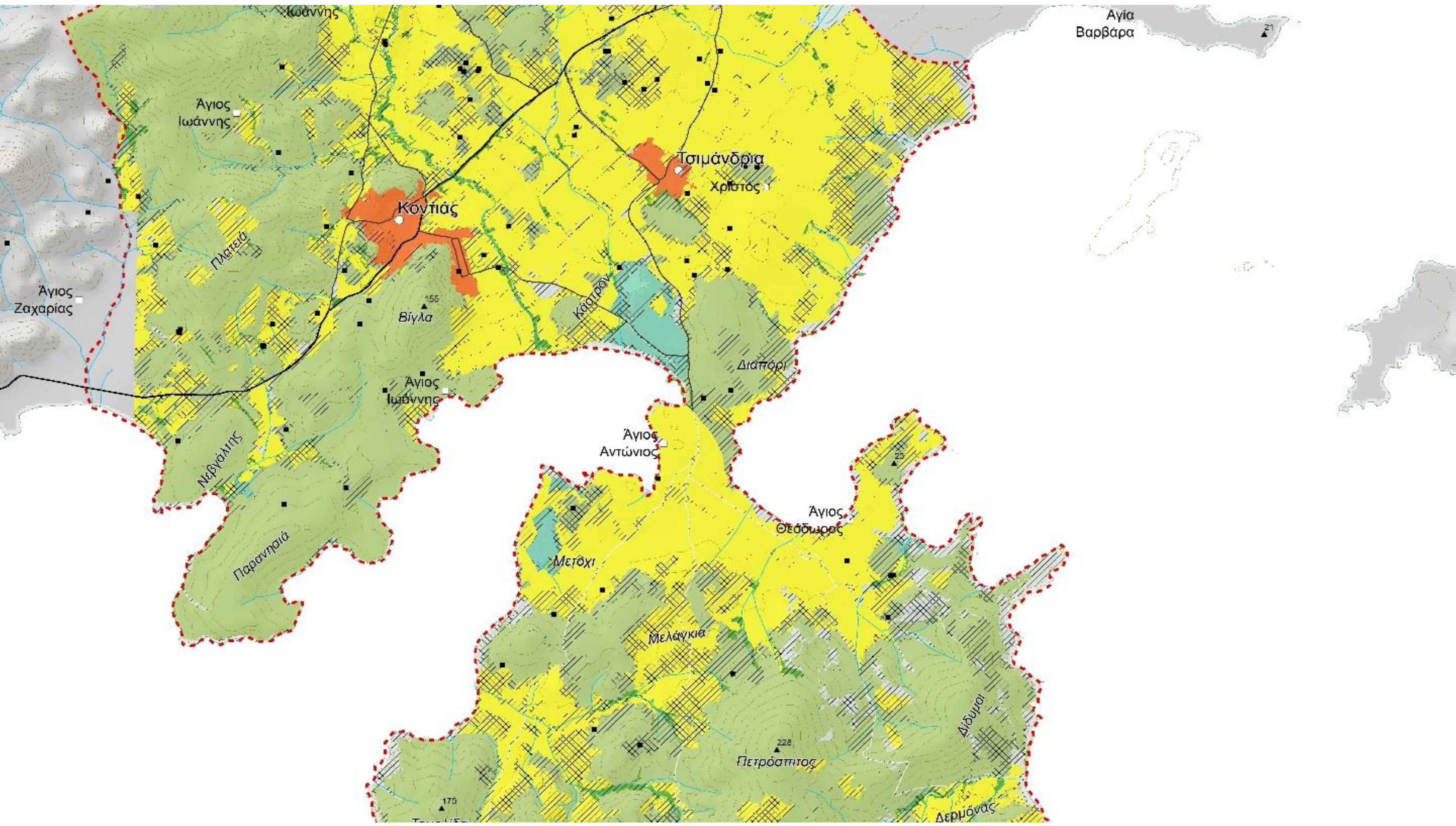

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Abstract

The agricultural landscape of Mediterranean islands 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 1960's and mechanization of the agricultural sector in the late 1970's and early 1980's have been the main factors of the transformation of the agricultural sector in Lemnos, resulting to 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 insular rural landscapes in Greece.

1.Introduction

In the past people in Mediterranean islands have applied complex strategies in production in order to cope with limitations in space, resources and connectivity, resulting in agricultural systems of high diversity and complementarity (Giourga Ch. 1991). This process has produced a unique landscape that characterizes the islands. The agricultural landscape of Mediterranean islands transformed radically over the last 60 years. The results differ, due to the interplay of macro, national and local factors for each setting. It has been acknowledged that those changes in some cases are linked with severe environmental problems such as soil erosion and desertification and biodiversity loss and with loss of cultural practices.

The study of landscape change and the evolution of landscapes provide a tool to understand today's land uses and landscape dynamics. As societies and nature are dynamic, change is an inherent characteristic of landscapes (Burgi et al 2005). The rate of change, the areas it takes place, the process behind it are all subjects of study. Landscapes represent a specific status of the dynamic relation between human and environment as it has been shaped over time in a specific topographic and spatial setting. Land use and management systems that have been formed from this interaction, leave their own imprint on the landscape through patterns of land use, settlement patterns, specific elements in the landscape such as walls and terraces, and more.

Studying traditional rural landscapes can be used as a source of essential knowledge about sustainable management techniques (Antrop M. 2005). These agro-silvo-pastoral systems developed through millennia of experience, permit a continuous but sustainable exploitation of environmental resources (Margaris 1993). For this reason traditional rural landscapes have been in focus by many studies in landscape history (Malek Z. & Verburg P. 2017)

The scope of this work is twofold. The first aim is to explore changes in an insular Mediterranean landscape and to study trajectories of change, understand the processes and the temporal trends. The second aim is to explore the socio-economic drivers that underlie landscape changes or lack of. This is a case study analysis of landscape history and driving forces of past landscape change.

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2. *Literature Review*

2.1 Definitions

Agricultural landscape

The landscape has been defined by many as the result of the interaction between humankind and nature (Papagyannis, T. and Sorotou, A 2008,) The meaning and significance of this interaction is perceived by human beings as they experienced it, attaching to it symbols, ideologies, and beliefs. This human to human and human to environment relationships, leave their footprint in the passing of time as intersecting layers, in the landscape. *Every current landscape is the result of contemporary processes, as well as a legacy of processes that took place in the past (Marcucci, 2000).* Especially in the Mediterranean the landscape has been shaped by human interaction for thousands of years, and this dynamic is expressed in the elements of the Mediterranean landscape.

A definition of the agricultural landscape must incorporate characteristics based on three broad categories: Natural characteristics, Productive characteristics and significative - perceptional characteristics (Kizos, 2002). In this sense an agricultural landscape, has been characterized *as a 'palimpsest' of interactions between farmers' efforts and the natural setting in an area (Kizos A. and Vlachos G. 2012; Louloudis et al., 2005).* And in this agricultural landscape one can identify the ideological, social and cultural structures that have resulted in the agricultural systems, land uses, and infrastructure that are visually present.

Insularity

Islands are defined by boundaries, and their corresponding natural systems are restricted by them and so are their resources. Vernicos describes islands and particularly small islands of the Aegean as open systems, as isolation and connectivity alternate in a history of mobility and remoteness. Mediterranean islands are characterized as fragile ecosystems, whose character has been historically defined by their limited potential for intensive agricultural production. The sea poses a natural barrier that limits physical interactions and exchange with neighboring ecosystems, both in natural and socio-economic terms (Vernicos, 1987).

The main characteristics of these ecosystems –restricted access to natural resources, intense fluctuation of rainfall, intense relief variation, limited presence of lowland plains, and the resulting variation of crop yield–create an uncertain environment in which islanders had to adapt, by creating complex systems of agro-silvo-pastoral management. These labour-intensive systems, with their further variations in accordance to the particularities of each island, allowed to exploit every possible resource, while simultaneously ensuring its renewability. The loss of resources could have devastating effects (Giourga, 1991; Vernicos, 1987). Characteristics of these agricultural systems vary according the island's size, resources,proximity to mainland, topography etc.

Socio-economic changes affect the elements constituting a landscape differently depending on the past use and their environmental characteristics (Alados et al., 2004; Sluiter & de Jong, 2007). Discontinuity, isolation and connectivity have had different effects on processes happening on a wider scale, resulting in different impact on landscapes. Insularity tends to amplify or diversify the effects of this process comparing to mainland areas (Vogiatzakis et al.; 2008, Royle, 2001). As discussed further in this document it creates a different spatio-temporal context for these changes to take place.

Moreover, connectivity and isolation seem to have a different impact on how people perceive the landscape of an island. Insularity is perceived and experienced differently by visitors and inhabitants (Vogiatzkis et al 2008) giving insular landscape a diversity of definitions.

Landscape change

Landscapes around the globe change. As societies and nature are dynamic, change is an inherent characteristic of landscapes (Burgi et al. 2005). Change in the landscape has different temporal scales. Natural change processes have affected the landscape in the long term but change within small temporal scale such as decades are primarily human-driven. Agriculture has been changing rapidly in the past 50 years, as technological innovations, economic transformations, social and political changes have transformed the agricultural sector and its practices. As a result, agricultural landscapes have been transformed either to more productive or to less intensive manifestations or even abandonment. The spatial patterns of these transformations through time are related to changes in land uses (Potter and Lobley, 1996) and landscape structure and configuration (Detsis et al 2010; Tzanopoulos 2008.)

Landscape change has been studied thoroughly in the recent years in an effort to analyze and understand not only change per se, but also the process of change and the contributing drivers of change. In the study of human-environment relationships a conceptual model of the relations between the driving forces of human-induced change, the processes and activities among them, and human behaviour and organization was introduced by Kates, Turner and Clark in 1990. Since then the concept of driving forces has become fundamental in the studies of landscape change, as more researchers drew interest in understanding not only where and how but also why these changes happen and especially what are the policies that affect them.

"*Drawing its origin from environmental policy, the concept of driving forces is now used as a framework for understanding the causes, processes, and outcomes of land-scape change and has become indispensable for the evaluation of policy interventions"* (Klijn, 2004 ; Pleinenger et al 2016)

(a) Processes or proximate drivers

In this framework processes of change, which are also reported as proximate drivers, refer to the framework of human activities that induce change in the landscape. As landscape change studies moved from changes in spatial patterns of the natural environment such as habitat fragmentation to the human processes, historical approaches where introduced to incorporate different temporal scales. In an overview of research in landscape change in Europe, Pleinenger et al (2016) found the most important process included land abandonment/extensification; agricultural expansion/intensification; expansion/intensification of forestry; and urban/infrastructure development. The study specifies that particularly in Southern Europe the processes of land abandonment and extensification have been documented as the most prominent both in the Eastern and the Western Mediterranean countries.

Looking more specifically into agricultural landscapes intensification of agricultural land may be attributed to different human actions such as increase in the use of fertilizers and nitrogen input in general (A.J.A.M. Temme and P.H. Verburg, 2010), aggregation of agricultural fields (B¨uhler-Natour and Herzog, 1999), conversion from rain-fed to irrigated crops, conversion from grasslands to annual crop cultivation, and other strategies to intensify production (Shriar A, 2000). Consequently, extensification may consist of a transformation from irrigated to rain-fed crops, decrease in nitrogen inputs and conversion from more to less intensively managed crops. Abandonment of agricultural land on the other hand can be defined as the stop of any agricultural activity, but as fallow practices are very common in the Mediterranean it is not so easy to define clearly the barrier between fallow and abandonment (Estel S. et al 2015). Urban development is not explicitly about urban areas expansion, but more likely refers to the intensification of urban uses in the landscape (such as urban areas, tourism development, roads and infrastructures, waste disposal) and use of resources for urban development (such as mineral extraction, sand extraction).

Landscape change is not univocal and con-current processes is a common phenomenon as landscape is a container of all forces. In many case studies in Europe land abandonment / extensification coexisted with agricultural expansion/ intensification, indicating that in the interaction between driving forces and human decisions, other determinant factors mediate. Rey Benayas, J. M. et al (2007) note in their meta-analysis on abandonment of agricultural land that not only agricultural intensification can occur alongside extensive farmland abandonment but also in some case has been identified as a driver of this abandonment (Burgi M. and Turner MG. 2008; Mottet A. et al 2006).

(b) Drivers of change or underlying drivers

The analysis of drivers of landscape change is essential in order to understand why landscapes change or remain unchanged, and to identify the causal mechanisms of regime shifts *(Verburg et al. 2015).* Temporal and spatial scale is important when studying drivers of change as the focus of interactions and dependencies change along scale.

The current debate on drivers of landscape change identifies five major types: socioeconomic, political, technological, natural, and cultural driving forces (Brandt, Primdahl and Reenberg 1999; Pleininger et al 2016). Socioeconomic drivers today include more global ones, like the market economy, globalization of trade, immigration, and urbanization, while political drivers are more regional, such as European Union policies, post socialism transition in Eastern European countries, even state policies. Technological evolution accounts many industrial revolutions, and the rise of information society, also coined as the 4th industrial revolution, is likely to become an important driving force of landscape change (Kienast, Bürgi and Wildi 2004). Natural disturbances and climate change are considered the most prominent natural driving forces. Culture although identified as a factor that leaves a very distinct trace in the landscape is often difficult to address as a driving force. As Nassauer (1995) notes culture and landscape interact in a feedback loop in which culture structures landscapes and landscapes inculcate culture, resulting in a complex system that is difficult to specify a way of measuring cultural influences on landscape.

Agricultural landscapes have been affected greatly through the 20th century as technological changes of the industrial revolution, followed by major political and socioeconomic changes brought irreversible breaks with the past (Antrop 2005). Zomeni et al (2008) notice that throughout Europe, before and after WWII, *"the predominant approach to agricultural policy was to maximize food production and modernize the sector (Evans and Morris, 1997; Marsden et al., 1993; Wilson, 2001; Hadjimichalis, 2003; Walford, 2003) leading to the "productivist era" characterised by intensive and industrialized agriculture (Lowe et al., 1993; Ilbery and Bowler, 1998),moving away from traditional low intensity regimes."* This approach was also imprinted in the Common Agricultural Policy (CAP) that has been the main lever of policy in agriculture in the European Union since its introduction in 1962. Among the impacts of this approach, some researchers have remarked, is polarization between intensified agricultural areas and extensively managed areas including islands. (Tzanopoulos et Vogiatzakis 2011; Antrop, 2005; Zomeni et al., 2008).

(c) Actors of change

In the understanding of this human-environment system the decisions and actions of the people (often called actors or agents) are the actual forces of change, the agents of the activities at the local level that result in landscape change. Hersperger et al (2010) distinguish between two types of actors: actors that affect driving forces, such as institutions, policy makers etc and actors that directly change land such as farmers. Their interaction with the driving forces lays in the core of studies of landscape history, especially for modelling of changes and policy recommendations.

Landscape change in the islands

In historic analyses of landscape change in Greek islands land abandonment, extensification of agriculture and tourism development have been noted as the major process, although specific characteristics have been crucial to differentiation of impacts (V. Detsis et al; 2010, T. Petanidou et al 2008; J. Tzanopoulos, and I.N. Vogiatzakis, 2011). Löw, Markus. (2017) is recording synchronic processes of overgrazing (a form of agricultural intensification) and cropland abandonment in the island of Samothraki. This process of extensification of land uses from cropland to grasslands but intensification of land use management from complementary grazing to overgrazing and soil degradation, seems to be typical for many islands (Giourga Ch 1993; Kizos 2002).

Among factors that seem to have played a major role in agricultural change in Samothraki and elsewhere is modernization of agriculture (mechanization, irrigation, chemical inputs to improve soil fertility and combat pests,) which seems to favor lowlands and productive plains and marginalize less productive area such as mountains and islands (T. Petanidou et al 2008). The CAP has impacted the landscape dynamics of many of the Mediterranean island landscapes (Tzanopoulos et al., 2007; Vogiatzakis et al.,2008). This has been acknowledged in the CAP, and marginal areas have been recognized by the Less Favoured Areas Scheme of the European Union that provides aid for farmers in such areas (Kizos and Koulouri 2005). Migration and the evolution of the agricultural sector in the islands are intertwined as the complex agricultural systems that characterized the insular landscape for centuries were labor intensive. More than one study is citing migration as a driving force (T. Petanidou et al 2008; Fetzel et al 2018) although sometimes it is also a result of changes in the agricultural sector at least at a greater spatial scale.

2.2 Different approaches to studying and understanding landscape change

(a) Drivers – Actors – change models

In the field of landscape change studies several models have been introduced to capture the complex system of drivers of change, processes and changes. Hersperger et al. (2010) distinguishes four basic models to represent the relationship of land change (C), driving forces (DF), and actors (A).

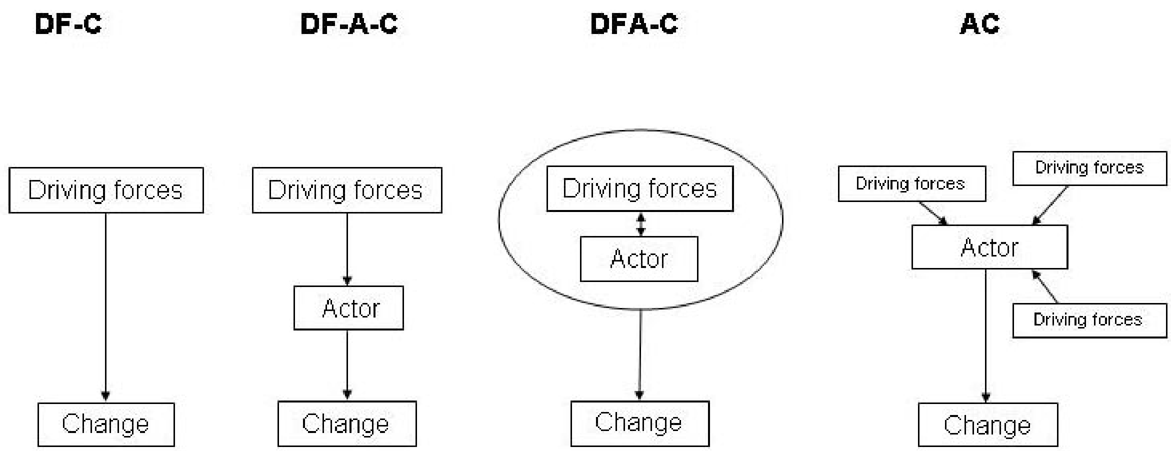


Figure 2.1: The four models to link land change with driving forces and actors
Source: Herspenger et al 2010

The first model is the DF-C model, in which driving forces are directly related to land change without mediation by the actors, focusing more on correlation of change with driving forces. According to Hersperger et al (2010) and Pleininger et al (2016) this is the most commonly used model in land change science. The DF-A-C model represents a chain of events from driving forces affecting actors and subsequently actors causing change. Driving forces assumingly determine the framework of actor’s decisions. The DFA-C model sees driving forces and actors as a closed system of interactions, which results in landscape changes. The focus of this model is on the interaction and feedback between driving forces and actors. In the A-C model, actors play the central role in land change. Driving forces in this model are elements of the environment in which actors respond and make their decisions.

(b) Quantitative and qualitative methods

Most studies in landscape change involve quantitative methods and especially, remote sensing techniques as means to conduct Land Cover – Land Use (LCLU) analysis (Plieninger. T. et al 2016) alongside socioeconomic data through official statistics to access driving forces usually with an expert opinion help. However, these cases do not explicitly address the role of actors but try to explain the effects of driving factors forces on land directly. In more complex models where actors are considered important in modeling of landscape change, qualitative methods such as surveys or face to-face interviews are required to get information on their actions. Moreover, Burgi et al (2017) stresses the matter of perception of the landscape as a component that needs to be incorporated in an integrated approach. An additional input, which is recording of the perception of landscape change and of the driving forces as remembered by the actors themselves can provide the cultural framework which is a driving force itselfon its own. In this direction, the combination of quantitative information from LCLU change detection with use of remote sensing, and qualitative information from social sciences has been proposed in order to gain a comprehensive understanding of landscape change (Burgi et al. 2017; Soova¨li et al. 2003; Rindfuss et al. 2004; Young et al. 2006; Yaeger and Steiger 2013)

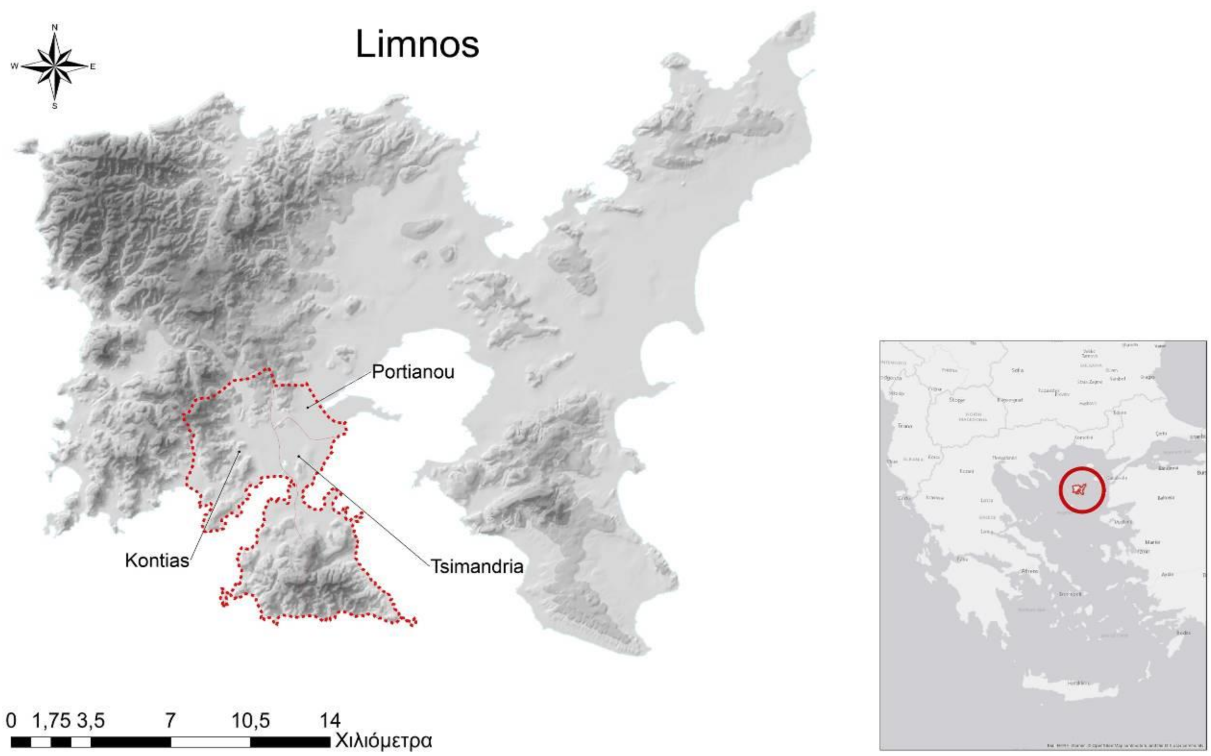
3. Methodology-Data processing and analysis

3.1 Study area

Limnos island

Limnos is the eight largest Greek island, occupying a surface of 477 km2, with a 260 km long coastline. Located in North Aegean Sea, Limnos is quite isolated geographically, both from the Greek mainland, the other Aegean islands and the Turkish coast.

The volcanic terrain, the alteration of low relief formations, medium inclines and semi-mountainous parts, the presence of coastal and inland sand dunes, rare geological formations, extensive coastal wetlands and agro-pastoral land, account for the diversity of Limnos' landscape. The western part, with its rugged relief and low evergreen vegetation, is dominated by livestock farming, complemented by arable crops, mainly for producing animal fodder. The central and eastern part, with its flat relief and fertile soils, is dominated by a lowland farmland mosaic, with livestock breeding being practiced in smaller areas, around soft hills. These farmlands are used both for production of fodder destined for the local livestock farms (i.e. barley and oats), as well as for other commercial (mainly rain-fed) crops, such as wheat, pulses, vineyards, sesame, etc. In fact, the proportion of rain-fed arable fields in Limnos is higher than in any other Aegean island.



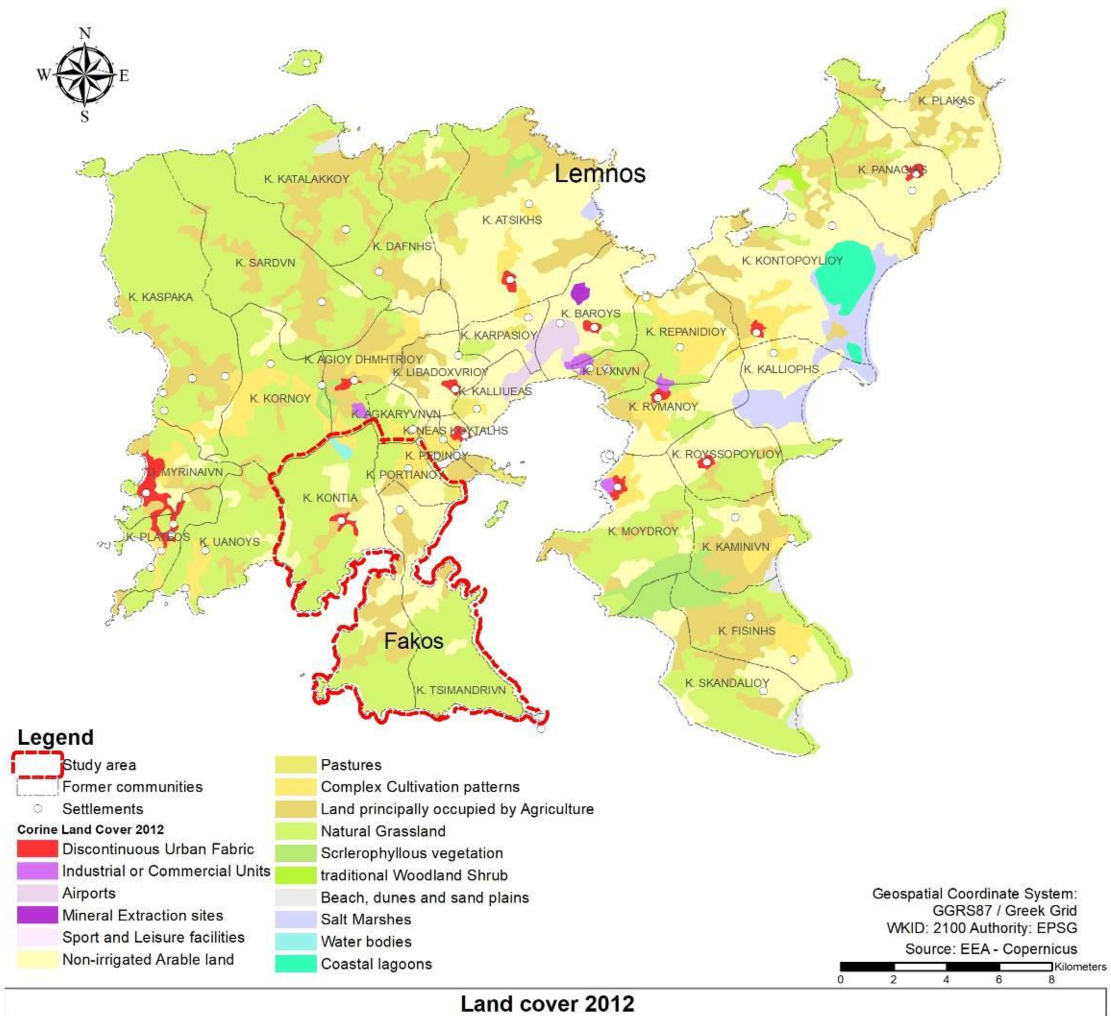
Map 3.1: Position of study area

Notwithstanding these topographic variations and general land use patterns, it must be noted that the 19th century administrative division of the island –partly in use today–has sought to ensure that all villages, with their respective surrounding communities, have a rather equal proportion of farmland and grasslands, hence ensuring sufficient space for agricultural production for all the communities of Limnos (Bakalis, 2007).

The adaptability of local farmers to the environmental and socio-cultural conditions of Limnos has formed a particular land use system, shaping the landscape of the island and characterizing its identity, economy and character.

Agricultural history of Limnos

Limnos has been an important agricultural centre since the antiquity, being the main wheat supplier to Athens during the “Golden Age of Greece” (around 500 to 300 BC) and retaining this character during the Byzantine and Ottoman times. The local economy is still based on the primary sector, although tourism is increasingly becoming an important activity. In more recent times Limnos faced significant population decline in the post-war period, when many residents migrated to mainland Greece and abroad –Australia, Canada and USA.



Map 3.2: Corine Land cover 2012, Source: Copernicus

Examining the evolution of agricultural land between 1961 (30207 ha) and 2001, the difference is just 331 ha, indicating that Limnos has kept its agricultural land, in contrast to the general trend of rural abandonment that is prominent in most of the other Greek islands (which count an average loss of 22%). According to the 2000 Agricultural Census, the majority (61%) of agricultural holdings in Limnos is mixed farms (i.e. both land farming and livestock breeding). Just 38.6% of the farms are only land farming oriented, which is a rather unusual pattern for an island of this size, coming into contrast with the other North Aegean islands. Although in average islands present a high proportion of total area occupied by mixed holdings (64.9%), in Limnos this proportion reaches 90.5%. Only 9.3% of the land used for agriculture is used by land farming holdings, in contrast with an average of 32.2% for the islands and 56% for the whole country.

Fakos study area

Fakos study area, at the southwest part of Limnos, covers 5450 ha and includes the communities of Kontias, Tsimandria and Portianou. The study area presents a mixed landscape as the hilly areas to the western part are succeeded by the fertile irrigated plain of Kontias, while the -uninhabited-peninsula of Fakos at the south has always been used for grazing. This mixed landscape character has led to a mixed pattern of arable farming and livestock breeding that is still present today. The average farm size in 2000 was 24.5 ha and the average parcel size was 2.3 ha, accounting approx. 10 parcels per farm. Portianou community has smaller parcel sizes, of 1.0 ha; this is representative of a more land farming character, but it can also be attributed to the fact that Portianou does not have land in Fakos peninsula, the territory of which is equally shared between the communities of Kontias and Tsimandria. The character of each community might differ, but the study area as a whole is characterized by the presence of both grazing lands (65%) and arable farmland (34%), while 16% of the agricultural land is irrigated, fed with water by the dam in the uplands part of Kontias. This variety offers a bigger range of choices for farmers. The demand for land can be seen by the high proportion of rented land, which accounts for over 80% of the Utilized Agricultural Area in the communities of Kontias and Tsimandria.

	Kontias			Tsimandria			Portianou		
	1960	2000	Change (%)	1960	2000	Change (%)	1960	2000	Change (%)
Number of holdings	290	76	-73,79%	160	42	-73,75%	128	61	-52,34%
Utilized agricultural area (ha)	2420,8	20938,6	-13,51%	1192,9	1656,3	38,85%	548,6	638,5	16,40%
Arable land	735,6	511,1	-30,51%	616,0	592,8	-3,76%	273,6	374,7	36,97%
Grazing land	1635,1	1576,9	-3,56%	532,2	1054,7	98,18%	241,9	246,4	1,86%
Grazing/Arable	2,22	3,09	38,80%	0,86	1,78	105,93%	0,88	0,66	-25,62%
Irrigated land	72,9	87	19,34%	64,9	24,4	-62,40%	30,9	14,4	-53,40%
Parcels	1780	626	-64,83%	1520	626	-58,82%	848	633	-25,35%
Parcel size	1,36	3,34	145,59%	0,78	2,64	238,46%	0,64	1	56,25%
Number of sheep	4504	6578	46,05%	3620	4994	37,96%	1112	2080	87,05%
Sheep per farm	35,74	111,49	211,90%	30,94	131,42	324,76%	17,10	59,42	247,38%

Table 3.1: Agricultural statistics for the three former communities

The UAA has increased by 5.4% between 1961 and 2000, although the number of holdings has decreased by 69%. This increase should be attributed to the increase in grazing land (19%), as arable land has decreased by 13%. The number of parcels has decreased by 55% and their average size has increased from 1.0 ha to 2.3 ha, indicating aggregation of land to fewer and larger holdings that are more economically viable. This trend is evident in terms of livestock breeding, as while the number of farms with sheep has decreased by 57% between 1961-2000, the total number of sheep has increased by 48% at the same time, showing an intensification of stockbreeding, from 30 sheep to 100 sheep/ farm. Today, Fakos study area holds over 25% of the total livestock and 26% of sheep of Limnos in over 90 farms, according to the Livestock Register of 2017.

According to IACS[1] data, 59% of the total surface of the study area (3223 ha out of 5450 ha in total) has been registered for agricultural subsidies, including grasslands. IACS data on agro-pastoral land uses of the three selected communities of Kontias, Tsimandria and Portianou, indicate a mix profile; grasslands are the main land use, occupying over 60% of the Utilized Agricultural Area, fodder and other cereals account for 34% of UAA, while 4.4% is declared as fallow. All other declared crops are marginal, accounting for less than 2% in total.

Agricultural uses	**Area (ha)**	**% Percentage**
Grasslands	1,916.49	59.47%
Fodder	205.28	6.37%
Hard wheat	15.47	0.48%
Other cereals	890.26	27.63%
Fallow land	140.81	4.37%
Vegetables	5.23	0.16%
Legumes	9.58	0.30%
Vines	18.98	0.59%
Bulbs	1.72	0.05%
Oilseeds	0.4	0.01%
Olive trees	14.32	0.44%
Nut trees	1.14	0.04%
Pomegranates	0.45	0.01%
Prunus trees	1.29	0.04%
Other tree crops	0.18	0.01%
Land not included in agricultural activity	0.97	0.03%
Total	**3,222.57**	**100.00%**

Table 3.2: Fakos study area: Agricultural land uses as declared in IACS, 2017

[1] IACS stands for Integrated Administration and Control System developed by OPEKEPE (Payment and Control Agency for Guidance and Guarantee Community Aids of Greece) for managing subsidies from the EU CAP scheme

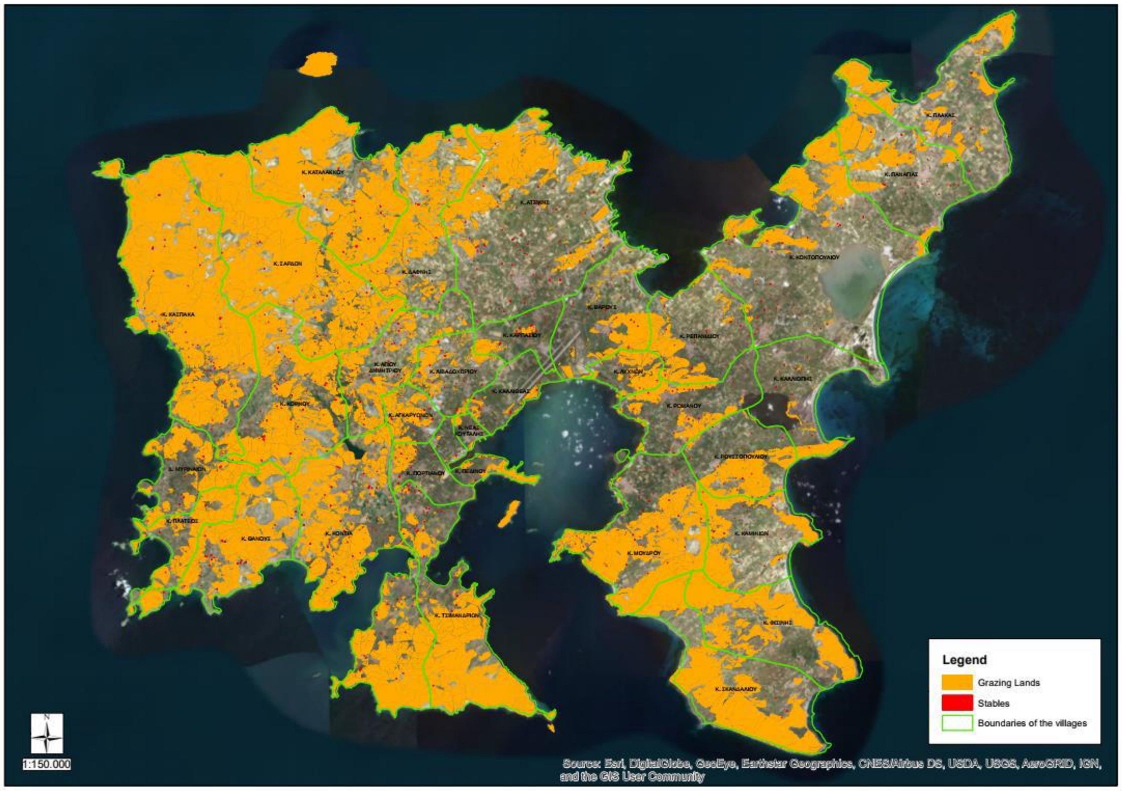


Figure 3.1: Spatial distribution of grasslands as declared in IACS, 2017

Population in the three communities has followed the general trend of Limnos and other islands of the Aegean; decline during the decades of 1960 and 1970, stabilization during 1980-1990 and partial growth during the next decade (Kizos and Spilanis, 2005; Bakalis, 2007). Migration to mainland and abroad, mainly Australia, during the decade of 1960 to 1970 played a major part in rural depopulation of the area.

Year	Kontias		Tsimandria		Portianou	
	Population	Change (%)	Population	Change (%)	Population	Change (%)
1961	1127	-	593	-	468	-
1971	755	-33,01%	379	-36,09%	297	-36,54%
1981	549	-27,28%	308	-18,73%	244	-17,85%
1991	551	0,36%	292	-5,19%	251	2,87%
2001	628	13,97%	314	7,53%	306	21,91%
Overall change	-499	-44,28%	-279	-47,05%	-162	-34,62%

Table 3.3: Fakos study area: Population change, 1961-2001

3.2 Theoretical approach

For the scope of this study the following questions are addressed:

a) How did the landscapes change?
b) What are the underlying processes and the temporal trends?
c) What driving forces are responsible for the changes and processes observed?

The main challenges that arise is to study such a complex system of human-environment relationships, taking into account dependencies, interactions, and feedback loops, on different temporal and spatial scales. As described above several models have been proposed for different temporal and spatial levels. Following Burgi et al (2017), a mixed model of driving forces (DF) – change (c) and driving forces (DF) - Actor (A) – change (c) was selected in order to produce a more robust result, as findings from the first model were validated through the second.

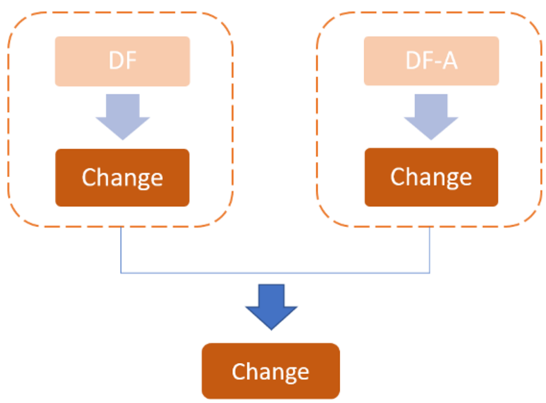


Figure 3.2: Theoretical model of human – environment relationships

The first model is referring in the first two questions, assuming driving forces are stable. The following understanding of the procedure of change is taken into account to construct the DF-C model. Change in macro factors in the last 60 years has affected agricultural management systems and practices. The degree of change and how this has been managed depends of environmental factors as well as local internal factors. These changes are affecting the agricultural landscape and thus leave a traceable mark on it. In the case of Limnos, the following macro factors were taken into account after literature review and local experts consulting:

Technological	*Mechanization of agriculture*
	Infrastructure development
Economic	*Tertiary sector development*
	Agricultural product prices
	Market development
Political and Institutional	*Common Agricultural Policy*
	Taxing policy
Social	*Migration*

Table 3.4: Factors affecting landscape change in Limnos

Accordingly, the determinant environmental factors that were taken into account were topography and soil characteristics, as climate doesn't really change in such a small area.

The second model explores mostly perceived landscape changes and related driving forces. In this model farmers are placed as actors of change, considering that agricultural landscape change depends on decisions made by the farmers. As such, the way that these changes are perceived by the farmers themselves reveals the connection between drivers of change and actors' decisions.

3.3 Materials and methods

Following Burgi et al (2017) a mixed-methods approach that combines quantitative and qualitative methods is selected in order not only to document and monitor land-cover changes but also to explore the human-environment system dynamics. Mixing remote sensing with social science approaches, this method is meant to produce more comprehensive results on landscape change.

The methodology can be distinguished in 3 separate steps:

First, an interview with key informants provided information on the agricultural history of Limnos island and a basic timeline of historical changes in order to decide which will be the focus of further analysis. This information was backed by secondary literature and statistical information in order to build a narrative of events and factors that might have affected the landscape. Using this information as a guideline, land cover classes, processes and drivers of change that were included in the literature review, were assessed to define the framework for land cover change analysis and oral history methods. This led to specific land cover classes for the classification. Also, it revealed specific changes that cannot be assessed through land cover change analysis and must be included in the participatory methods of the workshop (focus group). Two periods were selected after this step-in order to assess changes covering 20 years each, from 1960 to 1980 and from 1980 to 2002. This decision was made in the basis that remote sensing data availability and statistical data temporal framework so as to keep a unified temporal framework.

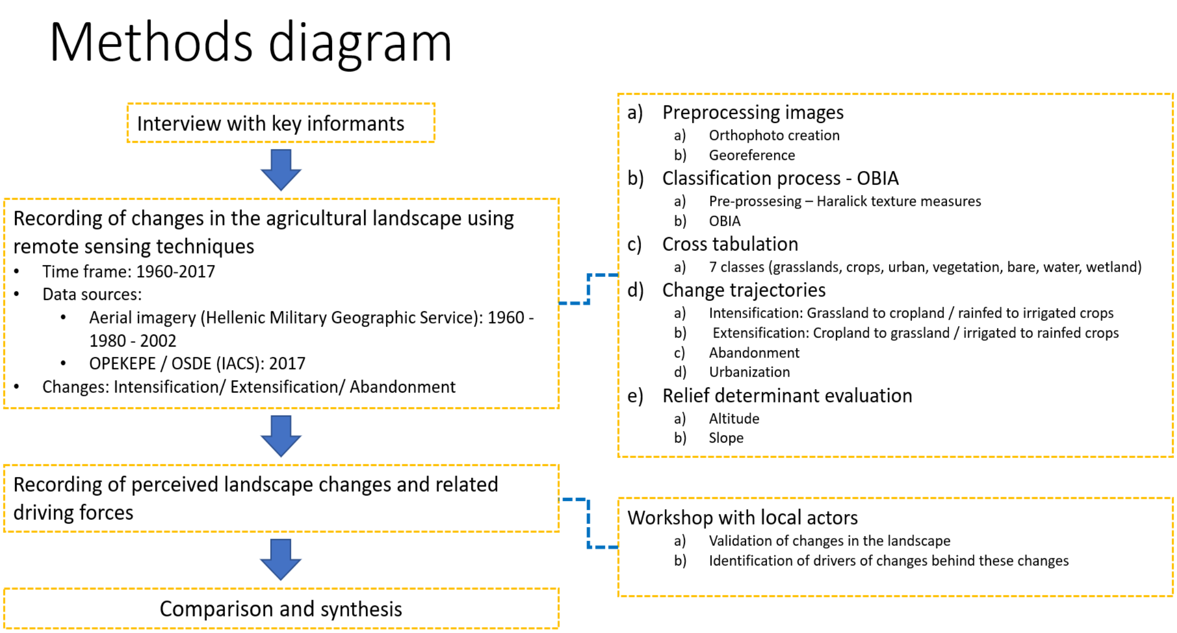


Figure 3.3: Methodology diagram followed in this study

Secondly, land cover change analysis was conducted to discover changes in agricultural landscape of Limnos during the period of the last 60 years. Remote sensing techniques were used in order to get information on land cover from aerial imagery on the selected dates. Comparison of the land cover results provides changes that occurred between these periods, while cross tabulation was used to assess land conversions. These land conversions were synthesized in overarching processes taking into consideration relevant literature as described below. Persistence in land cover was also analyzed in order to understand landscape dynamics and resilience. Relationships between findings and environmental layers of topography (slope, altitude) were investigated to understand patterns of land cover change (Detsis et al 2010)

Thirdly a workshop with local farmers (focus group) took place in order to validate the changes in the landscape derived from remote sensing, get qualitative information on perceived landscape changes as well as identify the drivers of change behind these changes.

The results from every step are then presented and discussed in order to provide a better understanding of the transformations that have happened during these periods in the study area.

Classification

Selection of classes for the classification was based on ground truth data obtained through a survey conducted in 2018[2], as well as data from the ministry of Agriculture [3], resulting in seven classes. It was then reassessed after interview with the key informants, in order to include any other information. A basic division was between land that is cultivated (crops) and land that is used for grazing (grasslands). Although the results of the survey show that in some cases farmers were sowing land that was not harvested but left for grazing,[4] this was something marginal. Crops included cereal, cotton, legumes, other fodder crops, vegetables. In the land that is classified as grasslands several species were included, namely herbaceous and phryganic formations (mainly Sarcopoterium spinosum). Other five categories – urban, shrublands, water, bare and wetland – complement the rest of the classification. Shrublands class includes both trees and maquis found in the plains of Kontias, Tsimandria and Romanou, in tree hedges, afforestations on roads and near settlements, as well as maquis and other shrubs in ravines.

Bare covers a wide range of different elements, from cliffs to roads and open areas with no vegetation thus, in some areas there might be misinterpretations. Moreover, ravines present difficulties in b&w classification as there is no clear evidence that land cover is bare land, shrublands or grassland mainly due to shadow of steep geomorphology which make these areas darker and thus closer to the spectral signature of shrubland vegetation. In general ravines that could be selected where assigned as shrublands.

Processes - Land use trajectories:

Following Burgi et al (2017), for the purposes of this study we distinguish between changes (in LULC proportion), conversions (between LULC classes), overarching processes and driving forces. Interpreting and synthesizing land cover conversions based on literature, overarching trends were selected to highlight the processes that affect the rural landscape (Burgi et al 2017).

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[2] Dimopoulos et al 2018

[3] In Kontos, Th (2007) data from maps from general secretariat of forestry and natural environment in 1996.

[4] This fact was crosschecked by the key informants during the interview

The trajectories of land cover change which represent land use changes in rural areas are categorized in the following patterns of change: Intensification of farm land, extensification of farm land, urbanization, abandonment of farm land. Other patterns of land use change include the construction of the water dam in the location of Kontias and flooding.

Change from vegetation and bare to grassland primarily identified as intensification has been assigned to other transformations as the majority of such changes occurred in ravines where there was a large probability of misclassification. Other changes and processes which appear in the landscape than cannot be assessed through LULC changes, were assessed through qualitative methods.

	Grasslands	Crops	Urban	Vegetation	Bare	Water	Wetlands
Grasslands	-	Intensification	Urbanization	Abandonment	Abandonment	Flooding - Waterdam	Abandonment / Flooding
Crops	Extensification	-	Urbanization	Abandonment	Abandonment	Flooding - Waterdam	Abandonment / Flooding
Urban	-	-	-	-	-	-	-
Vegetation	Other	Intensification	Urbanization	-	Other	Flooding - Waterdam	Other / Flooding
Bare	Other	Intensification	Urbanization	Other	-	Flooding - Waterdam	Other / Flooding
Water	Intensification	Intensification	Urbanization	Other	Other	-	Other
Wetlands	Intensification	Intensification	Urbanization	Other	Other	Flooding - Waterdam	-

Table 3.5: Land cover conversion and acknowledged processes

3.4 Data sets, data processing and analysis

- **Qualitative methods**

Interview with key informants

To build upon the information about the agricultural history of Limnos and the main facts that shaped its socio-economic and cultural context, an interview with key informants was required. The interview was done with 2 members of the regional department of agricultural economy in Limnos, through an open structure form, to get as much information as possible. The questionnaire focused primarily in historical changes of the agricultural history which brought changes in production, practices, characteristic of agricultural holdings. Processes, and drivers of change were also discussed covering all aspects.

Through this interview it became able to narrow our search in specific classification for land cover, specify a time frame and corresponding aerial imagery search and expand results on change and processes that could be addressed through the questionnaire for the focus group session. Specifically, it became clear that abandonment could not be addressed by remote sensing of aerial photographs. Moreover, conversion from irrigated crops to rainfed crops, that was described, is a conversion that needed to be captured through other methods. These led to a reassessment of specific aspects of the methodology and refinement of expected results.

Workshop with local stakeholders (focus group):

Farmers are the major actors of agricultural change. Farmers of an elder age (over 50 years) have a firsthand memory of the landscape history and the practices of the past and thus were targeted for participation.

The workshop took place on July 10, 2019 in Portianou, and lasted 2 h, with participation of 9 farmers from the area. Participants were mostly more than 60 years, from 2 out of 3 communities (Kontias and Portianou) and most of them were still active farmers with mixed farms, covering a range of farm sizes, from small to large[5].

Making use of the results from remote sensing, farmers were asked to point on maps what land use changes they have witnessed, with the help of toponyms and other landmarks such as mandras. Other explanatory information was also noted in order to understand the processes behind those land use conversions. Using questionnaires driving forces were recorded in association with those changes. A clear connection between the changes spotted and driving forces was not possible in all cases, as farmers tended to cite factors that refer to the wider context of the whole island. Elements of reference during this procedure were wide areas such a plains or toponyms, but also specific landscape elements such as mandras. This perception of the role of mandras in the organization of agricultural life on the islands is significant in order to understand change and specifically abandonment.

- **Remote sensing**

In historic landscape science aerial photographs and satellite data imagery are one of the resources used to get information alongside maps, official statistics and social surveys. In remote sensing a variety of techniques is used to perform LCLU change analysis. Many change detection techniques have been developed in order to address different scopes in land science (Lu et al.,2004, Hussein et al.,2013). Mas J. (1999), in a comparison of 6 change detection techniques concluded that post-classification comparison was found to be the most accurate procedure and presented the advantage of indicating the nature of the changes.

Most remote sensing techniques are pixel-based analysis with the use of satellite data, employing a variety of sensors to derive information that is useful for classification and change detection. In historic landscape analysis an additional problem is that temporal range of satellite data reaches back to mid 1970's, and thus in order to obtain information on land cover before that date, other resources must be used such as Panchromatic (often referred as black and white) aerial photos. Panchromatic aerial photos for past decades are widely available at a higher resolution and have been used for multiple purposes. However, classifying black and white aerial photos with the use of traditional algorithms is limited and thus a lot of researches use photo interpretation (Pillai R.B., et al 2005, Taylor et al 2000, Ihse M. 1995). In pixel-based image classification of panchromatic aerial photographs, the spectral signature of a class relies only in brightness, which can present great variation even for patches of the same class (Anderson and Cobb 2004).This produces inconsistent classification results although the resolution of the data may be high.

To address this challenge many researchers have been using object-based analysis. Object based image analysis (OBIA) is a two step procedure that first produces image objects through image segmentation and then classifies these image objects using forms, textures and spectral information into account (Mansor, et al., 2003; Pillai et al 2005). In addition, a multi-scale analysis is possible.

Preprocessing images

[5] Info on the characteristics of participants is found in the Aneex

Black and white panchromatic air-photographs were obtained for 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[6]. The photo-mosaics produced overlapped 97% of the area covering 5316,4 ha. Prior to analysis, the photo mosaics were georeferenced and rectified to EGSA87 Greek Grid projection with the same resolution in order to make comparison between images possible.

	points of reference	Mean error
1960 mosaic	453	11.6236
1980 mosaic	265	12.9122
2002 mosaic	380	9.1442

Table 3.6: Georeference procedure for each photomosaic

Spectral signature enhancement

The need to create meaningful image objects that will be classified through OBIA has resulted in some processing before the segmentation and classification prosses.

High resolution imagery can result to ‘salt and pepper’ effect due to inhomogeneity, affecting quality of classification (ref). In order to produce image objects that represent broad categories such as grasslands or urban, it is necessary to suppress local image inhomogeneities by applying low-pass filters.

Moreover, additional texture features are used to enlarge signature space and provide information on the pixel level for the segmentation process. Haralick has provided the most accredited and well-known texture measures based on the Grey Level Co-occurrence Matrix [GLCM.] Caridade et al (2008) have tested the Haralick features in pixel-based classification, suggesting that the method has proven useful with good results. Lena Halounová (2019) uses GLCM in OBIA in order to find solutions for automatic information extraction from B&W aerial orthophotographs.

Additional information was selected to contribute to OBIA analysis and especially segmentation process, based on the results of the discussion with key informants, as slope seems to be an important factor in distinguishing crops from grassland especially in recent years. As machinery was used to work the land, high slope became an obstacle for modern agriculture. In this way selecting slope as a layer that contributes to OBIA was considered important.

OBIA

In OBIA image pixels are aggregated into spectrally homogenous image objects using segmentation algorithms, which are then classified as objects (Liu D. & Xia F. 2010). Object Based Image Analysis uses pixel neighboring values to analyze image in segments through various segmentation methods. Then the image objects that are created from the segmentation process can be classified through know classification methods.

Here we use multiresolution segmentation in a 3 levels procedure. This is done in order to overcome the problem of under-segmentation as pointed out by Liu D. and Xia F. (2010). “under-segmentation results in image objects that cover more than one class and thus introduce classification errors because all pixels in each mixed image object have to be assigned to the same class”. The scene is segmented at a scale of 400, classified then specific classes are segmented again at a scale of 200, reclassified, and then the same procedure is done again for a scale of 75. This procedure has the advantage of refining the

[6] Using Agisoft Photoscan

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.

Scale 400 Scale 200 Scale 75

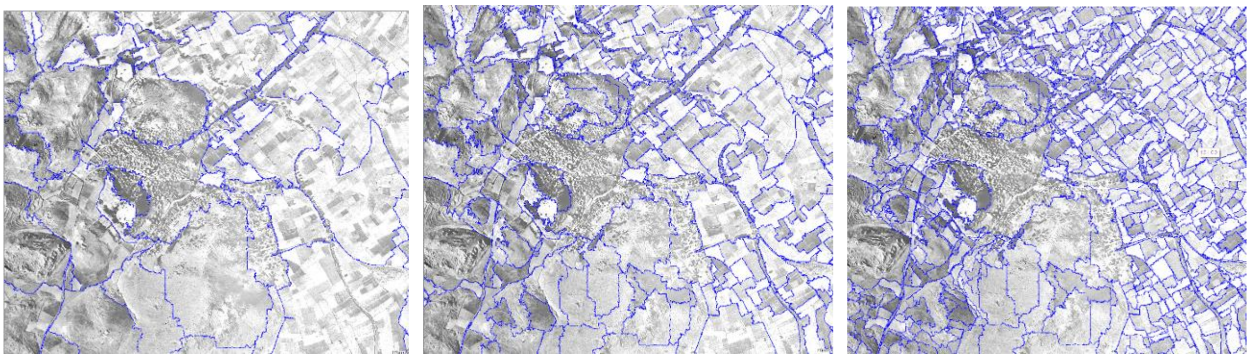


Figure 3.4 Different segmentation scale results

The Multiresolution Segmentation algorithm identifies single image objects of one pixel in size and merges them with their neighbors, based on relative homogeneity criteria. This homogeneity criterion is a combination of spectral and shape criteria.[7] In order to create meaningful image objects the following parameters were used for each year orthophoto. The use of different texture features has resulted in separate adequate combination for each year

1st level: scale 400								
Date	Shape	Compactness	Band combination					
			Original	Contrast	Homogeneity	Slope	Gaussian Filter
1960	0.2	0.8	1	1	0	0.7	0
1980	0.2	0.7	1	1	0	0.5	0
2002	0.2	0.8	1	1	1	1	0
2nd level: Scale 200							
1960	0.2	0.6	1	0	1	0.7	0
1980	0.2	0.6	1	1	0	0	0
2002	0.2	0.8	1	1	1	0	0
3rd level: Scale 75							
1960	0.6	0.3	0	0	1	0	1
1980	0.2	0.6	1	1	1	0	0
2002	0.2	0.6	1	1	1	0	0

Table 3.7: Segmentation parameters used for each year photomosaic

[7] eCognition Developer 9.0 User Guide Document Version 9.0.1 , 2014 Trimble Germany

Classification

After the multiresolution segmentation supervised classification based on nearest neighborhood classification was applied[8]. The classifier used for this study is based on fuzzy membership functions. Rahman, Md & Saha, S. (2008) gives a description of how this classifier works:

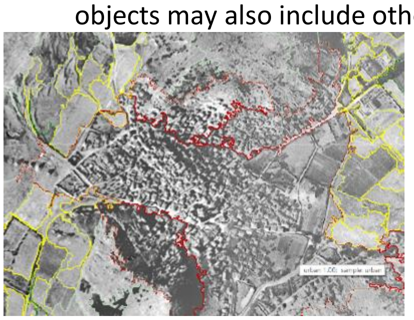
"*Each class of a classification scheme contains a class description and each class description consists of a set of fuzzy expressions allowing the evaluation of specific features and their logical operation. A fuzzy rule can have one single condition or can consist of a combination of several conditions that have to be fulfilled for an object to be assigned to a class. Fuzzy logic classifiers use a degree of membership/a probability to express an object's assignment to a class. Thereby the degree of membership/ probability depends on the degree to which the objects fulfill the class-describing properties/conditions*."

Samples selection:

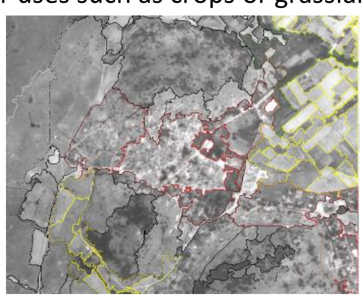
Supervised classification is based on training algorithms with characteristics of sampling areas that have been chosen for each land cover class. Through this procedure, spectral signatures are created for each land cover based on the statistics, texture, form and mutual relations of image objects, that are used to specify each objects class definition. In order to build these sampling areas, ground truth data, or prior knowledge is required.

Sample selection for each class was selected through interpretation of the photomosaics as no ground information was available on those dates, apart from the year 2000 where a Corine Land cover map is available. Number of samples for each date, level and class are provided in table 3.8. A description of the selection is provided below for each class:

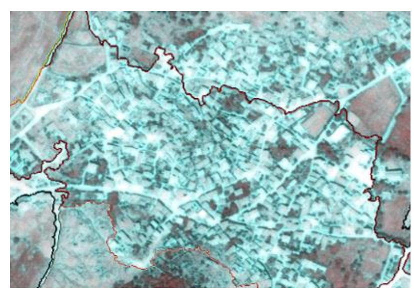
- Urban: Urban samples are defined by location and texture. The characteristic texture of urban is that of contrast between black and white features in a repetitive pattern. In this scale image objects may also include other uses such as crops or grassland.



Urban 1960



Urban 1980



Urban 2002

- Crops: Crop samples are defined by homogeneity of brightness, regularity of shapes or of features within the image object, similarity to other bordering image objects, and direction.
- Grassland: Grasslands samples are defined by irregularity and asymmetry of image objects, absence of regular features within the image object, and size.
- Bare: Samples are defined as generally linear features with high brightness, irregularity and asymmetry of image objects, as well as position.
- Water: Water samples are defined by homogeneity of brightness, large scale, irregularity of shapes, and low brightness.

[8] Nearest Neighbor classification uses a set of samples of different classes to assign membership values.

- Shrublands: Samples are defined as generally linear features with low brightness, homogeneity of brightness, direction and continuity, and position.
- Wetland: Samples are defined by irregularity and asymmetry of image objects, homogeneity of brightness, and low brightness.

Sampling Level 400								
User Class \ Sample	*grasslands*	*crops*	*urban*	Shrublands	*bare*	*water*	*wetland*	*Sum*
1960	36	43	5	6	3		*3*	*96*
1980	41	51	7	4	9	1	2	*115*
2002	38	57	5	-	2	-	3	*105*
Sampling Level 200								
User Class \ Sample	*grasslands*	*crops*	*urban*	*Shrublands*	*bare*	*water*	*wetland*	*Sum*
1960	104	227	5	14	3	-	6	*359*
1980	133	294	18	11	12	1	2	*471*
2002	123	352	21	11	15	-	21	*543*
Sampling Level 75								
User Class \ Sample	*grasslands*	*crops*	*urban*	*Shrublands*	*bare*	*water*	*wetland*	*Sum*
1960	241	563	8	46	19	-	11	*888*
1980	136	1163	18	11	22	1	2	*1353*
2002	143	1647	23	19	28	-	71	*1931*

Table 3.8: Number of samples used for each year classification

Classification parameters:

After training the classifier for each class of the classification date, multiple class descriptions were selected in order to build the fuzzy expression which will allows the evaluation of each feature for classification (Rahman, Md & Saha, S. 2008). A threshold for the required membership degree is defined. This threshold takes values from 0.0 to 1.0 where 1.0 expresses probability (a complete assignment) to a class and 0.0 expresses absolutely improbability. For this study it was set to 0.2. If this threshold is not reached, the object remains ‘‘unclassified’’. The class description parameters selected for each date are presented in the following table.

	Original	Max difference	Are	Length/Width	Asymmetry	Border index	Elliptic fit	Main direction	Radius of largest enclosed	Radius of smallest enclosing	Rectangular Fit	Roundness	Number of Edges
1960	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓
1980		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓

2002		✓			✓	✓	✓	✓	✓				✓

Table 3.9: Classification parameters used for each year classification

Accuracy assessment

In order to evaluate the results of the classification and assess the capability of the procedure, an accuracy assessment is critical. 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 et al. 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. For OBIA E-Cognition software provides 2 types of accuracy assessment: Classification Stability and error matrices. Conducting a thorough classification accuracy assessment requires validation data to compare to classification predictions. This was not possible for years 1960 and 1980. For year 2002 there is a Corine Land Cover map of 2000 but the scale of all output products of CLC according to European Environment Agency is set to 1:100000, facilitating the detection of essential features of the terrain by means of satellite images (Spot, Landsat MSS, TM and IRS) and their representation. This scale is not proper for accurate results. Interpretation of the aerial photos was needed in order to assess classification accuracy.

In this study 2 types of accuracy assessment were used. A polygon-wise validation with an error matrix and classification stability that were provided from E-Cognition software based on image objects.

Error matrix based on image objects

To produce the error matrix with a TTA mask in E-cognition, two scenes were used. Classification as produced from the classifier and a revised version that misclassification errors were corrected based on interpretation of the aerial photos. 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. User’s accuracy indicates the probability that an image object classified into a given category actually represents that category on the ground (Rahman, Md & Saha, S. 2008). Kappa statistics indicate how much the classifier omits errors, comparing to a randomly assigned classification.

	Classification 1960	Classification 1980	Classification 2002
Overall accuracy	0,84	0,91	0,88
Kappa Index of Agreement	0,71	0,83	0,79

Table 3.10: Classification accuracy for each year

Classification stability

The Classification Stability computes a set of statistics based on the difference between the best and the second-best class assignment. The statistical output displays basic statistical operations (number of image objects, mean, standard deviation, minimum value and maximum value) performed on the best-to-second values per class.

4. Results

4.1. Agricultural history of Limnos

The main events that affected the evolution of the agricultural sector in the post WWII period in Limnos are presented below. Distinguishing into 3 periods of interventions that led to modernization of agriculture, this narrative is constructed from literature review mainly Bakalis Ch. (2007) and Georgakopoulou A. (1996) and information gathered through the interview with key informants from the regional department of agricultural economy in Limnos.

- Prime modernization of agriculture and first productivism era from 1950 to 1960, were cotton production reached its peak and the first machinery for irrigation purposes were introduced.
- Second modernization of agriculture that happened around 1970 with the construction of a water dam along with an irrigation network and restructuring of the fields
- Third modernization of agriculture in the decade of 1980 to 1990 were cereals production reached its peak and machinery for ploughing and harvesting purposes was introduced along with the extensive use of chemical fertilizers

Agricultural policy

- In the 1950's state intervention prevailed by means of soft interventions (lending, consulting, aid in irrigation works).
- In the 1970's land reforms and agricultural development programs, such as the construction of the dam, irrigation and drainage systems prevailed.
- In the 1980's and 1990's the introduction of CAP measures and the subsidies for products such as wheat etc. led to a peak in cereal production and loss of traditional seeds (not certified, hence non eligible for subsidies).

4.2 Remote sensing

4.2.1 Land cover

Land cover classification results are presented in table 4.1. Grasslands are the dominant land cover throughout the 40 years period, followed by crops, constituting cumulatively over 90% of land cover. In 1960 grassland accounts for 50% and crops for 40%, while in 1980 grasslands increase to 60% and crops decrease to 32% of total land. In 2002 grasslands decrease to 55% and crops regain ground accounting for 37%. The other land cover classes are marginal as only bare land has a presence near to 4% and all others account for less than 2%.

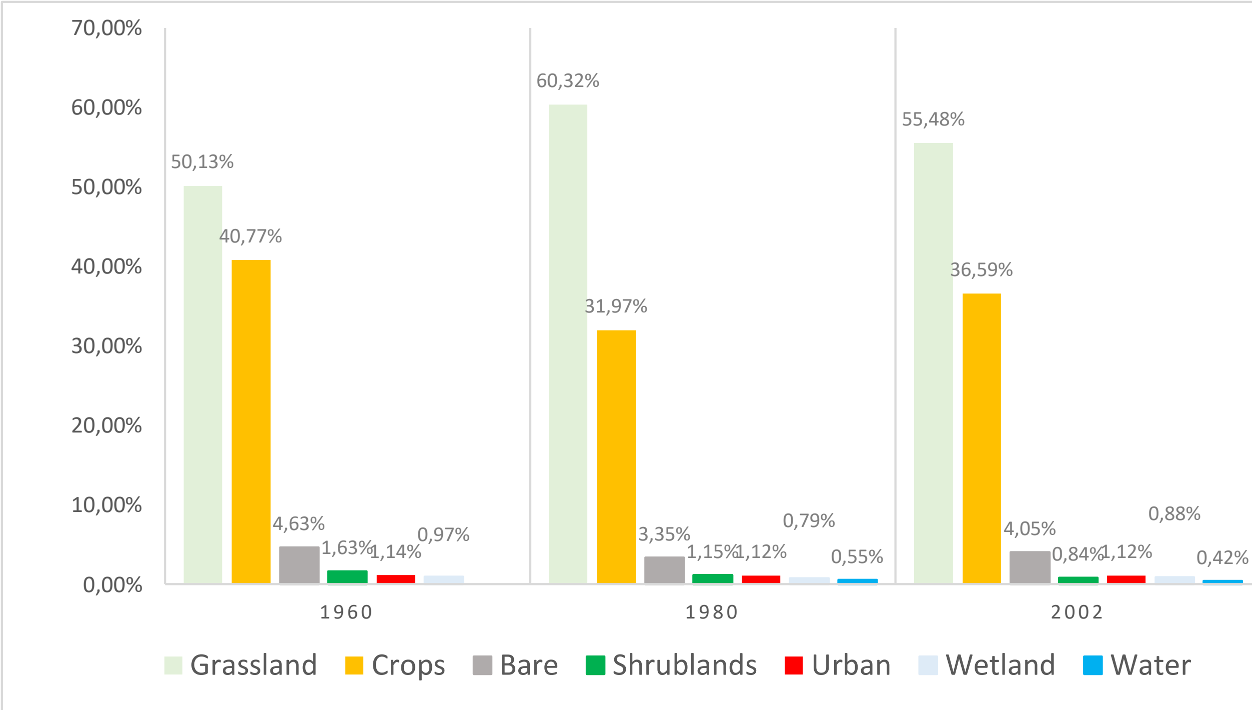
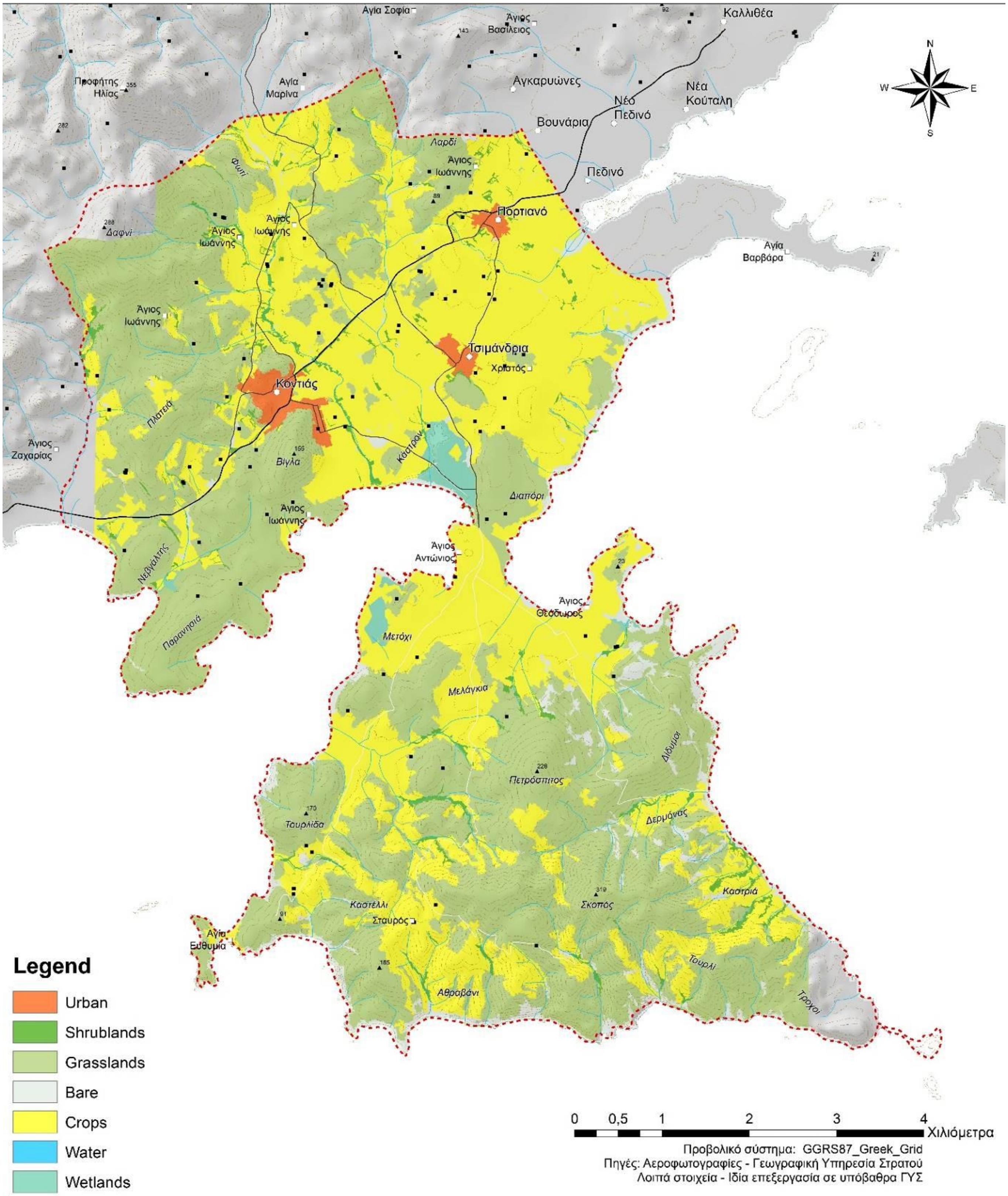


Figure 4.1: Land cover of study area through the years

1960 classification

Mainland: In the lowlands, crops create a continuous patch along the plains with small hilly patches of grasslands and riparian vegetation running alongside ravines complementing the landscape. On the feet of hills lay the settlements of Kontias and Tsimandria, while Portianou is located among cropland. A valley that starts from Profitis Ilias hill and the area of Aghia Marina, runs downhill until it reaches Kontias, providing suitable conditions for more crops to develop, while trees are running alongside its ravines. Another ravine that starts from Lardi valley ends up in a wetland near Diapori. Another small wetland can be found near Nevgatis. In the area west of Kontias village, hilly grasslands lay with patches of crop cultivation in Plateia and in other areas with suitable relief.

Fakos: In the peninsula of Fakos crops are primarily located in the plain at the lowlands near Diapori but they can also be found in the cultivated hilly terrain all around the hills of Petrospitos and Skopos. Small wetlands can be found in Metochi, some kind of maquis along the ravines in the hilly terrain, while the rocky shores appear to have no vegetation. Image objects identified as crop fields have an average size of 4750 m^2.



Classification 1960

1980 classification

Mainland: Cropland appears more aggregated in the lowlands but to a lesser extent, while it disappears from the uplands. Some less productive areas of the lowlands like the east coast of Tsimandria also turned to grassland. Grasslands appear more aggregated as well, as no crop patches are found in the hilly areas and small grasslands patches in the plains are diminished. The construction of the dam in Aghios Dimitrios at the start of Kontias Valley accounts for the presence of the land cover category of water. The wetland area near Diapori appears more or less the same while the small wetland near Nevgatis disappears. Shrublands appear more aggregated as well, possibly due to land reforms that have changed the field structure. The latter change is also made evident by the presence of a new, rectangular-shaped, road network in the plains due to construction of an irrigation network connected to the dam. Image objects identified as crops fields have an average size of 6481 m^2.

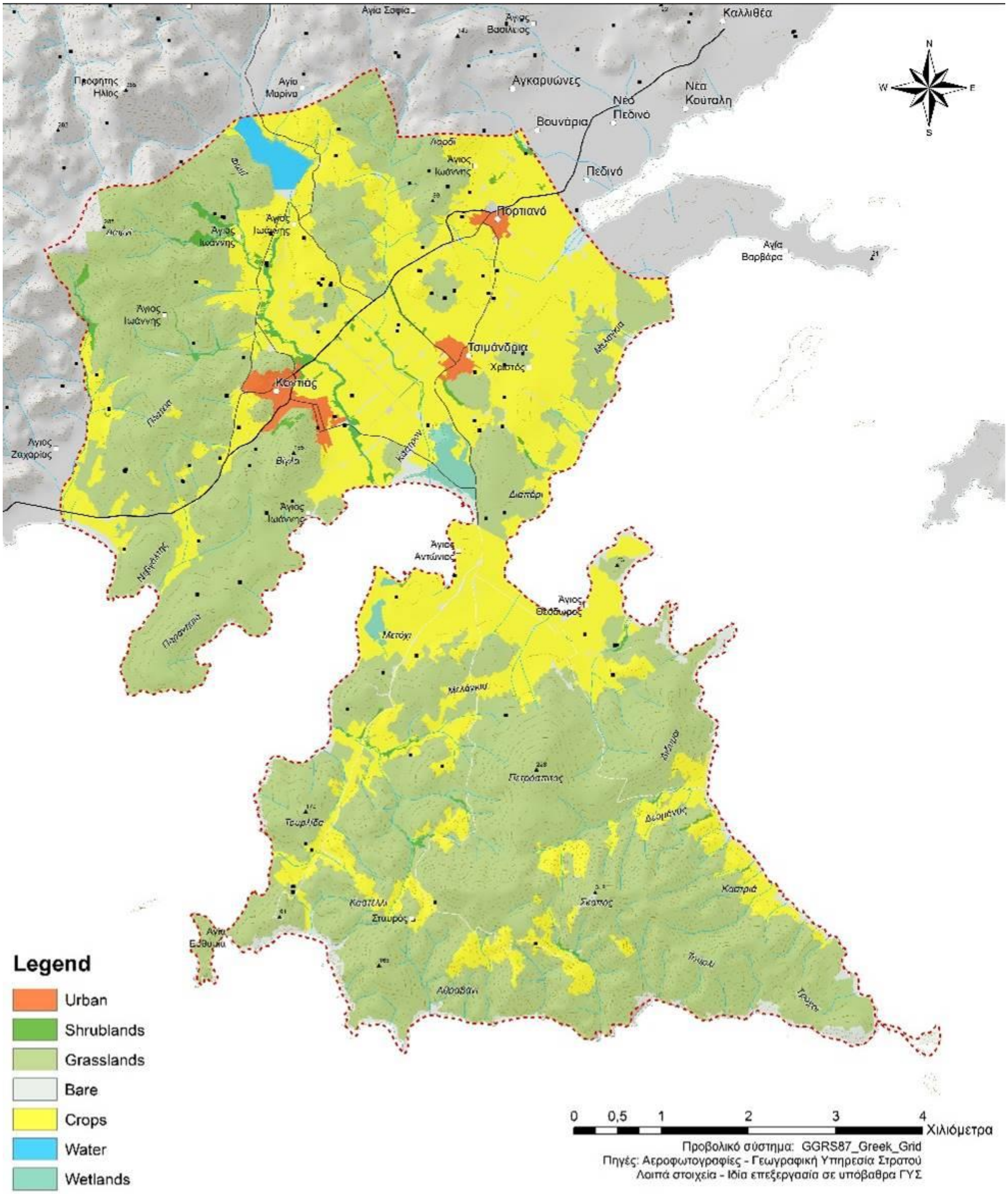
Fakos: The presence of crops is decreasing to fewer and smaller patches but does not disappear from the hilly uplands of southern Fakos. In Kastria cropland persists near the east coast while in the valley of Dermonas some areas preserve cropland. Grasslands seem to dominate, and wetlands remain the same.

2002 classification

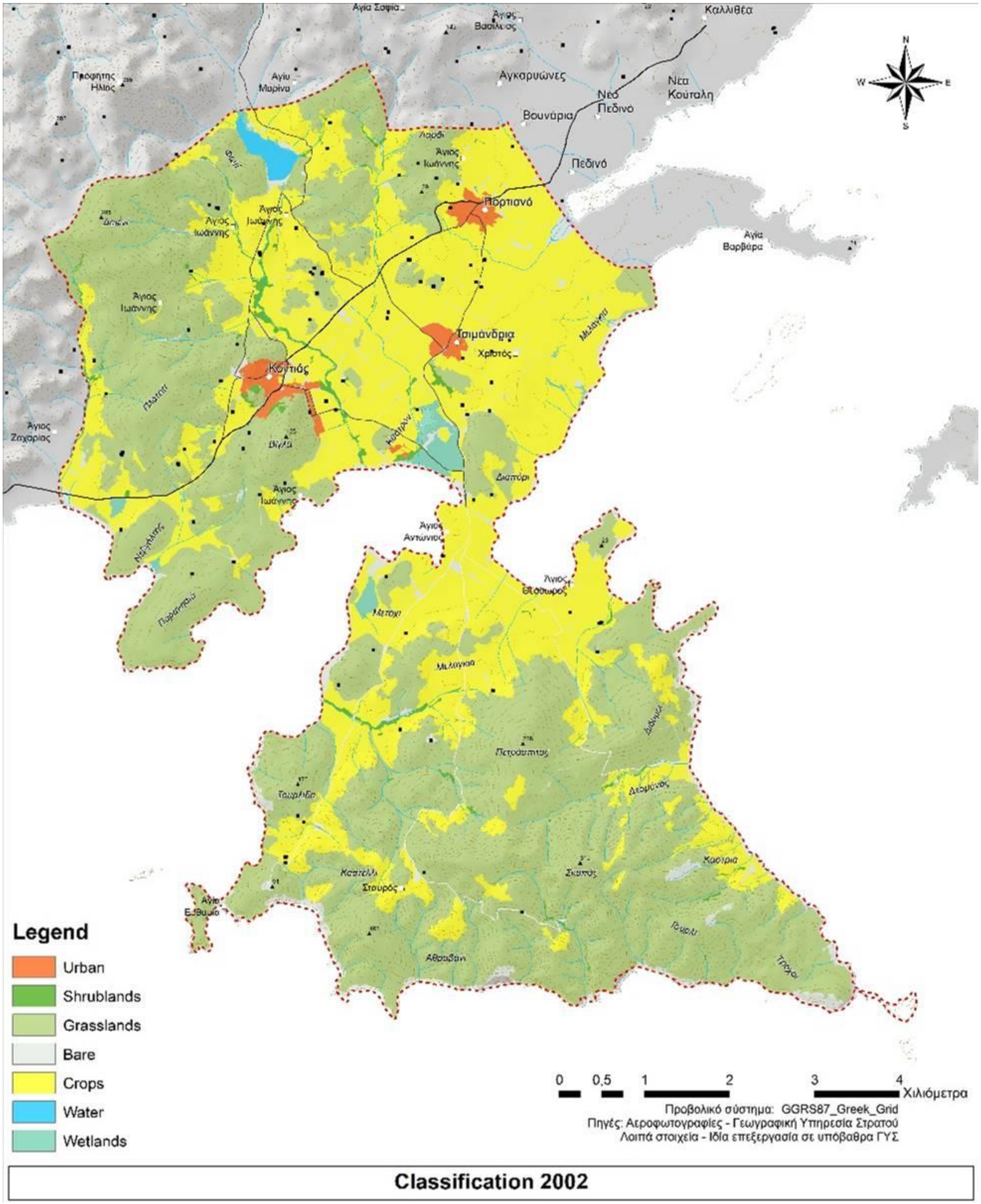
Mainland: Cropland appears to expand in the edges of the plain as less productive areas such as the east coast of Tsimandria and Lardi are incorporated. Grasslands are decreasing due to cropland expansion but remain in large patches, while some small patches reappear in the small hills in the plains. The water in the dam seems to be less as represented in land cover. Shrublands remain more or less the same and some changes should be attributed to misclassification, as they don't represent a meaningful procedure. The small wetlands near Nevgatis appear again though it is difficult to understand if this represents wetland seasonality or misclassification. Image objects identified as crops fields have an average size of 6289 m^2.

Fakos: Cropland seems to be expanding in the edges of the lowlands of the peninsula, incorporating Melangia, while in the hilly uplands very few patches of crops exist near some mandras. In Kastria and Dermonas cropland shrinks in the valleys and hills of the coast. Wetlands in Metochi remain the same.

Crops, as expected, are prominent in lowlands whereas the higher altitudinal zones are occupied by grasslands. Intermediate altitudinal zones such as that of 100 to 200 m, have a significant presence of crops in 1960 that is later decreased (figure 4.2). This data supports the fact that cultivation in the 1960's was present in more marginal areas such as hilly slopes, as 20% of all crops are located between 50 - 200m altitude. Grasslands are evenly dispersed in every altitudinal zone as localized geomorphological factors can limit crop cultivation even in the lowlands, leaving space for grasslands. Over 50% of grasslands are found on steep to very steep slopes (over 18%) where 76,4% of the area is grasslands. Bare land can be found mainly in the area of Fakos as the peninsula has steeper slopes, both at its shores as well as inland. Moreover, linear features such as roads were also categorized under this class. Roads were more visible in years 1980 and 2002 aerial photos, possibly due to structural changes in cultivation plots that followed the construction of the dam and clearance of roadside vegetation. The appearance of water class in years 1980 and 2002 is a result of the construction of Aghios Dimitrios irrigation dam.



Classification 1980


Legend
Urban
Shrublands
Grasslands
Bare
Crops
Water
Wetlands
0 0,5 1 2 3 4 Χιλιόμετρα
Προβολικό σύστημα: GGRS87_Greek_Grid
Πηγές: Αεροφωτογραφίες - Γεωγραφική Υπηρεσία Στρατού
Λοιπά στοιχεία - Ιδία επεξεργασία σε υπόβαθρα ΓΥΣ
Classification 2002
Πόρτιανό
Τσιμάνδρια
Κοντιάς
Καλλιθέα
Αγκαρυώνες
Νέο Πεδινό
Νέα Κούταλη
Βουνάρια
Πεδινό

Shrubland vegetation at this scale has been identified as ravines and linear features such as tree lines alongside main roads. Moreover, in some cases some 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 went under this class. Presence of sparse shrubland vegetation among cropland was recorded in 1960 but not in the consecutive years. Trees and shrublands were more visible in the aerial photos of 1960 possible due to sun angle at the time when the pictures were taken. Another possible reason is the structural change of Kontias and Tsimandria plains, resulting in channels, new roads and land redistribution scheme that may have destroyed tree hedges of the past. Urban areas occupy the edge of the main plains at the feet of hills over-looking the plain and are evenly dispersed across the mainland[9]. There are two areas that appear constantly as 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.

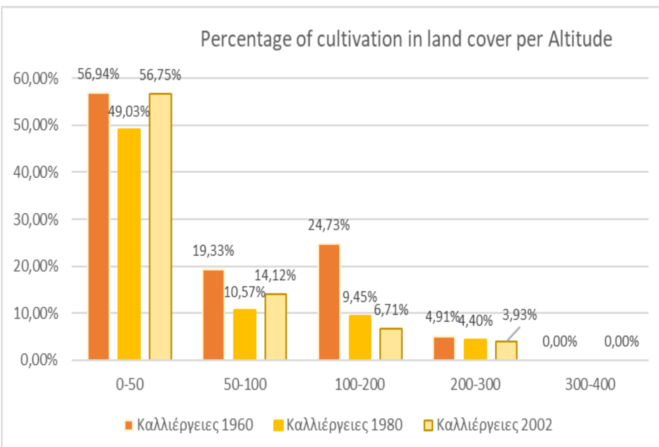


Figure 4.2: Evolution of cropland in relation to altitude

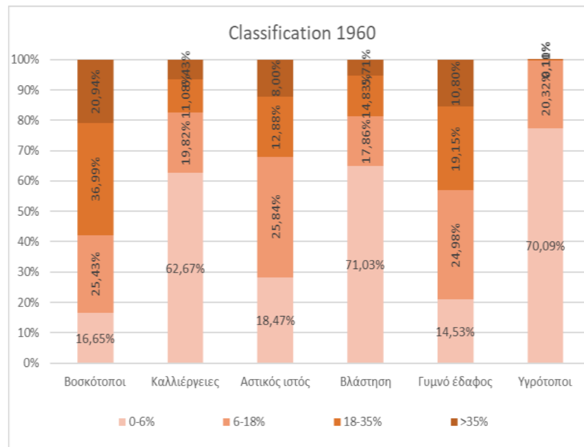


Figure 4.3: Distribution of classes in relation to slope

4.2.2 Changes and conversions

When comparing classifications of 1960 and 2002 it seems as the landscape hasn't undergone significant changes, as 75.66% of land is classified under the same class in both instances. If one looks separately the two intermediate periods, in 1960-1980 classification changes are 25.36% of total, while in 1980-2002 changes were 20.85% of total land. Cumulatively, 65.76% of total land cover has not been transformed at all retaining its assigned class in both periods.

		1960-1980	1980-2002	1960-2002
Change	km^2	13.397	11.320	12.963
	Percentage	25.36%	20.85%	24.34%
No change	km^2	39.434	42.961	40.290
	Percentage	74.64%	79.15%	75.66%
Total area classified		52832088	54281613	53254458

No change	65.87%
Change once	22.10%
Change twice	12.04%

Table 4.1: Evolution of areas under change

[9] According to Bakalis (2007) the distribution of villages in the 19th century and their according communities and their land has been created in a way that each community had sufficient space for agricultural production, and a rather equal proportion of farmland and grasslands.

Another 22.18% undergoes some kind of transformation once in the period of 40 years, while 12.06% 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.

Most of the changes occur in the lowlands, up to 50m of altitude, but in all altitudinal zones there is some kind of transformation. A rate of change that ranges from 30 to 37 %, is a transformation that occurs in most altitudinal zones from 0 to 200m. Above this altitude change is rather marginal. Overall, changes seem to occur more on very gentle (0-6%) and gentle slopes (6-18%), as percentages of persistent classification are greater in steeper slopes. Change is more evenly distributed to all slopes in the period of 1960 to 1980, in contrast to the following period, where change seems to occur more on gentle slopes.

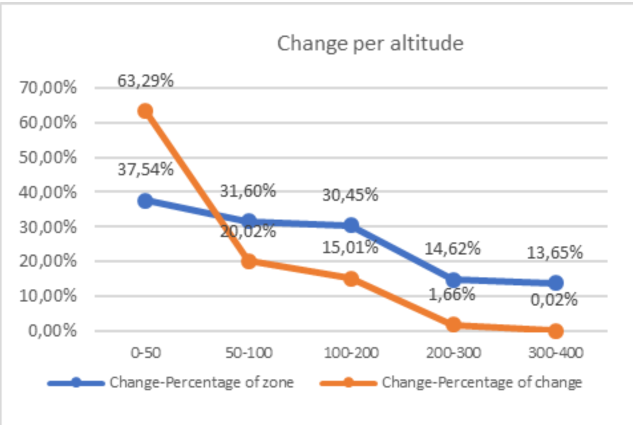


Figure 4.4: Change 1960-2002 in relation to altitude

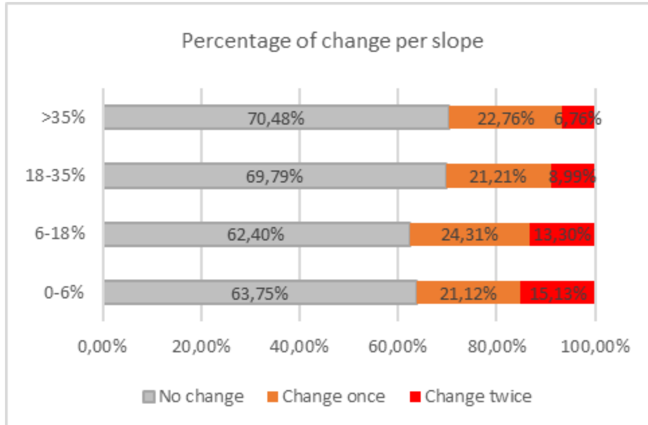


Figure 4.5: Distribution of change 1960-2002 in relation to slope

Looking more closely to the characteristics of change patches, two different types can be distinguished. The first one is linear patches that are close to roads, streams or ravines and the second one is non-linear. Linear change patches can be the result of either misclassification of some kind due to small scale features such as roads and trees, or true transformations. Especially linear change patches that are situated in the lowlands, at the plain of Kontias, seem to represent changes in the structure of cropland rather than a change in classification, as linear shrubland vegetation features seem to be replaced by crops near old ravines and bare land linear features appear amidst cropland representing the new crop grid system of canals after construction of the dam. So, what appears to be replacement of one class by another at the small scale, at a larger scale represents the structural changes in cropland.

Grasslands have been growing in surface during the period of 40 years, showing an overall increase of 13.56%, although the actual increase happened between 1960 - 1980, to be followed by a decrease in the following period. Most of this increase is cropland replaced by grassland, as 67 and 26 Hectares went under this transformation in the periods 1960-1980 and 1980-2002 respectively. The opposite trend is observed in crops, as cultivated land shrinks by 19,71% between 1960-1980, recovering to -7.94% in 2002 comparing to 1960. Cropland lost 30% and 15% of land that turned to grassland in the periods 1960-1980 and 1980-2002 respectively. At the same time grasslands that turned to cropland over the same periods account for 23 and 53 Ha, or 9% and 16% of grasslands. So, it seems that there is an interchange of land between the two classes, as the dominant trend in the period 1960-1980 is cropland turning to grasslands, while in 1980-2002 the opposite trend is recorded, although in lesser degree. 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.

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 vegetation is also prone to false classification due to steep geomorphology. Nonetheless it presents a steady decrease trend between 1960 to 2002, shrinking to almost half of its initial surface. Wetlands presented an overall loss of 7.09% with fluctuation between -16.50% to 11.27%. This fluctuation should be attributed to their seasonal appearance rather than a transformation to another class. As marginal areas with salination problems, wetlands are not always favorable for conversion to cultivated land, as this would require costly infrastructures. According to Dimopoulos et al. (2018) in Lemnos wetlands were used mostly as grazing areas for kettle.

Classification persistency was high for grasslands as 79,71% of what was grasslands in 1960 remained unchanged throughout the years, accounting for 72,99% of what is grasslands in 2002. Cropland underwent more transformations during this period, as 55,77% of cropland in 1960 remained the same representing 61.48% of cropland in 2002. A 63.78% of urban areas in 2002 seem to remain the same since 1960, but looking into class persistency in 1960, it seems that just 87.03% of the class that was classified as urban remained urban the whole 40 years, as the remaining 12.97% seems to have changed to a different use, which is highly unlikely. Wetlands, although characterized by small overall change, appear less persistent as only 55.77% of what was classified as wetland in 2002 has remained the same for the whole period of 40 years. Bare land and shrubland vegetation seem to undergo changes constantly (21.61% and 13.08% respectively for 2002); changes in these two classes might also be attributed to a high rate of misclassification as explained above.

		1960	1960-1980	1980	1980-2002	2002	1960-2002
Grassland	km^2	26,86	6,23	33,09	-2,59	30,50	3,64
	Percentage	50,13%	23,21%	60,32%	-7,83%	55,48%	13,56%
Crops	km^2	21,84	-4,30	17,54	2,57	20,11	-1,73
	Percentage	40,77%	-19,71%	31,97%	14,66%	36,59%	-7,94%
Urban	km^2	0,608	0,004	0,613	0,004	0,618	0,009
	Percentage	1,14%	0,79%	1,12%	0,73%	1,12%	1,52%
Shrubland	km^2	0,872	-0,239	0,632	-0,168	0,463	-,408127
	Percentage	1,63%	-27,46%	1,15%	-26,66%	0,84%	-46,80%
Bare	km^2	2,480	-0,640	1,839	0,385	2,224	-0,255
	Percentage	4,63%	-25,83%	3,35%	20,94%	4,05%	-10,30%
Water	km^2		0,299	0,299	-0,069	0,230	0,230
	Percentage		100,00%	0,55%	-23,07%	0,42%	100,00%
Wetland	km^2	0,520	-0,085	0,434	0,048	0,483	-0,036
	Percentage	0,97%	-16,50%	0,79%	11,27%	0,88%	-7,09%
Unclassified	km^2	0,395	0,012	0,408	-0,068	0,339	-0,056
	Percentage	0,74%	3,20%	0,74%	-16,82%	0,62%	-14,15%

Table 4.2: Land cover per year and changes in cover between the two periods

CLASS 1960/ CLASS 1980	Grassland	Crops	Urban	Shrubland	Bare	Water	Wetland
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%
Wetland	4,49%	24,00%	0,00%	0,26%	7,27%	0,00%	63,97%
CLASS 1980/ CLASS 2002							
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%
Υγρότοποι	2,43%	19,26%	0,07%	2,85%	9,63%	0,00%	65,76%
CLASS 1960/ CLASS 2002							
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%
Wetland	1,71%	21,94%	0,04%	1,31%	8,84%	0,00%	66,16%

Table 4.3: Cross tabulation of classes between the two periods

4.2.3 Land use trajectories – Processes of change

Land use trajectories reveal that extensification process is prominent overall, as the basic trend seems to be that of cropland transforming to grasslands. Intensification is also a main trend as different land uses are turned to agricultural land and grasslands are converting 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 of 1960-2002. The construction of the dam in Aghios Dimitrios represents 1.60% of total land change although it initially seems to occupy a greater area (29 Ha in 1980 comparing to 20 Ha in 2002).

Looking at the two periods separately, although the main processes coexist there seems to be a distinct pattern between them. Extensification seems to be the main process of change from 1960 to 1980, whereas intensification is the main trend for the next 20 years.

		1960-1980	1980-2002	1960-2002
Extensification	km^2	67.108	2.634	4.939
	Percentage	50.09%	23.28%	38.10%
Intensification	km^2	34.093	6.132	4.299
	Percentage	25.45%	54.17%	33.17%
Urbanization	km^2	0.141	0.175	0.171

		1960-1980	1980-2002	1960-2002
	Percentage	1.06%	1.55%	1.33%
Waterdam	km^2	0.299		0.207
	Percentage	2.23%		1.60%
Other	km^2	1.444	0.827	1.516
	Percentage	10.78%	7.31%	11.70%
Abandonment	km^2	1.392	1.582	1.614
	Percentage	10.39%	13.98%	12.45%
Change	km^2	13.397	11.320	12.963

Table 4.4: Processes of change between the two periods

Relief seems to be a determinant factor of the forms of change. Extensification seems to take place in all altitudes from 0 to 200m while intensification and abandonment is a process that characterizes the lowlands. Extensification appears to be happening on all slopes, while slope seems to be a major determinant for intensification. In steeper slopes, extensification appears as the main process of change, as it accounts for 60% of changes in slopes over 18% between 1960 and 2002.

Trajectories of each process as percentage of total change present a different relationship with relief. Intensification, as noted, is affected by slope, so in steeper slopes, irrespective of altitude, intensification plays a lesser role. On the other hand, extensification seems to be following altitude, but over 200 m there is a drop in percentage of total change. This appears to be marginal as over 200m accounts for just 4.5% of the total area, so we can consider these trends as more or less valid.

	Slope				Altitude				
CHANGE 1960-2002	0-6%	6-18%	18-35%	>35%	0-50	50-100	100-200	200-300	300-400
Abandonment	61,81%	17,47%	8,91%	11,81%	80,60%	9,64%	9,23%	0,53%	0,00%
Extensification	22,33%	25,15%	29,87%	22,65%	39,62%	26,70%	31,78%	1,90%	0,00%
Intensification	49,70%	28,28%	18,74%	3,28%	74,99%	19,26%	3,49%	2,27%	0,00%
Other	32,37%	23,78%	28,74%	15,11%	61,53%	29,26%	8,72%	0,50%	0,00%
Urbanization	68,55%	21,23%	5,26%	4,96%	99,37%	0,63%	0,00%	0,00%	0,00%
Water dam	62,59%	2,38%	0,24%	34,79%	99,97%	0,00%	0,03%	0,00%	0,00%
No change	38,95%	22,03%	25,02%	14,00%	56,83%	21,52%	16,91%	4,69%	0,06%
Total	**38,71%**	**22,68%**	**24,52%**	**14,08%**	**57,53%**	**21,64%**	**16,82%**	**3,97%**	**0,05%**

Table 4.5: Processes of change as distributed through slope and altitude

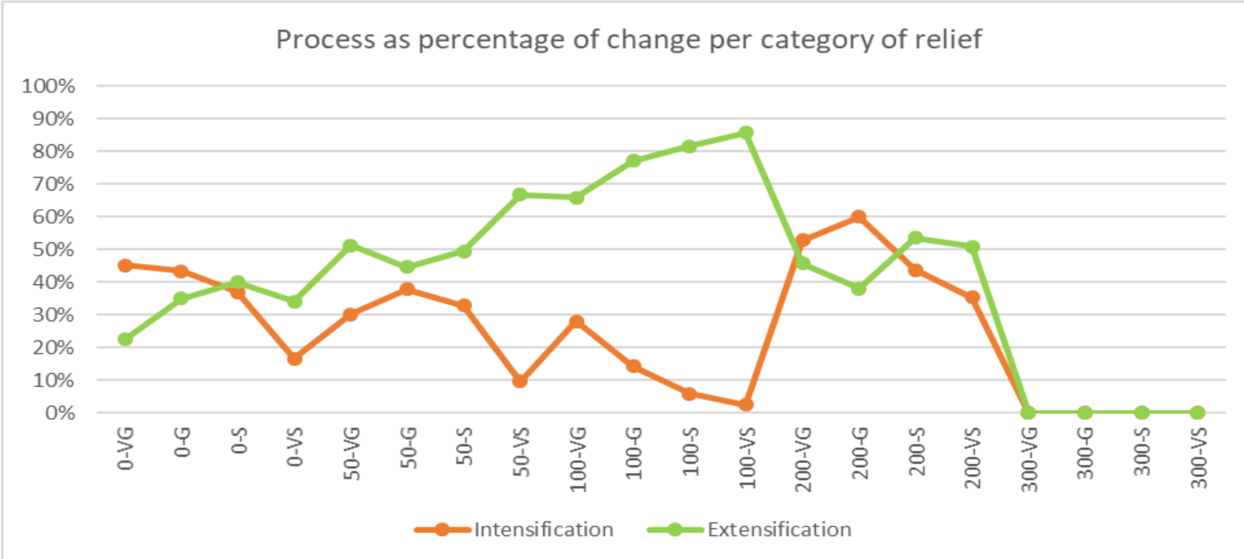


Figure 4.6: Relation of processes and relief in the period of 1960-2002

4.3 Workshop results

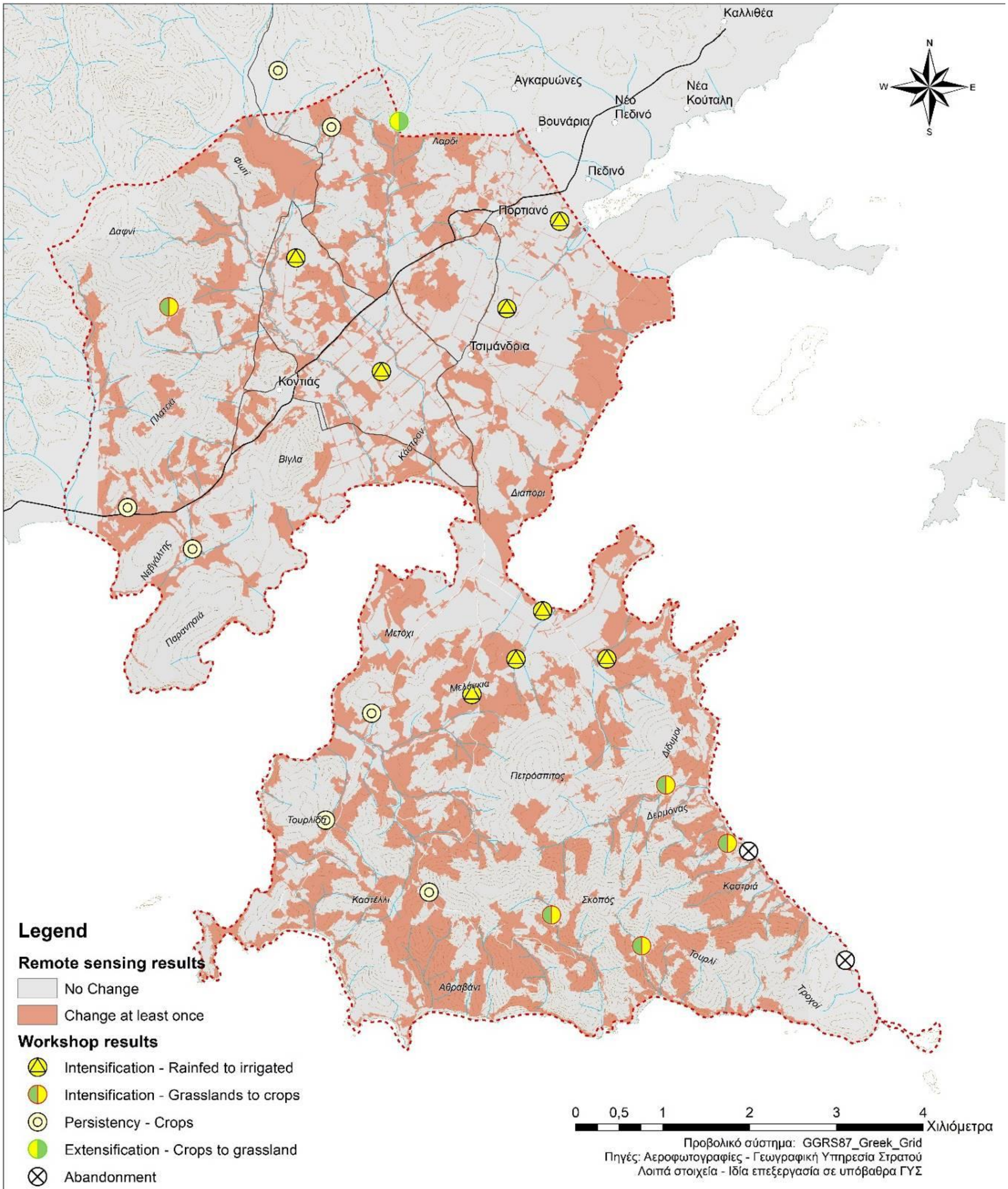
4.3.1 Processes:

Recalling actual memories of past changes, participants stated their own perception of changes in the landscape. Reference units used in this oral procedure were less exact, as they varied from the whole plain of Kontias, a toponym, 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 and the subsequent change from cotton crops to cereal crops. This process is characterized as extensification as it has been a change between irrigated crops to rain-fed crops. Over one participant did mention that cotton cultivation was accompanied by opening of wells for irrigation of crops, an observation that has been cross-checked with information from the interview with key informants. These wells that are still present today can be observed in the 1960 aerial photos and they can be considered as landscape features which indicate the presence of cotton in the 1960's.Reported areas where cotton was cultivated in the 1960's were the plain of Kontias, Tsimandria and Portianou, and the lowlands of Fakos area. There was also a place that was recorded with cultivation of cotton after 1980.

Cropland to grassland: This process of extensification was directly connected with the use of machinery and access to roads. Participants focused more in the area of Fakos, where they seemed to be more able to identify changes. Their understanding of the landscape was described through the division of Fakos into "North" and "South" or "wild", where the first part is still cultivated while the "wild" one has been either turned to grasslands or abandoned. Through the use of more specific elements of space such as the mandras or toponyms, changes from cropland to grassland were located in the hilly areas of south and east Fakos.

Abandonment: In the case of southeastern Fakos peninsula participants described the area as abandoned, i.e. neither cropland nor grasslands. This is a hilly area with steep slopes and the most remote part of the peninsula, and it seems that there are only goats left there, grazing freely. No other place was mentioned.



Workshop and remote sensing results

Intensification: In one case the participants recognized an area of grasslands that have turned to cropland, after 1980. This is a mild-sloped area near Portianou village where the use of machinery made possible to cultivate what used to be grasslands.

Persistent areas: When it came to define what has remained unchanged, participants tended to refer to specific holdings (mandras) inside areas that had undergone some kind of change, usually extensification or abandonment. The cases mentioned were land that is still cultivated. These areas were pointed out as mandras which are still operative, cultivating crops in areas that have been otherwise turned to grasslands. Most of the records could be cross checked as livestock holdings are registered and could also be seen on the map. The operative mandras could thus be considered as landscape features which represent the persistence of the mixed livestock-crop system characterizing the landscape of Lemnos.

	Extensification		Intensification	Abandonment	No changes areas	
	A: Cotton to cereals	B: Cropland to grassland	Grassland to cropland	Croplands / grasslands to abandoned fields	Cropland	Grassland
References	9	4	1	2	4	1

Table 4.6: Changes recorded through participatory mapping during the workshop

4.3.2 Driving forces:

In the first period, 1960-1980, emigration, mechanization of agriculture, crop disease, irrigation works and dam construction, cotton prices, and ownership status were the factors reported to contribute to changes. In the period between 1980 and 2002 subsidies, mechanization of agriculture, cheap fertilizers and cost of production in general, decrease of livestock products' prices, and loss of traditional seeds were factors recorded as driving forces.

The results of the questionnaire on driving forces indicate emigration as the most prominent factor, as everybody recognized that the flows of people leaving the island had a great impact on its agricultural sector, resulting in major changes. A second factor that seems to be of great importance is mechanization of agriculture, which has affected the way people work the land. Economic drivers were also mentioned, 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 1970's was mentioned only by two farmers although it had 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 in seeds from own production to purchase of commercial seeds, was also considered a contributing factor of change. The change in the relationship between "kechagias" (farmer / shepherd who used to rent land) and landowner was also mentioned as a driver of change, 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 led to changes in the landscape. The factors 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) but also to cultivation of some mild-sloped areas that were previously grasslands, as mentioned above. It is important that people recognized the effect of mechanization of agriculture during both periods. Crop disease was also directly connected to cotton production decline and a change towards cereal production, which is a process of extensification. Emigration seems to have affected more than one processes, as it was mentioned as a factor related with cotton production decline and with crops turning to grassland.

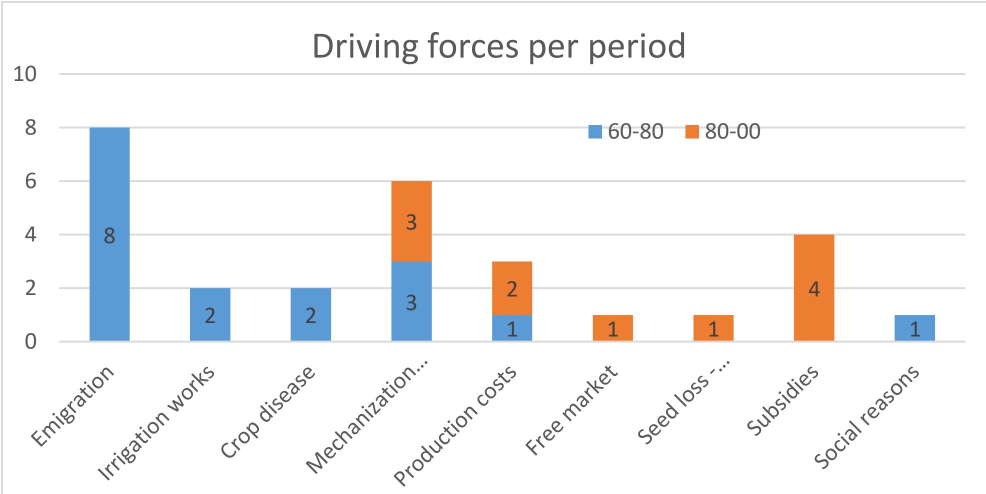


Figure 4.7: Driving forces as recorded through questionnaires

	Driving forces								
	Emigration	**Dam construction – Irrigation works**	**Cotton disease**	**Mechanization of agriculture**	**Production costs**	**Market prices**	**Seed loss**	**Subsidies**	**Social reasons**
1	**60-80**			**80-00**			**80-00**	**80-00**	
2	**60-80**			**60-80**				**80-00**	
3	**60-80**			**60-80** [10]	**60-80** [11]	**80-00**[12]			
4	**60-80**			**80-00**				**80-00**	**60-80** [13]
5	**60-80**		**60-80**	**80-00** [14]					
6	**60-80**				**80-00** [15]				
7	**60-80**	**60-80**	**60-80**						
8	**60-80**	**60-80** [16]		**60-80**	**80-00**[17]			**80-00** [18]	

Table 4.7: Driving forces as recorded through questionnaires

[10] Agricultural machinery came to Lemnos in the 1970's.
[11] Cotton prices went down.
[12] Dairy products prices went down.
[13] Change in relation between "kechagias" and landowner.
[14] Improvement of professional skills as well.
[15] Cheap fertilizers in the 1980's.
[16] The construction of the dam led to clover production.
[17] Cheap costs.
[18] There was a turn to livestock production due to greater profit margin.

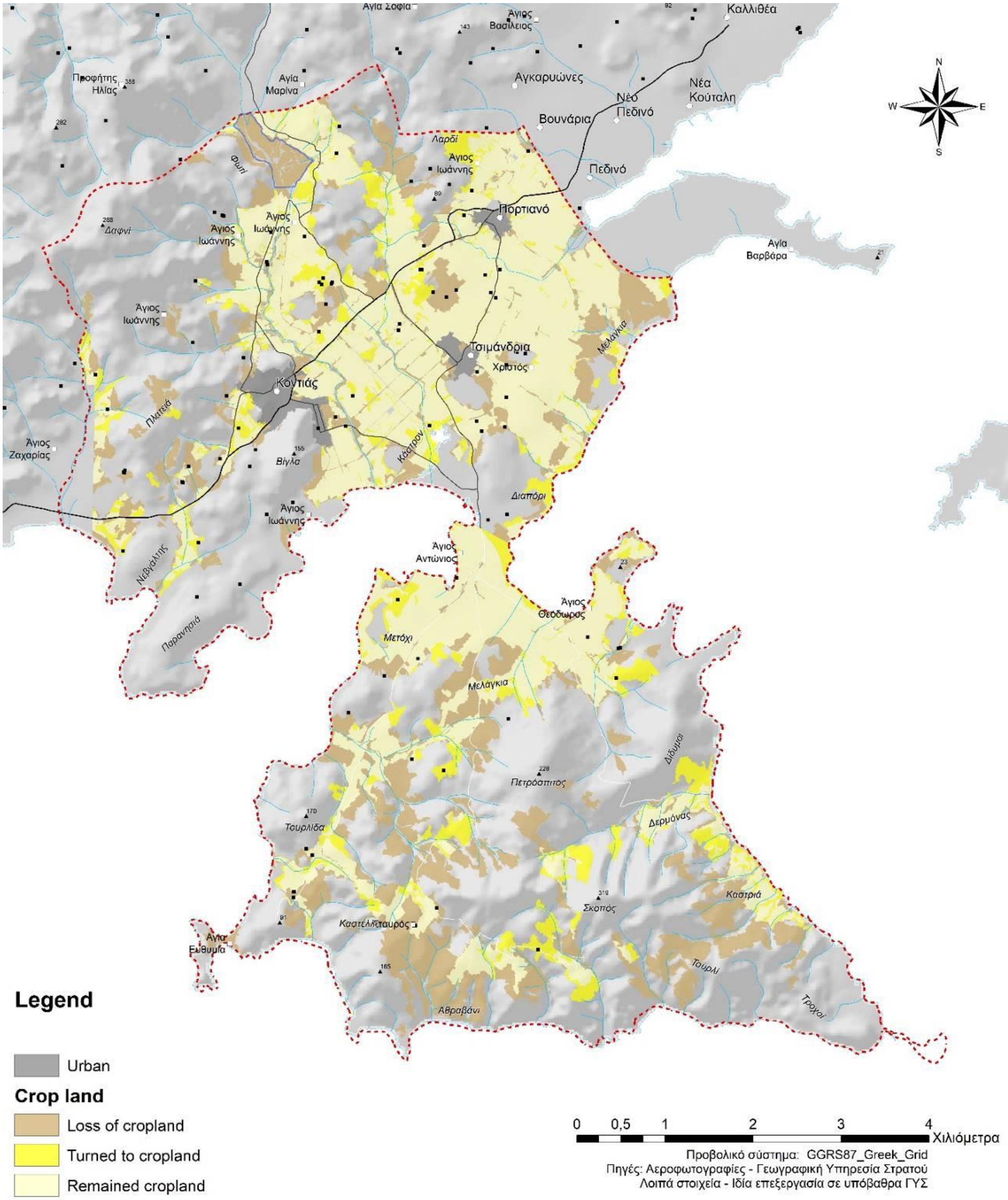
5. Conclusions

5.1 The evolution of the agricultural landscape of Fakos through the period of 1960 to 2002

In order to construct a holistic narrative over change in the study area, one must take account of the various changes that the landscape has undergone in the past years, as farmers were adapting to external challenges and forces of change according to the capabilities of the land and of their communities.

The end of the golden "cotton decade" of the 1950's, was followed by a rural depopulation due to emigration, mainly abroad, in the period of 1960 to 1970, leading to a transition from cotton well-irrigated cultivation to rain-fed cereal production in the fertile lowland plains. Evidence of the driving forces behind this change were confirmed both by officials and by farmers, as decrease of cotton prices, cotton disease and primarily emigration were identified during the workshop (See table 4.7 above). As also evidenced by agricultural statistics, this change was accompanied by a reduction of the number of holdings and a decrease of arable land, which at the time was still a labor-intensive work and hands were short in this period. Marginal areas, in uplands and in steep slopes that were cultivated with cereals in 1960 are left uncultivated and are being transformed to grasslands, representing 12.70% of total land of the area and almost half of the changes in land cover during that period. This is happening to all uplands but in Fakos some upland areas retain crop cultivations. It seems that farmers reacted to cotton decline and rural depopulation through extensification and aggregation of land. Fewer people were needed for cultivation of cereals compared to cotton harvesting and at the same time agricultural land was used depending on fertility, accessibility and required effort, causing marginal areas to be left for grazing. At the same time livestock farms are reduced but livestock is increasing, revealing a trend of intensification. Irrigation wells that provided water for the cultivation of cotton are gradually being abandoned. Also, abandonment of terraces starts in this period and ends up in the 1980's, as these areas are the first to be left uncultivated as agricultural production shrinks, a trend that is noted throughout the Aegean islands (Petanidou et al, 2008).

Major irrigation works take place in the 1970's, as the dam of Aghios Dimitrios on Chandrias stream at the upland part of Kontias and an extensive irrigation network in the lowlands are being constructed, resulting in a redistribution of land and bigger parcels. This change did have a great impact on the landscape, as the structure of the plains of Kontias and Tsimandria changed dramatically; this appears in farmers' memory as a major change in the landscape and as a driving force of change. According to key informants, this has been a major milestone for stopping the negative population trend, keeping especially young farmers in the area (actually local population is still declining during this decade, however at a lower rate). Construction of road and canals network and loss of riparian vegetation along the old canals, were among the changes in the lowlands (expressed as land cover conversions from crops to bare land, and from shrublands to crops, respectively). This modernization of agriculture can be seen as a response by the state to the agricultural decline and rural depopulation of the previous decade. The results of this policy were observed in the following period, along with other contributing factors. At the end of this period a small number of emigrants from Australia are returning to Lemnos and are buying agricultural land, changing the traditional ownership status in some areas. This is an element recorded in other studies (see Bakalis, 2007) but it has also been mentioned by a farmer during the workshop, bringing into our attention cultural driving forces.



Cropland conversions 1960-1980

The beginning of the following period, i.e. the decade of 1980, can be referred as the start of a productivism era, as the implementation of the Common Agricultural Policy (CAP) and further mechanization of agriculture led to a peak in cereal production. The new agricultural machinery is used to push the limits of cultivation crops to the edges of lowlands, regaining some of the cropland that had turned to grasslands in the previous period. This is represented in 9,80% of total land and almost half of the change in this period. This trend is represented also in the recovery of crop presence in slopes of 6-18% and 18-35%. Nonetheless, the leading trend is aggregation of cropland, as new cropland is added adjacent to previous crops and unique patches of cropland are rare. Landscape homogeneity is a trend of the productivism agriculture as bigger fields are easier to manage and thus more productive.

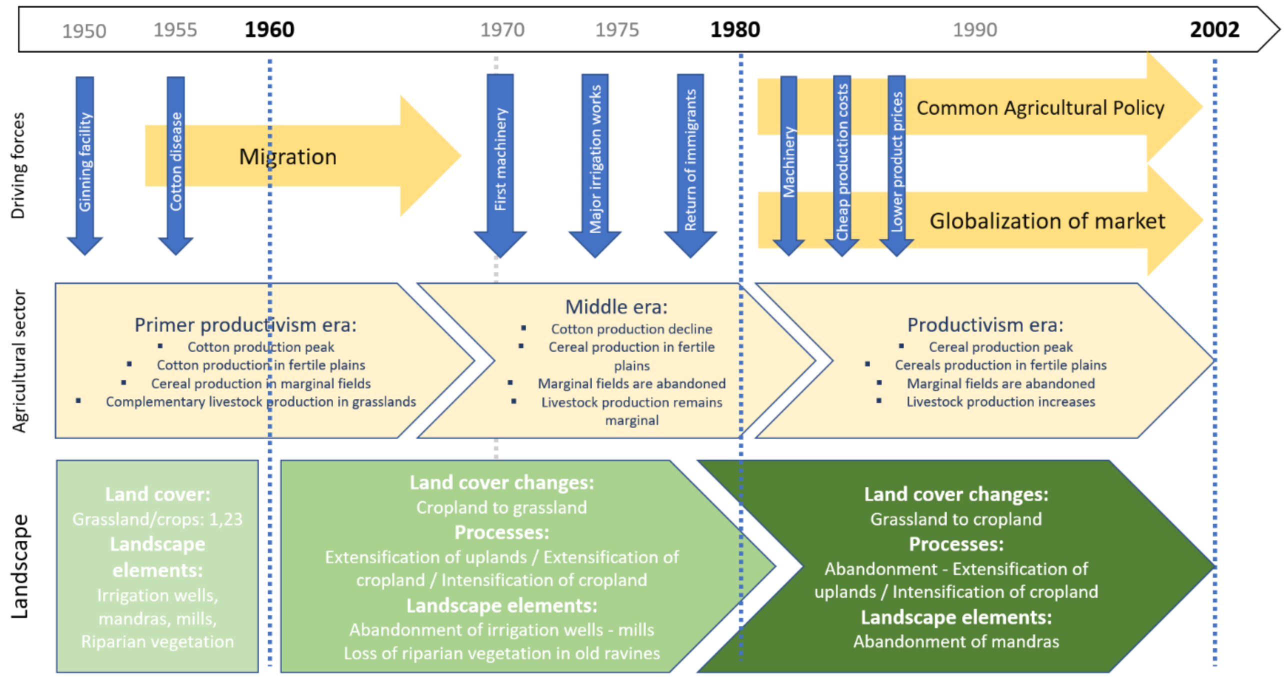


Figure 5.1 Basic timeline of historical changes in agricultural history of Limnos and evolution of the landscape

On the other hand, uplands and areas inaccessible to machinery due to their geomorphology were not suitable for intensification and mechanization of production, leading to further marginalization. Despite grassland turning to cropland in most of the areas, the opposite trend also exists, basically in marginal areas in the uplands, representing 23% of total change in this period. According to officials, mandras at marginal areas of Fakos, mainly in the area of "wild" southeastern Fakos, are being abandoned in the same period. As accessibility plays a big role, the farthest point of the peninsula is gradually being abandoned, leaving only goats for free grazing. Small patches of cropland that persist are attributed to the few mandras that are still operational in the area, something that was also mentioned during the workshop with farmers.

The underlying forces can also be found in the agricultural policy of the time, as cheap fertilizers and subsidies related to production were mentioned by many farmers as a major driving force in the post-80's period. CAP subsidies boosted cereal production, which was exported to the mainland, in Pireas and elsewhere. Among the impacts of these changes is seed loss, as traditional seeds have been replaced by commercial seeds which were certified and, thus, eligible for subsidy. These agricultural policies, together with the development of a global market economy, have further impacted local agriculture after 2002, especially with the CAP reform of 2006.

The role of CAP subsidies has also been associated with increased livestock numbers all over Greece (Hadjigeorgiou, 2011). This fact was also verified by studies in other Greek islands (T. Fetzel et al., 2018; Low, M., 2017; Schaich, H. et al., 2015; Petanidou, 2008). In the study area gradually, there is an increase in livestock production as herd sizes grow during the decade of 1990, after decline between 1970-1990. Livestock is still a secondary employment along cereal production, which is the main source of income according to officials. Livestock production offers also an alternative employment for many residents that are also occupied in other sectors (Georgakopoulou, 1996). It seems that livestock production is sustaining the role of mandras and the presence of crops in the uplands of Fakos where ease of access has increased through roads construction.

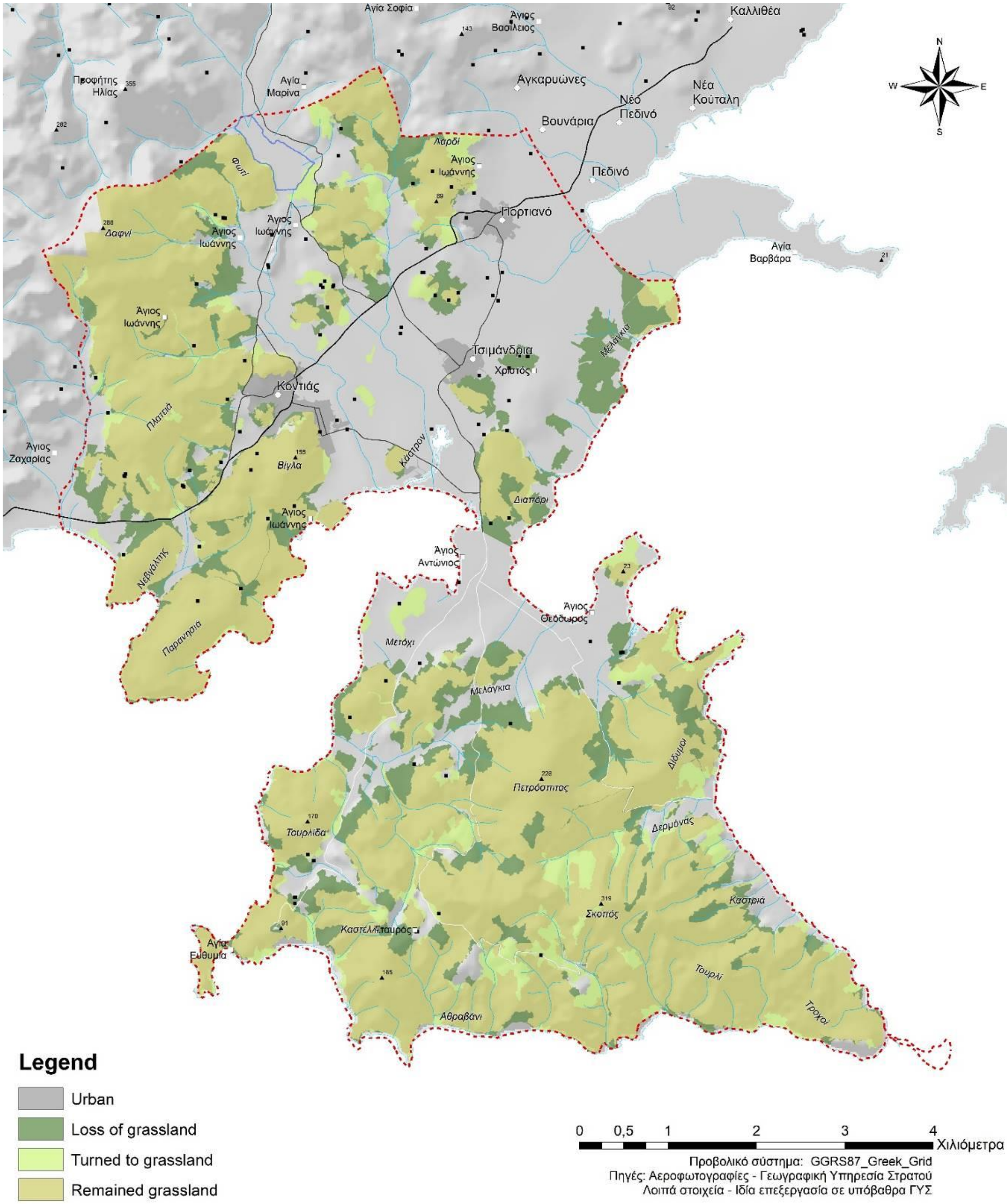
6.Discussion

6.1 Discussion on land conversion and processes

It appears that the processes of change are complex as spatial and temporal patterns interrelate. Looking solely into driving forces one might be tempered to come to easy conclusions. Irrigation works usually results in an intensification of crop cultivation as the construction of irrigation canals provides means for a more productive cultivation. But through information gathered from the workshop this process appears more complex in the study are, as the plains were first irrigated by wells for the cultivation of cotton, then changed to rainfed cereal crops – a process of extensification – and then the construction of the dam and the irrigation network made possible the cultivation of clover – a process of intensification. Summing up, it seems that the plains of Kontias and Tsimandria initially underwent an extensification process (1960-1980), followed by intensification in the following period, 1980 to 2000.

Zomeni et al (2008) have concluded that in postwar Greece *"the notion of productivist agriculture is applicable to rural Greece but its land-use impacts and patterns are spatially differentiated leading to intensification at the lowlands and extensification and land abandonment at the uplands"*. This process has been described as a polarization between extensive and intensive use of land (Antrop, 2005; Jongman, 2002). This pattern has been observed across the islands of the Mediterranean (Tzanopoulos, 2011), presenting a duality between large islands (such as Crete), where investments in irrigation made intensive agriculture possible, and small islands where decline in total cultivated land and abandonment of traditional agricultural practices prevail (Tzanopoulos, 2011; Petanidou et al., 2008).

The existence of this polarization in such a small area and particularly in an island demonstrates the special character of Lemnos which may be largely attributed to its particular geomorphology, producing an agricultural landscape that is unique among the islands of the Aegean. On the other hand, polarization has resulted in decline of low intensity crop production and abandonment of terraced fields as in other cases in the Aegean (Kizos and Koulouri, 2005; Kizos et al., 2009; Tzanopoulos et al., 2007, Petanidou et al., 2008). Agricultural abandonment nonetheless has been rather marginal in the study area and may be a result of a combination of factors. The succession of these processes and the fact that the abandoned land is small in surface, reveals a general process of spatialization of production in response to changing driving forces, as farmers try to make the best out of their land. From irrigated cotton fields in the lowlands and cereal production in terraced fields in the uplands at the 1960's, to clover and cereal production in the lowlands and grazing land in the uplands in the 2000's, diversification is a main strategy for farmers.



Grassland conversions 1980-2002

Of great importance is also complementarity between crop and livestock production which has been present all along this period, until today (Dimopoulos et al., 2018). As the majority of farms in Lemnos are mixed (table 6.1), agricultural land is managed in a holistic way and the polarization process described above does not lead to abandonment as observed in other cases.

	Mixed holdings		**Land farming holdings**		**Livestock farms**	
	% of total farms	% of total area	% of total farms	% of total area	% of total farms	% of total area
Greece	23.5%	42.6%	75.2%	56.0%	1.3%	1.4%
Islands	23.7%	64.9%	75.6%	32.2%	0.7%	2.9%
North Aegean	23.8%	61.4%	74.9%	31.9%	1.3%	6.7%
Lemnos	61.0%	90.5%	38.6%	9.3%	0.4%	0.2%

Table 6.1: Farm types in Lemnos, North Aegean and Greece, 2000

6.2 Discussion on landscape change and persistency

Changes in the landscape are studied in order to understand processes of the past that affect the human and natural environment (Burgi et al., 2007). Results and findings of such studies have been used in relation with environmental problems such as deforestation (Lele, N. and Joshi, P.K., 2009), soil erosion (Blaikie, 1985) etc., but also for linking landscape change with changes in biodiversity (Walz, U. and Syrbe, R., 2013). Critical areas of change in the landscape are used as indicators to understand biodiversity and ecosystem services change. On the other hand, persistent land uses represent more stable land use systems and thus conclusions can be exerted on the impact of drivers of change in the landscape.

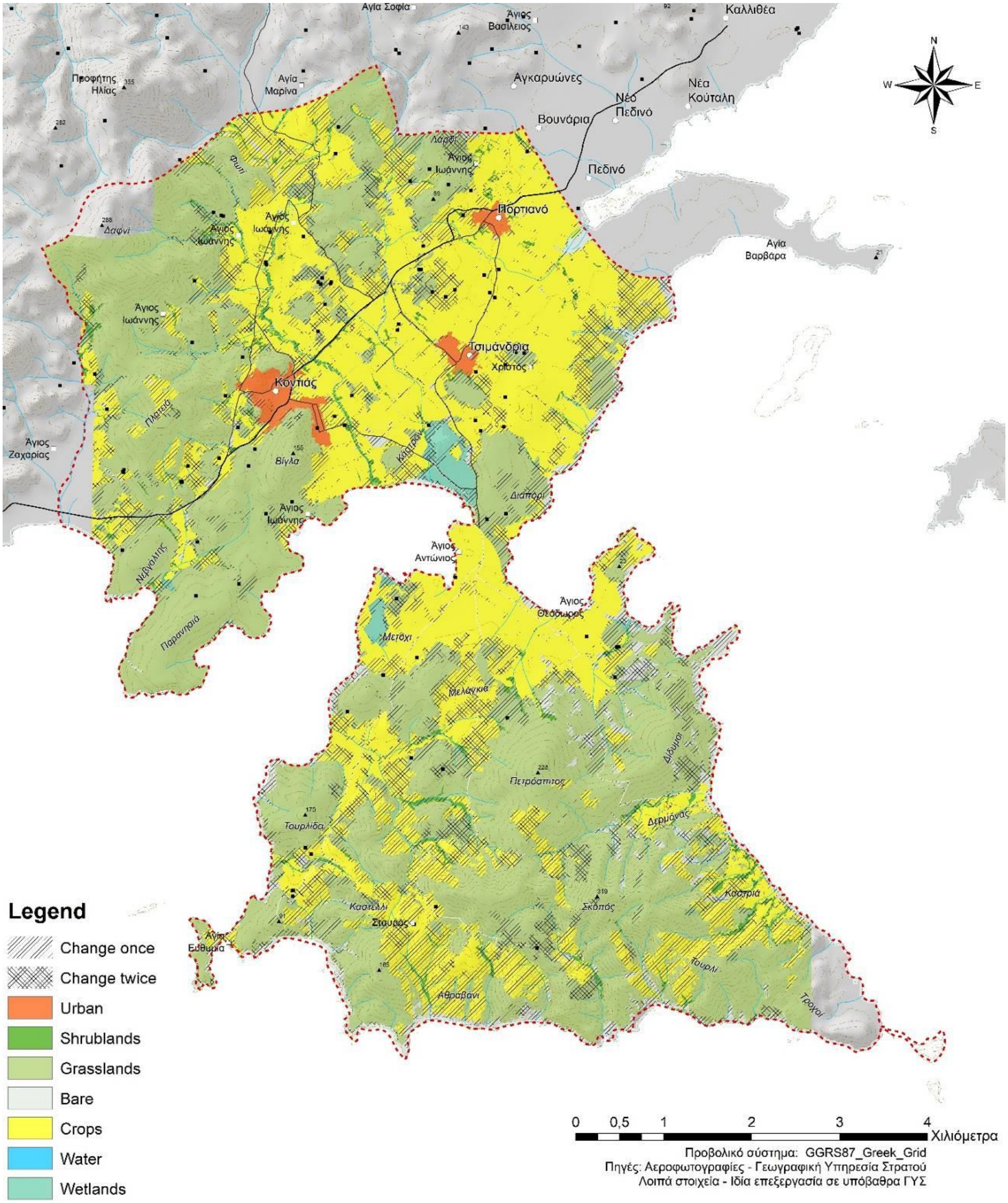
In this study two basic critical areas of change have been the hilly uplands – a transitional area between mountainous grasslands and lowlands – and the lowlands. Different processes affect these two areas:

- Extensification/ abandonment in the hilly uplands, as more remote and marginal areas are being converted from crops to grasslands, and
- intensification in the lowlands, as modernized agriculture (irrigation fields, aggregation of land, use of machinery) replaces more extensive land uses and traditional landscape elements such as tree hedges.

Change tends to happen more on the break of slopes and along corridors, whether ravines or roads. Grasslands in the hills and mountainous slopes is the most persistent land use although in some areas abandonment is a threat.

6.3 Discussion on drivers of landscape change

Bakalis (2007) describes a chain of events that led to the big migration flow of the 1950's-1960's attributing the failure of further growth of cotton production as the major cause for people to leave the island in search for work. Looking into rural depopulation in a wider frame though, it seems that this has been a major trend for all islands in the period of 1950 to 1970 (Kizos, 2002). Modernization of agriculture was decreasing labor-intensive work in the mainland, whereas the islands had low capacity for agricultural modernization due to their geomorphology. This affected the profitability of island agriculture more severely than mainland agriculture (Petanidou et al., 2008), resulting in shrink of the primary sector and emigration in most islands.



Change and Persistency

Lemnos was affected by these pressures but, similarly to other large Aegean islands, it had more options for growing a more competitive agricultural sector. The presence of a dynamic cultivation such as cotton, although in decline, must have been a factor that sustained part of the population in the island. State intervention by means of irrigation infrastructure and land reforms provided a shift towards productive agriculture in the area of study, but it is the agricultural system's own characteristics that sustained the agricultural economy in the years between the cotton peak of the 1950's and the cereal peak of the 1980's and 1990's. The characteristics of this mixed crop-livestock system as described in Dimopoulos et al. (2018) and Bakalis (2007), gave solutions to the pressures exerted not only by cotton decline and rural depopulation but also by the growing competition in prices of products.

Complementarity played a major role in sustaining agricultural population as farmers were able to develop alternatives to the loss of income by the decline of cotton production, making use of the areas that were left uncultivated. This hypothesis is backed by the fact that mandras were used throughout this period, when the uplands were extensified. The concurrent presence of 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 been described as abandoned by both farmers and official (i.e. Kastria and the southeastern part of "wild" Fakos) [19].

The Common Agricultural Policy has been described as a force that has contributed to the polarization between extensive and intensive use of land (Zomeni et al 2008, Antrop 2005, Tzanopoulos et al 2011) and to the increase of livestock production in the islands (T. Fetzel et al. 2018, Low M. 2017, Schaich H et al 2015, Petanidou 2008, Kizos et al 2013). In the case of Lemnos, it is related to the productivism era of 1980-2000, and the cereal production peak, as farmers using machinery were expanding cropland into the edges of the plains in order to maximize their production. Livestock production remained a secondary production alongside crop cultivation, although at the end of this period starts growing as an activity. The effect CAP had on agriculture in the study area seems to be a polarization of uses and process between uplands and lowlands. The mixed crop-livestock system although not abandoned seems to have been impacted as areas and mandras of low accessibility are abandoned.

6.4 Further steps:

- Assess specific LCLU changes with the use of landscape features such as wells, linear structures and mandras
- Assess links between landscape change and changes in agricultural practices
- Assess links between landscape change and changes in biodiversity
- Comparison of OBIA and pixel based classification using Haralick Textures and PCA
- Assess landscape structure changes through landscape metrics

[19] *"The people still stayed at the mandras until 1980. It is after the 1980's that they started to leave the mandras and settle in the villages".*

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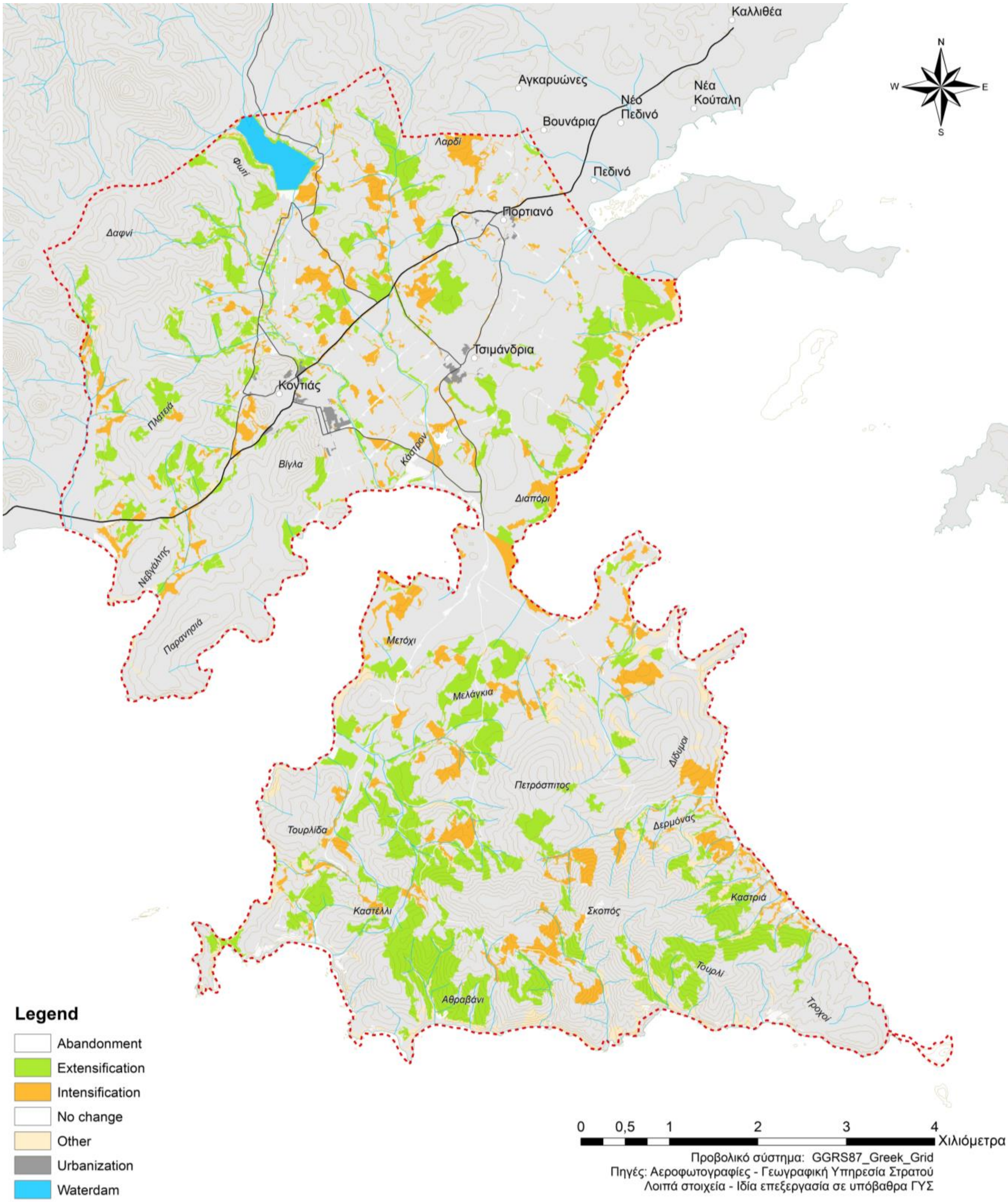
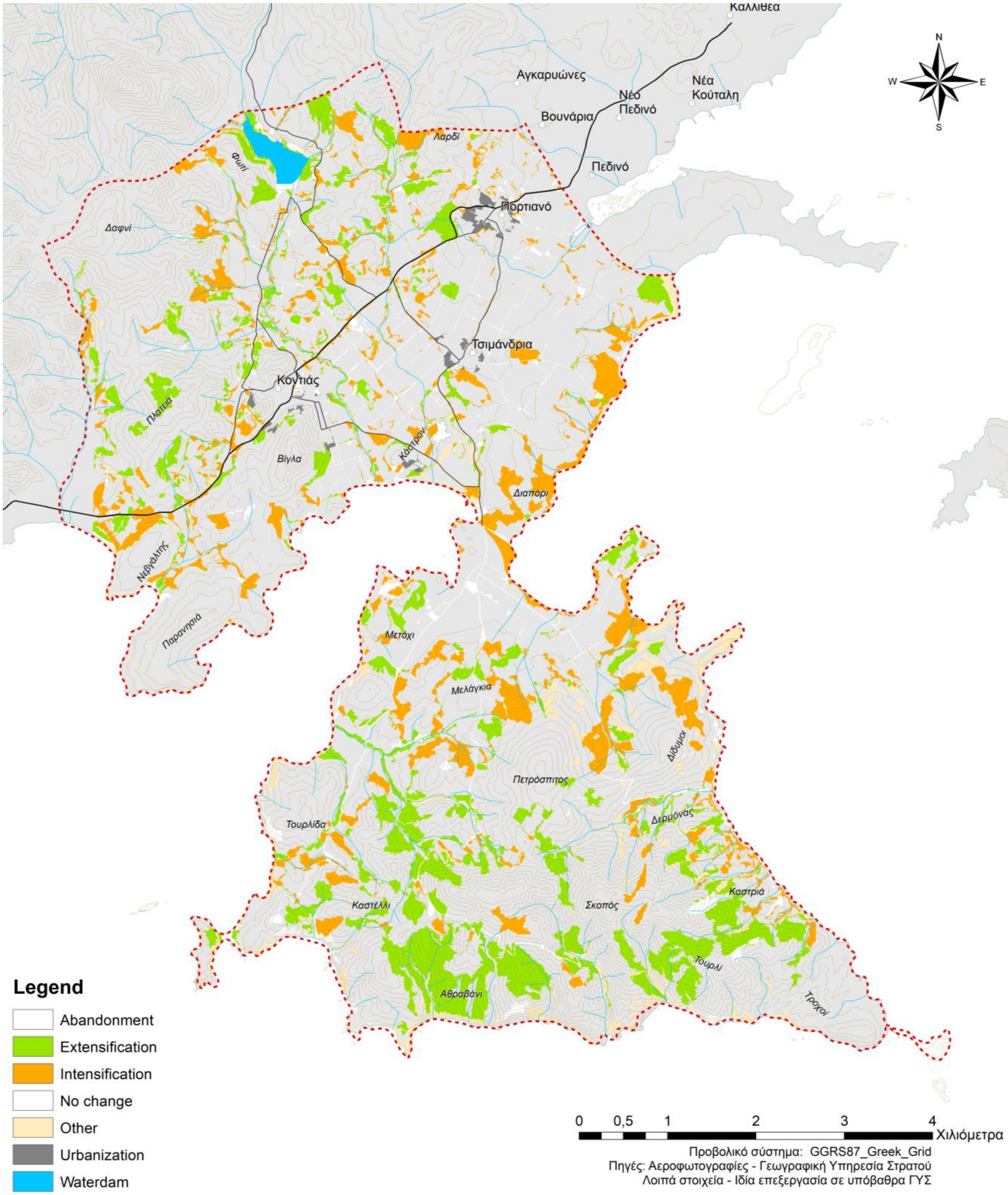
ANNEX 1 – workshop participants:

	Age	Community – Village	Active farmer	Full/ partial employment	Successor	Type of holding	Livestock number	Agricultural land in Ha (grazing land/ crop land)
1	40-60	Κοντιάς	Yes	Full	No	Mixed	380 sheep	200 /20
2	> 60	Κοντιάς	No					
3	> 60	Κοντιάς	Yes		Yes	Livestock		
4	> 60	Πορτιανού	Yes	Partial	Yes	Mixed	50 sheep	8/3
5	> 60	Κοντιάς	Yes	Full	Yes	Mixed	500 sheep	150/100
6	57	Πορτιανού	Yes	Full	No	Mixed	300 sheep	40/10
7	> 60	Πορτιανού	No					
8	> 60	Κοντιάς	No					

ANNEX 2 – Additional Maps:



Processes 1960-1980



Processes 1960 - 2002