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A process-based land use/land cover change assessment on a mountainous area of Greece during 1945–2009: Signs of socio-economic drivers

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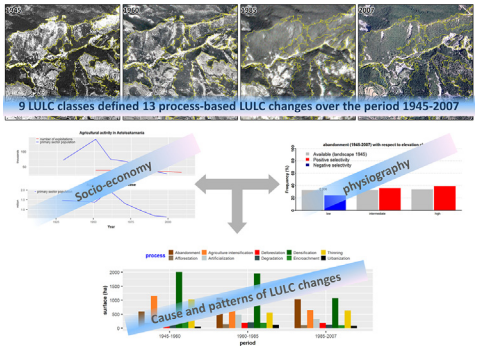
HIGHLIGHTS

- Land use/land cover (LULC) changes over more than 50 years were identified and grouped in process-based LULC changes that exhibit similar characteristics.
- Abandonment of agricultural land increases through the examined periods while the dominant process-based LULC change over the period 1945-2007 was densification of natural vegetation types (shrublands and forests).
- Changes were spatially arranged along elevation and slope gradients. Crops at high altitudes and at steeper slopes were more prone to abandonment.
- Temporal patterns of the process-based LULC changes coincide with socio-economic milestones in Greece and exhibit a spatial arrangement with respect to physiographic variables.

GRAPHICAL ABSTRACT



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ABSTRACT

In the Mediterranean region, natural vegetation has been strongly affected by human activities for thousands of years. During the last decades, there has been a notable tendency for abandonment of marginal agricultural land that is further associated with a number of ecological consequences. In this study we recorded and mapped the temporal changes of land use/land cover (LULC) classes that were further aggregated into major process-based changes for the period 1945–2009 in Aetoloakarnania prefecture, Greece. LULC mapping was based on aerial photographs acquired in 1945, 1960, 1985–1986 and 2007–2009. Object-based image analysis allowed the classification of the region's LULC classes and, consecutively, the assessment of process-based LULC changes for each time period. The results indicated that agricultural land increased during the first post-war years while abandonment of agricultural land took place during more recent decades, especially after the period 1960–1985. The observed land abandonment is combined with a simultaneous densification of shrublands and forests. Radical socio-economic changes that took place in the 1960's include the migration of rural populations towards big cities and the beginning of the development of the tourist industry. We argue that these socio-economic changes play an important role in shaping the observed LULC changes.

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1. Introduction

Mountainous areas are significant regions of biodiversity and landscape diversity and have undergone acute changes as a result of natural processes and human activities (Falcucci et al., 2006; Kolios and Stylios, 2013; Mallinis et al., 2011). Especially in the Mediterranean region, natural vegetation has been intensively affected by human activities for thousands of years and it is widely agreed that landscape and humans co-evolve, regardless of the relative importance that human- and natural-processes play on Mediterranean landscaping (Blondel, 2006; Klein Goldewijk et al., 2011). The co-evolution of humans and landscapes began with the first human presence on earth and it is roughly estimated that as much as 60% of the world's landscape has been somehow modified by humans (Klein Goldewijk et al., 2011).

The intensity with which humans modify the landscape has varied throughout history. Globally, agriculture, thus a landscape with considerable proportion of agricultural LULC classes, starts to be more developed during the Greek-Roman period, especially in the Mediterranean basin, in northern India and in eastern China (Klein Goldewijk et al., 2011). Nevertheless, the large population growth and the technological advances after WW II resulted in a massive expansion of cropland area globally (Klein Goldewijk et al., 2011). In Greece, the post-war period was also marked by a rapid growth of agricultural production although that emigration of marginal and mountainous areas took place at high rates (Petmezas, 2006). More specifically, a notable tendency to abandon marginal land has been observed since the 1960's, although some agro/environmental policies may have contributed to land use intensification up until the end of the 20th century (Mottet et al., 2006; Salvati and Sabbi, 2011). Additionally, this time period has seen some major worldwide socio-economic changes related with rural depopulation and the decline of traditional agricultural practices and forest use (Gellrich et al., 2007; MacDonald et al., 2000). In Greece, the period after 1950 was marked by the abandonment of the less productive, mountainous sites alongside the mechanization of agriculture production, the use of fertilizers and pesticides, and the adoption of scientifically based practices. These facts allowed for the significant increase of land/labour ratio (Petmezas, 2006). Such socio-economic processes are, to a great extent, related to those changes in land use/land cover (LULC) observed today, and their impact is especially pronounced in mountainous areas where sites of agricultural activity are considered marginal in terms of productivity.

Landscape changes of high intensity have also been observed in post-socialist Eastern Europe and the former Soviet Union (Lieskovský et al., 2015; Václavík and Rogan, 2009; van Vliet et al., 2015). It is believed that the trigger of such changes was the transition from a centralized regime to privatization (van Vliet et al., 2015). Abandonment of agricultural land was a dominant process, yet it did not occur with the same intensity across and within countries and regions. For example, despite differences that may have arisen due to variations in applied methods, in west Ukraine, farmland abandonment reached 56% (Baumann et al., 2011), while in south east Ukraine (Carpathians) it was as low as 13% (Kuemmerle et al., 2008). Some spatial determinants such as physiographic and other ecological factors (Baumann et al., 2011; Biró et al., 2013; Müller et al., 2009), demographic variables (Baumann et al., 2011; Müller and Munroe, 2008), and landscape arrangement (Biró et al., 2013; Müller et al., 2009) have been found to play an important role in shaping landscapes in different regions. Yet, one common finding among all studies is that post-socialist agricultural land abandonment concerns marginal sites of low productivity.

Land abandonment has a number of ecological consequences that are anticipated at various spatial scales. Abandonment is often associated with landscape homogenization and densification adjacent extended patches of dense shrublands and forests (Roura-Pascual et al., 2005). This homogenization can result in decreasing erodibility and land loss, however, densification can have significant negative ecological consequences. Floristic compositions can be altered drastically following the shrub encroachment which is often associated with agricultural land abandonment (Vassilev et al., 2011) or the shift of traditional, extensive, transhumance pastoral systems (McCracken and Huband, 2005). Shrub encroachment also results in shifting community composition to passerine favoring species that are related to closed canopies (Zakkak et al., 2014). Land abandonment is also associated with the mechanical collapse of terraces, a very common cultivation practice in mountainous regions of the Mediterranean basin, that may lead to phenomena of extensive erosion and land degradation (Tarolli et al., 2014). Moreover, densification is related to fuel accumulation and a change in fire regimes, from large numbers of small fires to small numbers of large fires (Koutsias et al., 2012). Changes that do not involve transitions between LULC classes, like vegetation density (Lasanta and Vicente-Serrano, 2012; Zakkak et al., 2014), are not easy to identify at national to continental scales and are not often embodied in studies on landscape changes. Lastly, the significant effect of land abandonment on carbon sequestration has to be considered. Abandonment of agricultural land and the consecutive secondary succession of vegetation allows for an increase in soil organic carbon stock (Nadal-Romero et al., 2016; Novara et al., 2017) and above-ground carbon sinks (Schulp et al., 2008). Land abandonment may influence local/regional tree and forest limits. It is argued that at local and regional scales tree limits are controlled by anthropogenic factors such as grazing, fires, etc. (Vitasse et al., 2012). Climatic drivers may play an important role in forest expansion, however, a number of studies have shown that the influence of land abandonment on forest expansion is critical (Chauchard et al., 2010; Gehrig-Fasel et al., 2007; Hofgaard, 1997).

Greece cannot be considered an exception from the observed general tendency of socio-economic factors and their relation with LULC change patterns. Numerous studies have pointed out this tight relation (Mottet et al., 2006; Tzanopoulos and Vogiatzakis, 2011), often describing the different trajectories of vegetation succession following land abandonment (Tzanopoulos et al., 2007). Nevertheless, only a few studies (Mallinis et al., 2011; Mallinis et al., 2014; Zomeni et al., 2008) have focused on the spatially explicit analysis of observed LULC changes that includes all the major, post-war, socio-economic milestones over a specific time period.

This study focuses on the analysis of post-WW II LULC changes observed in mountainous areas of Aetoloakarnania prefecture, western Greece. The analysis was based on the photo interpretation of aerial photographs taken from 1948 to 2009, and identifies the major LULC changes that have occurred in the region. We hypothesize that LULC changes can be spatially arranged along physiographic factors and can be associated with socio-economic conditions and milestones. We broadly consider possible links between socio-economic changes and respective LULC changes at a considerably local scale. Special emphasis was given to the description of land use/land cover process-based changes and the estimation of changes in tree line altitude. Identification and spatial representation of the major changes that occur in the landscape, can assist managers in the elaboration of locally oriented, spatially explicit, management plans that focus on the mitigation of all negative consequences related to land abandonment and LULC changes. Provided that the driving factors behind the observed LULC changes remain at more or less stable, LULC changes are expected to increase in the near future, while analogous changes should be expected in regions with similar climatic and socio-economic conditions.

2. Material and methods

2.1. Study area

To study LULC changes, seven sites were selected from the Prefecture of Aetoloakarnania (Fig. 1). Aetoloakarnania is the largest prefecture in Greece covering a surface area of about 5448 km^2. It is characterized by extensive mountain massifs and large water bodies (natural and artificial) that cover > 3.87% of the prefecture's land surface.

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