Evolution of Forest Cover in Andalusia (1956-2007). Processes and Drivers

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1. Introduction

The spatial distribution of land cover types and land use derives from the interaction between biophysical factors and human activities over time. In many regions, the human activity have been the main driver of land changes. This is the case of the Mediterranean landscapes. In Spain, the woodland areas remain in the mountains as a result of a long historical process in which the main human activities (agriculture, cattle) occurred mainly on flat and moderately steep areas, although also in some mountainous areas. Perhaps for this historical reason, in the Spanish language, the term "monte" means "mountain" as also "forest areas or scrubland areas".

The main objective of this work is to study the distribution and evolution of forest cover in Andalusia from 1956 to 2007, by using land-cover change analysis techniques. A set of factors to address a first explanation for understanding the spatial patterns of forest cover in Andalusia was selected.

2. Materials and methods

The study area is Andalusia (south of Spain), region with an extension of 87.609 km^2. This region is a very diverse territory located in the southern part of the mid-latitudes of north hemisphere, and it has multiple physical and anthropic contrasts in the

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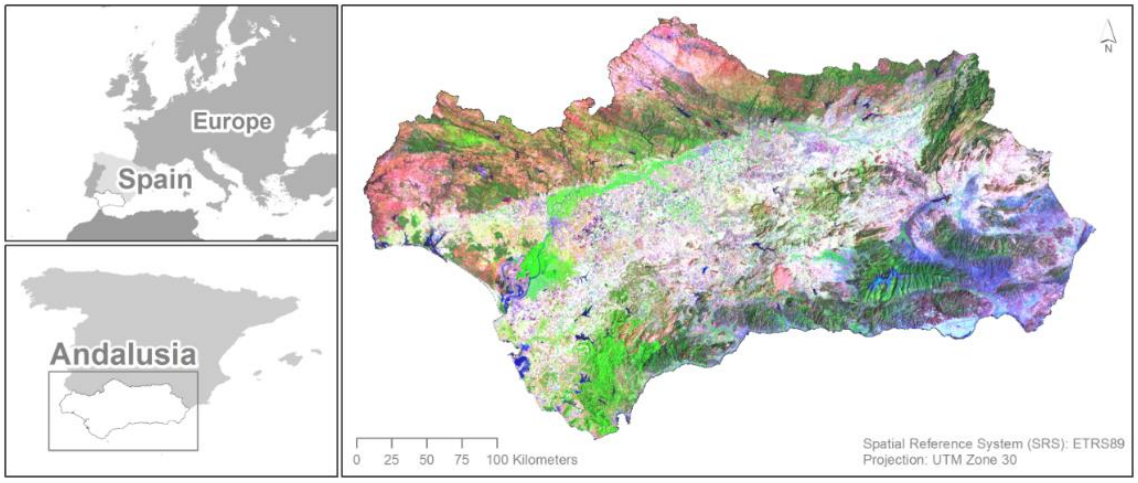
geographical and historical context of landupheaval of the Mediterranean basin with a large history of human activities that it have changed the land-covers.

Map 1. Study area.



We performed a land change analysis based on the information drawn from the Land Use and Land Cover Map of Andalusia (scale 1:25.000), corresponding to 1956 and 2007, supported by the photo-interpretation of use and coverages drawn from the aerial photographs of 1956 and 2007. We defined as “natural areas” the following land-covers: woodlands, shrublands, grasslands or opened unproductive areas (rocks, sands, etc.). These areas are defined generally as “forest and natural areas” by the regional Government of Andalusia.

Firstly, we converted the original vector maps to raster maps at a resolution of 250 meters. The spatial data were processed with two Geographic Information Systems (GIS): 1) QGIS to manage the original vector data registered as land-cover maps. 2) TerrSet (formerly called Idrisi) for processing and analysis of raster data. We worked with the Land Change Modeller module and we used the sub-modules "Change Analysis" and "Transition Potentials". Secondly, we analysed the land cover changes, the processes of land cover changes as gains, losses and persistence, and the processes of transfer between every pair of land-covers. Finally, we selected a set of driver variables uncorrelated to address a first explanation about the existing spatial patterns in the distribution of forest cover, and calculated the Cramer’s V, a quantitative measure of variable association. In general, the variables that have a Cramer’s V of about 0.15 or higher are of some value to explain the association between the driver variable and land cover one, while those with values of 0.4 or higher are really good to explain this association.

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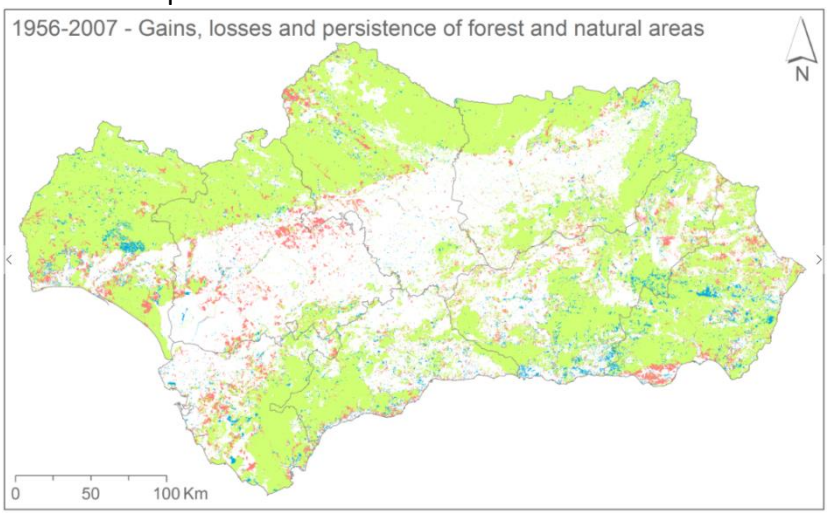
Table 1: Driver variables.

Variables	Code
Elevation	elev
Slope	slope
Solar radiation	solar
Geological map	litologic
Distant to coast	dist_cost
Distant to rivers	dist_hidro (5) We used 5th order stream
Distant to populated areas	dist_pob
Distant to primary roads	dist_via1
Distant to secondary roads	dist_via2

3. Results and discussion

In general, the forest areas and the cultivated areas were the most representative landscapes in Andalusia for the period between 1956 and 2007. There has been a persistence of forest and natural areas (Map 1).

Map 1: Evolution of forest and natural areas.



The persistence in natural covers represents an area of 4.208.0310 hectares (48 % of the regional area). It is important to highlight that "natural" areas are not strictly natural areas because of they have been also a consequence of human activities. From 1956 to 2007, woodland areas were increased (Δ +371.550 hectares). Indeed, it has occurred a huge increase in closed forest areas (Δ +44%) because of the implementation of many reforestation programs. In this sense, the scrubland and grassland areas evolved into forest areas because of reforestation projects and natural regeneration processes.

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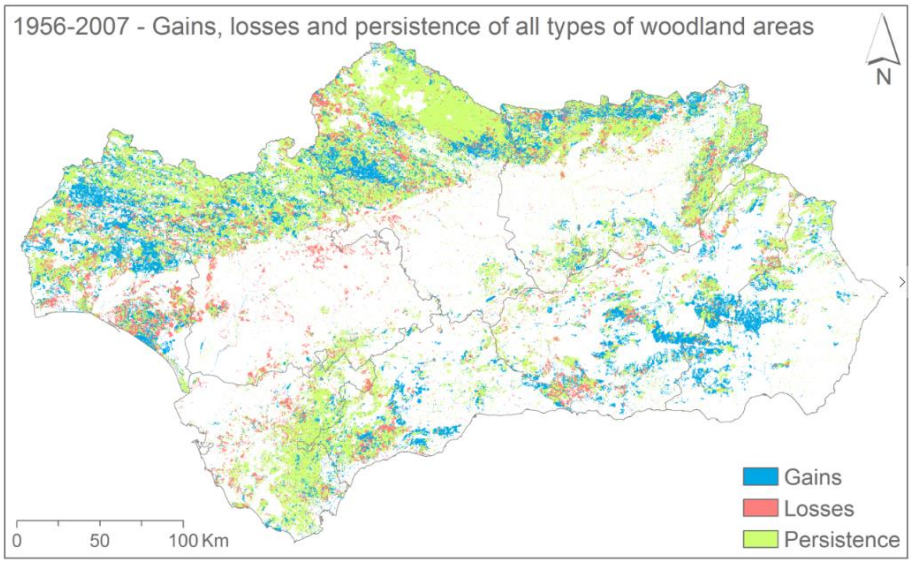
Along the study period, oak forests were dominant in the west and north of the region (1.539.931 hectares). This was the most stable forest cover, including species such as the cork oak (Quercus suber) and holm oak (Quercus ilex), which are the main species of the "dehesa", which is a "man-made" agroforestry system characterised by a savannah-like physiognomy. In the rainiest areas, there are very closed cork oak forests. This is also a dense forest because of the cork oak has been facilitated by human action for the cork industry.

Typically, in Andalusia the conifer forests were always in mountainous or unproductive areas. From 1956 to 2007, there was a huge expansion (Δ +346.918 hectares; Δ +78,7 %) of several species of the genus Pinus which were massively used in reforestation projects in very different environments. This explains why there are several different species of Pinus for the main different environments: coastal and mountainous, arid and humid; mainly in places in which oak forest were not present in the recent past. These reforestation programs produced the change from grassland covers and scrubland covers to closed forest covers. Generally, the woodland areas formerly dominated by the same tree species improved their canopy.

Map 2: Evolution of all types of woodland areas.



Other woodland areas also expanded (Δ +16,9%) because of natural regeneration and the regional conservation policies. Moreover, the eucalyptus forests were used to reforest areas in the western of Andalusia for the production of cellulose, mainly in the Huelva province. Finally, since the middle of the sixties of last century, the coastal dunes and beaches were reduced in extension, mainly because of urbanization processes, although in the case of sand dunes also occurred an artificial process of afforestation and dune stabilization.

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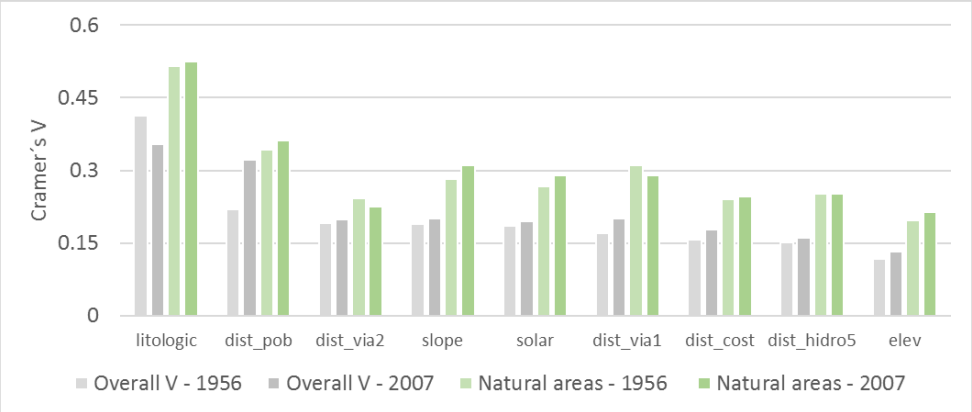
The forest and natural areas (in general) were kept in mountainous or unproductive areas, conditioned by factors such as lithology, slopes and gradients proximity to urban areas. The explanatory power of the driver variables was better to explain the distribution of natural areas than to predict the general land uses. The data on Table 6 show the importance of the driver variables calculated according to the Cramer's V for 1956 and 2007.

Figure 1: Driver variables importance.



4. Conclusions

In general, the extension of natural areas remained stable. However, from 1956 to 2007, it has occurred an increase in area of all types of woodland covers because of the reforestation projects, and -in a minor extent- as a result of the natural forest regeneration processes.

The most extensive and stable forest cover areas were dominated by the two mains oak species: Quercus suber and Q. ilex. The largest increases were observed in planted forests dominated by species of Pinus and Eucalyptus. Other woodland areas also expanded their distribution areas.

The analysis of the main explanatory variables, according to a first approximation based on the V Cramer, helped us to confirm that the lithology is the most important factor in order to explain the general distribution of natural areas and forest uses.

We think that the land change analysis based on land cover maps is an essential first step to undertake predictive modelling of land use changes. In this sense, it is very important to conduct a systematic review of published studies related to the land change in specific areas in order to integrate the results and conclusions of other researches. Predictive modelling of land-use and land-cover is much more than predictive modelling of pixel allocation.

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