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Assessing land cover changes in the French Pyrenees since the 1940s: a semi-automatic GEOBIA approach using aerial photographs

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Abstract

This paper presents the first results of the MODE-RESPYR project that aims at assessing past and present land cover changes in the French Pyrenees at various spatial and temporal scales. A semi-automatic GEOBIA approach is proposed to produce land cover maps since the 1940s in three local study sites. The major change observed resulted in forest encroachment by scrubs. However, the spatial distribution and the dynamics of changes differ from one site to another. Even if the main drivers of encroachment are the same, local disparities exist because of specific natural and anthropic factors. The results will be combined with the regional trend to provide knowledge for building prospective scenarios.

Keywords: land-cover change, retrospective analysis, forest encroachment, agro-pastoral system, mountain landscape

1 Introduction

As in many mountain areas in Europe, agro-pastoral landscapes in the valleys of the Pyrenees are subject to fast spontaneous reforestation [1,2]. The main driving forces and the consequences of these transformations have been widely studied during the last decades [3]. Encroachment is mainly related to the abandonment of farmland in combination with rural depopulation and agriculture modernization while impacts are both of environmental and social orders. But encroachment does not occur uniformly at the entire mountain range. Observed changes of land abandonment or land-use extensification can be similar at the regional scale but the local dynamics (magnitude of changes, rhythm) can vary [4]. In 2011, a new research project called MODE-RESPYR (*Modelling Past and future land cover changes in the Pyrenees*) started with the aim of studying landscape dynamic of the French Pyrenees by integrating different spatial and temporal scales (from regional to local spatial dynamics using both palaeo-environmental data for the older time period and remote sensing data for the most recent period). This work is a part of the project. Its purpose is to contribute to the understanding of the patterns of land-cover changes at the local scale. We present the methodological approach that has been followed to produce land cover maps since the 1940s and investigate landscape changes in three study sites. We hypothesised that local disparities exist because of specific conditions related to natural and anthropic factors.

2 Study sites

The method was conducted on three case study sites along a West-East gradient of the French Pyrenees: the Davantaygue (48,2 km²), the Haut-Vicdessos (245 km²) and the Garrotxes (49 km²). The first site is located in the peripheral area of the Pyrenees National Park. The second site includes several municipalities of the department of Ariège, and the third site is situated in the Eastern Pyrenees.

3 Material and method

3.1 Data

Land cover changes have been identified from a large set of digital aerial photographs (0.5-m resolution) covering the whole surface of the three study areas. Black and white historical photographs (from IGN) were used to cover the period from the 1940s to the 1980s in addition to true color photographs for the more recent period (1990-2000). The number, the dates and the scale of the photographs differ from one site to another but a land cover map was produced for each decade. Table 1 illustrates the data set related to the Haut-Vicdessos.

Table1. Specifications of the photographs used to produce land cover maps for the Haut-Vicdessos.

Year	Mission number	Scale	Date	Number of photographs	Emulsion
1942	2048-2248	1/25000	08/08/1942	59	B&W
1953	2048-2348	1/25000	20/07/1953	53	B&W
1962	1948-2248	1/25000	11/08/1962	43	B&W
1976	FR2810	1/20000	19/09/1976	43	B&W
1983	2048-2248	1/30000	06/08/1983	23	B&W
1993	FD 09-31	1/30000	28/07/1993	22	True color
2003	FD 09	1/25000	11/07/2003	Ortho IGN	True color

3.2 Land cover mapping method

The method developed to produce land cover maps at each date adopts the principles of the GEOgraphic Object-Based Image Analysis (GEOBIA) [5]. This approach has already proved its effectiveness for mapping shrub encroachment from panchromatic aerial and high-resolution satellite imagery [6]. Our method consists in several conventional steps: pre-processing, segmentation, classification, validation. During the first step, aerial photographs are georeferenced, orthorectified and mosaicked. Then, the data are segmented using a bottom-up region-growing technique to create image objects (Definiens software). In the third step, each object is classified from spectral features according to a hierarchical nomenclature defined (see figure 1). This classification procedure is not carried out automatically. Objects are labelled manually, after a visual interpretation, in order to obtain a land cover map of higher accuracy. Then, a classification-based fusion is carried out to merge all adjacent objects of the same class (post-processing step). Finally, the classification is validated using either ground truth data (for the current period) or some historical oblique views (for the older period) when this kind of data is available. On the contrary of the conventional multi-temporal analysis approach, the land-cover maps are not generated independently. There are constructed by updating (projecting forward in time) the older land cover map, in order to reduce the object-boundary mismatches between the dates [7].

3.3 Land cover change analysis

A cross-tabulation matrix was computed to assess the total change of land categories and determine net change and swap, as well as gross gains and gross losses. The forest expansion with its speed was also studied by computing the annual rate of forest change. The analysis was conducted according to each landscape unit of the traditional agro-pastoral systems: (1) the landscape unit including valley bottom and lower slopes (with crops, hayfields and village), (2) the unit including valley upper slopes (with hayfields and pastures on steeper slopes), and (3) the altitude commons (for summer grazing).

4 Results

For each study site, the major change resulted in forest encroachment by scrubs since 1950s. An increase in built up areas is also observed while agricultural land decreased (see table 2). However, the localization and the magnitude of changes differ from one site to another. In the Davantaygue valley, the intermediary agricultural parcels located on valley upper slopes are the most impacted by encroachment (fig. 1). These parcels are not suitable for mechanization. The steeply meadows located far from the villages are therefore abandoned. In the Haut-Vicdessos, the forest expansion also appears in the valley bottom (+13% of closed forest since the 1960s), with a temporal shift of approximately one decade compared with the intermediary areas. In Garroxtes, land cover changes are the most important and affect all the agro-pastoral landscape units. A drastic decline of pastures (from 57% to 32% since 1942) occurs with the total disappearance of crops since 1980 (loss of 1176 ha since 1826).

5 Conclusion and perspectives

As expected, the preliminary analysis of the results suggest that even if the main drivers of forest encroachment are the same (depopulation, cessation of traditional farming), the process of spontaneous reforestation vary from one site to another because of underlying local conditions (environmental, climatic and socio-economic). The investigation of these local landscape dynamics is the first step before to combine them with the regional trend which will be address in a second time.

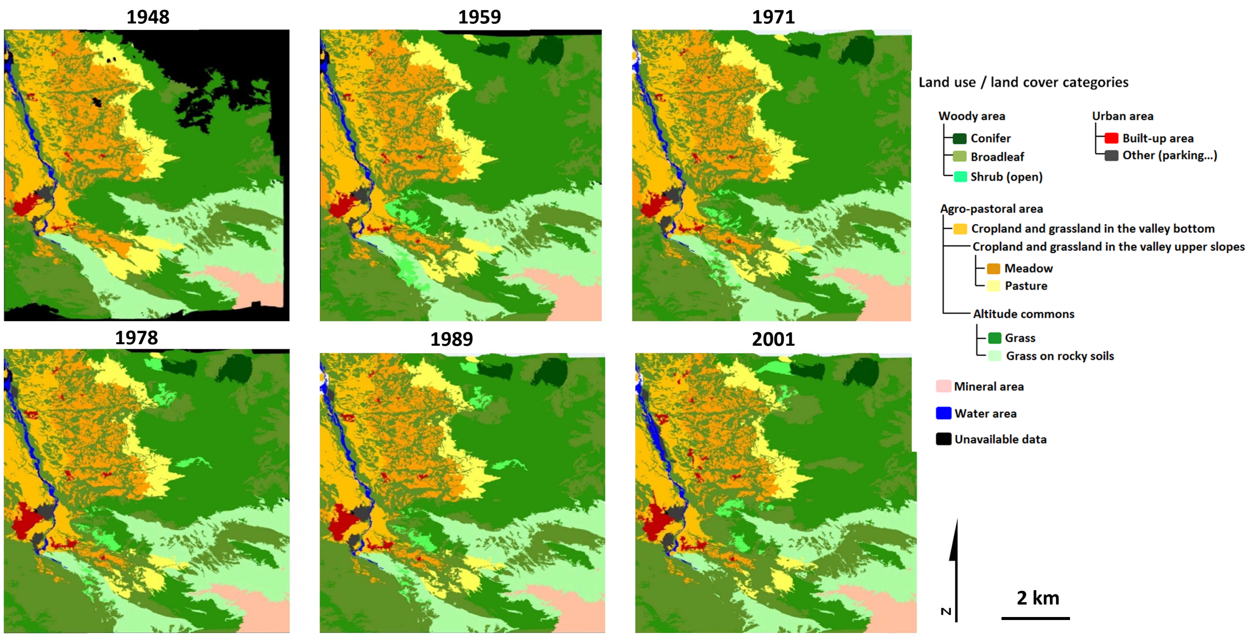

Figure 1. Land cover maps of the Davantaygue valley.

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Table 2. Transition matrix (in ha) of land cover types between 1942 and 2003 for the Haut-Vicdessos study site.

		1942							
		Crop	Pasture	Shrub	Urban	Forest	Water	Bare soil	**Total**
2003	Crop	157.9	1.1	0.0	0.4	1.5	0.0	0.2	161.1
	Pasture	2.3	268.4	0.7	1.3	1.3	0.0	0.1	274.1
	Shrub	0.1	7.9	11807.1	0.0	14.9	1.8	47.6	11879.4
	Urban	27.9	12.9	27.0	74.3	4.9	0.1	0.4	147.5
	Forest	**390.0**	**1494.9**	**1772.8**	15.7	4436.9	0.9	244.2	8355.4
	Water	0.0	0.0	61.0	0.0	0.1	285.7	3.5	350.3
	Bare soil	0.1	1.4	50.2	0.0	3.1	0.3	2875.6	2930.7
	Total	578.3	1786.6	13718.8	91.7	4462.7	288.8	3171.6	24098.5

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