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Is the abandonment of traditional livestock farming systems the main driver of mountain landscape change in Alpine areas?

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ABSTRACT

Agricultural land abandonment and the consequent natural forest regrowth in areas once cultivated has significantly transformed Alpine ecosystems and landscapes. In this paper, we estimated the loss of agricultural areas due to reafforestation in the Belluno Province (Eastern Italian Alps) and integrated socioeconomic indicators with topographical features to evaluate the drivers of this change. Land use mapping, obtained from photo-interpretation of aerial photographs and technical maps, was used to quantify changes in forest and agricultural areas (crops, meadows and pastures) during the period of 1980–2000. On average, the forest surface expanded by 21%, while the agricultural areas decreased by 40%. This loss increased in areas with steeper slope, which confirms that the areas that would be first abandoned are those that are less productive and more difficult to manage. The reafforestation rate was particularly strong in the north of the province, where the livestock sector experienced a dramatic decline. In light of this situation and using multiple regression models with a large set of socioeconomic and agricultural indicators, we found that the loss of agricultural areas in 69 municipalities was primarily counterbalanced by the maintenance of livestock farming. The loss of steeper agricultural areas was counteracted by traditional extensive systems; however, it was not counteracted by modern intensive systems, which has important implications because steeper areas have higher landscape and biodiversity values. In addition, tourism development had a positive, although smaller, effect on the maintenance of agricultural areas, while industry development had a negative effect. The results of this study suggest that efforts are needed to maintain a territorial network of traditional extensive farms to avoid further landscape deterioration in Alpine areas. Likewise, certain choices toward the economic development of local communities might have an impact on land conservation.

Introduction

Over the past decades, mutually dependent social, economic, technical and cultural changes have led to a dramatic transformation of agricultural systems and land use in European rural societies (MacDonald et al., 2000; Giupponi et al., 2006; Mottet et al., 2006; Gellrich and Zimmermann, 2007; García-Martínez et al., 2009, 2010). In mountain regions, where livestock farming have traditionally been of great importance for the vitality of rural economies (Baldock et al., 1996), technological development, the economic importance of off-farm activities, gaps in social infrastructure and significant disparities in income levels have encouraged many farmers to migrate, increasing depopulation, especially in marginal areas (Collantes and Pinilla, 2004; Conti and Fagarazzi, 2005). In addition, the Common Agricultural Policy (CAP) and other national policies supported the prices of final products (i.e., milk and meat) until the 1980s; these strategies encouraged the shift from traditional to more profitable and intensive farming systems in the more productive regions (Fjellstad and Dramstad, 1999; MacDonald et al., 2000). In the Alps, 40% of farm holdings were abandoned between 1980 and 2000, leading to a decrease of 17% in livestock units (Streifeneder et al., 2007).

These changes in the agricultural sector resulted in landscape and biological transformations (Mazzoleni et al., 2004; Bielsa et al., 2005; Gibon, 2005; Mottet et al., 2006). Traditional extensive livestock systems, primarily based on the maximisation of forage use, have shaped unique landscapes and habitats of high aesthetic and ecological value (MacDonald et al., 2000; Gellrich et al., 2007b); therefore, both abandonment or intensification have led to a loss of cultural heritage elements, local identity and landscape attractiveness (Hunziker, 1995). Often, changes in landscape and vegetation composition and structure after abandonment are also linked to a reduction of animal and plant biodiversity (Bebi and Baur, 2002; Giupponi et al., 2006; Marini et al., 2007); however, in the short

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term, land abandonment could increase landscape heterogeneity and biodiversity on different scales (Marini et al., 2008).

Agricultural land abandonment and landscape changes follow different trends in different contexts (Baudry, 1991; Lambin and Geist, 2006). Structural characteristics in agriculture influence land abandonment (Baldock et al., 1996; MacDonald et al., 2000), but the predictions of the relationships between related variables are difficult to make because of conflicting influences. For example, large farms are more likely to be abandoned because of labour shortages. In contrast, large farms might be less frequently abandoned because these farms are generally better equipped (Giupponi et al., 2006). In addition, agricultural abandonment follows a scale-dependent pattern of variations in explanatory variables (Lambin and Geist, 2006; García-Martínez et al., 2009). At the farm scale, the process is primarily influenced by social and accessibility constraints. At the landscape scale, topography and climatic conditions seem to be determinant factors, while at coarser scales (the regional or national level), economic and social factors are the most important drivers of land use change. For instance, Baldock et al. (1996) studied land abandonment in different European countries, identifying changes in labour markets, relative prices of agricultural products, agricultural structures and policies, migration and infrastructure developments as important drivers of land abandonment.

Given the complexity and the scale dependency of agricultural land abandonment, the identification of the most important drivers influencing this process needs to be approached with a methodology that integrates socioeconomic and geo-bio-physical variables (Lambin et al., 2001). The knowledge of drivers is also an essential prerequisite for developing realistic socioeconomic and ecological scenarios of land use change (Gibon et al., 2010; Houet et al., 2010).

This paper aims at identifying drivers of landscape change in a mountain area of the eastern Italian Alps. The spatial scale of the analyses comprises a province and 69 municipalities to provide information for policy measures at the scale where these measures are planned and implemented. In particular, the specific objectives of the study were: (i) to quantify the loss of agricultural land due to natural forest regrowth occurred during the period 1980–2000 and (ii) to identify the changes in the general socioeconomic context and in the agricultural sector that acted as drivers of these changes. Because in mountain areas the land morphology is a major factor affecting costs and ease of management, these analyses were conducted based on slope classes corresponding to increasing complexity of mechanisation.

Materials and methods

Study area

The study area is between 45°50′N and 46°40′N in the Province of Belluno, which is divided in 69 municipalities and covers an area of 3676 km^2 in the north eastern area of the Veneto region (Fig. 1). The climate is continental with average precipitations of 1400 mm/year and average monthly temperatures ranging from −5 °C in January and +23 °C in July. The study area is prevalently mountainous with an average altitude of 1276 m a.s.l. (min 257 m a.s.l.; max 3313 m a.s.l.), and it is divided in several valleys with a dense hydrographical network (Giupponi et al., 2006). Agriculture is predominantly dedicated to livestock farming (about 60% of the holdings are livestock farms). The livestock sector is characterised by strong differences between the northern and the southern parts of the province (Sturaro et al., 2009): in the north, livestock systems are characterised by small farms of dairy and mixed cattle, but the farmers also raise goats and sheep, and in general, they suffer from deficiencies in equipment, limited access to capital, lack of technical support and difficulties with market relationships; in the south, there is a prevalence of larger units with dairy cows and, in a few cases, beef cattle, with better structural and technological facilities.

During the period of 1980–2000, the number of cattle and dairy farms in the province decreased by 76 and 81%, respectively. The total number of dairy cows decreased by 44%, while the average herd size increased from 3.7 to 11.2 cows per farm. In the same period, agricultural employees decreased by 55%, while those in the industry and service sectors increased by 7% and 16%, respectively (ISTAT, 1981, 2001). The employment increase in the secondary and tertiary sectors is mostly related to the expansion of the eyewear industrial production and of the tourism sector, which are currently the most important sources of income for the inhabitants.

Land use datasets (1980–2000)

The land use/cover data were visually interpreted and digitised from raster images of regional technical maps (RTM) of the year 1980 at a 1:10,000 scale and aerial photographs, with 1-m ground resolution, of the year 2000 (CGR, 2001). To minimise the bias expected when maps are derived from manual digitisation of polygons (Geri et al., 2010), the same spatial resolution (1:10,000 scale) and mapping procedures (minimum polygon area of 2000 m^2) were used for the two different sources.

To obtain indicators of landscape changes, four main land use categories were identified. *Forest* (F) included all land patches with 30% of tree cover and a minimum area of 0.2 ha, as defined by the land use classification systems of the Veneto region since 1980 (Regional law 52/1978). Dense shrub areas (>30%) were also included in this category because they may represent the early stage of a natural vegetation succession resulting in forest transformation of previously cultivated land. *Agricultural areas* (A) included meadows and pastures, arable land and other vegetation categories with a tree or shrub cover below 30%. At elevations above the treeline, land use is marginally affected by agriculture and animal husbandry, due to ecological constraints, and minimal changes in landscape features are expected; therefore, a climatological treeline was defined at 2200 m a.s.l. (Pecher et al., 2010) and areas located above this limit were excluded from the analysis of landscape changes. Finally, *unproductive areas* included all natural land cover categories with no vegetation (i.e., rocks, glaciers, lakes and other water bodies) and *urban areas* included residential, industrial and commercial complexes, as well as the road network. The sum of *agricultural* and *forest areas* (AFA) was also used to obtain indicators related to landscape change.

To perform the accuracy assessment of land cover in the year 2000, 400 points located in the study area were selected to implement field surveys after a stratified random sampling procedure. An initial screening of selected points in the laboratory avoided the effort to verify land cover in the field where the answer was obvious (e.g., lakes, rocks, urban centres). Several points were "*a priori*" excluded from site visit, due to their limited accessibility. Therefore, 371 points were visited in the field between spring and summer 2002. The correct location of points was determined with a GPS unit, and the dominant land use cover was recorded. The field interpretation of polygons was subsequently compared with that produced by photointerpretation. The degree of agreement was tested using the K statistic ($K = 0.84$; $P < 0.001$; Cohen, 1960), and overall statistics for the accurate assessment were finally produced (overall accuracy = 0.959; overall omission error = 0.040; overall commission error = 0.013).

For the land cover of 1980, no accuracy assessment was performed. The RTM was obtained through stereoscopic analysis of high altitude aerial photographs at a 1:10,000 scale. The accuracy of the data representation (planimetric representation of terrain features) of this type of maps is around 4–5 m (Veneto Region, 1992). We are aware that land cover derived from this source is expected