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Assessment of land cover changes and spatial drivers behind loss of permanent meadows in the lowlands of Italian Alps

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ABSTRACT

The loss of permanent meadows in the lowlands of the European Alps due to land use/land cover changes is a major underestimated process, which affects the status of these habitats and their provision of ecosystem services. In the Italian Valtellina valley (80 km^2) change detection analysis estimated meadows loss and spatial bivariate analysis and GIS-based logistic regression model analysed the spatial environmental drivers behind meadows loss in the period 1980–2000. A strong decrease in meadows (−18.5%) was found, in a context of agricultural land decrease and human settlements increase. This was the land cover type with highest loss and conversion rate during the study period. Meadows were converted to human settlements (urban, industrial and roads), other agriculture uses (cultivation, orchard, vineyard), bushland and uncultivated land. Meadows loss occurred mainly in soils with good land capability, low slope, exposed to south and in proximity of roads, urban settlements and bushland. Densities of urban, industrial and bushland and land capability were the only significant drivers for meadows loss, while distance to meadow edge, meadows density, distance to roads and soil degradation were the only significant drivers for meadows preservation. The conflict by land in locations densely occupied by other land cover types with good land capability is the major threat to meadows and avoidance of fragmentation may be a good strategy for its preservation. The meadows habitat needs a well-designed landscape and farming planning, which should account the economic value of the ecosystem services provided by this habitat.

1. Introduction

Loss of grasslands due to alterations in land use/land cover (LUCC) affected the status of this ecosystems worldwide, resulting in loss of biodiversity (Niedrist et al., 2008), encroachment of shrubs and forest (Tasser et al., 2007), decrease of the forage production (Liu et al., 2006), altered water cycle (Mingliang et al., 2008), soil degradation (Snyman and du Preez, 2005), flood events (Flez and Lahousse, 2004) and desertification (Yong-Zhong et al., 2005). In the European Alps, loss of grasslands is a major multidimensional issue (e.g. environmental, economical and social impacts) documented since the 1950s, following the decline in agricultural activities (Gellrich et al., 2007; Hersperger and Bürgi, 2009), and the Common Agricultural Policy (CAP) of European Union and World Trade Organization (WTO) negotiations, which promoted intense farming practices and liberalization of markets (Kristensen et al., 2004). This loss in grasslands threats centuries of traditional land use and also its ecologically and economically relevant values (biodiversity, water conservation, forage production, dairy products, aesthetic tourism attractiveness) in a context of global environmental changes and increasing need for food supply (Ceballos et al., 2010).

Three major LUCC processes have been shown to reduce grasslands: (1) abandonment or extensive land use in the uplands with bush encroachment and marginalization with transformation of meadows into pastures in steep slopes (Fischer and Wipf, 2002), (2) intensification in the lowlands (agro-industry) and (3) human settlements expansion into agricultural land (Marini et al., 2007; Pimm and Raven, 2000; Sergio and Pedrini, 2008). Recent studies have shown that these processes affected plant and animal diversity (Bolli et al., 2007; Kampmann et al., 2008; Sergio and Pedrini,

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2008), increased floods (Ranzi et al., 1999) and decreased soil respiration, evapotranspiration and water use efficiency (Tappeiner and Cernusca, 1998). It has also been shown that rates of land cover change vary according to landscape features (Falcucci et al., 2007; Schneeberger et al., 2007). In particular, conversions and loss in grasslands can be explained largely by topographic features (e.g. slope), soil related conditions (e.g. land capability) and local neighbourhood attributes related to proximity factors (e.g. distance to urban) (Gellrich et al., 2007; Hersperger and Bürgi, 2009; Rutherford et al., 2008).

However, while these studies documented alpine and subalpine regions, few studies addressed the loss in grasslands in the lowlands of mountain regions, which are the heart and last refugee for local farming systems after abandonment in uplands, and the locations most susceptible to changes due to anthropogenic pressure. In addition, in Italy, a country bounded by the Alps, these evaluations are rare and a quantification of grasslands loss is missing. This study assessed and modelled the conversion and loss of meadows in the lowlands of Valtellina, an Italian region in the Southern Alps, in order to better understand LUCC in lowlands and contribute to the creation of guidelines for the preservation and the sustainable management of this key habitat for the European Alps. In specific, for the period 1980–2000, it aims to analyse the following facets: (1) mapping of land cover for the study area (80 km^2) to quantify changes and transitions in different land cover classes, focusing in meadows, (2) analysis of the spatial pattern of meadows loss according to spatial environmental features and (3) development of a GIS-based logistic regression model to identify significant drivers for meadows loss.

2. Materials and methods

2.1. Study area

The study area (80 km^2) is located in Italy, in the lowlands of middle Valtellina, Southern Alps (46.10′N, 9.50 E; Fig. 1). The elevation ranges from 250 to 750 m a.s.l. (above sea level) and slope rarely exceeds 5%. It is a U-shaped valley carved by glacial erosion during the Quaternary, with a west–east orientation, discharged by the river Adda and surrounded by high elevation mountains (>3000 m a.s.l.). Main soil types are Eutric fluvisols, Dystric and Eutric cambisols (FAO, 1988). Owing to the proximity to Lake Como, the climate is temperate continental with mean annual temperature of 11.9 °C and precipitation of 970 mm (Sondrio at 298 m a.s.l., 1973–2007). The landscape is composed by five main categories: meadow, urban settlements, vineyard, bushland and orchard. It is strongly influenced by local farming activities, including activities in uplands (Rudini, 1992). The meadows are permanent, mown 3–4 times per year for hay making (Fava et al., 2010) and subject to intensive farming practices (e.g. dung deposition, mechanical farming operations) since the increasing abandonment of grasslands at higher elevation and concentration of farming activities in lowlands from the 1960s. According to the Habitats Directive, the meadows belong to *Ahrrenatherion elatioris* and *Polygono-Trisetion* alliances (EU habitat codes 6510 and 6520). The use of these meadows still signifies an important income source for local farmers and economy, as well as an important platform for Valtellina Valley tourism.

2.2. Land cover mapping and detection of changes in meadows

To determine land cover changes over time and loss in meadows at Valtellina, a visual classification with hand digitizing of two digital colour ortho-rectified aerial photographs (27/08/1980, scale 1:20,000 and 01/09/2000, scale 1:36,000) was made using ArcGIS 9.1 software (ESRI, 2005). The aerial photographs were produced by the Region of Lombardia, registered and geo-referenced to the national grid system Gauss Boaga-Zone 1. The landscape was classified into 11 land cover classes (meadow, cultivation, orchard, vineyard, bushland, uncultivated, water, urban, industry, roads, hedges) adapting the European Nature Information System (EUNIS) habitat classification (http://eunis.eea.europa.eu/) for the study area. The land cover maps (vector format) were converted into grid format (10 m spatial resolution) and land cover change was quantified through the cross-tabulation algorithm, a post-classification change detection technique that performs a cross-correlation between independent classified images (Lu et al., 2004). The cross-tabulation table showed the frequencies of classes, which had remained the same (frequencies in the diagonal) or had changed (off-diagonal frequencies) (Shalaby and Tateishi, 2007). Meadows loss was located calculating a difference image (later image *minus* earlier image) with the differencing algorithm (Singh, 1989). The change detection operations were executed in IDRISI Andes 15.0 (Eastman, 2006).

2.3. Spatial bivariate analysis of meadows loss according to spatial environmental features

Spatial bivariate analysis quantified the degree of meadows loss respect to the variation of 11 auxiliary variables selected from the literature based on their expected influence in this process (Gellrich et al., 2007; Hersperger and Bürgi, 2009; Rutherford et al., 2007, 2008). They were grouped into 3 thematic fields: topography-related, soil-related and neighbourhood-related and are described in detail in Table 1. The variables elevation, slope and aspect measured the effect of temperature, diffuse solar radiation, landscape shape and exposure and were derived from the digital elevation model (DEM), resampled from 20 m to 10 m, to adjust spatial resolution. Soil type and land capability (likelihood for agriculture use) measured the influence of soil features, they were obtained from the geo-environmental database of Region of Lombardia (http://www.cartografia.regione.lombardia.it/geoportale/ptk), converted from vector to grid format to adjust data format. The variables measuring distance to other particular land cover type (e.g. distance to urban settlements) or landscape feature (e.g. distance to meadow edge) evaluated the effect of proximity to meadows loss. In particular, the variable distance to potential flood areas represents the distance to areas under high flood risk. These distance variables were defined using land cover data from 1980 and estimated through a two-step process: first, delimitation of edges (5 × 5

Fig. 1. Location of the study area in the Italian Valtellina valley, Southern Alps.