Data Integration and Modelling for the Assessment of Future Climate Change Impacts on Natural Pasturelands of the Alps

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Data integration and modelling for the assessment of future climate change impacts on natural pasturelands of the Alps

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Introduction

Evidence shows that in the last century in the Alps area warming was roughly three times the global average and, according to future projections, this trend is expected to worsen in the next decades. Moreover, the species-rich permanent grasslands characterizing the marginal areas of the Alpine landscape are acknowledged as very sensitive and vulnerable ecosystems to climate change (IPCC 2007). So far several studies have investigated the climate effects only on specific Alpine grassland species at a very small scale, while a comprehensive assessment of the impact of climate change on Alpine mountain grasslands distribution and composition at a territorial scale is still lacking. Building on these premises, ground-breaking tools (classification models coupled with data integration by GIS techniques) were used to identify and environmentally characterize the main pastoral communities over the Alpine chain and to assess future climate change impacts on these fragile resources.

Methods

Current distribution and composition of pastures were derived by the integration of local pastoral cartographies, Corine Land Cover Map, and Habitats Natura2000 Map. By means of a methodological approach coupled with semi-automatic GIS procedures, seven main pastoral macro-types were identified. Reference to Corine Biotopes nomenclature was the key element to find a cross-correspondence among all map legends. Current suitable areas for the Alpine pasturelands and for the identified pasture macro-types were determined using a classification algorithm (Random Forest) (Breiman *et al.* 2001) that was trained with environmental variables comprehensively describing areas suited to the Alpine pasturelands and pasture macro-types. Topographic and climatic parameters, related to the present and future A2 and B2 Special Report on Emissions Scenarios (SRES), as simulated by HadCM3 General Circulation Model (GCM), were extracted from the WorldClim database; whilst soil data (pH) were obtained from the Harmonized World Soil Database. Seven gridded predictive variables were thus acquired and calculated: the average of mean maximum temperature of the warmest month (July), the average of mean minimum temperature of the coldest month (January), four seasonal cumulative precipitations, and soil pH. Environmental and pastoral dataset were then overlain and integrated within a GIS environment in a unique grid spatial dataset at a 1 km x 1 km of resolution. Since to build the model the Random Forest algorithm required an input predictor/response table, the environmental dataset represented the predictors and the presence/absence of pasturelands or macro-types was the binary response variable (1/0, respectively). Considering that pasture macro-types dataset, vector in origin, often overlapped with each other within the same 1 km x 1 km grid cell, each pixel of this dataset was reclassified and assigned to the mostly prevalent macro-type, in terms of extension, within the grid pixel. The Random Forest model was first trained to simulate pasturelands and pasture macro-types distribution for the present period. The accuracy of Random Forest simulation was then evaluated by the out-of-bag error (OOB) sample, and calculated for each tree over the data split of the corresponding random bootstrap sample. Scores produced by Random Forest were converted into presence/absence prediction maps by computing the True Skill Statistic index – TSS (Allouche *et al.* 2006) which minimized the prediction error. Finally, the calibrated Random Forest model was applied to the spatial datasets in order to forecast potential expansion/reduction and/or altitudinal shifts of pasturelands and of the identified pasture macro-types in three future time slices (centred on 2020, 2050, 2080) under A2 and B2 SRES (HadCM3) climatic scenarios.

Results

According to the methodological approach that considered the extension, the pastoral relevance, and the ecological importance of the main pastoral types over the Italian Alpine mountain range, seven pasture macro-types were identified: (1) pastures encroached by shrub species (SP) (mainly belonging to *Vaccinium*, *Rhododendron* and *Calluna* genus); (2) pastures dominated by *Carex curvula* (CC); (3) pastures dominated by *Carex firma* (CF); (4) pastures dominated by *Nardus stricta* (NS); (5) pastures dominated by *Festuca* gr. *rubra* (FR); (6) pastures dominated by *Sesleria varia* (SV); and (7) pastures dominated by xeric species (XS). For all these macro-types, representing in terms of coverage 83.5% out of the total pastures mapped by both Habitats Natura2000 Map and the

Table 1. Percentage of expansion (+) or reduction (-) of the Alpine pasturelands and pasture macro-types with respect to present period.

	A2			B2		
	2010-2039 (%)	2040-2069 (%)	2070-2099 (%)	2010-2039 (%)	2040-2069 (%)	2070-2099 (%)
Pasturelands	*+3*	*-13*	*-10*	*+1*	*+1*	*-16*
SP	+16	-95	-96	-10	-87	-97
CC	-17	-83	-97	-33	-77	-87
CF	-12	-100	-100	-98	-100	-100
NS	-19	-5	-30	-4	-3	-5
FR	-72	-100	-100	-81	-100	-100
SV	+22	-81	-90	-20	-76	-79
XS	+88	+200	+356	+115	+294	+179

pastoral maps over the whole study area (about 202,000 ha), the main environmental, pastoral and botanical characteristics have been briefly described (data not shown). With regards to the present period, the application of Random Forest model proved to be robust and very efficient to predict areas suited to pasturelands (OOB = 12%) and the seven pasture macro-types (OOB = 14.3%). According to model simulations, in the present period 2.08 million ha of the Alpine lands are eligible to pasturelands which are mainly dominated by NS; whereas CF and FR macro types are the most rare and restricted macro-types. Despite a slight contraction of lands suited to pastures (< -16%), the future climatic conditions, as depicted by HadCM3 in A2 and B2 scenarios, will have impacts of great concern on the Alpine pasture composition. More specifically, with respect to the present period, the climatic conditions projected in both SRES scenarios from the middle of the century will likely determinate a high decline of areas potentially suitable to the macro-types examined. Pastures dominated by XS showed wide expansion (+356% and +294%, for A2 and B2 scenarios, respectively), whilst NS showed a slight reduction (maximum reduction by -30% in A2). Conversely, a troublesome decrease or even loss (-100%) of lands suited to the mountainside (CC, CF and SV) or rarest (FR) macro-types was predicted by Random Forest simulations at the end of the century (Table 1).

Conclusion

Classification models integrated with background data by GIS techniques proved to be a reliable tool to classify pastoral resources of the Italian Alps at a territorial scale and as a consequence may be applied to assess climate change impacts on pastures distribution and composition. Despite a moderate reduction of areas potentially suitable to pasturelands, the projected climatic conditions at the end of the century will likely threat the unique and rare herbaceous biodiversity characterizing the Alps. In particular, an overall decline, or in some cases complete loss, of suitable lands of the most endangered macro-types is forecasted by Random Forest simulations under future climatic conditions.

According to these results, the expected global warming, coupled with an increasing abandonment of the traditional grazing practices over the Alps, will likely threat the unique and rare herbaceous biodiversity characterizing the Alpine mountain range.

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