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A spatial agent-based model for assessing strategies of adaptation to climate and tourism demand changes in an alpine tourism destination☆

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A R T I C L E I N F O

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A B S T R A C T

A vast body of literature suggests that the European Alpine Region is amongst the most sensitive socio-ecosystems to climate change impacts. Our model represents the winter tourism socio-ecosystem of Auronzo di Cadore, located in the Dolomites (Italy), which economic and environmental conditions are highly vulnerable to climate variations. This agent-based model includes eight types of agents corresponding to different winter tourist profiles based on their socio-economic background and activity targets. The model is calibrated with empirical data while results are authenticated through direct interaction of local stakeholders with the model. The model is then used for assessing three hypothetical and contrasted infrastructure-oriented adaptation strategies for the winter tourism industry, that have been previously discussed with local stakeholders, as possible alternatives to the "business-as-usual" situation. These strategies are tested against multiple future scenarios that include: (a) future weather conditions in terms of snow cover and temperature, (b) the future composition and total number of tourists and (c) the type of market competition. A set of socio-economic indicators, which are strongly coupled with relevant environmental consequences, are considered in order to draw conclusions on the robustness of the selected strategies.

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Software availability

Name of software: AuronzoWinSim1.0 (AWS1.0), Version 1.0 (August 2012).

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Hardware required: PC with Windows 7, Vista, 2000, or XP. Mac OS X 10.4 or newer. Any other platform on which Java 5 or later is installed.

Software required: NetLogo 5.0.2

Availability: NetLogo is a freeware downloadable from http://ccl.northwestern.edu/netlogo/. AWS1.0 is freely accessible from the website http://virgo.unive.it/climalptour/download.html. The ODD description (Grimm et al., 2006) of the model is available at the same link.

1. Introduction

The European Alpine Region is among the areas that are most rapidly affected by climate change. In general, the mean temperature of this region has increased up to +2 °C for some high altitude sites over the 1900–1990 period against +0.78 °C in the last 100 years at a global level (IPCC, 2007; ClimChAlp, 2008). With a certain degree of local variability, glaciers in the Alps have lost 50% of their volume since 1850 and snow cover is decreasing especially at the lowest altitudes and in autumn and spring. While precipitation records don't show any dramatic change yet, it is expected that the risk of extreme events like floods, avalanches, glacial hazards, and large-scale mass movements will increase (Castellari, 2008). Major predictable consequences in the Alpine region include impacts on

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hydrological cycles, biodiversity, agricultural productivity, energy management, and winter tourism sustainability. The latter is the focus of this paper.

The World Tourism Organization started warning about the possible negative implications of climate change for winter tourism and sports since 2003 (UNWTO, 2003). By 2007, already 57 of the main 666 ski resorts of the European Alps are considered not to be snow-reliable[1] (OECD, 2007). However, climate change is also an opportunity for those resorts that are snow-reliable, as they will face less competition in the future (Simpson et al., 2008). Indeed, a model of tourism development based on snow, no matter if natural or artificial, is still somehow surviving notwithstanding the aging of traditional skiers and stagnation of market demand (Macchiavelli, 2009). At this point very careful assessments should be carried out before any further snow-based development planning (WWF, 2006).

In recent years several cooperation projects funded by the European Commission have been dealing with the issue of adapting to climate change in the Alps (e.g. ClimChAlp, CLISP, etc.). ClimAlpTour is a project of the Alpine Space Programme, bringing together institutions and scholars from all countries of the Alpine arch, in view of dealing with the expected decrease in snow and ice cover, which may lead to a rethinking of tourism development beyond the traditional vision of winter sports. The project analyses 22 pilot areas with diverse environmental, social and economic conditions in order to provide a global perspective on the alpine tourism. Raising the awareness of the stakeholders including tourists, population and businesses on the impact of climate change on tourism economy of the Alps and on possible adaptation strategies is one of the goals of the whole project.[2]

This paper explores the implementation and the analysis of an agent-based model (ABM) capable of gathering the available heterogeneous information in view of assessing different scenarios of future local development, taking into account complex social and environmental dynamics and interactions. We drew inspiration from previous ABM applications that have already proven to be successful in the field of natural resource management (i.e. Werner and McNamara, 2007; Barthel et al., 2008; Perez et al., 2009; Soboll and Schmude, 2011; Gao and Hailu, 2012).

In the materials and methods section we present the case study, the model development, and the model implemented in the software application. While the model development section is more concerned about the conceptual model (developed in Unified Modeling Language (UML)) and its entities (Balbi et al., 2010), the description of the software is more focused on the processes of the implemented model.

In the discussion and results, we first describe the calibration of the model with empirical data, which allows us to define the population of agents and fine-tune some tourists' behavioral parameters. Then, we perform a sensitivity analysis for the most relevant tourists' behavioral parameters. The results are discussed, making use of a simple multi-criteria analysis applied to a selected set of socio-economic indicators, which are strongly coupled with relevant environmental consequences. Finally, we assess the model validity from the final users' perspective.

In the conclusion we highlight the strengths and weaknesses of the model and we propose further elements that could be added to the implemented version.

[1] In general, a ski resort is considered to be snow-reliable if, in 7 out of 10 winters, a sufficient snow covering of at least 30–50 cm is available for ski sport on at least 100 days between December 1 and April 15 (Burki et al., 2007).

[2] In addition, many dissemination products and research papers have been produced as side efforts, and in particular: Balbi et al. (2011), Urbanc and Pipan (2011), and Weiermair et al. (2011).

2. Materials and methods

2.1. Study region

Our pilot site is the municipality of Auronzo di Cadore, located in the province of Belluno, in the Veneto Region of north-east Italy. It covers a vast area (22,000 ha), which includes Misurina and the most famous peaks of the Dolomites, namely the “Tre Cime di Lavaredo”. The village of Auronzo (866 m above the sea level) hosts almost the entire population of the municipality of approximately 3600 inhabitants. The migration balance is stable. Misurina is a small settlement at 25 km western of the main village, placed at an altitude of 1754 m (see Fig. 1).

The local economy depends on tourism which is currently focused on the summer season, while the winter season is weak, with only 25% of total yearly arrivals (Regione Veneto, 2010). The total hosting capacity is of approximately 6000 beds of which 25% are in the hotel sector and the remainder in the extra-hotel sector (i.e. B&Bs, house lodges, etc.). In 2008, 63,700 arrivals and 305,400 tourist nights were registered, showing a slight decrease from the previous year. The last 10 years have witnessed the increase of arrivals and the contraction of average stay.

Notwithstanding the presence of two small downhill ski-areas and two cross-country ski-centers some hotels don't even open for the winter season. The four ski-lifts of Monte Agudo, which reach a maximum elevation of 1600 m, supply seven ski-trails covering 15 km. In the locality of Palus, halfway between Auronzo and Misurina, there is the Somadida forest, one of the largest of the province, which becomes a vast cross-country ski center during the winter season. Misurina, which has a hosting capacity of approximately 500 beds is endowed with the two ski-lifts (from 1754 m to 2220 m) that supply five ski-trails (3 Cime downhill), and 15 km of cross-country ski loops (3 Cime nordic). In addition, the area to the east of Misurina, including Val Marzon and Val d'Onge, is regarded as one of most beautiful spots for back-country skiing in the Dolomites. Snow precipitation and cover are significantly more consistent around Misurina, compared to Monte Agudo. However, the latter is equipped with a superior snow-making system.

Lately the local administration has been considering options on how to stimulate a further development of the winter tourism. Indeed, there exist several projects of further development of ski-areas. After preliminary consultations with the local stakeholders we decided to focus our study on how to develop winter tourism in the next 40 years, in a context of climate change and market demand that is not favorable, given the expected warming effect and the aging of the population of traditional skiers.

2.2. Model development

The purpose of the model is to identify the most robust among three active adaptation strategies that are presented, in general terms, in Burki et al. (2007):

1. traditional downhill ski-intensive tourism (*SKINT*),
2. an alternative light ski-oriented post-modern development (*ALTSKI*),
3. the process of diversification and enlargement of beyond-snow tourism (*BYDSNW*).

We also included a passive “business as usual” (*BAU*) strategy, which represents the actual configuration of the tourism facilities. Thus, we have defined four case-specific and spatially explicit alternative strategies which are able to take into account various orientations towards tourism and the perception of climate change from the local stakeholders' point of view. Fig. 1 shows the areas of interest in the Municipality of Auronzo di Cadore, where the adaptation strategies are simulated with AuronzoWinSim1.0 (AWS1.0).

The three alternative adaptation strategies (*SKINT*, *ALTSKI*, and *BYDSNW*) were presented to a group of local stakeholders and further tailored according to their suggestions. Each strategy consists of a specific set of *non-snow-facilities* (*accommodations*, *restaurants*, *retailers* and *other facilities*) and *snow-facilities* (*downhill* skiing areas, *cross-country* skiing areas, *off-piste* skiing areas and *snowparks*) located in certain areas of interest. Every adaptation strategy implies a different configuration of new tourism facilities, compared to the *BAU* situation, which becomes available at the end of the first winter season. A detailed description of each strategy is given in Section 2.3.2 and in Appendix A.

The entities of the model are presented in the UML class diagram in Fig. 2. Each *non-snow-facility* type is further divided into categories according to the costs associated with their corresponding services. For instance, *accommodations* include house lodges, 1–2 stars hotels and 3–4 stars hotels. Each accommodation is characterized by a specific number of bed units and related rates per night and per individual tourist (i.e. 22, 30, 43 €). While the number of bed units can vary for each single entity (there can be apartments with 10 beds and houses for holiday camps with 100 beds, and both are defined as house lodges), the rates are related to the accommodation category. These values correspond to actual average prices across a winter season. According to its category every bed unit is also characterized by: (a) a fixed seasonal energy consumption cost (i.e. 1, 2, 3 €), (b) a variable human labor cost that applies at each utilization (i.e. 3, 4, 5 €), and (c) a cost related to the investment required to build a new one (i.e. 15, 25, 45 thousand €).

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