Insight Maker(S) To Support The Management Of Protected Areas And Related Ecosystem Services: Example For Recreational Value

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Abstract

The management of ecosystems and the resulting services requires exploring and understanding the complexity of both ecological and socio-economic processes. Participatory modelling approaches that involve the local stakeholders provide an opportunity for managers of protected areas to promote a better comprehension of biodiversity conservation and to improve the modelling itself. In this study, we developed three generalised models of the cultural ecosystem service "recreational value" for small protected areas, such as those of the Natura 2000 network, considering three different contexts with an increasing number of "management variables". The models are presented to potential users and stakeholders in the web-based interactive learning environment Insight Maker. Although further steps would be needed to translate the formed insights into decision support, such as quantitative analysis, assumption verification, model validation and calibration, these simplified models have an educational utility concerning the complexity of ecosystem services and may work as tools guiding towards social learning within social-ecological systems.

Keywords: Protected areas, ecosystem services, group model building, dynamics model library, Natura 2000, recreational value

1. Introduction

The achievement of conservation targets of protected areas depends on many interconnected ecological, societal, and economic processes, all these interacting at different temporal and spatial scales (Scolozzi et al., 2014a). The management of protected areas requires the involvement of local stakeholders to be effective (Antunes et al., 2009; Hare et al., 2003), however, managing authorities are usually faced on the one hand with environmental issues, such as degradation of habitats, fragmentation, and climate change. On the other hand, they are confronted with constraints of funding, conflicts with local stakeholders, and increasing demand of recreational activities of nature-based tourism (Brandon et al., 2005; Europarc Federation, 1995). Moreover, they are often overwhelmed by external pressures (between institutional obligations and duties, social demands, and economic drivers) and limited by time and human resources to tackle with the increasing complexity of natural resources (Scolozzi et al., 2014b). Several experimental studies about the performance of people confronted with complex dynamic systems revealed that they were unable to correctly infer how these systems will behave or how they should be managed (Sweeney and Sterman, 2000).

Management strategies that are unaware of system complexity may cause negative cumulative impacts such as unexpected ecosystem degradation and unsustainable use of habitat, affecting the provision of ecosystem services. Ecosystem services are defined as the benefits people obtain from ecosystems and are classified into four categories, including provisioning, regulating, cultural and supporting services (Millennium Ecosystem Assessment, 2003). The assessment of ecosystem services has advanced during the past decades (Egoh et al., 2012; Staub et al., 2011), and the recreational value was assessed based on (spatial) indicators (Nahuelhual et al., 2013; Paracchini et al., 2014; Szücs et al., 2015) or surveys (Plieninger et al., 2013; van Riper et al., 2012). However, these assessments usually do not provide information about the relationships between different ecological, social and economic variables and may be not enough to anticipate possible side effects of management actions, because, in almost all cases, ecosystem services depend on complex links (including circular feedbacks) among ecological and socio-economic processes (Abelairas-Etxebarria and Astorkiza, 2012; DeFries et al., 2010). The final users of such assessment tools, like decision makers and managers, may remain unaware about the full complexity of ecosystem services provision and about potential consequences of management choices.

2. SD modelling for understanding ecosystem services in protected areas

The approach of system dynamics (SD) supports the understanding and management of complex systems, such as environmental and social systems, providing an effective contribution to environmental decision-making (Antunes et al., 2006). SD models have been already developed and used for the assessment of ecosystem services (Batker, 2010; Costanza et al., 2007; Costanza and Voinov, 2001), and dynamic modelling has been used to collect data, synthetize knowledge and communicate key issues of environmental problems (Costanza and Ruth, 1998). In particular, building dynamic models through stakeholder participation, named "group model building" (GMB) (Vennix, 1999) or "mediated modelling" (Antunes et al., 2006), revealed to be effective to improve the understanding of complex environmental problems (Rouwette et al., 2002). In this approach, stakeholders collaborate to the construction and application of dynamic models and simulations, creating an helpful context for consensus building and sharing of visions (Gaddis et al., 2010; van den Belt et al., 1998). In GMB, SD modelling promotes elicitation of participants' knowledge and mental models, helping to articulate and reframe perceptions, and create maps of the feedback structure of a problem from those perceptions (Forrester, 1987). SD simulations allow to assess the dynamics of those maps and test new policies (Chen et al., 2014).

While GMB applications for environmental management are increasing, those concerning small protected areas are still rare, especially related to the European-wide Natura 2000 network which includes a large number of relatively small areas (the smallest areas cover only few hectares). Specific administrators or management organisations, belonging to local administrations (e.g. municipalities, consortium of municipalities, or provinces) are responsible for these sites. In most cases, the different authorities generate overlapping and complicated institutional settings with many actors and levels of governance, sometimes disagreeing in perspective and objectives. Additionally, the results of Scolozzi et al. (2014a) revealed for most sites in Italy that they were subject to strong pressures from urbanization and intensification of land use in the surroundings.

Protected areas can be considered as social-ecological systems (Olsson et al., 2006), in which ecosystems are evolving with the local community; promoting the comprehension of ecosystems services provision and sharing management scenarios might support better decisions and consensus building on management options (Resilience Alliance, 2008). In many cases, this could be more salient or urgent than the exact quantification or mapping of ecosystem services. Building models of itself, the local community becomes an "anticipatory system" (Scolozzi and Poli, 2015), capable to move towards an "anticipatory governance" (Boyd et al., 2015), able to anticipate and manage current and future changes rather than endure them. In this paper, we propose the use of Insight Maker (Fortmann-Roe, 2014) for ecosystem services modelling to improve the understanding and to promote the social learning about Natura 2000 sites. We developed three different models for the recreational value considering three different contexts with an increasing number of "management variables" to demonstrate the potential of SD modelling in context with the management of the Natura 2000 network.

3. Basic SD models of recreational value (as cultural ecosystem service) of Natura 2000 sites

The recreational value of an area exists only if the area is accessible and can be visited, i.e. only if the visitor or tourist can enjoy the landscape and its features, for example scenic views, or can practice recreational activities such as hiking, cycling, bird-watching etc.. Access depends not only on geography but also on dedicated infrastructures (e.g. hiking trails, mountain huts) that facilitate the visit or enable recreational activities. This ecosystem service, therefore, partly depends on the natural component (ecosystems that offer recreational spaces and opportunities) and partly on the work of humans (enabling access and enjoyment of said spaces).

The recreational value of Natura 2000 sites in particular depends on many factors according to the context, and various levels of human intervention and/or naturalness can be distinguished. For example, in remote areas (e.g. high altitude), human intervention is generally limited to the opening and maintenance of access tracks. In flat areas, which are naturally easier accessible, the recreational value may depend more on artificial structures (e.g. bird-watching towers) that make one site more attractive than another in the same area.

In the relation between the recreational value of a site and its biodiversity, here for brevity called "environmental quality", there is a recurrent dynamic typical of nature tourism: the number of visitors/tourists increases (decreases) with increasing (decreasing) environmental quality, but their increase eventually affects environmental quality. In SD terms, the process includes a negative feedback cycle that reduces environmental quality with respect to its initial value before the arrival of visitors (Figure 1), until reaching an equilibrium.

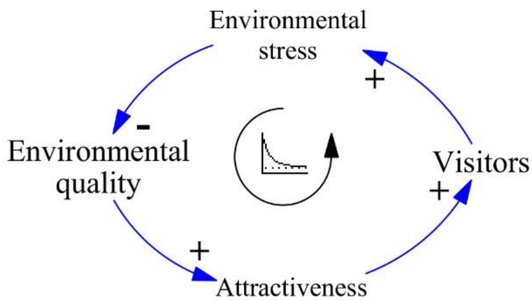

Figure 1 Elementary model of recreational value service: negative feedback reduces Environmental quality and number of Visitors.

In a basic model, the variables that link *visitors* and *environmental quality* may be *attractiveness* and the level of *environmental stress,* namely the set of negative impacts on the functionality of the area to host its biodiversity. While *attractiveness* may in some cases increase through *marketing* (left, Figure 2); the number of visitors can locally provide resources for *investments* for improvement or maintenance of *environmental quality* (right, Figure 2). This creates two opposite feedback loops: a negative one tending to stabilise the system and a positive one tending to promote exponential growth; the two can strike a balance that can result in sustainability of the recreational service.

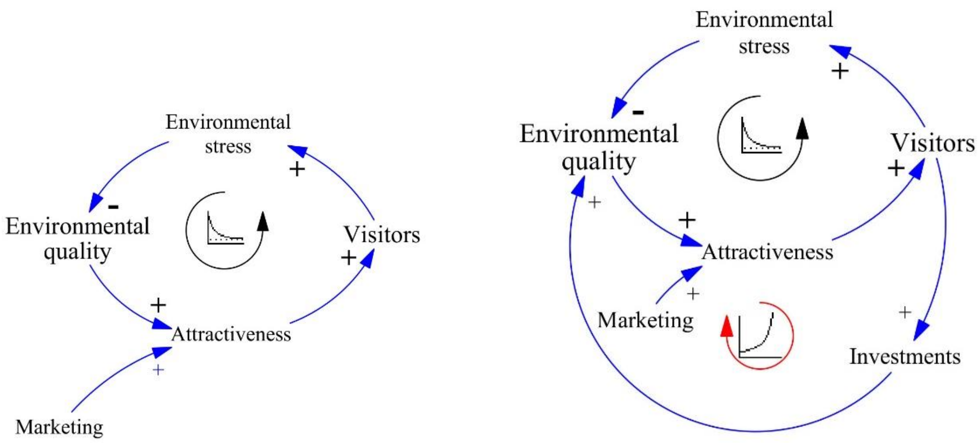

Figure 2 Causal diagram with a negative loop (left, model 1), and with two opposite loops (right, model 2).

Unsustainable dynamics may occur if *investments* are aimed at increasing *attractiveness* through *marketing* and *structures* for recreational activity, without proportionally increasing or maintaining *environmental quality*. In these conditions, two feedback loops, decoupled from *environmental quality* (Figure 3) may destabilise the system: decreasing (or annulling) the stabilising function of the feedback between *environmental quality* and *visitors*, and leading to a rapid increase in environmental stress (no longer controlled internally by the system). Dynamics, even worse for environmental quality, may occur when *investments* and *structures* attract new human settlement and population.

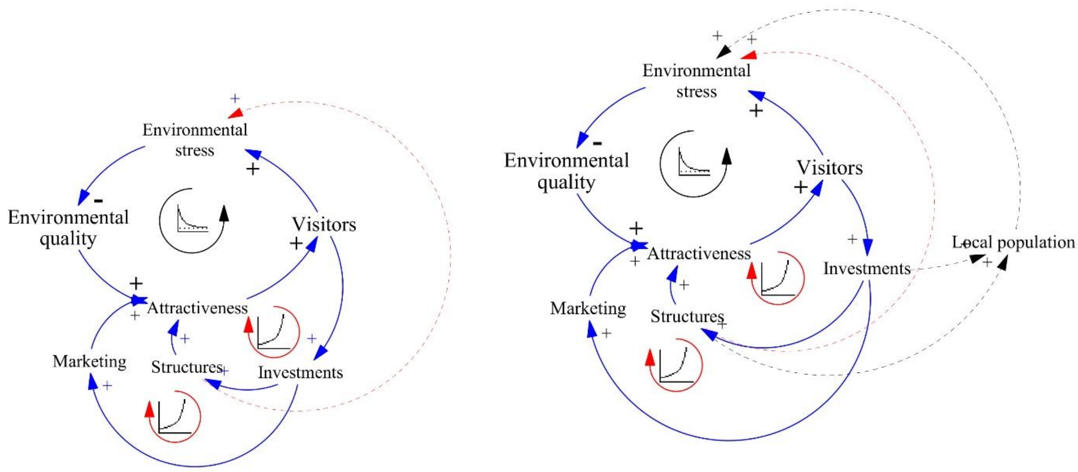

Figure 3 Model 3 (left) and model 4 (right) with feedbacks potentially independent of environmental quality.

Considering these dynamics, different types of social-ecological system, in which ecological and human variables are interdependent, can be distinguished, as shown in Table 1. Each model is accessible in the web platform Insight Maker (searching in "Explore insights" the tag "SD Conference 2016"). In the following sections, many details of the models are not reported, for those we invite the reader to explore the models in the associated web pages (https://insightmaker.com).

Table 1. Three models of increasing complexity (according to different socio-ecological systems) for recreational services.

Model	Type of system/protected area	Key variable	Management variables
S1	Remote areas with reduced human presence	Environmental quality Visitors	Marketing
S2	Natural areas with margin for environmental improvement	Environmental quality Visitors	Marketing Investments on environment quality
S3	Areas where infrastructure could be developed	Environmental quality Visitors Infrastructure	Marketing Investments on environment quality "Artificial" attractivity

3.1. The simulation model M1

In the proposed model (Figure 4), the stock variables are environmental quality and visitors; the first is qualitative (more is better) with values measured in an ordinal scale; the second one represents a value in an interval scale but without a real reference (the range could be scaled with real data of a site). The variable *environmental stress* associates the number of visitors and the level of environmental quality; in other words, the environmental stress caused by a single visitor is greater in a site with the maximum environmental quality than in a degraded site. The number of visitors is initially set at 0 and oscillates around a level of equilibrium depending upon marketing success and environmental quality, realizing the negative (stabilizing) feedback loop in the Figure 2.

In general, all variable values of this and subsequent models are not realistic numbers, the interest of modelling here is the understanding and making evident the dynamics between variables; thus, comparison between variables is more relevant than their absolute values. Some variables could be scaled with real data and calibrated, in following steps of modelling and simulation.

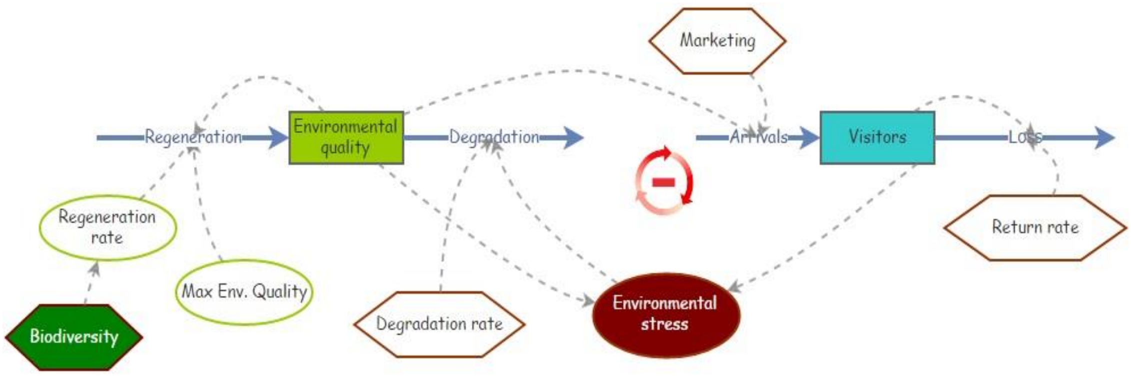

Figure 4 Model S1 (hexagons represent “management variables”).

Useful considerations from model S1

Some of the model variables could be modified through hypothetical management actions: the biodiversity could be enhanced through specific actions on habitat restoration or enlargement (Figure 5); marketing effort can be increased or measures could be taken to improve the return of visitors (Figure 6). Such variables can be changed in simulations with stakeholders within Insight maker©.

Relevant dynamics to be shared with stakeholders concern the equilibrium between visitor number and level of environmental quality. Depending on the negative feedback loops between key variables, the system stabilises to a lower value of environmental quality and a “sustainable” number of visitors in relation to the regeneration rate and environmental degradation.

With doubling of the degradation rate (Figure 5, left), *environmental quality* and *visitors* reach equilibrium values that are almost half those of initial conditions (blue and red lines). With the hypothesis of +20% increase in the regeneration rate (Figure 5, right), these values would increase almost proportionally (green line).

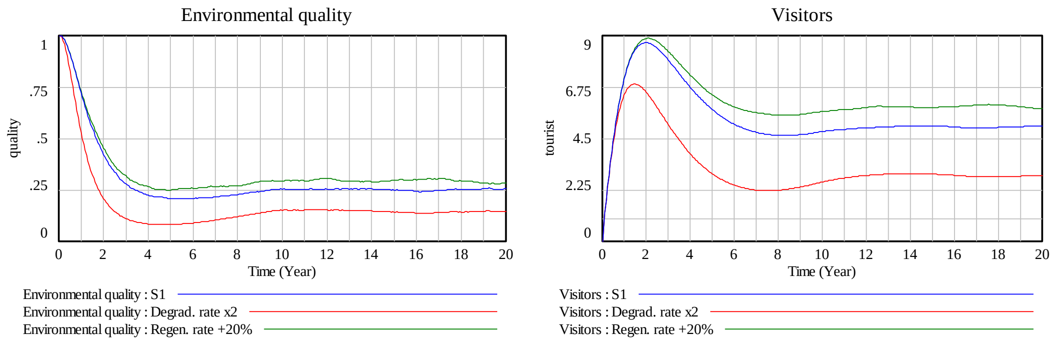

Figure 5 Dynamics of Environmental quality and Visitors in scenarios with different regeneration rate (+20%, green line) or degradation rates (doubled, red line).

The dynamics of environmental quality and number of visitors oscillates to reach an equilibrium, which is also related to management variables. If marketing is doubled (Figure 6, left), environmental quality decreases (by about 50%), but the number of visitors does not increase proportionally (Figure 6, right), rather the dynamic shows a larger oscillation, finally reaching close values.

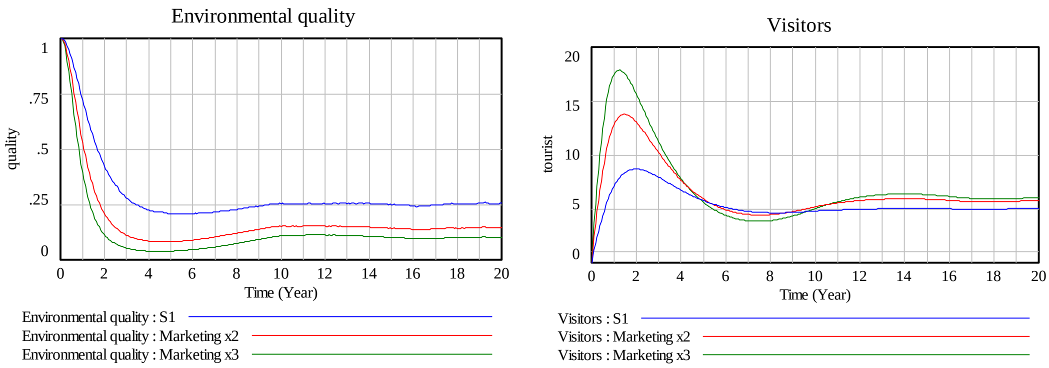

Figure 6 Dynamics of Environmental quality and Visitors in scenarios with different marketing levels.

3.2. The simulation model S2

A second model (Figure 7) introduces further realism with the variable *investment* to support an active *improvement* of *environmental quality* (e.g. through active maintenance), standing for an environmental remediation or compensation of tourism impacts. Such *investment* would depend on the partial reinvestment of the revenues obtained from the expenditure of the tourists/visitors in the site. Another new element is the variable *attractiveness*, dependent on the environmental quality and limited by the number of visitors according to a threshold of congestion (the number of other visitors tolerated by each visitor).

Among the management variables, which could be changed in simulation and hypothetical scenarios, there are *expenditures per visitor* and *re-invested fraction*. Again, the values are purely fictitious and could be integrated and calibrated, for instance in supplementary field surveys.

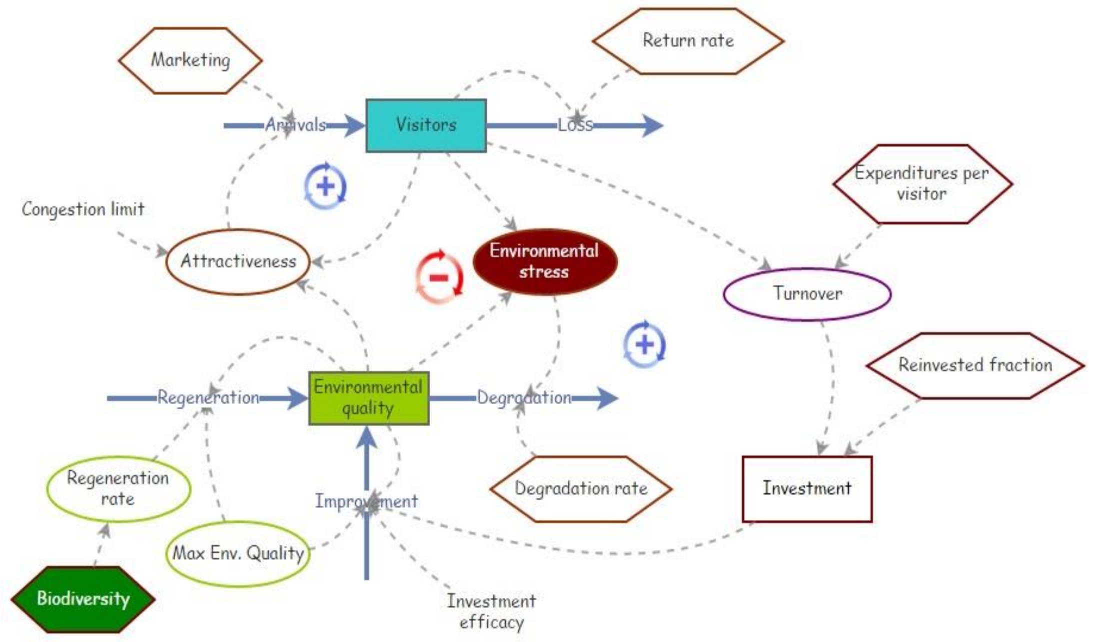

Figure 7. Model S2 (hexagons represent "management variables").

Useful considerations from model S2

In such model, three feedback loops emerge (Figure 7), creating a balancing dynamics between the positive feedbacks on visitors through *investment* and *attractiveness* and the negative feedback on *visitors* through the *environmental stress*. The *investments* in the environmental improvement partially compensate the negative impact of visitors on *environmental quality* (Figure 8), which reaches an equilibrium with higher value than in the previous model (S1).

The model simulations allow exploring interesting scenarios, for instance: doubling the marketing efforts, environmental quality decreases, but less than in the previous model (Figure 9, left), because it is compensated by improvements induced by higher investments (funded by higher incomes, due to higher number of visitors).

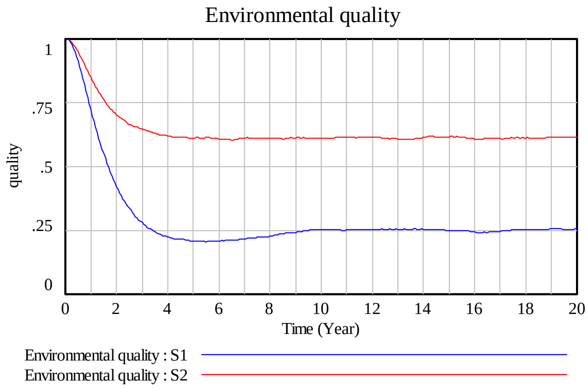

Figure 8 Dynamic of the *environmental quality* in the model S1 (blue line) and the model S2 (red line).

This model includes several management variables (expenditures per visitor, fraction reinvested, and marketing) that can guide management and/or local development strategies. Considering possible changes in investments, cost per visitor and marketing, the model provides answers to questions such as: what strategy most increases the volume of business and at what price for environmental quality?

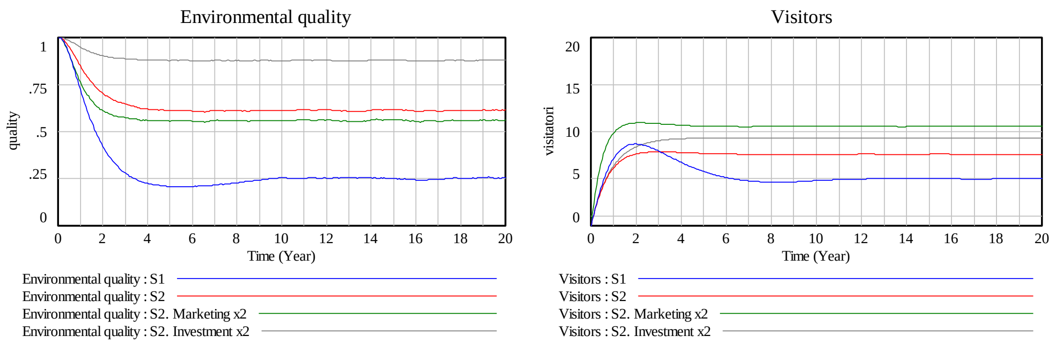

Figure 9 Dynamics of environmental quality in Model S2 with changes in marketing (x2, green line) and investment (x2, grey line).

In the model S2, the best strategy appears to be to increase spending per visitor (Figure 10): it increases the environmental quality (with an impact identical to that derived from the option of doubling the rate of re-investment of revenues) and increase revenues (on condition to keep other variables unchanged, e.g. the rate of re-investment in environmental quality).

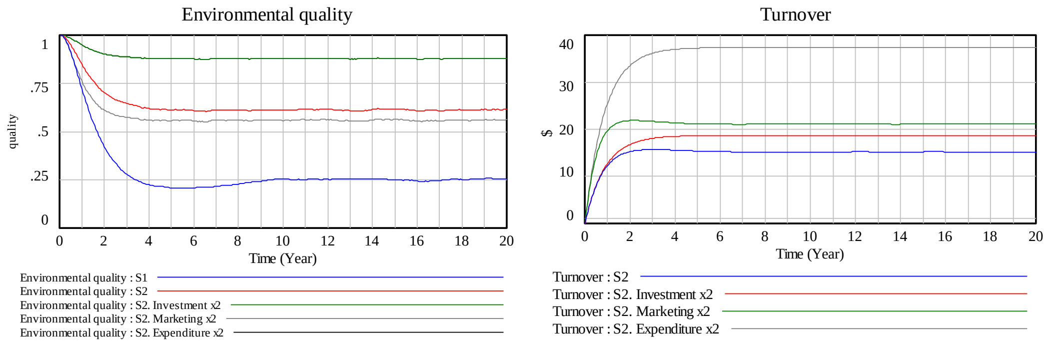

Figure 10 Dynamics of *environmental quality* and *turnover* with changes in marketing, reinvestment rate, and expenditure per visitor.

3.3. The simulation model S3

As mentioned above, in certain situations the number of visitors may depend only on external inputs (Figure 11), such as investment in artificial attractions (or structures) and in marketing, which builds "artificial" instead of "natural" attractiveness. When *visitors* and *environmental quality* are decoupled, the *environmental quality* of the system becomes eroded (Figure 12).

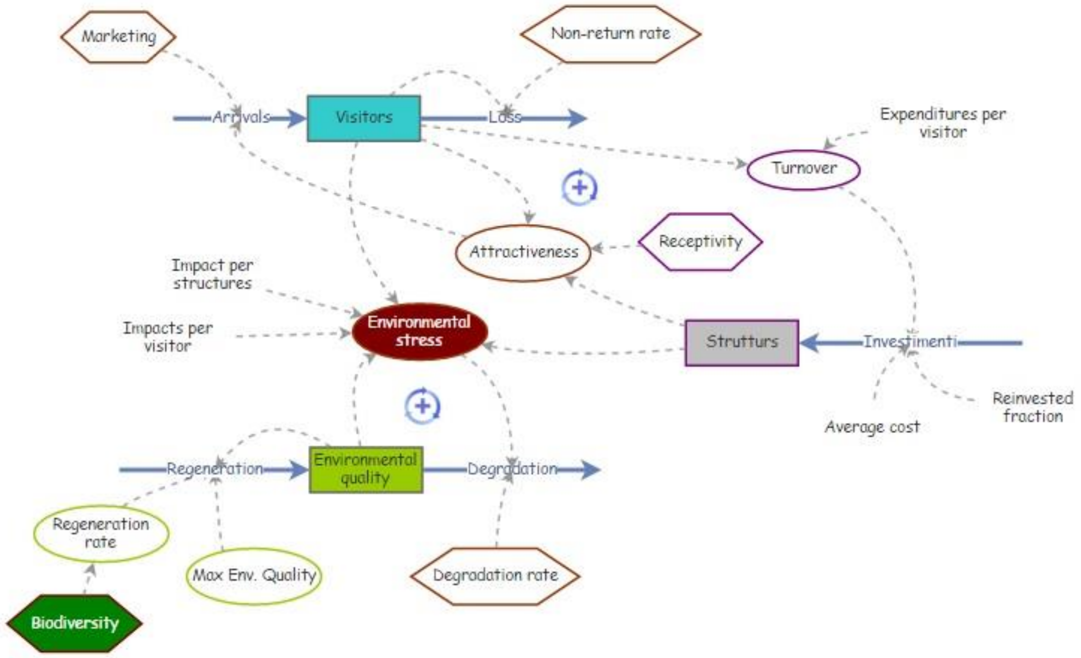

Figure 11. Model S3: the variable Visitors and Structures are connected by positive feedback loop, but not influenced by the Environmental quality.

The model S3 includes the variable *structures*, measured in terms of number of beds, recreational spaces or other equipment for visitors, measured as "equivalent visitors". The variable *attractiveness* is simplified as free spaces/beds, or the difference between the number of available places and the current number of visitors, assuming that a greater number of free spaces is more attractive. In such model, each visitor and each structure determines its own specific impact that sum in generating environmental stress.

Useful considerations from model S3

The system represented by the model 3 has two positive feedback loops, as shown in Figure 11, that are not offset by any negative feedback; from the simulation, we can see how visitors and structures can grow indefinitely until destroy environmental quality (Figure 12). Specifically, the presented model shows the unsustainable dynamics of recreational use in the absence of investments for environmental maintenance and/or compensation, in other words, in absence of negative feedback loops stabilizing the system.

In general, some of negative loops cannot be totally controlled, such as congestion effect (see model S2); others are crucial issue for management, such as investment in environment conservation or maintenance; both these types should be at least considered and possibly investigated at site level for effective local policies.

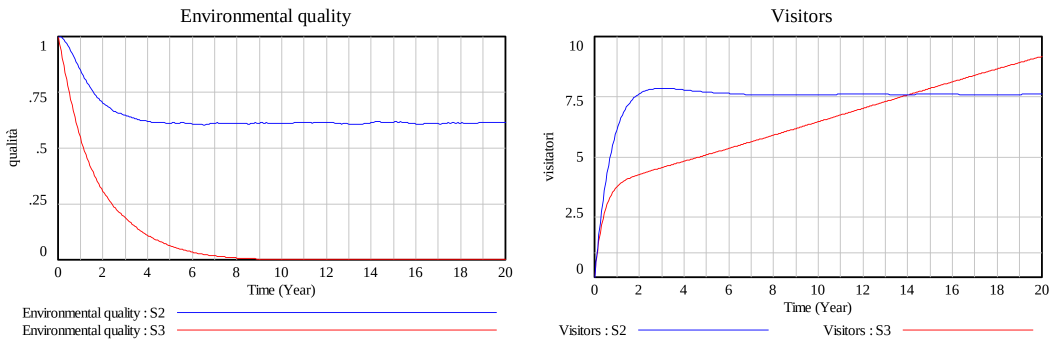

Figure 12. Dynamics of *environmental quality* and *visitors* in model S2 (blue line) and model S3 (red line).

4. Discussion and conclusion

In this study, we stress the importance of the modelling itself, rather than of final models. Modelling together with local stakeholders may be a way to bridge local knowledge (hold by land managers, owners, beneficiaries in general) and science knowledge (by experts, academics, and researchers). Hence, we use a general-purpose tool for web-based modelling and simulation (Fortmann-Roe, 2014) to present specific models of ecosystem services which are open to an interaction by users. The ideal outcomes of the use of such web-based interactive environment is to start a library of models dedicated to ecosystem services, in which experts can take materials to develop own models and stakeholders can easily interact with the complexity of "own" socio-ecological systems.

Although most of the presented trends related to the recreational value are intuitive and well known when they are considered separately, the diagrams and semi-quantitative scenarios, resulting from simulations, provide clear and relevant information (insights) that can be shared with stakeholders and actors in the tourism sector for planning purposes. The process of SD model building, if shared and enriched by stakeholder involvement, may support a more informed and robust ecosystem management.

The proposed SD models have various aims and potentials. They can be used to represent the main variables involved in site management and in the process of reproduction of the ecosystem service, and they facilitate the understanding by visualising feedbacks between possible management measures and ecosystem services. The models allow to reveal implicit assumptions that would be deleterious for the aims of enduring development and biodiversity protection in Natura 2000 sites, and they may sustain collaborations for promoting ideas, knowledge, interests and positions, based on cognisant discussion among stakeholders. Furthermore, management problems and strategies can be defined from new and possibly varied perspectives (e.g. tourism, landscape ecology, biodiversity conservation) to develop more specific models for the sites and to simulate management scenarios.

Nevertheless, the presented models have several limitations because they are hypothetical and generic, based on theories and assumptions derived from general notions of ecology and environmental economy and not from local data. They are incomplete as they do not include all variables involved but mainly those linked to possible management measures (e.g. "productive area" rather than "vegetation growth"). The variables have dummy values with an essentially qualitative meaning (often zero stands for minimum quantity or value, 1 or 10 stand for maximum quantity or value). For an operational use, as the definition of local actions, these models are not sufficient and could even be misleading, since they require validation and verification with real data and, probably, reformulation with new variables.

In conclusion, the simulation of scenarios and immediate viewing of the possible consequences can help effective communication and facilitate an informed discussion among stakeholders. The simplified models are good starting points to develop more operative dynamic models of ecosystem services. Attention to the time variable, typical of dynamic models, can help to spread among the same decision-makers and stakeholders a medium-to-long term perspective (Hjorth and Bagheri, 2006) that is necessary for a wise management of ecosystems and landscapes. Ideal developments include participatory modelling that is specific for each interest area (included or not in protected areas) and for each ecosystem service by mixed communities of experts (from different research fields) and stakeholders, including citizens as well as public or private managers of ecosystem and landscapes.

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