Alessandra La Notte (Italy), Margherita Turvani (Italy), Sergio Giaccaria (Italy)

Economic valuation of ecosystem services at local level for policy makers and planners. The case of the island of St. Erasmo in the Lagoon of Venice

Abstract

This study presents a valuation exercise of a specific ecosystem located within the Lagoon of Venice in northern Italy, the island of St. Erasmo, a complex habitat historically generated by the co-evolution of both ecological and economic processes. Mapping the spatial distribution of biophysical characteristics of the island, the authors link the economic assessment to specific areal units, in order to obtain total and per hectar physical, then monetary values. The range of assessed ecosystem services includes recreational benefits (92,320 €/hectare), the service of protection from floods (315,000 €/hectare), the presence of genetic diversity and maintenance of life cycle of migratory species (120,000 €/hectare). Additionally, the paper analyzes the level of co-location and spatial association among ecosystem services and market asset values, in order to suggest a spatially explicit tool to explore the compatibilities and trade-offs among local planning priorities.

Keywords: ecosystem services, economic valuation, geographic information systems, land use, conservation policy.
JEL Classification: Q57, Q01, R14.

Introduction

Achieving sustainable development has proved to be a complex goal, requiring a new and better decision-making capacity in the sphere of conservation and ecosystem safeguarding. The development of ecological economics, by emphasizing methodological pluralism (Norgaard, 1989), and by supporting a trans-disciplinary effort to link the natural and social sciences, has helped to achieve a deeper scientific understanding of the complex links between human and natural systems, contributing to answer to the new demand for effective policies (Costanza, 1991).

By recognizing the importance of nature as one of the most important assets available to societies, by developing a more profound understanding of nature's economic value and by properly appreciating the services nature contributes towards human well-being, ecological economics has moved forward and developed a recent stream of empirical researches focusing on the evaluation of ecosystem services, and proposing classifications for a taxonomy of components of value. Departing from the ongoing debate on the topic, the case study we present in the paper aims at exemplifying how decision making in land use and ecosystem conservation policies may be operatively supported by integrated biophysical and monetary evaluations, and by an explicit reference to the spatial structure. The evaluation techniques we refer in the paper find their theoretical and methodological foundation on the core of environmental economics, based on neoclassical theory and welfare economics. The targets of the applied evaluations are here defined through the conceptual support of ecological economics. The discipline is not *per se* designing tools and aids to support policy making, but the adoption of an ecological economic perspective is here employed to choose the typologies of ecosystem services under evaluation (deGroot et al., 2002). The topic of classification of ecosystem services is addressed and discussed in detail in Section 1. The literature on this topic shows that integrating the multidimensional nature of ecosystem values within a decision framework in a meaningful and useful way is difficult, and methodological disputes are rather common (Turner et al., 2010; Liu et al., 2010). In this work we consider the case of the Lagoon of Venice, a complex ecosystem which has been a World Heritage Site since 1987, where ecological and economic functions have co-evolved over time. The specific site under investigation is the island of St. Erasmo, which is situated within the Lagoon. Over time, anthropic actions have deeply altered both the hydrodynamic and the morphological features of the Lagoon, causing a progressive deepening of the waters and a continuing transformation of its typical lagoon transition environment towards a fully marine environment (D'Alpaos and Martini, 2005).

The Lagoon is a unique site which provides habitat for wildlife while also offering opportunities for economic, social and recreational activities for both residents and visitors[1]. A wide range of safeguard actions have been, and continue to be, carried out in order to preserve Venice and its Lagoon from the risks of flooding; the ongoing works for the construction of mobile barriers (Mo.S.E.) at the three inlets connecting the Lagoon with the sea, while offering protection from the recurrent phenomenon of high waters, may contributing to further changes in the features of the Lagoon. The Mo.S.E., is a major public work project

[1] Tourist presence was around 8 million between 2004 and 2005 according to the regional statistic unit (ref. http://statistica.regione.veneto.it/dati_settoriali_ turismo.jsp).

under construction and realized by Consorzio Venezia Nuova[1], which has been carried out for many years now and is expected to be finished by 2014, implying public expenditure, so far, of almost 5000 billion euros. The barriers aim both to protect Venice and its Lagoon against high waters and sea storms, and to safeguard the Lagoon's natural environment. The north-western Adriatic coastal area is characterized by tidal ranges among the highest in the Mediterranean (APAT, 2006) and these interventions will prove particularly useful, given that climate change is expected to induce an even higher risk of flooding within the Lagoon. The conservation and environmental safeguarding of the Lagoon of Venice will require a continuous financial effort in the years to come, giving rise to a large debate concerning the most appropriate management of the barriers and the costs and benefits of such management, not only at the local and regional level, but also at a global scale, posing a challenging task for policy makers, tax payers, and the relevant communities.

By referring to an ecological economic approach in the context of applied evaluation, our case study benefit from the recent advances in the classification and description of ecosystem functions/services. We then proceed assessing the value of the most relevant ecosystem services offered by the Lagoon of Venice. For this purpose we construct an empirical exercise specifically on St. Erasmo island, that is located right in front of one of the inlet where the Mo.S.E. is being built and thus more sensitive to biophysical changes. The procedures implemented during this empirical study aims to systematically link biophysical features and monetary values.

Section 1 of this paper introduces the background framework of our approach. Section 2 provides a description of the geographical area under investigation, and presents the general procedures and methodology adopted. Section 3 defines the 'patch', i.e., the minimum area of reference assumed to perform our calculations. Section 4 introduces the ecosystem services under evaluation and their specification both in physical and monetary terms. In section 5 we comment the results obtained and propose the analysis to be undertaken. Section 6 reports the results of a further exploratory spatial descriptive analysis. In the last section we draw our conclusions and discuss our results.

1. Methodological background: the ecosystem service framework and spatial explicitness

The Millennium Ecosystem Assessment (MA, 2005) contributed to the development of a debate concerning the methodology used for valuing ecosystem services. One main conceptual issue that it addresses within this framework is the pathway from ecosystems to humans by differentiating biophysical structures, functions, services, and benefits.

Liu et al. (2010), after recalling a rich literature on this subject, offer an interesting framework linking the quantification of ecosystem services to the ecosystem structures and biophysical drivers. They suggest that the valuation of each ecosystem service should be performed according to different economic approaches, on the basis of their appropriateness. Notwithstanding the debate on ecosystem function/service classification (Costanza et al., 1997; de Groot et al., 2002; MA, 2005; Wallace, 2007), there is still no standard classification to which one can refer. For example, the MA (2005) classifies provision, regulation, and supporting and cultural services, while other economic valuation studies avoid the specific calculation of supporting services because they are propaedeutic to provision, regulation and cultural services, thus inducing problems of double counting. However, the exclusion of supporting services in the overall calculation may result in neglecting those services linked to habitat existence and habitat health. For this reason, the TEEB (the Economics of Ecosystems and Biodiversity) classification includes 'habitat services' together with provisioning, regulating and cultural services, focusing specifically on the maintenance of life cycles and genetic diversity (TEEB, 2010).

However, in order to propose a new commonly agreed standard a group of experts has been working together on the Common International Classification of Ecosystem Services (CICES) in order to develop a flexible and internationally research-based standard (Haines-Young et al., 2009). Table 1 shows the classification we are going to use for our application combining TEEB and CICES.

Table 1. Classification of ecosystem services

CICES	TEEB		
Food and drinks	Food[1]	Water[1]	
Materials	Raw materials[1]	Genetic resources[1]	Ornamental and medicinal resources[1]

[1] The Consortium is made up of major Italian construction companies and local cooperatives and firms, the Consorzio Venezia Nuova is the Ministry of Infrastructure and Transport – Venice Water Authority concessionary for work to safeguard Venice and the lagoon delegated to the State in implementation of Law No. 798/84.

Table 1 (cont.). Classification of ecosystem services

CICES	TEEB		
Energy[4]			
Regulation of waste assimilation processes	Air purification[2]	Water purification[2]	
Regulation against hazards	Regulation of water flows[2]	Erosion prevention[2]	Disturbance prevention or moderation[2]
Regulation of biophysical conditions	Climate regulation (including C-sequestration)[2]	Maintaining soil fertility[2]	
Regulation of biotic environment	Gene pool protection[3]	Lifecycle maintenance[3]	Pollination[2]
Information	Information for cognitive development[4]		
Symbolic	Aesthetic information[4]	Inspiration for culture, art and design[4]	Spiritual experience[4]
Experiential[4]	Tourism and recreation[4]		

Source: Adapted from Roy-Haines et al. (2009).
Notes: [1] Provisioning services; [2] Regulating services; [3] Habitat services; [4] Cultural services.

The ecosystem service framework and their classification is not the only methodological input we adopt from the TEEB. It clearly states that ecosystem service assessment must be spatially explicit (TEEB, 2010). Also Liu et al. (2010) claim that the benefits/services humans receive from any ecosystem can vary according to specific 'local' characteristics, therefore implying the need to account for a 'spatial element' in the valuation process. Both morphological and biophysical characteristics can strongly influence ecosystems and the services they provide although the inclusion of local and contextual features, including their variation in space, needs to be considered in order to produce a meaningful valuation of any given ecosystem. The recent EU Communication on Biodiversity suggests that biophysical maps of ecosystem services are a major tool for policies devoted to controlling the loss of biodiversity (EC, 2010).

Bateman et al. (2003) noticed that Geographic Information System (GIS) techniques can improve the way in which the complexities of the real world can be brought into economic analysis, and in Turner et al. (2010) 'spatial explicitness' is a qualifying element in performing any serious ecosystem services assessment. De Groot et al. (2010) point out that land management decisions are related to spatially oriented questions.

The spatial dimension of each ecosystem service can be included in the assessment in a number of ways and at different stages of the analysis. For example, when valuing each function, both physical and biological characteristics of specific units can be accounted for, together with distance, size and fragmentation. This process can be used for both physical and monetary valuations. Furthermore, the existence of spatial patterns can be taken into consideration, enriching the significance of the results both from a methodological and a policy analysis perspective. The suitability of spatially-structured assessments is proposed as a methodology to support decision-making for the economic analysis of land-use values (Bateman, 2009). In defining the ecosystem services it is important to know not only the societal choices and values, but also the spatial context in terms of geographical location (Haines-Young and Potchin, 2010).

The application of St. Erasmo island first spatially assesses physical quantities and monetary values of some ecosystem services and then analyzes the presence of spillovers and interdependencies among market and non-market values through space, thus contributing to a finer design in locally-integrated management strategies.

2. Valuing the St. Erasmo ecosystem

St. Erasmo is one of the largest islands in the Lagoon of Venice, which is situated in the northern part of the Adriatic Sea. St. Erasmo has a surface area of 3.26 km^2, is approximately 4 km long and between 500 and 900 m wide. The Venetian Lagoon, which is connected to the sea by three inlets, covers a surface area of approximately 55 km^2, of which only 8%, including Venice and the other islands, is land cover. Around 80% of the Lagoon area comprises mud flats and salt marshes, and the remaining 11% is water, made up of natural and dredged channels (canals).

The island of St. Erasmo has always been directly exposed to the sea, offering protection to the Lagoon and the city of Venice. Given its location, St. Erasmo is subject to large variations in water levels, on both a daily and an annual basis, and its surface is directly affected by the natural movement of waters, providing a natural defense from high waters, which are more frequent in fall and spring. Over time, various artificial interventions in the management of the Lagoon, such as the 19 century construction of long piers at the Lido inlet in front of St. Erasmo island and the ongoing construction of the Mo.S.E, have resulted in a number of changes to the island's ecosystem.

The St. Erasmo area is characterized by the presence of many marshy islands, which are a typical wetland feature. Largely comprised of mud, the island's form, surface, and state, change dynamically in time due to the continuous deposition and erosion of sediments. They offer precious habitat for wildlife including bird breeding grounds, resting sites for migratory birds, and nursery areas for fish. The St. Erasmo area also plays an important role in preventing mainland coastal erosion and the vast surface exposed to the tide provides habitat for a variety of wildlife.

The Island of St. Erasmo has supported human populations since Roman times, and agriculture has been the main source of revenue for the people living there (currently 800 inhabitants), serving the Venetian markets with fruit and vegetables throughout the centuries. Locally, the Island is commonly known as the 'Orchard of Venice', producing fine artichokes, grapes, asparagus and fruit. Apart from its very important protective function with respect to the Lagoon and the City of Venice, the Island is an attractive place for tourists coming from both the local Venetian and the Veneto Regions, and also from much further afield, particularly as an excursion during a visit to the hugely popular Venice.

Fig. 1. Location of St. Erasmo within the Lagoon of Venice

Given the complexity of the relationship between natural and man-made environments, a systematic but flexible procedure is required to assess market and non-market values of environmental goods and services. Figure 2 summarizes the procedure adopted for the quantification and valuation of the selected ecosystem services.

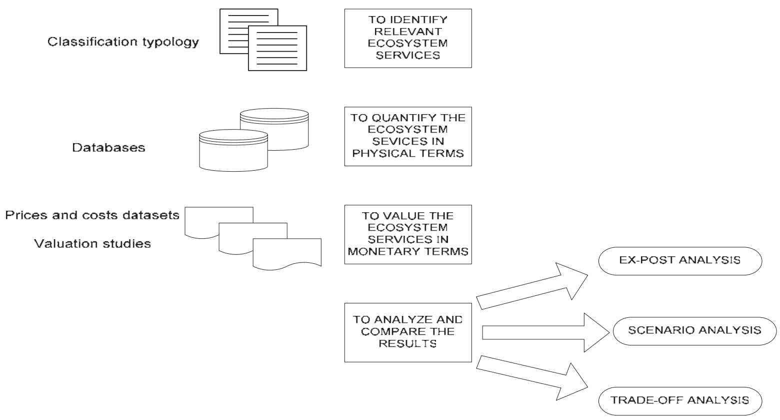

Fig. 2. Procedural steps

The first step of our procedure requires the identification of relevant ecosystem services once a proper reference classification typology has been chosen. As already mentioned (§ 2) the classification we refer to is the one proposed within the TEEB project that finds in CICES its full transposition.

Bearing in mind that the choice of ecosystem services varies according to the type of resources and land cover that are under assessment, we choose to assess some of the ecosystem services belonging to the categories that do not have a direct link with the market (and thus: regulating, habitat and cultural services). The main goal of valuing environmental goods and services, in monetary terms, is to provide decision-makers with management tools and measures that can be used during the decision making process, particularly in sensitive fields, and to discourage activities and choices that may threaten nature if valued solely on a strictly market-based criteria.

In our analysis, each ecosystem service is assessed first in physical, and then in monetary terms. The physical assessment requires a quantitative and qualitative assessment (per classes of hectares) of the relevant areas within the Island. Valuation in monetary terms is carried out using methods such as damage avoidance and stated preference approaches. The criteria for choosing the valuation method depend upon the ecosystem service being assessed, the available data and other features.

The adoption of a variety of data sources is in fact required. The possibility of using existing databases offers advantages in terms of cost savings and of using well-known procedures. However, using databases that are not specifically designed for the purpose, introduces the risk of double counting. This risk is always present when aggregation across different services is performed and when certain keystone processes and related functions underpin other functions (Turner et al., 1998). This is a considerable limitation to data collection given that building any dataset requires specific scientific and technical language, reflecting previous ‘value judgements’ in choosing what and how to record data (Scrase and Sheate, 2002). We believe that a way to overcome these limitations is to keep transparent about the metadata associated with our selected data sources, taking into consideration the ‘value judgment’ influencing how data were chosen, classified and aggregated. By clearly identifying the services to be valued and the values to be used, according to the internationally accepted frameworks, we can track the data processing behind each step of the procedure, to correctly interpret data and to compare results over time.

The procedure, therefore, has to be extremely flexible and able to take into consideration the evolution of data sources and valuation methods, together with improvements of GIS platforms.

The St. Erasmo case study is based on the following main information sources: land use and land cover geo-referenced data provided by Consorzio Venezia Nuova; the economic valuation studies supported by CORILA (Alberini et al., 2004a and 2004b); and aerial photographs, which were rich in territorial information, provided by the Information Service of the Venice Water Authority, the datasets on engineering works provided by the Consorzio Venezia Nuova. Figure 3 reports in more explicit terms the procedural steps of Figure 2 applied to our case study St. Erasmo.

4. The definition of minimum reference units

The setting of the GIS platform required a preliminary definition of the minimum reference unit. In our specific case we are able to refer to land use maps with destination polygons, and also to cadastral maps, a product from the land register. However, problems exist with both types of map. When using land use maps, the subdivision of polygons may cause problems if land use changes over time. However, information is poor using cadastral maps as they are based on a purely bureaucratic definition of land parcels, which is linked to property rights regardless of land or environmental characteristics.

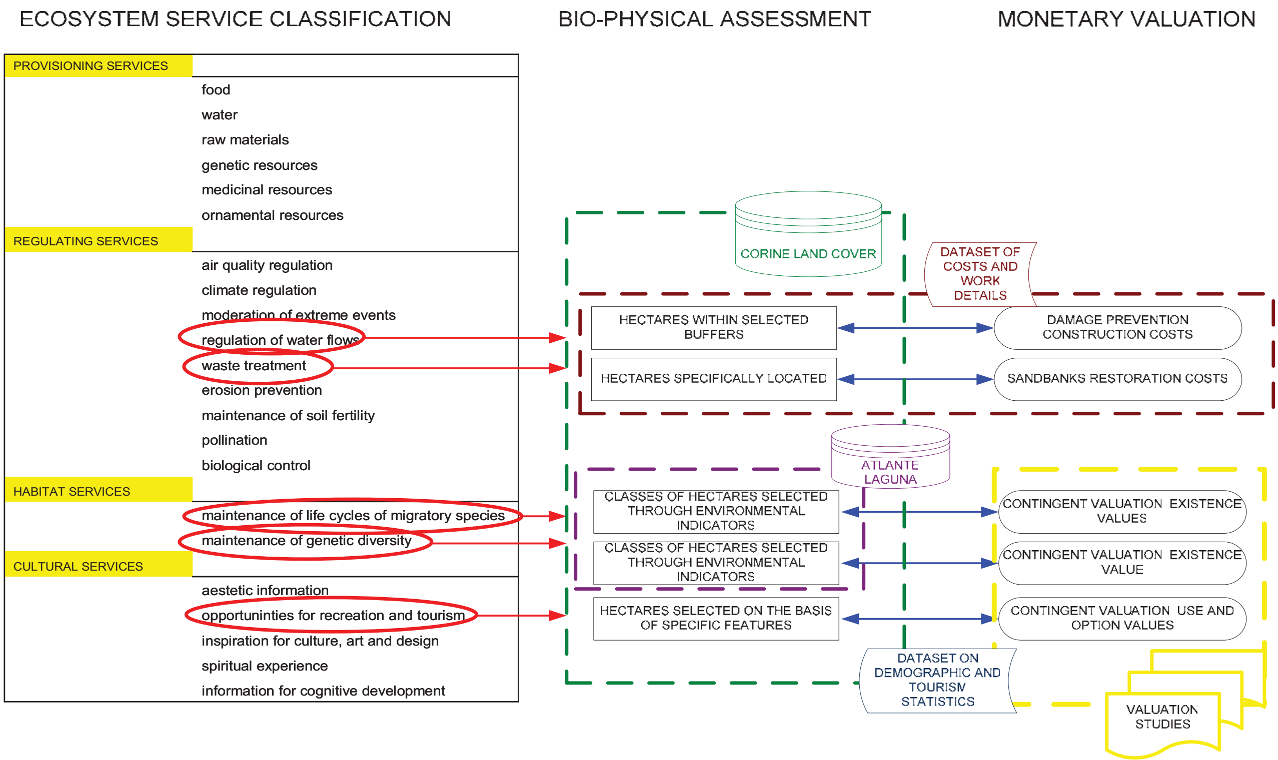

Fig. 3. Procedural steps applied to the St. Erasmo case study

In both cases it seems difficult to report environmental changes over time, thus introducing major difficulties in any dynamic assessment. We therefore, chose to proceed with the raster processing methodology, creating a grid whereby the individual cells each represent the reference unit to be valued. Technically, the process implied the shift from a vector to a raster model in order to obtain homogeneous reference units, and then again from a raster to a vector model, in order to facilitate the assessment process by referring to tables of data. By overlaying the land use map it is possible to assign a land use code to each specific cell.

It is necessary to decide the size of each cell, which is not an easy task considering the distribution of land-use types on St. Erasmo. The island is partly residential, partly cultivated and partly left undisturbed for natural regeneration to occur; therefore, both natural and man-made environments exist within a relatively small space, resulting in an extremely varied landscape.

Overall, we find that the most appropriate unit to use is a cell of 100 m², which provides an adequate representation of the actual distribution of land use[1], and allows the identification of the most important territorial features necessary in order to allocate physical and monetary values. The total area under consideration equated to 177,008 pixels and this area is broken down into units, or cells, of 100 m².

4. The assessment and valuation of ecosystem services

The vast variability in land uses and environmental characteristics of the area under consideration, together with the specific location of the island in the Lagoon of Venice, provides a base for the identification of the various ecosystem services to be assessed and valued.

The island offers important recreational services to a number of visitors, largely coming from the residential areas in the province of Venice and the city of Venice itself, and this is the reason why we consider important to value the 'opportunity for recreation and tourism' ecosystem service. Given its location right in front of the Lido inlet, it is important to consider the flood prevention service to protect the mainland, its activities and its inhabitants. The morphology of St. Erasmo makes it relevant the role of sandbanks as pollution sinks, and thus the waste treatment service. Finally, the more naturalistic aspects of this island can be valued through the maintenance of life cycles of migratory species and genetic diversity ecosystem services.

[1] To represent such a variety, attempts were made on a scale from 5x5m to 10x10m to 20x20m. On the 20x20m map the cell does not reproduce sufficient detail of the territorial features, on the 5x5m map too much detail involves a very heavy handling of the information with no counterparts in term of quality of the resulting evaluation.

While proceeding with the valuation exercise it is important to consider that the local ecosystem constituted by the St. Erasmo island is not isolated but that it contributes to the wider ecosystem composed by the Lagoon of Venice, the City of Venice and the mainland of reference.

4.1. Opportunities for recreation and tourism service. In order to value the recreational function, the basic characteristics which attract tourists and visitors needed to be identified. These characteristics were ranged according to their importance and mutually crossed to obtain a classification of areas with higher and lower values. In addition to typical tourist activities such as fishing, swimming, riding, etc., the recreational function also included the aesthetic and landscape features which characterize the Lagoon in general and can be enjoyed from the island.

Recently, the island of St. Erasmo has been the subject of a study by local research institutions (such as CORILA) and local Universities and the results of this research have been a valuable source of information. We were, therefore, able to specify the type of recreational facilities, the typology of visitors and a monetary value estimate (Alberini et al., 2004a, 2004b).

The aforementioned valuation study offers a portrait of typical visitors: mostly local lagoon excursionists, appreciating the island's beach and environmental amenities, and the historical and architectural features of the island.

The identification of the main attractions for recreational purposes were spatially zoned, distinguishing between those attractions where tourist interest depends on distance, and those where 'existence' alone is the important factor. Appropriate ranges were established and buffered.

Examples of critical features that allow recreational access are offered by piers and jetties, which are critical infrastructures on the island, representing the only means of access to the island and thus affecting the distribution of visitors over the island surface. Buffered areas of 500 m, 1,000 m and 1,500 m from the critical features were set.

Monuments and ruins (19 century heritage from the Austrian defense line) are important sites on the island, particularly after the restoration of the Torre Massimiliana. Other attractions include: the recently developed urban park, which is mainly used by residents, but can also be an enjoyable area for visitors; the presence of the 'ex-valli da pesca' (fishing valleys), an important natural element for those who are interested in environmental walks around the island; and lodging, food and beverage services, appreciated by all kinds of visitor and important in terms of location.

A 'Greenway' path runs around most of the island's perimeter offering visitors an opportunity to enjoy the charming landscape of the lagoon sandbanks. The path is represented by a unique buffer of 5 m. Additional recreational attractions that were accounted for include the sports ground and the local branch of the Società Remiera (rowing society).

We do distinguish between the landscape value for recreational purposes relates to visitors as the landscape 'user', and the landscape value for residential purposes that concerns only residents as the 'user'. This distinction between the two categories of landscape user is presented in review surveys (Moran, 2005) and valuation studies (Ellingson and Seidl, 2009; Tangerini and Soguel, 2004).

Within the category of landscape value for recreational purposes, we considered 'preferences' expressed by tourists for both present use (use value) and for future use (option value).

In order to proceed in a consistent way, it is necessary to create detailed buffers to be utilized in the valuation exercise. First, three buffers of increasing distance are created for each pier or jetty, forming potentially overlapping buffers, and additional recreational attractive spots are subsequently identified. Second, a qualitative ranking is assigned to the recreational features and the cells with the maximum value were assigned to Class 1, cells with the medium value were assigned to Class 2, and cells with the minimum value were assigned to Class 3.

To give an example, the maximum value was attributed to those cells which hold at least one pier and at least one basin within the 500 m buffer plus the presence of at least one of the recreational attractive spots. Class 1 is also attributed to those cells where the presence of sandbanks is visible throughout the 'Greenway'. The medium value is attributed to those cells which hold at least one pier and one basin within the 500 m buffer, and to those cells which have at least one pier or at least one basin within the 500 m buffer plus the presence of at least one of the recreational attractions of the island. The minimum value is attributed to those cells which have at least one pier or one basin within the 500 m, and to those cells in which there is at least one attractive feature. No other relevant combination of features can be found on the island.

The performed spatial query indicates that areas with the highest recreational value are not necessarily located together on the same part of the island, and that the coastline generally holds a much higher value than inland regions.

In order to value the recreational function of St. Erasmo in monetary terms it is necessary to obtain information on the tourist flows and activities on the island.

A recent study, which also provided the source for the monetary valuation of the recreational function of St. Erasmo, provides the results of a contingent valuation (CV) study aimed at estimating the use and non-use value of the island (Alberini et al., 2005, 2004a, 2004b). This CV study, through dichotomous choice questions, assess the willingness to pay where respondents are randomly selected from among residents of the Veneto region, and stratified by distance from the Venice lagoon. The services/attractions for which residents were asked if they would be willing to pay are: a public program to preserve the lagoon, use of the beach and use of the infrastructures on St. Erasmo[1]. The CV study of Alberini et al. is aimed at disentangling the use and option values (elicited from the preferences of users and potential users) from existence values related to the conservation plan (elicited by preferences of non-users). We decide to use this primary study undertaken for St. Erasmo island in order to assess the monetary value of recreational services (use and option values) and habitat services. However, as our study focuses on a spatial representation of the economic values, the use of individual willingness to pay forces us to assume a reference size for the target population, in order to transform per-person values into per-hectare values. In fact, in some of the major studies, such the COPI (IEEP, 2009), 'per-visit' or 'per-household' values are reported but not taken into account because of the difficulty of transforming them into 'per-hectare' values. The issue of transformation from individually to spatially-structured values remains in our study somewhat tentative; in our application we first aggregate and weight individual values, and then calculate 'per hectare' values. We thus prefer to rely on the specificity of the primary study, applying certain rules to transform the CV results into per-hectare values, instead of adopting secondary-study value transfer results. Nevertheless, the assessment of population size during the aggregation phase is clearly a crucial issue, and we act quite conservatively. For our purposes, recreational value is calculated using the following information:

- visitors to St. Erasmo during the current year: 7.6% of the overall respondents belong to the category of 'lagoon users' and express a use value of €25 per person;
- potential users of St. Erasmo: almost 42% of the overall respondents belong to this category with the intention of visiting the island sometime in the future and expressing an option value of €60 per person; and
- the distinction between those who use the Ven-

[1] For the CV study, a sample of respondents, were interviewed by telephone. Respondents chose how willing they are to pay by selecting the tax amount. The CV study assumed that WTP is distributed as a Weibull with scale σ and shape parameter θ estimated using the method of maximum likelihood.

ice Lagoon and those who know of the island of St. Erasmo and their stratification according to distance from the island.

One of the main findings from the CV interviews is that St. Erasmo is almost unknown to people living 50 km or more from the Venice Lagoon. As the study identifies the willingness to pay per person, only data regarding residents from the Veneto region, hence those residents who are already aware of the island, were considered in order to calculate a total value that could be applied per hectare and per square meter. The data source is a demographic survey which refers to the year 2004 and is downloaded from the regional statistic unit database[1].

To calculate use value, the percentage of Lagoon users (i.e., those who typically enjoy the Lagoon as a whole) is multiplied by the percentage of those users who typically visit only St. Erasmo (yearly average percentage: 7.59%). The result is multiplied by the share of willingness to pay related to the use value (€25 per person).

Regarding option value, the percentage of people familiar with St. Erasmo is multiplied by the percentage of potential users (those who are willing to visit the island: 41.88%). The result was multiplied by the share of willingness to pay related to the option value (€60 per person).

The total recreational value was represented by the sum of both the use and the option values. The value of €41,417,482 was calculated for the whole island, with the value per hectare calculated at €127,438. Data processing is shown in Table 2.

Table 2. Monetary calculation for the recreation service (1,000 €)

	Resident population	Lagoon users	Those familiar with St. Erasmo	Use value population	Option value population	Use value	Option value	Total
Range A[1]	271,251	38.66%	87.77%	7,970	99,992	199	5,999	6,200
Range B[2]	252,872	16.93%	64.55%	3,254	68,556	82	4,113	4,195
Range C[3]	1,143,417	13.48%	34.75%	11,714	166,882	293	10,013	10,306
Range D[4]	643,965	5.88%	23.53%	2,878	63,640	72	3,820	3,890
Range E[5]	2,388,445	3.03%	27.73%	5,500	278,173	138	16,690	16,830
Total	4,699,950							41,418

Notes: [1] This range includes residents from Venice and those who live at an approximate distance of 5 km from Venice. [2] This range includes residents who live at an approximate distance of 5-15 km from Venice. [3] This range includes residents who live at an approximate distance of 5-15 km from Venice. [4] This range includes residents who live at an approximate distance of 30-50 km from Venice. [5] This range includes residents of the Veneto region who live more than 50 km away from St. Erasmo.

The per hectare value is then weighted according to the qualitative classes identified through the procedure shown in Table 3. The maximum value reflects the full value of willingness to pay. Medium value and minimum value report 80% and 60% of the willingness to pay, respectively.

Table 3. Monetary valuation per class for the recreational function

Area class	Mean value per hectare (1,000 €)
Max	130
Med	102
Min	76

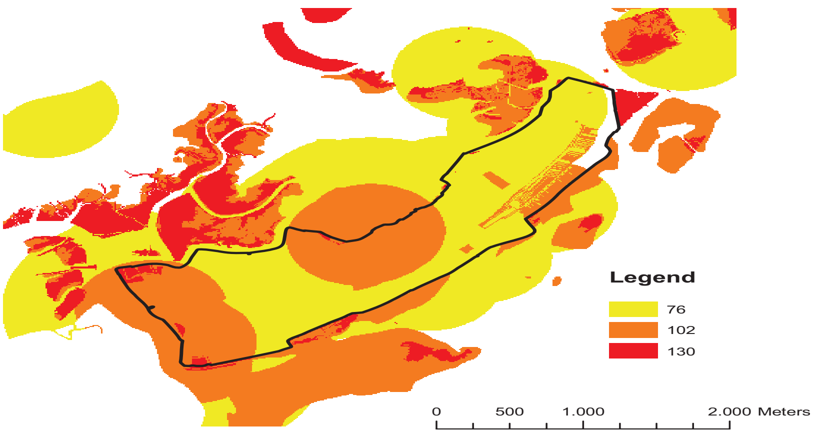

Fig. 4. Recreational function/opportunities for recreation and tourism service (1000€/ha)

[1] [1] http://www.regione.veneto.it/Temi+Istituzionali/Statistica/.

4.2. Flood prevention and waste treatment services. Given the position of St. Erasmo within the Lagoon towards the Lido inlet, the protection against high tides and flooding can be considered as the major contribution to the safeguarding of the island environment and to the control of island erosion. Moreover sandbanks perform an important protective role in terms of pollutant sinks (Guerzoni et al., 2006) and therefore the existence and 'maintenance' of sandbanks is crucial. Recently, several public works were undertaken by the local authority responsible for this objective (Magistrato alle Acque, 2007).

The extent and the type of works relevant to our study are identified, and then located and buffered in order to proceed with the valuation in monetary terms, through damage avoidance and restoration expenditures.

The main works undertaken within the island and related to environmental protection are:

- the restoration and raising of the water barriers and embankments distributed all around the island perimeter;
- the restoration of internal seaways which affect the hydro-geological setting of the island, reclaiming them for water circulation and thus improving the storage capacity and the disposal of meteoric waters; and
- the reconstruction of sandbanks which positively affect the lagoon equilibrium.

The protective value resulting from the overall calculation is €345,626,750. Table 4 shows how costs are attributed to island features and sandbanks, while Figure 6 shows how the value of the island changes in monetary terms as defensive costs are applied.

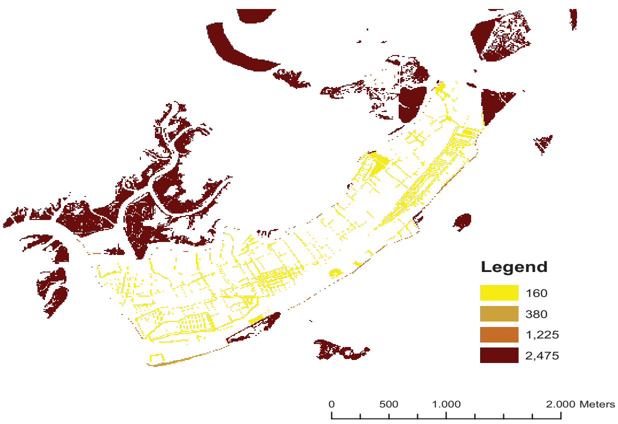

Fig. 5. Protective function/flood prevention and waste treatments services (1000€/ha)

Table 4. Damage avoidance and restoration expenditures over the St. Erasmo area

	1,000 €/ha	Hectares	Total value (1,000 €)
Flood prevention			
Channels	160	36.96	5,915
Beach	380	1.90	720
Embankments	1,225	2.49	3,050
Waste treatment			
Works on sandbanks	2,475	135.90	335,945
Total			345,627

Source: Adapted from the data provided by Consorzio Venezia Nuova.

In this valuation exercise we considered only the monetary stock involved while leaving aside both the issues of maintenance and cost of the works.

4.3. Services related to the maintenance of life cycle of migratory species and genetic diversity. The procedure followed for the valuation of habitat services involves the calculation of environmental indicators in order to qualitatively classify the area according to different values of selected environmental characteristics.

An invaluable source of information is constituted by the '*Atlante della Laguna*' (Guerzoni et al., 2006). This publication includes a vast amount of environmental indicators which describe the physical and biological components of the Venetian Lagoon environment and can be used for our purposes.

We select an indicator to value the biotic function linked to the existence of flora and fauna, which involves the pedological classification of sandbank soil and reporting the typology of the sandbanks with its existing vegetation. According to the typology and characteristic of the soil, an index for biotic function is then attributed to each relevant area.

We then choose a second indicator relevant to the 'Secca del Bacan' area, which is remarkable for several reasons, among which is the presence of phanerogams, vascular plants known as sea grass, which are extremely important for the Lagoon ecosystem as they guarantee the existence of benthic and ichthyic communities. Spatial distribution of the different types of phanerogam (*Zostera* sp.) existing within the Bacan area is also taken into account. This area is particularly important for the maintenance of life cycles of migratory species. The concentration of typical fish species during the summer season was also relevant, given that this area is a 'nursery' for fish during their juvenile stage. Classes of increasing value were assigned according to the spatial distribution of the concentration of such typical fish species. In addition, the distribution of bird species that use the Bacan area for feeding, roosting and foraging is also included in the valuation, as is the spatial distribution of the important high-tide root zones.

Another important environmental indicator we include is the intertidal zone of the Bacan area, located between -0,25 and +0,25 m above sea level for a mean tide. Ecologists strongly claim that intertidal areas are peculiar environments and extremely valuable from an ecological point of view, the aforementioned *Atlante* (Guerzoni et al., 2006) offers a wide variety of examples.

The *Atlante* (Guerzoni et al., 2006), however, does not provide data in respect of inland vegetation and, therefore, information is obtained from a lithological map which allows us to attribute values according to soil type. The same procedure is used to value both inland and sandbank soils.

The overall picture shows that areas mainly comprising marshes and thin sand have the highest values in terms of biodiversity; these areas are in fact the richest in floral composition. The combined use of all environmental indicators enable the identification of several different zones to which respective economic values could be attributed. Table 5 describes these zones.

Table 5. Identification of relevant areas

	GIS location	Motivations
A	Feeding, nesting and roosting site areas of Tringa tetanus	30% of the Mediterranean population of this species is found in this part of the Lagoon. Nest-building opportunities are linked to the survival of this area
B	Calcari-Oximorphic Marshsol (COM) sandbanks	High value of the biotic function
C	Ochri-Oximophic Marshsol (OOM) sandbanks	High value of the biotic function
D	Barene constitued from Ochri-Redumorphic Marshsol (ORM)	Medium-high value of the biotic function
E	Calcari-Redumorphic Marshsol (CRM) sandbanks	Medium-high value of the biotic function
F	‘Secca del Bacan’ area	Presence of phanerogams; species richness of fish and birds
G	Intertidal areas (quota: -0,25 e + 0,25 m)	One of the most important habitats within the Lagoon from an ecological point of view
H	Areas on St. Erasmo rich in humus; marshes	Natural regeneration of vegetation; areas not used for cultivation
I	Agricultural areas	Terrains used for cultivation
L	Anthropic areas	No environmental value

Zoning of biodiversity can be broken down into 6 classes, as summarized in Table 6.

Table 6. Qualitative classes for habitat services

Classes	Description of class elements	Value attribution
B, C, F	Sandbanks COM and OOM, ‘Secca del Bacan’	Very high
D, E	Sandbanks ORM and CRM	High
G,A	Velme and shallow waters, feeding areas of Tringa tetanus	Medium-high
H	Marsh areas on the island	Medium
I	Agricultural areas on the island	Medium-low
L	Anthropic areas on the island	Low

There is no agreed national/international standard to compare and calibrate the value of the environmental indicators that we adopt for St. Erasmo. Therefore, in order to establish a hierarchy among the different areas in terms of biodiversity value, we record the location of each environmental indicator. The co-existence of multiple environmental indicators within a cell will determine a higher value for biodiversity; this together with a change in the value of the environmental indicators will modify the physical assessment of an area and thus the economic value attributed to that area.

In order to assign a monetary valuation to biodiversity, the existence value obtained from Alberini et al.’s (2004a and 2004b) CV study is used. As with the recreational function, it is necessary to transform the per person value into a per hectare value. Surface zoning, created by means of the selected environmental indicators, is used to attribute per hectare monetary values and enables us to proceed with the calculation of the value of the biodiversity function.

The CV study (Alberini et al., 2005, 2004a, 2004b) estimates the total WTP (Willingness to pay) for St. Erasmo. Due to the structure of the questionnaire, it is possible to distinguish between the use value, the option value and the existence value. This latter value can be derived by considering the WTP for the island enhancements public program from those respondents who have never been to St. Erasmo or who are not considering going in the future. While use value and option value are used to calculate the recreational function, the existence value is the most appropriate to calculate the value of biodiversity.

The existence value, as derived from the CV study, is the *per person* WTP, which amounts to €27; this estimate was then extrapolated to calculate a per hectare value.

Primarily, we need to choose a procedure to estimate how many people to account for; a criteria is then identified in order to set a threshold regarding the relevance of St. Erasmo in relation to the Lagoon systems. However, the following information is relevant to this procedure: first, St. Erasmo is an essential part of the Lagoon and its ecosystem plays a critical role within the whole area (in which case we will calculate a maximum threshold), or at least within a large part of it (in which case we will calculate a minimum threshold). Second, the Lagoon of Venice is not only widely known worldwide, but it has a very important role within the Mediterranean Sea; outside of the Veneto region there are many people sensitive to the Lagoon's existence and to the natural elements it offers. The overall population of tourists within the Lagoon is included in the study as a reliable proxy of a local potential basin of people able to express an assessment of existence value of the island. Data on tourist flows can be used to extrapolate a potential demand whereby preferred accommodation type and the time of year is selected.

Visitors who prefer the natural elements are likely to go for excursions within the Lagoon, thus spring and summer are shown as the best time of year for this visitor group to come to Venice. The 'naturalistic' attitude could similarly be extrapolated from preferred accommodation type; stays in agri-tourism centers or camping might serve this purpose.

The selected time of year for the visit and preferred accommodation type can therefore be used to identify the percentage of the general tourist flow that is relevant to the valuation of the biodiversity function in St. Erasmus. This percentage will vary according to a maximum and a minimum threshold as shown in the following formula:

Thresholds percentages for tourist flow = (total flow)/accounted arrivals.

Accounted arrivals for the minimum threshold are calculated by using arrivals in hotels from May to September and arrivals in agri-tourism lodges from March to October. When compared with the total flow of tourists during the whole year, the flow percentage associated with the minimum threshold is calculated to be 37%. Accounted arrivals for the maximum threshold are calculated by considering stays in all types of facility for the period from May to September. When compared with the total flow of tourists during the whole year the flow percentage associated with the maximum threshold is 58% of the total. The following formula illustrates calculations which are reported in Table 7:

Monetary values = [(Survey data on residents and tourist flow)(thresholds percentages)]*(Per-person WTP).*

Table 7. Monetary value calculation for habitat services in St. Erasmo

	2004 survey data	Accounted percentage		Biodiversity value (1,000 €)
Minimum threshold				
No. regional residents	4,699,950	80	3,759,960	101,520
No. tourist arrivals	3,820,546	37	1,413,602	38,167
Total				139,687
Maximum threshold				
No. regional residents	4,699,950	100	4,699,950	126,900
No. tourist arrivals	3,820,546	58	2,215,917	598,230
Total				186,730

When calculating the value of habitat services for St. Erasmo, the sandbanks and intertidal areas must also be taken into account for the important naturalistic role they play. The per-hectare value for biodiversity is calculated using 989 as the total number of hectares in order to take into account the island surface and the surrounding area that includes sandbanks and intertidal areas.

The value of biodiversity calculated for St. Erasmus ranges from the minimum threshold of €139,686,175 to the maximum threshold of €186,728,400; the per hectare value will thus range from €141,240 to €188,805.

Table 8 presents the described environmental indicators ranked according to 5 qualitative classes. A monetary value is attributed to each qualitative class. The maximum value corresponds to the full monetary value calculated and is attributed to Classes B, C, F, which are labeled with a 'very high' value. Ninety per cent of the full monetary value is attributed to Classes D and E, which are labeled with a 'high' value, and so on. The table shows how the values are attributed to each qualitative class for both maximum and minimum thresholds. Figure 7 maps the value attribution results.

Table 8. Monetary valuation per class for habitat services in St. Erasmo

Area class	Qualitative class code	Value attribution	Value per hectare (1,000 €)
Minimum threshold			
Very high	B, C	100	140
High	D, E	90	130
Medium-high	G, A	80	115
Medium	H	50	70
Medium-low	I	30	40
Low	L	1	1.4

Table 8 (cont.). Monetary valuation per class for habitat services in St. Erasmo

Area class	Qualitative class code	Value attribution	Value per hectare (1,000 €)
Maximum threshold			
Very high	B, C	100	190
High	D, E	90	170
Medium-high	G, A	80	150
Medium	H	50	95
Medium-low	I	30	57
Low	L	1	1.8

The value of 0.01 attributed to anthropic areas (L) is justified by the inclusion of the whole area into the SIC and BioItaly[1] list. Anthropic areas alone would not actually register any value as they are awarded only the minimum value.

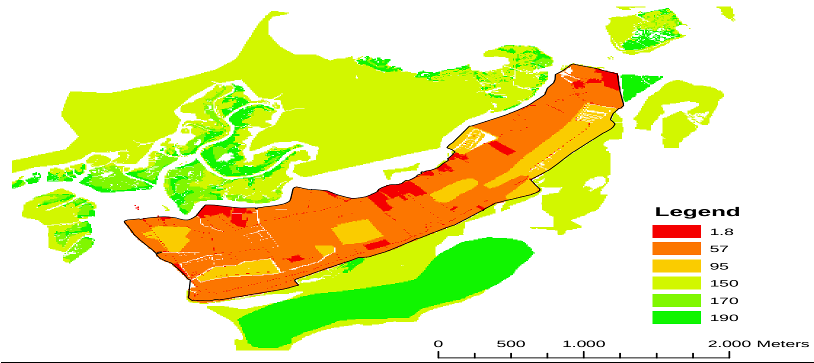

Fig. 6. Services related to the maintenance of life cycle of migratory species and of genetic diversity (1000€/ha)

The per-hectare values of habitat services are multiplied by the number of hectares allocated within each qualitative class codes. Aggregation of each class allows us to calculate the monetary value for habitat services. This value for St. Erasmo ranges from €94,819,100 (minimum threshold) to €126,751,410 (maximum threshold). By dividing this with the total number of hectares, the mean per hectare values range from €95,874 (minimum threshold) to €128,160 (maximum threshold).

5. Results and comments

Table 9 shows each of the ecosystem services we have valued in this application and the revenues of two assets that St. Erasmo provide directly to the market (real estate and agricultural activity).

We can notice that how similar the value of the regulating services we have calculated are to real estate values. When comparing the total values of market assets with the total value of ecosystem services we obtain almost the same amount. It means that not considering ecosystem services would lead to a serious underestimation of this island and its surroundings. We only consider some of the ecosystem services and just their values overcome the value of market assets. When local planners make projects even on small but ecologically sensitive areas, they must take these non-market values into account.

Table 9. Monetary value of ecosystem services and market assets for St. Erasmo

	Economic value (1,000 €)	1,000 €/ha
Ecosystem services		
Opportunity for recreation and tourism	106,700	100
Flood prevention and waste treatment	345,630	315
Maintenance of life cycles of migratory species and genetic diversity	126,760	120
Market assets		
Real estate[2]	395,550	360
Agricultural products[3]	131,820	120

[1] Refer to http://wwwbioitaly.casaccia.enea.it/wwwbioitaly/.
[2] The data have been taken from the Osservatorio Immobiliare database at http://www.agenziaterritorio.it/servizi/osservatorioimmobiliare/consultazione/.
[3] Agricultural production was valued through INEA (National Institute of Agricultural Economics at http://www.inea.it/) estimated prices considering the € per hectare of agrarian regions and the type of cultivation. Artichoke price (a typical product of the island) was estimated through interviews to the Consortium that unifies local producers.

When compared to other studies (e.g., King et al., 1995; Berger and Associates, 1997; Woodward and Wui, 2001; Pacheco et al., 2003; Brander et al., 2004 and 2008; Schuyt and Brander, 2004; EEA, 2010), the high variability of the values we calculate may be partly attributed to the significance of the island as an internationally protected area; for example the existence-value of the island, as calculated from the data obtained in the CV survey (Alberini et al., 2004b) reflects the worldwide attention to the conservation of this precious, historical, heritage site within the Venetian Lagoon.

However, economic values of ecosystem services make sense for policy makers not in absolute terms but when considering differential values from two states of the words. These differentials can be calculated ex-post, when we dispose of time series, or ex-ante, when we run alternative policy scenarios. Figure 7 illustrate this final step of our procedure.

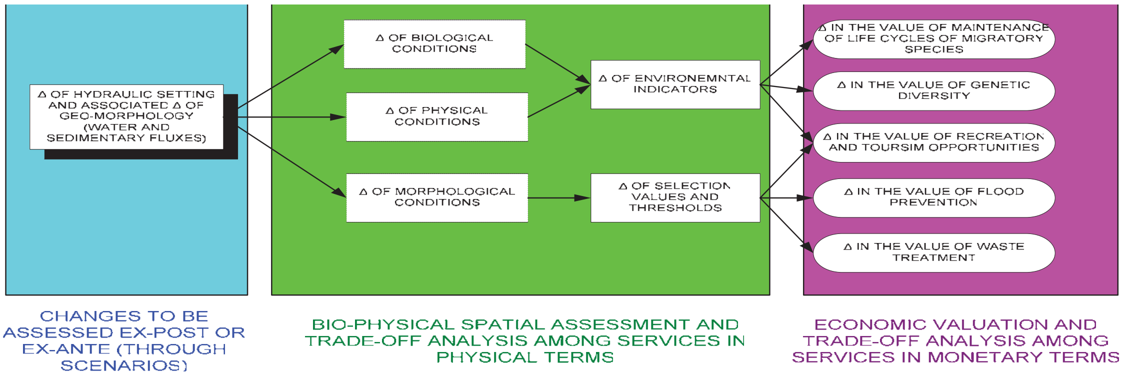

Fig. 7. Linkages between changes and monetary values

The data we calculate for St. Erasmo refer to year 2005, when the Mo.S.E. only started to be built. It makes sense to re-assess the values of these ecosystem services ten years later (for year 2015) to check how the functioning of Mo.S.E. has changed the physical assessment and the monetary valuation of these services. Moreover, the different functioning regimes of the Mo.S.E. and the changes it provokes in the inner Lagoon morphology, physical and biological conditions can be simulated by running different scenario hypotheses. Although it is sure that changes will take place, it is hard to forecast whether there will be a growth or decrease and for which ecosystem services. It is likely that not all ecosystem services will change following the same trend: trade-off assessment can thus help to locate where and for which ecosystem services major changes (improvements or deterioration) takes place. It is rather likely that the change in some ecosystem services will lead to a change also in those market values of man-made commodities, for which Figure 8 provides an example.

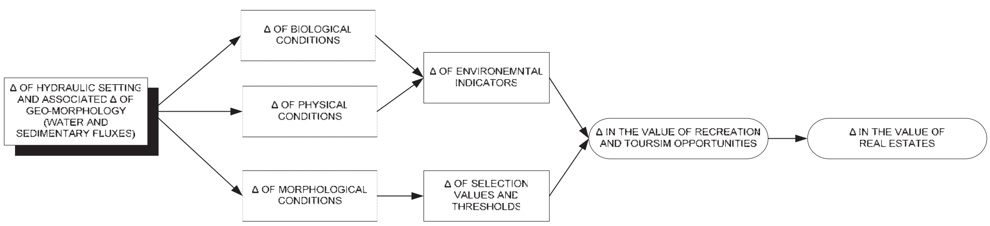

Fig. 8. Linkages between changes and market assets

6. Exploratory spatial data analysis

The planning of biodiversity conservation has been previously treated in a spatially explicit way (Chen et al., 2009), in order to compare the level of spatial association between biodiversity conservation priorities and other ecosystem services. We add to the list of planning priorities the presence of market assets aiming at integrating the bundle of possible land use planning objectives, treating the trade-off between conservative and consumptive priorities.

Table 10 reports the Pearson's correlation indexes, determining how much each ecosystem service and market assets (sum of agricultural production and real estate values of the stock of built environment of the island) tend to be co-located in the same land parcel. The recreational services are more associated (overlapped) to flood prevention (0.40), and in a weaker but appreciable way to genetic diversity (0.30). Trade-offs between the presence of market values and ecosystem services are revealed by negative correlations at a very low level with biodiversity (-0.07) and flood prevention services (-0.04).

Table 10. Correlation matrix of value components

	Flood prevention	Diversity	Recreational	Market assets
Flood prevention	1			

Diversity	0.2555	1		
Recreational	0.4039	0.3091	1	
Market assets	-0.0445	-0.0761	0.0823	1

The popular Moran index is used to explore the level of interconnection (i.e., the presence of spatial autocorrelation across the economic values of ecosystem services in neighbor patches). Its general form is specified as follows:

$$Z(I) = \frac{\sum_i \sum_j w_{ij}}{N} \cdot \frac{\sum_i \sum_j (X_i - \overline{X}) \cdot (X_j - \overline{X})}{\sum_i (X_i - \overline{X})^2},$$

where N is the total number of spatial units (the patches, or cells of the grid), i is the generic cell and j all of the other (surrounding) cells, and w_{ij} are taken from the NxN spatial weight matrix, now describing the structure of the relationship of contiguity between units (Anselin, 1988). The criteria adopted here includes, in the subset of neighbors, those j cells contiguous to each i cell, sharing a part of their boundary (either sides or corners) with i. A test allows us to confirm if the level of spatial association pointed out by the index value $Z(I)$, is statistically significant, when the ecosystem services values tend to be spatially linked through non-random and organized patterns. The Moran I is statistically significant for all the value components at a 99% level. Values of the $Z(I)$ (Table 11) confirm a strong positive relationship of each value component between a single patch and its neighbors, with values that give clear evidence of positive spatial autocorrelation.

Table 11. Spatial autocorrelation of value components (spatial weighting matrix with a nearest neighbor criteria with threshold at 150 meters)

	Total St. Erasmo area	Island only	Surrounding areas
	Z(I) [p-value]	Z(I) [p-value]	Z(I) [p-value]
Market assets	0.7222 [0.0010]	0.7014 [0.0020]	0.6159 [0.0000]
Opportunities for recreation and tourism service	0.9409 [0.0020]	0.9278 [0.0020]	0.8785 [0.0020]
Flood prevention and waste treatment services	0.7447 [0.0010]	0.8685 [0.0022]	0.6159 [0.0000]
Services related to the maintenance of life cycle of migratory species and of genetic diversity	0.8849 [0.0011]	0.6541 [0.0010]	0.8110 [0.0000]

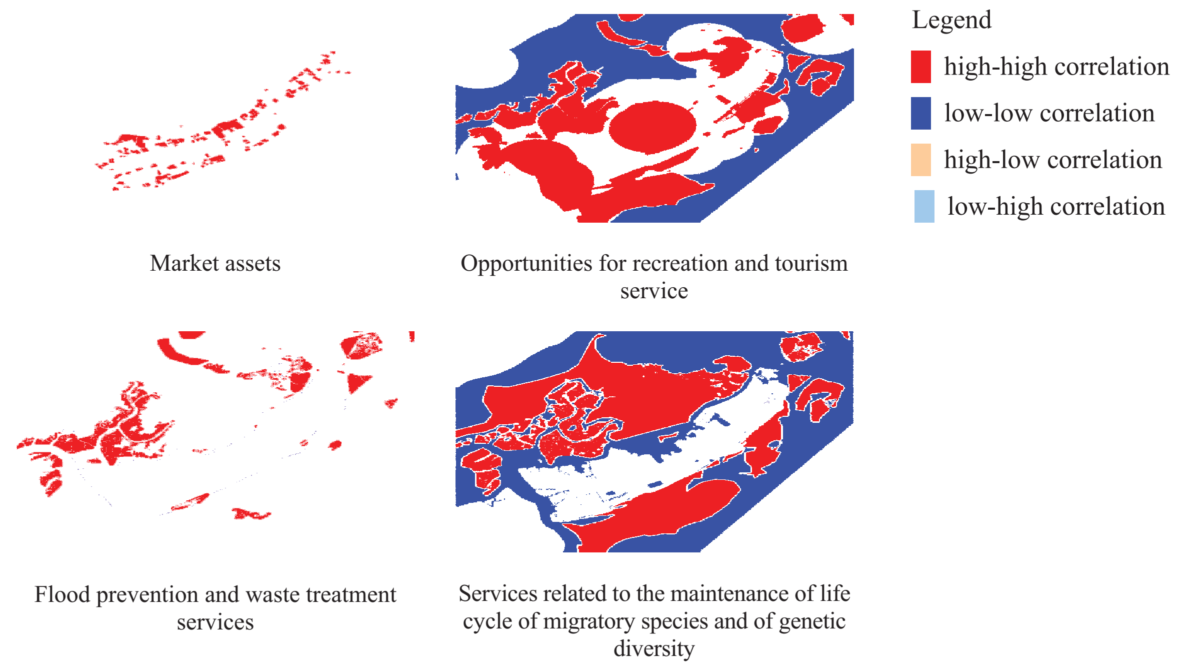

Fig. 9. Maps of the local index of spatial association for TEV components

The pattern of values from market assets as real estate and agricultural productions has a $Z(I)$ of 0.76; for the recreational benefit we obtain a value of 0.94, while for the protection 0.76; $Z(I)$ is 0.89 and 0.78 respectively for biodiversity and carbon sequestration. The recreational values exhibit the highest level of autocorrelation. This first test (Table 11) confirms the theoretical expectation of spatial patterns of values that are not randomly distributed in the island space, with a quite high level of similarity (homogeneity) of neighbor areas.

The concept of spatial dependence points out a more specific type of correlation across areas, as occurred in the case of hierarchical linkages, agglomeration due to localized spillovers or clusters. This is examined here through the Local Index of Spatial Association (LISA, Anselin 1995). The Moran *I* can be considered as an average of individual specific covariance values. It is a local adaptation of the global Moran *I*, which permits mapping levels of autocorrelation for each specific location. The values of LISA, statistically significant at the 0.05 level for all the economic components of value, are mapped in Figure 9. The autocorrelation of values of market assets is, as previously mentioned, strictly associated with a central corridor on the island, corresponding to the portion of the built-up area mixing residential and commercial productive services. Both the Moran and the LISA analyses have been iteratively repeated on grids of bigger sizes, confirming the stability of these results[1] to the scale of aggregation of data. The LISA clusterization help in classifying how different type of value components (market assests, ecosystem services) are related across space. Beyond testing the existence of spatial patterns. From a practitioner and policy maker perspective, some insights form such an analysis can help to coordinate land use and conservation strategies, and help to find those sub-areas where more type of values components are at the same time overlapped and intertwined to other zones.

Conclusions

Conservation and environmental safeguards are highly debated issues; worldwide and large financial resources are devoted to protect ecological, environmental, economic and social features of important ecosystems and protected areas. Climate change may have a dramatic impact upon these areas, which in many cases can be found in the most vulnerable coastal areas, where both temperature modification and variation in tidal ranges may put vital ecological and economic areas at risk.

Economic and ecological resources will be threatened and in the future a continuous financial effort is expected in order to mitigate and adapt to the foreseen changes, while at the same time many voices call for finer environmental regulation. Achieving old and new goals of conservation, and environmental safeguards, while enhancing economic development, is a major challenge in the European Union where sustainability is assumed as a common goal for policymaking. Within this vision, economic valuation offers an important tool to examine and compare policies and public interventions, taking into consideration both cost and benefits accruing to communities.

[1] Supplementary maps and tables are available on request to authors.

As stated by Daily et al. (2000) putting theory into practice requires locally-based information.

This study provides the opportunity to elaborate a complex valuation exercise of a specific valuable ecosystem located within the Lagoon of Venice, a World Heritage Site since 1987 and a complex ecosystem created by the co-evolution of ecological and economic functions. The purpose is to highlight the necessity to improve our awareness of ecosystem services' values in providing a contribution to human well being and to develop finer valuation tools. The assessment undertaken for the island of St. Erasmo is based on some crucial and controversial elements such as a multi-datasets approach, the development of a flexible procedure, and the introduction of 'space' in both assessment and results analysis.

The economic results obtained through this valuation process could be used in several different ways. Impacts of specific economic/environmental policies could be simulated and their effects over different functions could be monitored. We calculate the value of ecosystem services which are not visible by the market. The relevance of these services could address many conservation policies that often need to be supported by a proven economic value (McNeely, 1988). Another potential use is related to environmental damage calculation where the functional approach (APAT, 2007) facilitates damage assessment and thus valuation.

The St. Erasmo case study emphasizes important dif-ferrences in value calculations especially when physical and biological features are present, and together with size and distance, they play a very significant role in the determination of the extent of monetary attribution and overall value. Moreover, the correlation analysis offers interesting results on the co-location and interconnection among areas. It could be used to assign priorities conservation policies where more ecosystem services are more densely interconnected and overlapped in space. The Moran *I* clearly shows that all the components are not structured according to a random spatial distribution while the LISA analysis showed that the detailed scale of the spatial unit of GIS data can become a suitable tool for the calibration of policy actions, either in zoning, or in the choice of conservation strategies aimed at assigning localized priorities. On the other hand, we realize that this study is only a starting point and more applications on different ecological systems and over different scales are needed. The issue of which patch unit to adopt, what degree of resolution to use, how to process 'per person value' to calculate 'per-hectare value', how to link environmental indicators to a hierarchical range for monetary attribution when there is no reference scheme at international (or national/sub-national) level, still need to be improved and refined in order to prove robustness and consistency.

Furthermore, the use of per-hectare monetary indicators of value does not imply particular limits or weaknesses if referred to market assets. The adoption or transfer of indicators elicited by stated preference or other valuation techniques imply that all the assumptions and decisions of analysts can affect the final results of each monetary measure of ecosystem values. Avoiding the presence of subjective and arbitrary components is difficult or rather an impossible task, but a sensitivity analysis can represent a possible future line of research to be developed.

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