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Summary

Safeguarding the future of Venice is a globally recognised challenge of urban sustainability. We propose a sustainable management model, alternative to the current strategy, that primarily focuses on the built heritage and which interprets the city together with its encircling lagoon as a matrix of interlinked natural, cultural and social capital. In particular, Venetian natural capital can be valued as a stock of wealth that produces a flow of income, its ecosystem services. Such values can be measured in economic, including monetary, terms. Using the examples of salt marsh and seagrass carbon sequestration, together with sediment retention, water purification and artisanal fishery and aquaculture, we show that it is economically viable to develop and reorientate the near-future trajectory of Venice and its lagoon with reference to a more sustainable pathway, where the natural capital is a driver of future economic development and, as such, is comparable with the value of currently dominant economic activities (port and mass tourism).

Keywords: Natural Capital, Ecosystem Services,Eecosystem Services Economic Valuation, Sustainability, Venice Lagoon, Alternative Management Strategies
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Rethinking Venice from an Ecosystem Services Perspective

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Abstract

Safeguarding the future of Venice is a globally recognised challenge of urban sustainability. We propose a sustainable management model, alternative to the current strategy, that primarily focuses on the built heritage and which interprets the city together with its encircling lagoon as a matrix of interlinked natural, cultural and social capital. In particular, Venetian natural capital can be valued as a stock of wealth that produces a flow of income, its ecosystem services. Such values can be measured in economic, including monetary, terms. Using the examples of salt marsh and seagrass carbon sequestration, together with sediment retention, water purification and artisanal fishery and aquaculture, we show that it is economically viable to develop and re-

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Keywords: natural capital, ecosystem services, ecosystem services economic valuation, sustainability, Venice Lagoon, alternative management strategies

Jel Code: Q56, Q57, R58

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1. Introduction

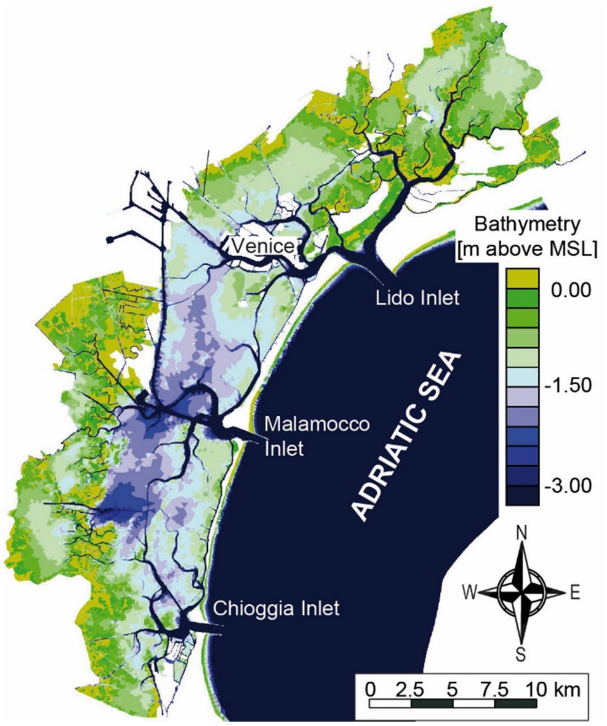
The current activities of dominant economic stakeholders and policymakers support behaviour patterns in the Venice lagoon environment that are based on high, short run profit objectives. This generates both short and long-term externalities, ranging from the socio-cultural (both city congestion and at the same time depopulation[1]) to the environmental (including air pollution, land degradation and damage to building foundations by boat wakes and lagoon erosion due to displacement of large volumes of water by ships[2]). Additionally, Venice suffers from longer-term ecological degradation, including loss of topographic complexity on the lagoon floor, a sediment exporting budget, wetland loss (-80% since early 17th century), high nutrient and pollution loads, and from sea level rise and an increased frequency and severity of high water events[3-9].

As a radical alternative to the unsustainable current situation[1], we here discuss the possibility of managing the city and its lagoon with reference to a more resilient pathway, where natural capital, and derived ecosystem services, are the focus and drivers of future economic development.

In our framework, Ecosystem Services are defined as the supporting, provisioning, regulating and cultural services[17, 18]. These services are identifiable and can be measured in both ecological/physical terms, and in economic terms, including monetary terms. Natural Capital is the stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits– ecosystem services - to people[16].

Rethinking Venice from a natural capital and ecosystem services perspective is not a purely academic exercise, but rather a policy tool to reconnect management of the lagoon and management of the historic city within a long-term perspective.

The Venice lagoon extends over 550 km^2. It is characterized by a semidiurnal microtidal range (average tidal range of 1 m) and connected to the Northern Adriatic Sea by three inlets (Fig. 1).



The lagoon, permeated by channels, tidal creeks, artificial waterways and canals[10], is characterised by subtidal flats (with bottom elevations at ca. -0.50 to -2.5 m below mean sea level (msl)), in places vegetated with seagrasses; intertidal mudflats (-0.5 to 0.0 m below msl); salt marshes (+0.1 and +0.6 m above msl); 'valli da pesca' (semi-enclosed basins for aquaculture located at the borders of the lagoon); and land surfaces (consisting of supratidal sandbars, 'casse di colmata' (i.e. land reclamations left to renatuaralise) and settled islands).

Preliminary investigation of ecosystem services has been undertaken for the lagoon, initially of provisioning and cultural services[11], subsequently extended to include regulating services[12]. Here

we build on this work to present quantitative estimates of the current economic value and gross value added (GVA) to gross domestic product (GDP) per year, of those ecosystem services for which calculations are variously possible. Future economic value is estimated under the assumption of both i) a sustainable management scenario, where the natural resource/natural capital is managed with policies directed at preserving, maintaining and possibly increasing the stock of natural capital; and ii) a business-as-usual (BAU) scenario, assuming the continuation of current management practices.

The note is organized as follows. Section 2 reports the economic valuation methodology. Section 3 presents the main results. Section discusses the findings and alternative, sustainable management strategies for the city. Section 5 concludes.

2. Valuation Methodology

The monetary figures are calculated and derived from the existing literature and surveyed studies with criteria illustrated in what follows. As a preliminary caveat, we acknowledge that estimates of both the market and non-market value of ecosystem services are subject to significant uncertainty bands, and in some cases it has not been possible to find any estimates in the literature nor raw data from the relevant authorities. Up to date data availability for Venice, across the spectrum, has been challenging.

2.1.Regulating services: Carbon sequestration by salt marsh and seagrass

We calculate separately the carbon sequestered by salt marshes and seagrass beds, considering only the amount of organic carbon that is buried. We do not refer to carbon that is stored in the

aboveground / aquatic biomass of the vegetation (halophytes and seagrasses). The methodology for computing the amount of carbon sequestration and the data for the amount of salt marsh-sequestered carbon comes from Roner et al.[20]. The data for the amount of seagrass-sequestered carbon comes from the SeResto LIFE project[21], carried out in the Venice lagoon (2014-2018). Salt marsh annual sequestration rate is 1.32 tons of carbon per hectare per year. The area of salt marsh in the Venice lagoon is estimated at 4,300 ha. Seagrass annual sequestration rate was found to be 40.1 tons of carbon per hectare per year[21]. The area of seagrass beds in the Venice lagoon is estimated at 4,200 ha[21]. We use estimates of the social costs of carbon (SCC)[22] to calculate the net present value of the cumulative, worldwide impact of an additional ton of carbon emitted to the atmosphere today over its residence time in the atmosphere[23]. We compute the yearly value of the flows of benefits that the Venetian marshes and seagrasses generate by the sequestration of atmospheric carbon. This is a flow value that relates to the annual returns on the natural capital. It can also be interpreted as an avoided social cost, amounting to the values calculated with the figures provided by a report[24] which computes the SCC until 2050 based on different discount rates. Our selected discount rate is 3%.

2.2.Regulating services: Sediment retention and water treatment and purification

Based on the assumption that lower nutrient and sediment loads reduce the need for wastewater treatment, the value of waste treatment performed by the Venice lagoon is measured with the "replacement cost method"[25] which computes three different costs (12.61, 41.40 and 243.66 dollars per kilogramme) according to varying concentrations (low, medium and high, respectively) of nitrogen in the system. We acknowledge that these estimates refer to replacement costs for a freshwater lagoon. To our knowledge, it is the only existing study that

estimates the value of sediment retention in a lagoon via the replacement costs methodology. Although denitrification can be different for a fluvial watershed and a tidal lagoon, the study contains a reasonable, applicable variance between minimum and maximum economic costs that allows us to determine values which are realistic estimates of the alternative treatment system, including, but not exclusively, infrastructure. The cost relating to a medium concentration of nitrogen was used here, converted to euro. It is worth highlighting that the denitrification capacity of the Venetian Lagoon varies considerably spatially and at different times of year, also depending on the amount of nitrogen inputs, the residence time and the presence/absence of marshes and seagrass meadows. The estimated amount of nitrogen in the Venice lagoon is taken from ref. 26. It is estimated that 75% of these inputs is retained, to yield the amount in tonnes to be treated, in various ways, each year. Using this same approach, comparably high values were obtained for computing the ecosystem services of removing nitrogen, phosphorus and carbon in a study of seven different temperate coastal biotopes in the UK[27]. The future value under the sustainable management scenario was calculated using a standard 3% interest (as applied to carbon sequestration).

2.3. Provisioning services: Traditional fishery and aquaculture

Figures for this section are limited by data availability specific to the productivity of the Venice lagoon[28] and excludes some types of fish that are bundled in total data for the Veneto. There are also other fish species that divide their life-cycle between the Venice lagoon and the Adriatic Sea. The numbers reported here are therefore a low estimate of the total value of this category. Lagoon clams (10,274 tonnes in 2018) constitute over 40% of total value of fisheries and

aquaculture for the Veneto Region[28]. The residual value used as the "current economic value of the ecosystem service" refers specifically to the produce and excludes other elements of the supply chain (e.g. labour and equipment). It is calculated using the methodology of the UK Office of National Statistics[29]. The future value under the sustainable management scenario was calculated using a standard 3% interest (as applied to the other regulating ecosystem services above) and based on the assumption that the current management policy is sustainable.

3.4. Cultural services: Eco-tourism and lagoon recreation

There are no available figures for ecotourism and lagoon recreation in Venice. We have simulated this value for the future using research that models demand generated by an additional one percent of well conserved wetland. This potentially attracts 18,490 additional "eco-tourists", distributed amongst the islands of the lagoon[14]. According to the 2017 Tourism Census of the Venice Municipality[30], the non-day tripper segment of tourists spends on average three days (two nights) in Venice. The average expenditure per tourist, for the period, is around 800 euros (266.67 euro/day). The most recent available estimate of visitor fluxes in Venice reports that in 2014, this segment was made up of 6.4 million tourists (compared to 2.7 million in 2002). This indicates the sharp growth in arrivals.These estimates might be useful in showing the advantages of the transition from a local economy dominated by mass tourism (principally day-trippers) associated with significant negative externalities in the historic city to a new concept of sustainable tourism that builds on ecosystems and natural resources.

3.5 Cultural and Cruise tourism

One significant ecosystem service provided by the lagoon is the attenuation of tidal currents that also protects the historic city, in terms of its urban fabric. Hence the inclusion of the total value of the tourism sector[31] in Table 1. Tourist numbers were sourced from ref. 30. Data on GVA (2018) was obtained from the Chamber of Commerce[32]. For bequest and existence value, we use the non-market values estimates[31] for Venice cultural heritage (per person), multiplied by the number of tourists visiting Venice in 2017[30]. Bequest and existence values are therefore estimated at 484 million euro (capital value). Cruise ship numbers and GVA (2019) are taken from the Port Authority[13]. Data on total tourism and GVA (2018) is from the Chamber of Commerce[32].

3. Results

Results are summarized in Table 1[1], which reports the economic value (measured in monetary terms of selected Lagoon ES). We can highlight some findings.

Salt marsh and seagrass carbon sequestration, together with sediment retention and water purification, and artisanal fishery and aquaculture, generate ca. 198.9 million euro per year, a value that can be compared to the annual returns from the cruise ship sector (376 million euro for the Venice area[13], especially considering that a small proportion specifically benefits the economy of the lagoon and the historic city where most of the environmental and social costs occur) and without the negative externalities of the cruise ship sector impacting the lagoon system and the socio-economic fabric of the historic city. We note that other ecosystem services are mentioned in the literature[11, 12.] No figures are available to compute their contribution to

[1] (R): Regulating Service. (P) Provisioning Service. (C) Cultural Service. (S) Supporting Service.

annual GDP but we acknowledge their potential significance. The adoption of a sustainable pathway, with less mass tourism and more eco-tourism, also offers the possibility of generating additional financial flows from cultural ecosystem services.

Thus, for example, the additional demand generated by an additional one percent of well conserved wetland could attract 18,490 'eco-tourists', to be redistributed and relocated amongst the islands of the lagoon. This cohort could generate an additional annual income of 15 million euros from tourism and recreation[14].

Under a sustainable management scenario, in the longer term (2050), salt marsh and seagrass carbon sequestration, together with sediment retention and water purification, and artisanal fishery and aquaculture, could generate more than 375 million euros, whereas the cruise sector returns are likely to decline with reduced attractiveness of Venice as a destination (Table 1) and as a consequence of the increase in the frequency of closures of the mobile barriers system as sea level rises[15]. It is important to highlight that Column 4 reports the gross value added (per year) of the selected ecosystem services. Many of these are embedded in economic accounts at both local and national levels, e.g. agricultural and fishery output, tourism and some recreational activities and transport. In these cases, the contribution of the ecosystem services to the gross value added can be estimated by extracting the contribution of all other factors (e.g. the parts attributable to capital and labour) and allocating the balance to the ecosystem. This has been done to prepare accounts for natural capital in some countries, such as the UK and The Netherlands, for

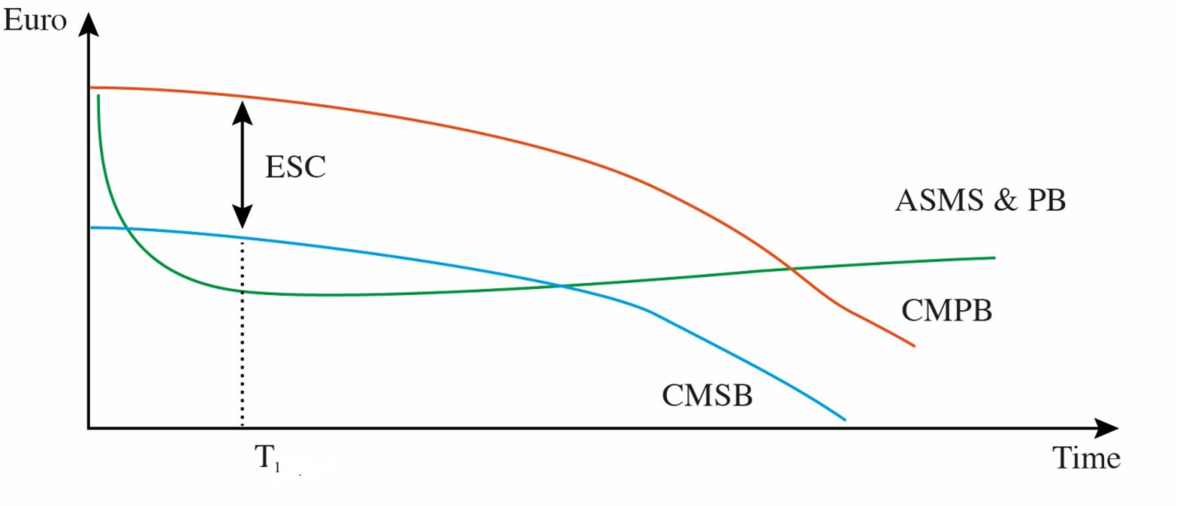
agriculture and fisheries[29]. Twenty percent of the GVA has been assigned as the current economic value of ecosystem services for traditional fisheries and aquaculture in Table 1[2].

[2] A second method is to estimate the value based on a 'production function', in which the inputs include non-produced inputs from ecosystems as well as from labour, land and other contributions. Regarding ES economic valuation and data for Venice we do not, at the present time, have such 'attributable fractions'

ECOSYSTEM SERVICE	Contribution of ecosystem service (amount/year)	Current Economic Value of ES (Euros/year)	Gross Value Added (GVA) to GDP (Euros/year)	Future Value in 2050 under Sustainable Management (Euros)	Future Value under Business as Usual (Euros)
Carbon Sequestration Salt Marsh (R)	Carbon sequestration 5,700 tonnes	187,110	0	419,580	Likely to decline due to marsh degradation
Carbon Sequestration Seagrass (R)	Carbon sequestration 168,420 tonnes	5,557,860	0	13,490,385	Likely to decline due to seagrasses loss
Water Purification and Sediment Retention (R)	Annual nitrogen load entering the lagoon 6,650 tonnes	174,650,000	Most of the GVA is attributable to the ecosystem	316,354,300	Likely to decline as capacity of the lagoon to absorb nitrogen declines
Traditional Fishery& Aquaculture (P)	Mullet (valli da pesca) 500 tonnes Lagoon clams 10,274 tonnes Lagoon mussels 4.164 tonnes	18,514,000	92,570,000	44,938,330	Likely to decline as quality of lagoon degrades
Eco-Tourism and Lagoon Recreation (P/C)	No. visitors attracted to the natural features of the lagoon	Not considered therefore 0	0	An additional 1% of well conserved wetland would produce around €15m for tourism and recreation	Likely to decline alongside deterioration of environmental quality and natural capital
Cultural Tourism (C)	29 million visitor-days (presences) in historic city (2018)	Not estimated	741,000,000	Should be smaller considering generally accepted situation of over tourism	Expected to decline as quality of experience continues to deteriorate

4. Discussion

The values presented here allow the comparison of different management strategies, as illustrated in Figure 2.



In Figure 2, the x axis maps time (from the current state) and the Y axis maps values (measured in monetary terms). The red downward slope is the 'current management private benefits' (CMPB) curve. It illustrates private benefits, in monetary terms, generated by Venice's current, tourism-intensive economy. The blue downward slope is the 'current management social benefits' (CMSB) curve, representing the social benefits. It is positioned below the CMPB to highlight that private benefits are larger than social benefits as the environmental externalities (the segment ESC) are not considered. Both functions are non-linear because they capture and embody complex relationships (including technology and preference structures) and both are downward sloping with time, due to the unsustainability of the current management of Venice and its lagoon. By comparison, the green curve represents 'alternative sustainable management social and private benefits' (ASMS&PB). It represents sustainable management of the city and its lagoon that may produce lower benefits in the beginning (because some extra investments in transition (technology, training etc.) might be required) but presents the twofold advantage of

internalizing any negative environmental externalities and generating stable (or even increasing) returns in the long term.

5. Conclusions

The Venetian Lagoon produces ecosystem services with clear economic value. The value of those services, if correctly managed and measured, and with the benefits distributed more equitably and locally, according to estimates based on currently available information (Table 1), could substitute the value produced by less sustainable economic activities. Obviously, the transition from a city with an economy dependent on quick returns associated with mass tourism to a more sustainable, but in the short term less profitable, model would have to be implemented carefully.

The associated strategic planning aspects are beyond the boundaries of the present paper, which aims to scientifically frame the potential for change and the need for deeper investigation. This exercise has produced general indications of the potential contribution that healthy ecosystems could make to overall wellbeing, as measured in monetary terms. Such analyses demonstrate the importance of natural capital relative to other assets and aid in the justification of measures to protect the Venice lagoon that require the allocation of scarce resources.

This framing should trigger more sustainable policy-making for Venice and its lagoon, with associated higher economic returns in the long term. The resulting well managed ecosystems and natural capital could also support the preservation of the city's cultural capital.

Cultural capital is 'an asset that embodies a store of cultural value, separable from whatever economic value it might possess; in combination with other inputs the asset gives rise to a flow

of goods and services over time which may also have cultural value (i.e. which are themselves cultural goods and services)[19].

Thus, for example, salt marsh reconstruction is also a nature-based solution to attenuating water levels and consequently helping to protect the built fabric. The generated economic value is fundamental to guaranteeing the survival and continuity of the social capital of this remarkable and unique city.

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