AN INTEGRATED APPROACH TO PREVENT THE EROSION OF SALT MARSHES IN THE LAGOON OF VENICE

Alberto Barausse*, Laura Grechi, Nevenka Martinello, Tommaso Musner, Dario Smania, Alberto Zangaglia, Luca Palmeri

LASA – Environmental Systems Analysis Lab, Department of Industrial Engineering, University of Padova, Italy

* Corresponding author E-mail: alberto.barausse@unipd.it

Abstract

The loss of coastal habitats is a widespread problem in Europe. To protect the intertidal salt marshes of the lagoon of Venice from the erosion due to natural and human causes which is diffusely and intensely impacting them, the European Commission has funded the demonstrative project LIFE VIMINE. LIFE VIMINE aims to protect the most interior, hard-to-access salt marshes in the northern lagoon of Venice through an integrated approach, whose core is the prevention of erosion through numerous, small but spatially-diffuse soil-bioengineering protections works, mainly placed through semi-manual labour and with low impact on the environment and the landscape. The effectiveness of protection works in the long term is ensured through routine, temporally-continuous and spatially-diffuse actions of monitoring and maintenance. This method contrasts the common approach to managing hydraulic risk and erosion in Italy which is based on large, one-off and irreversible protection actions. The sustainability of the LIFE VIMINE approach is ensured by the participatory involvement of stakeholders and the recognition that protecting salt marshes means defending the benefits they provide to society through their ecological functions, as well as protecting the jobs linked to the existence or conservation of this habitat.

Keywords: *salt marsh erosion, Venice lagoon, soil bioengineering techniques, sustainability*

1. Introduction: the erosion of coastal habitats in Europe

The gradual loss of coastal habitats, such as intertidal salt marshes, sand and mud flats, seagrass beds, coastal dunes and beaches, is a widespread problem in Europe. About 15'000 km of European coasts are actively retreating and the area lost or seriously impacted by erosion is estimated to be 15 km^2 per year (EEA, 2006). The Mediterranean coasts display the longest stretch of the coast affected by erosion (30%), while in the Black Sea and North Sea regions erosion is impacting 13% and 20% respectively of the coast length. The Atlantic Ocean coasts have the highest □rends in growth of artificial surfaces. In the whole Europe, the estimated loss of wetlands and seagrasses habitats exceeds 50% of the original surface with peaks of 80% in some countries (Airoldi and Beck, 2007). Coastal habitat loss is driven by multiple natural processes (e.g. waves and currents induced by wind and tide, sea level rise) and anthropogenic causes (e.g. alteration of hydrodynamics or sediment

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budgets, tidal restrictions, impoundments, diking, introduction of invasive species, fishing, nutrient enrichment, high-energy waves produced by motor boats, human-induced soil subsidence). Coastal ecosystems are among the most productive systems in the world, sustain a rich biodiversity and contribute to maintain several ecosystem services (Costanza et al., 1997) which support human well-being.

These services include provisioning services (i.e. supply of food or energy resources and natural products), regulation and support services (i.e. water quality regulation, functions of nursery and shelter for marine life, carbon sequestration, buffering from floods and storms) and cultural services (e.g. opportunities for tourism and recreation).

Aiming at reducing the loss of coastal habitats and biodiversity, the European Union (EU), through its Natura 2000 network, has designated special coastal sites to be protected covering approximately 15% of the European coastal zone (EEA, 2006). This network is the EU's principal policy instrument for ensuring the conservation of valuable habitats and species and it includes sites designated under the Habitats Directive (Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) and under the Birds Directive (Directive 2009/147/EC on the conservation of wild birds). The EU's LIFE+ financial instrument contributes to the implementation of these directives and support the further development and implementation of the Natura 2000 network with a focus on long term sustainable conservation.

Concurrently, the environmental policy of the EU is aligning itself to the wider framework integrating nature conservation and human well-being as described for example in the Millennium Ecosystem Assessment (MEA 2005), whose foundation is the concept of "ecosystem services", which are the benefits that people obtain from ecosystems. To make decision makers better aware of the societal importance of the benefits that we obtain from ecosystems, it is important to value ecosystem services from the economic and social point of view (see the European Commission's Biodiversity Strategy to 2020, COM (2011) 244 final). The ecosystem services framework helps to reconcile local socio-economic development with nature conservation.

The lagoon of Venice in Italy is a paradigmatic example of the close link between man and the environment; there, the lagoon ecosystem and society have co-evolved for centuries. Venice would not have grown without the lagoon, and the lagoon would not exist anymore without the past protection actions of man, even dating back to the Serenissima Republic of Venice and before. Such deep connection is highlighted by the fact that it is "Venice and its lagoon" which were inscribed on the World Heritage List of the United Nations Organization for Education, Science and Culture (UNESCO) in 1987. The lagoon ecosystem, the biodiversity it hosts and the services it provides are now threatened by multiple human pressures, of which erosion is perhaps the most outstanding example.

This paper presents the approach proposed by the project LIFE VIMINE (www.lifevimine.eu), funded by the EU's LIFE+ financial instrument, to contrast the erosion of intertidal salt marshes (known as *barene* in Italian) of the lagoon of Venice and ensure their sustainable conservation in the long term.

2.The Lagoon of Venice and erosion

The lagoon of Venice, north-eastern Italy, is the largest wetland along the coast of the Adriatic Sea and one of the most important coastal lagoons in Europe due to its surface (about 550 km^2), high productivity, valuable habitats and history. This shallow (mean depth 1.1 m) coastal lagoon is separated from the sea from two elongated islands, with three inlets permitting the exchange of water with the Adriatic. The lagoon can be divided in three distinct water bodies: the central lagoon (400 km^2), only partly covered with macro-algae and seagrasses, and the southern and northern parts of the lagoon, which host tidal flats (*velme* in Italian) and intertidal salt marshes supporting a rich biodiversity. Salt marshes are a key tidal landform of the lagoon. They are crossed by a network of creeks and channels and are surrounded by other typical morphological elements such as tidal flats and vegetated or bare bottoms. They are regularly submerged during tidal cycles, but complete flooding occurs only during pronounced high tide (D'Alpaos, 2010). The soil of salt marshes is composed of silty and clayey sediments with a high organic component. Salt marshes are generally covered by halophytic, specialized and largely herbaceous vegetal species adapted to the high soil salinity (Bonometto, 2003). An important feature of this habitat is the continuously evolving morphology resulting from dynamic interactions between erosion and sedimentation processes connected to tidal currents, wave energy, suspended sediment fluxes and the presence of vegetation that stabilizes the ground.

The whole Venice lagoon is affected by widespread erosion which impacts all its typical tidal landforms. Over the past century, the surface of salt marshes has strongly decreased (from 170 km^2 in 1901 to 47 km^2 in 2003, i.e. –72%; D'Alpaos, 2010), with a concurrent deepening of lagoon bottoms; erosion is still ongoing. Another striking effect of erosion is the flattening of the bottom topography (Carniello et al., 2005), a process linked to disappearance of salt marshes which leads to the accumulation of eroded sediments on the surrounding tidal channels.

Erosion is caused by a mixture of both natural and human processes. Among the natural causes, there are tidal currents and wind-induced waves, whose combined effect is the resuspension and transport of sediments out into the sea. The ability of the wind to generate waves, and thus transmit shear stress to the lagoon bottom inducing resuspension, increases with wind speed and fetch length, which in turn depends on salt marshes whose presence limits the fetch itself (D'Alpaos, 2010). Thus, the disappearance of salt marshes is a cascading, self-reinforcing process. Anthropogenic causes are numerous, such as the nearly absence of riverine sediment and freshwater inputs to the lagoon, due to the diversion of major rivers driven out of the lagoon by the Venetians over the past centuries to prevent the lagoon from being filled up with sediments (indeed at the time sedimentation rather than erosion was the problem). Other key causes are the construction of long jetties at the inlets and the excavation of deep lagoon channels to allow the passage of

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large cruise and cargo ships, which have modified the system of lagoon currents. The combined effect of these human actions is a net negative sediment budget for the lagoon: more sediments are lost to the sea with respect to those that enter the lagoon and can rebuild salt marshes. Smaller daily activities carried out in the lagoon also contribute to erosion: motor boats generate waves that erode bottoms and salt marsh borders, while clam fishing resuspends sediments and destroys the microphytobenthos film which stabilizes the lagoon bottoms, thus speeding up the loss of sediments to the sea (D'Alpaos, 2010). Finally, salt marshes are endangered by soil subsidence (due both to natural soil consolidation and human extraction of groundwater) and sea level rise, which can submerge them if the combined effect of these processes is quicker than the capacity of salt marshes to build up soil.

3. Techniques to protect salt marshes in the lagoon of Venice

The above mentioned human causes of the gradual erosion of tidal landforms in the lagoon have clear socio-economic drivers and thus are linked to our lifestyles and models of development, i.e. issues that can be tackled only in the medium-long term. In the meanwhile, actions are urgently required to protect the lagoon morphology and preserve the outstanding ecological, cultural and socio-economic values of its tidal landforms. Salt marshes are a distinctive trait of the lagoon landscape and a key functional element of the ecosystem due to their ability in providing various services, such as their influence on tide currents, e.g. they act as buffer zones dissipating current and wave energy and mitigating their erosive effect on other surrounding emerged surfaces (coastal hazard mitigation) and canal banks (Shepard et al., 2011, King and Lester, 1995). Salt marshes play a key role in the cycling of nutrients (Valiela and Teal, 1979), sequestrate CO_2 (Chmura et al., 2003), abate pollutants (Kadlec and Knight, 1996), and provide food, shelter or nursery habitats to fish, crustaceans and birds thus supporting biodiversity as well as coastal fisheries (including traditional fishing, in the case of the lagoon of Venice) and hunting activities. Lastly, their beauty and the animal and plant species they host provide opportunities for eco-tourism and recreation.

The following short non-exhaustive overview classifies in two categories the current protection measures acting directly on the lagoon morphology in order to defend existing salt marshes: local protections of salt marsh edges and techniques to promote sedimentation or soil stabilization. For a more complete review see Bonometto (2003); we will not discuss attempts to affect the sediment budget or the system of currents at the lagoon scale, nor restoration actions such as the construction of artificial salt marshes. Local protections of salt marsh edges essentially differ in their capability to contrast wave energy and in their environmental impact and durability. Screens of wooden poles or gabions are used when the salt marsh edge undergoes intense erosion. A *screen of wooden poles* is composed by poles placed side-by-side along the salt marsh edge with a geotextile layer on the internal side (between the wooden screen and the edge). Bonometto (2003) discusses some issues of this technique: it is expensive since every meter of the screen needs about 4-5 wooden logs of carefully-selected resistant tree species, bulky instruments are needed to drive the poles into the ground, and screens repulse the wave instead of absorbing its energy. *Gabions* can be used as an alternative: they are tubular structures made by nets (in natural or synthetic fibre) filled with different materials (e.g. sediments, wooden fibres, branches, fascines, halophyte clods, sand, stones, shells), to be placed on the tidal flat close to the salt marshes edge. Gabions better dissipate wave energy but their duration strongly depends on the materials used (Bonometto, 2003). Gabions made of biodegradable materials need more frequent maintenance but they are more compatible with the naturally evolving lagoon morphology, than those made of synthetic or hard material. *Screens of wooden fascines* are an edge protection technique that has been experimented when the salt marsh undergoes low-energy erosion. Fascines are made of wooden branches wrapped in a plastic net.

Protection techniques for promoting sedimentation and soil stabilization include sediment pumping, sedimentation-inducing barriers, e.g. made of fascines to be placed on tidal flats, and the transplantation of vegetation (Comune di Venezia, 2001, Bonometto, 2003).

When designing protection works, it is fundamental to recognize some key principles that are also at the basis of the LIFE VIMINE approach. One is the transitional nature of salt marshes, not only in space, since they are located where the land meets the sea, but especially in time, as the lagoon landscape is constantly evolving. All protection works, to be efficient and not to change the nature of the habitats they aim to protect, should be designed by carefully considering the site-specific morphological and functional features and the evolutionary trend of the salt marsh area that is being targeted. Another one is the key role of the salt marsh edge, which represents an ecotone, i.e. the interface where the salt marsh and tidal flat habitats meet. Indeed local protection techniques are usually placed onto the salt marsh edge, thus their design should guarantee the ecological functionality of the edge. To satisfy these principles, the salt marsh should not be isolated, but protection works placed on the edges should reproduce the intrinsically-plastic character of natural systems, avoiding static elements and hard substrata (which would form a rigid and artificial habitat) and employing materials which are biodegradable, are easy to colonize by autochthonous plants and animals and preserve the exchanges (of water, matter, nutrients, organisms, etc.) between salt marshes and the lagoon. Such exchanges are fundamental for the proper functioning of the salt marsh ecosystem and the survival of the organisms they host. Indeed, the role of salt marshes ecosystems as nursery and refuge habitat is well-established (Beck et al., 2001). Deegan et al. (2000) analysed how estuarine dependent species seem to place juveniles in marsh habitats because they offer different benefits for the growth of young fishes (e.g. food provision, shelter, suitable physico-chemical conditions). Organic matter is transferred from salt marshes to fish through microbial and invertebrate intermediaries that frequent or live in the adjacent tidal flat. The salt marsh role as refuge habitat is probably due to a mixture of proper factors found close to or on salt marshes such as temperature, turbidity, shallow depth and vegetation reducing predation.

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4. The soil bioengineering protection techniques used in LIFE VIMINE

The demonstrative project LIFE VIMINE runs from 2013–2017 and aims to protect the most interior and hard-to-access salt marshes of the northern part of the lagoon of Venice, by implementing an approach based on the prevention of erosion through numerous, small but spatially-diffuse soil-bioengineering protection works, to be created mainly through semi-manual labour. Its core idea is to carry out regular actions of monitoring and ordinary maintenance of the landscape. The project area (Fig.1) is found between the mouth of the river Dese and the Lido inlet in the northern lagoon.

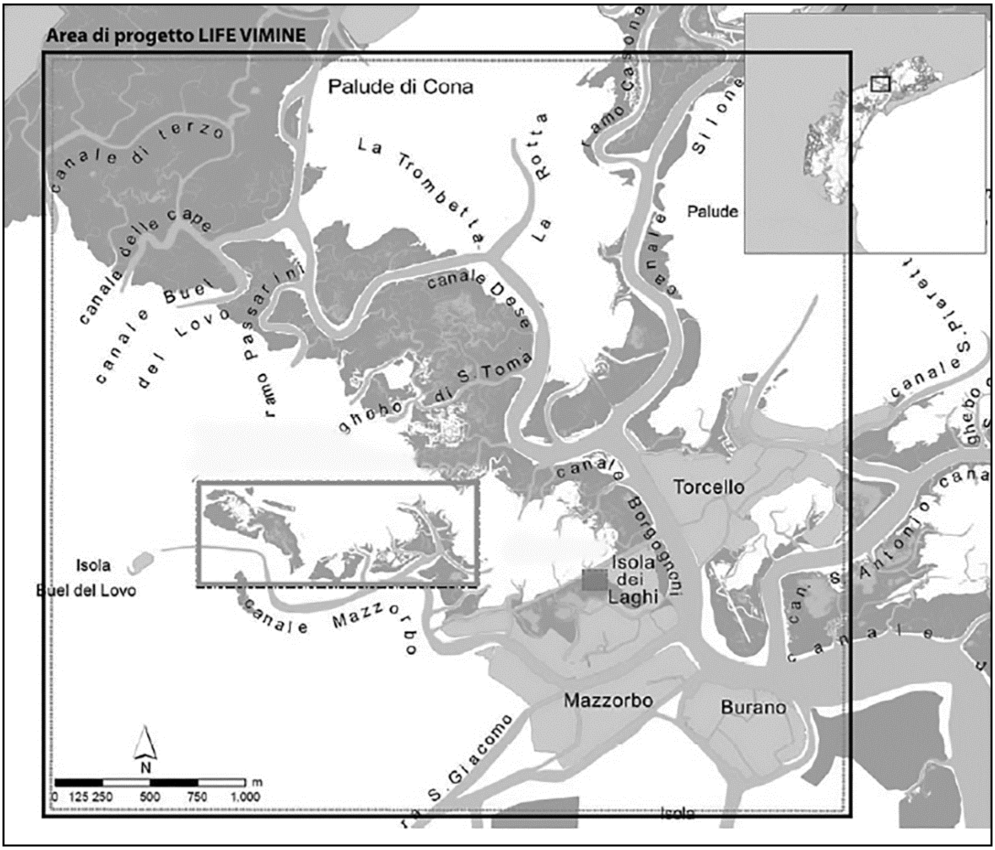

Figure 1. *The project area of LIFE VIMINE. The black rectangle indicates the area targeted by the project, while the smaller grey rectangle encloses the area where the installation and testing of protection works is most intense (cartographic base provided by Provveditorato Interregionale per le Opere Pubbliche per il Veneto, Trentino Alto Adige e Friuli Venezia Giulia – former Magistrato alle Acque di Venezia, processing by SELC Soc. Coop.).*

It is characterized by a high diversity of habitats, including two priority habitats (coastal lagoons and Mediterranean salt steppes) according to the EU's Habitats Directive. Human settlements (important to activate local participatory processes, see below) are found in the southern part of the area and are represented by small islands such as Burano, Mazzorbo and Torcello which have been inhabited for centuries. The area hosts interior and hard-to-access (due to the shallow bottoms and the intricate network of channels) salt marshes, among the best conserved ones in the lagoon. Even these delicate habitats are attacked by erosion (e.g. D'Alpaos, 2010) and their peculiarity and fragility demand for proper, non-invasive protection measures, as proposed by LIFE VIMINE. Novel techniques to protect these salt marshes are urgently needed, since current methods to combat coastal erosion (e.g. based on large boats and mechanical means) cannot be applied in this shallow habitats without the risk of damaging them during the construction phase.

The core of LIFE VIMINE are soil bioengineering works to protect the shallow interior salt marshes from erosion and concurrently promote sedimentation and halophyte colonization; through them, LIFE VIMINE aims to demonstrate an alternative to the emergency one-off actions and large irreversible (hence, inherently impacting the environment and the landscape) works which are common to contrast hydraulic risk and erosion in Italy. Such alternative is especially efficient and provides value for money in the peculiar context of the interior salt marshes, and relies on the implementation of a *prevention*-based approach characterized by the promptly defence and repair of the salt marshes edges through *many* (to contrast a diffuse erosion) but *small* protection works, installed as soon as such edges start to erode. To avoid the artificialization of the site, not all eroding spots are protected and repaired, but only carefully-selected ones which are critical to stop erosion before it gets out of control becoming impossible or too expensive to stop. Salt marshes are thus defended as a "system", both on the local salt-marsh scale, since only critical spots are defended, and on a larger wetland scale, since salt marshes which are critical to maintain a low fetch and avoid the abovementioned cascading erosion are protected as a priority.

In practice, the basic module of the protection works is the *fascine,* i.e. wooden branches wrapped in a vegetal net and tied together with vegetal cords (Figure 2). Its length is about 1.5–2.0 m and the diameter about 0.35–0.40 m. The fascines are installed by anchoring them to wooden poles using cords made of natural fibre. A guiding principle is that each site to be protected needs an *ad hoc* design of the work typology depending on the site morphology, its evolutionary trend, the state of the salt marsh edge and the characteristics of the erosion process, etc. Indeed the fascines are used to created different types of protection structures: the most common is the fascine barrier (here also referred to simply as "fascines"), but experimental small groynes and wind barriers are also created.

To create a barrier, a set of fascines is placed on the salt marsh edge to protect it from erosion and reinforce it. Typically, a set of fascines with a total length ranging from 1.5 m up to tens of meters is placed along the salt marsh edge, functioning as a screen from impacting waves and at the same time as a permeable obstacle that

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slows currents down promoting sedimentation. Fascines are semi-permeable and hence respectful of the ecological role of the salt marsh-tidal flat interface whose continuity is not interrupted. Once installed, the limited space between the fascines and the edge of the salt marsh is filled with small amounts of sediments, collected from neighbouring tidal flats to minimize environmental impacts due to the nourishment phase (in this manner small pumps and boats can be employed) and to the use of allochthonous sediments. In this way, fascines are saturated by the sediments and, thus, protected for longer time from the degradation caused by oxidation processes, biodegradation and weather, ensuring greater durability. Furthermore, the collection of sediments from neighbouring tidal flats contributes to create slight variations in bathymetry that favour the development of ecological niches and counteract the current general bottom flattening trend in the lagoon. Nourishment on such small scales can also be used to restore small salt marsh surfaces behind the fascines, contributing to a careful, non-impacting reconstruction of this habitat. Indeed these micro soil-bioengineering works are realized only through light equipment, small boats and a large amount of manual labour: this way of acting minimizes environmental impacts on salt marshes, tidal flat and bottoms during the construction of the protection works and, at the same time, allows a great precision in the activities of salt marshes edge reconstruction and sediment nourishment. Such precision is fundamental to carefully reconstruct the correct levels of the soil typical of the salt marsh internal surfaces and edges, which are needed to promote pedogenesis and the colonization by halophytic vegetation – very sensitive to soil levels – which further stabilize the soil (furthermore, halophytic vegetation is a peculiar trait of these habitats) (Bonometto 2003). To accelerate the colonization of halophytic vegetation promoting soil and edge stabilization, clods carrying plants which had been eroded from the edges are recovered and transplanted behind the fascines, onto the newly-pumped sediments.

Small groynes and wind barriers, made of fascines, are used to modify the local hydrodynamics. Groynes are shore-perpendicular structures, extending from the backshore towards water (length ranging from about 1.5–9.0 m). They aim to slow alongshore currents down and thus trap sediments. Wind barriers (about 2.5–25 m long) are structures perpendicular to the dominant wind direction, placed up to 10–15 meters away from the salt marsh to reduce wind and wave energy, slow currents down and enhance sedimentation.

To summarize, the protection works of LIFE VIMINE are designed on the basis of these principles: 1) use of soil bio-engineering techniques (which we have identified to be the optimal means to protect the most interior salt marshes) and selection of possibly-local (see the short supply chain of wooden material described below) biodegradable and ecologically-friendly materials characterized by low environmental and landscape impact and low cost; 2) care for the intrinsic features of the salt marsh "system", such as the natural plasticity (as opposed to the artificial rigidity of classical concrete- or rock-made engineering works) and the continuously-evolving morphology, leading to a careful *ad hoc* design of the protection works; 3) promotion of natural processes such as sedimentation and the colonization of soil-stabilizing plants; 4) employment of working means and tools that allow the lowest impact possible on the lagoon bottoms and salt marsh geomorphology during the construction, monitoring, and maintenance phases. We note that the proposed protection works are reversible, in agreement with the conditions set by the Special Law for Venice (Italian Law 29/11/1984 n. 798).

Fascine-based protection works are fit to protect the shallow and intricate interior salt marshes undergoing low-energy erosion but are not resistant enough to be used along high-energy channels where fast motorboats or ships transit. Even if placed on interior salt marshes, fascine duration is limited by the use of biodegradable materials, which are inevitably destroyed by weathering, biodegradation, salinity and waves in the harsh lagoon environment. This criticality is actually the strength of the approach of LIFE VIMINE because, to overcome it, the integrated approach which is now described had to be developed.

To repair or substitute fascines as soon as they are damaged, routine actions of surveillance and monitoring and, when required, maintenance are implemented in LIFE VIMINE. Such monitoring and maintenance actions are temporally-continuous and spatially-diffuse to promptly locate damaged fascines or new spots in the salt marsh edges starting to erode and, thus, to be soon protected. Such approach to control erosion is based on small actions of prevention and, hence, is inherently cost-efficient.

Figure 2. *Examples of fascines produced locally (upper left) and then placed to protect salt marsh edges from erosion in LIFE VIMINE (upper right and bottom).*

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A key choice made in LIFE VIMINE is that the actions of monitoring and maintenance are carried out by local workers hired in the project. This is important for several reasons: local workers know very well the lagoon, how to work in it and how to navigate through it, therefore they work efficiently; they live in the lagoon, hence they should be more motivated to work to defend it and to report new erosion spots or damaged fascines identified during their daily activities (or during the abovementioned regular monitoring; and indeed the edges to be protected in LIFE VIMINE have been identified together with local workers from Burano following a participatory methodology); their involvement represents an opportunity to raise local awareness of the erosion issue; the population of these isolated lagoon islands is decreasing due to lack of jobs, hence nature conservation based on this participated approach represents an important socio-economic opportunity.
To improve the project sustainability from both the economic and carbon-footprint points of view, a short supply chain to produce locally the wooden material to create the fascines and poles needed to perform soil bioengineering works is set up in LIFE VIMINE. The wooden materials are obtained from routine pruning and forest management activities carried out by public bodies along rivers and channels and in parks in the mainland of Venice as well as in the lagoon islands. This wooden material is currently a waste generated by woodland management, but it becomes a resource according to the project re-use approach, which integrates the management of the lagoon with that of its watershed and islands.

5. The integrated approach and sustainability

LIFE VIMINE aims to demonstrate an integrated approach to the protection of the salt marshes, building resilient links between human and ecological systems as a key to sustainability. The fragility of the low-impact bioengineering works used in LIFE VIMINE is the factor that triggers the integration of these two systems, by making nature protection and socio-economic needs converge. Indeed, because of their fragility, the soil bioengineering works need a routine, temporally continuous and spatially diffuse maintenance to remain efficient. Such kind of maintenance requires continuous human presence and manual labour, leading to the creation of new jobs in conservation and contributing to support the local economy. In LIFE VIMINE this maintenance is carried out by local people who know the lagoon, strengthening the relationship between the environment and the people who inhabit it and can survey it. Indeed, the integrated approach of VIMINE cannot work if local communities are not involved. For this reason care is paid in the project not only to the construction of protection works, but also to implementing participatory activities aimed to involve local people who know the lagoon, such as local fishermen and hunters, in the protection works. Through these and other participatory (Reed 2008) and divulgation activities foreseen in the project (such as the creation of a network of ecotourism stakeholders, whose economic activities at least partly depend on the conservation of salt marshes; not described here due to space reasons), LIFE VIMINE aspires to stimulate the discovery and the awareness

of the value of nature and ecosystem services. It communicates that we are not forced to preserve the environment for ethical duties only, but instead there are additional reasons which are related to the quality of life of everyone: indeed, it is important to protect the salt marshes because they offer several benefits to society, too often neglected in decision making or unknown.
The mix of new jobs in conservation activities, of participation and of environmental education in LIFE VIMINE represents its integrated approach and is the key to sustainability. A final project output will be an estimate of the socio-economic value for the lagoon territory and society of this integrated approach, in terms of new jobs created in conservation, of newly-created local economic activities such as the wood supply chain, of economic activities which have been preserved by defending the salt marshes because they rely on the existence of this habitat (such as ecotourism), of protected valuable ecosystem services (see Costanza et al., 1997), etc.; this value will be communicated to the institutions in charge of safeguarding and managing the lagoon to assess if the benefits of the integrated approach exceed its costs. Following this approach, ultimately, the demand to institutions for more investments in conservation should naturally emerge from local communities and stakeholders engaged in conservation activities or indirectly benefitting from them, triggering self-reinforcing feedbacks between local development and nature conservation and thus starting to target also the long-term socio-economic drivers of erosion.

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UN APPROCCIO INTEGRATO PER PREVENIRE L'EROSIONE DELLE BARENE NELLA LAGUNA DI VENEZIA

Riassunto

La perdita di habitat costieri è un problema diffuso in Europa. Per proteggere le barene della laguna di Venezia dall'erosione di origine naturale ed umana che le sta velocemente e diffusamente distruggendo, la Commissione Europea ha finanziato il progetto dimostrativo LIFE VIMINE. LIFE VIMINE mira a proteggere le barene e paludi più interne e difficilmente accessibili nella laguna nord di Venezia attraverso un approccio integrato, il cui cuore è la prevenzione dell'erosione attraverso numerosi, piccoli ma diffusi interventi protettivi di ingegneria naturalistica, principalmente creati attraverso lavoro semi-manuale e con un ridotto impatto sull'ambiente ed il paesaggio. L'efficacia degli interventi di protezione è garantita nel lungo periodo da azioni di monitoraggio e manutenzione ordinarie, diffuse e continuative. Questa metodologia è alternativa al comune approccio alla gestione del dissesto idrogeologico e dell'erosione in Italia che è basato su grandi opere irreversibili e realizzate in emergenza. La sostenibilità dell'approccio di LIFE VIMINE è garantita dal coinvolgimento partecipato dei portatori d'interessi e dal riconoscimento del fatto che proteggere le barene significa proteggere i benefici che esse forniscono alla società attraverso le loro funzioni ecologiche, ed anche proteggere i posti di lavoro che sono connessi all'esistenza o alla conservazione di questo habitat.

Parole chiave: *erosione delle barene, laguna di Venezia, ingegneria naturalistica, sostenibilità*