The ecosystem can be defined as a dynamic complex of plant, animal, and microorganism communities and the non-living environment, interacting as a functional unit; based on this definition, the Ecosystem Services (ES) are the components, processes and functions of Ecosystems (Millennium Ecosystem Assessment, 2003). The concept of ES is meant to assign a monetary value to a commercial activity or/and the natural environment where it takes place. ES concept received considerable impetus with the publication of the Millennium Ecosystem Assessment in 2005 and now it is integrated in current policies at global and European level. The ES have a public value because they provide irreplaceable benefits, direct or indirect, for the inhabitants of a territory. The integrated ecosystem approach to resources management and the importance of investing in natural ecosystem as a source of economic development is one of the main EU goals by 2050.

ES contribute to the needs and demands of modern society in various forms, including cultural, economic, environmental, institutional and social aspects. Recently, the debate on ES has involved several disciplines, especially on the ways to valuate ES and integrate them into the planning processes and management for sustainable development (Ignaccolo et al., 2013 “Ecosystem services…”).

In particular port systems can be considered ideal contexts on which to ponder about the link between the functions of nature and the general development of an economic system. Port is a transport infrastructure characterized by important environmental impacts both in the construction and in the operating phase. These impacts affect not only aquatic and coastal ecosystems but cultural ones also especially when the port is included or is close to an urban area. The conversion from natural ecosystems to semi-natural or artificial systems is a major cause of loss of biodiversity. Moreover, the port is a Water/Land Interface (between the Marine ecosystem, Coastal ecosystem and Land/Urban ecosystems) and appears as “semi-natural” complex.

According to EU policies, many cities are experiencing an ecosystem approach in the port systems, in order to conciliate promotion of economic growth and environmental conservation. In fact, the assessment of ecosystem services is a valuable and meaningful input to support port planning and management.

The port areas, in recent years, have dominated the attention of urban planning, in terms of urban regeneration, recovery, integration between different areas and opportunities for development. The ports are the engine and the opportunity to implement new strategies for planning and management at different scales, from local to regional, and are opportunities

to restore/insert some ES and their services. Thus, according with the EU policies, a future challenge for the European ports will be the ecosystem approach to resource management and spatial planning.

Despite the role of ecosystems in port area, ES are still not fully included in traditional port planning and management, and they are not adequately quantified in terms comparable with economic services. For this reason, they often have a low weight in the decision-making processes. Based on this premise, this work aims at defining a methodology to integrate the ES benefits value, through a Costs/benefits and a Multi-criteria analysis, in port planning and management.

The paradigm of ES can be, therefore, the basis for a review of the economic terms with which to consider the port and its capitals through an improved awareness of the significance of ecological processes and more oriented towards a long-lasting sustainability land use planning, through the identification of Impact Indicators (environmental, social/cultural and economic), to be integrated in the planning and management process.

Literature review

In recent literature most of existing ecosystem services classification systems do not address the management of port coastal systems (García-Onetti et al., 2021). A reference point for addressing the issue is the "No-impact ports/Ports of the future" project, developed by Deltares (Schipper et al., 2015; PIANC-EnviCom, 2014): the document has been developed in collaboration with WWF and it deals about port policies development aiming at guaranteeing healthy ecosystem functioning. Other studies are those made by Taljaard et al. (2021) and some applications to real cases (de Boer et al., 2019; Kolman, 2014; Zhao et al., 2020). However, excluding the recent work by García-Onetti et al. (2021), these documents do not take into consideration stakeholders' engagement in the implementation of integrated and ecosystem-based management models.

According to Wang (Wang et al., 2013), "the externalities are created when the scale of decision making is not sufficiently holistic, with the existence and sustainability of ecosystem services during the decision-making process".

The costs of individuals using the ecosystems services are valued less than they should be, resulting in negative externalities (Van den Bergh, 2010). Thus, the need to promote the

Community Involvement (CI) (Ignaccolo et al., 2013 "Guide on Port Action Plan") in decisions making. The CI ensures maximum transparency in decisions making and, through the contributions of stakeholders, the sharing of final decisions. In particular, in the port systems, which are characterized by strong environmental, social and economic impacts, it is important to involve all the stakeholders from the beginning of the planning process.

The planning process starts with the identification of the invariants to be protected and the possible scenarios of transformation, in terms of environmental, economic and social sustainability, identifying potential stakeholders and their interests, needs and principles (Cascetta et al., 2013). The coordination of all involved actors is essential to obtain a transparent decision-making process, with the contributions of all the categories (Ignaccolo et al., 2013 "Guide on Port Action Plan") necessary to achieve a sustainable management of port systems.

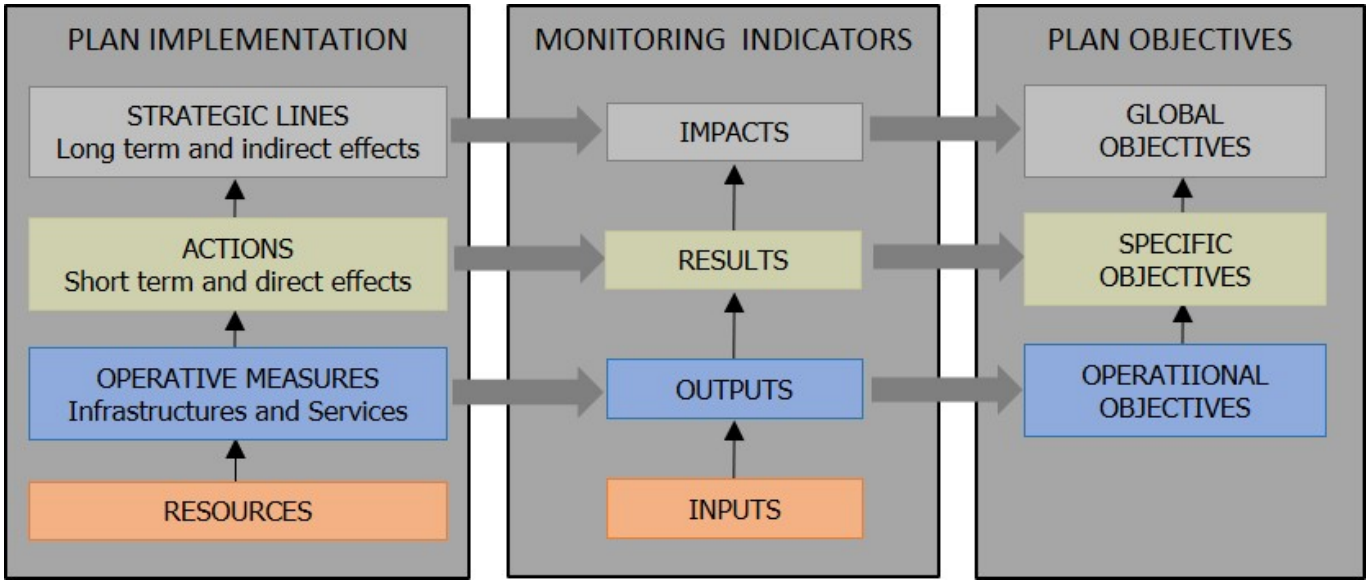
According to the current literature (Abson & Termansen, 2011), the value of ecosystem and their services can be expressed through their use value (direct or indirect) and non-use value, which are the most difficult to measure because they depend on multiple factors and their associated benefits may be much more intangible. Thus, in order to integrate the ES restoring/inserting in the planning process a quantitative analysis should be used to study the economic benefits that usually are well suited to be expressed in monetary terms. For the others, the difficulties to evaluate social and environmental ES benefits can be overtaken by adopting a more qualitative approach.

A first step to assess the value of ES benefits in port planning

To ensure that ES are taken into consideration by administrators and stakeholders during the planning process, it is necessary to adopt a robust and structured engagement methodology.

Within the PORTA project (PORTs as a gateway for Access inner regions), co-financed by the European MED Programme, a Port Action Plan (PAP) scheme and a set of tools for supporting decisions, defining priorities of intervention and plan monitoring were proposed by the authors. Both planning and monitoring phases are based on a hierarchic structure, derived by from the so-called IORI scheme (Input-Output-Result-Impact), adopted by the European Commission for the evaluation of operative programmes. A PAP framework is based on three hierarchic levels: the first of the strategic lines, which refers to the global

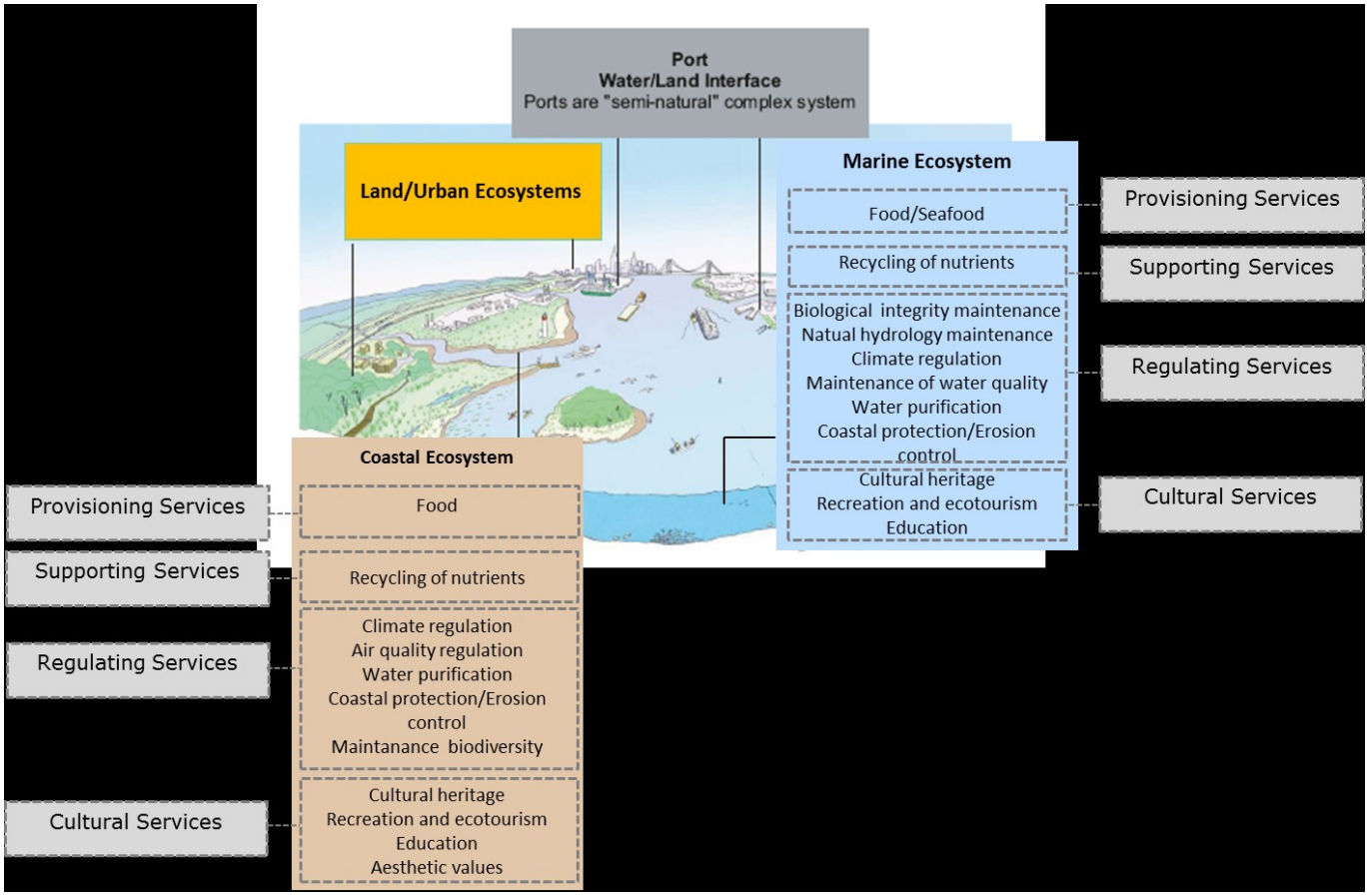
objectives which are relevant for social, economic and environmental impacts of the plan thereby taking into account the ES; the second of the actions, which refers to the specific objectives; finally, the third of operative measures, which refers to the operational objectives.



IORI (Input-Output-Results-Impact) monitoring approach. (Source: Adapted from Ignaccolo M., Inturri G., Cocuzza E., Le Pira M., Rubulotta E., "Port Action Plan Guidelines").

To this aim, a consistent structured three level set of indicators has to be set up, respectively impact indicators to monitor the sustainability of the strategic lines; result indicators to monitor the effectiveness of the designed actions; output indicators to monitor the efficiency of the operative measures designed to implement the actions.

In port areas, Marine and Coastal ecosystems deliver a wide range of services, many of which provide material benefits. They include provisioning (food), supporting (recycling of nutrients) and several regulating services, related to climate, air and water quality, coastal protection, biodiversity.



Ecosystem and their services in port areas. (Source: Adapted from New York/New Jersey Harbor & Estuary Program).

Moreover, recreational, cultural and aesthetic services have a noticeable role, both when they are based on the direct and indirect use of the ecosystems. Recreational use of ecosystem can include consumption of resources (e.g. fishing) or non-consumptive recreational activities; passive activities are, indeed, cultural/scientific related.

Subsequently in order to assess the impacts of Ecosystem Services on the port planning process, the set of indicators should be related to:

- Provisioning: it means that the aquatic and coastal ecosystems provide material benefits, such as food provisioning from fish, wood production and transportation.
- Regulating: this refers to benefits by ecosystems for maintaining and providing, like

climate, water quality air quality regulation, flood protection and sedimentation and erosion regulation.
- Culture: these criteria refer to aesthetic/ethical value and recreation, education and ecotourism opportunities linked to port activities.

The following table shows a proposal of ES indicators to be adopted for the evaluation of the port planning and management sustainability, according to the IORI approach.

STRATEGIC LEVEL	ES FUNCTION	SUSTAINABILITY	INDICATORS
OUTPUTS	Provisioning	Environmental	Support of food chains/native plant population
		Environmental	Maintenance of biological integrity
		Environmental	Maintenance of natural hydrology
		Environmental	Provide Landscape heterogeneity
	Regulating	Environmental	Water purification and waste treatment
		Environmental	Protection of coast from erosion
		Environmental	Recycling of nutrients
	Cultural	Social	Ecotourism values
		Social	Attractive landscape features
		Social	Ethical heritage
		Social	N. green spaces
		Social	N. beaches, marinas, shoreline parks
RESULTS	Provisioning	Environmental	Seafood (fish, shellfish)
	Regulating	Environmental	Air quality regulation
		Environmental	Microclimate regulation
	Cultural	Social	Accessibility Index
		Social	N. inhabitants and tourists
IMPACTS	Regulating	Environmental	Global climate regulation
	Cultural	Economic	Employment (direct/indirect)
		Economic	Value added
		Economic	Investments
		Economic	Value of real estate
		Economic	Value of areas

Impact Indicators Ecosystem Services. (Source: Adapted from Ignaccolo M., Inturri G., Cocuzza E., Le Pira M., Rubulotta E., "Port Action Plan Guidelines").

It is easy to understand how provisioning and regulating activities are those most

threatened by port operations (especially due to dredging, waste and paints used in vessels building). Cultural activities are more of anthropogenic inspiration (i.e. they are generally an integral part of port economic planning), but they can yet be threatened by some heavy activities carried out within the port which could reduce the attractivity and the natural quality of the landscape.

The evaluation of the planning scenarios (by decision makers and stakeholders) can be carried out in two steps: first, the value of the ES indicators can be analyzed through Multicriteria Analysis techniques (including group), which allow a first selection of the scenarios also by evaluating those ES indicators that cannot be monetized. Subsequently, the feasibility of the selected scenario can be analyzed using Cost-Benefit Analysis methods traditionally used in transport planning.

Conclusions

The evaluation of Ecosystem Services sets the stage for a review of port management more conscious and oriented toward a concrete sustainability, both economic, social and environmental. Indicators of the Ecosystem Services associated to port activities must be taken into account in decision-making processes. The explicit inclusion in the planning process of Cost/benefit and Multi-criteria analysis through ES indicators might allow the estimation of losses or gains in terms of ecosystem services and supports a better decisions-making process as well.

References

Abson, D. J., & Termansen, M. (2011), “Valuing ecosystem services in terms of ecological risks and returns” in *Conservation Biology*, vol. 25(2), pp. 250-258.

Cascetta E., Pagliara F. (2013) “Public Engagement for Planning and Designing Transportation Systems”, in *Procedia Social and Behavioral Sciences*, vol. 87, pp. 103-116.

De Boer, W. P., Slinger, J. H., Vreugdenhil, H. S., Taneja, P., Appeaning Addo, K., & Vellinga, T. (2019), “Identifying ecosystem-based alternatives for the design of a seaport’s marine infrastructure: The case of Tema port expansion in Ghana” in *Sustainability*, vol. 11, issue 23, 6633.

García-Onetti, J., Scherer, M. E., Asmus, M. L., Sanabria, J. G., & Barragán, J. M. (2021), “Integrating ecosystem services for the socio-ecological management of ports” in *Ocean & Coastal Management*, vol. 206, 105583.

Ghermandi A., A.L.D. Nunes P., Portela R., Rao N., Teelucksingh S. (2009), *“Recreational, Cultural and Aesthetic Services from Estuarine and Coastal Ecosystems”*.

Ignaccolo M., Inturri G., Cocuzza E, Le Pira M., Rubulotta E. (2013), *“Guide on Port Action Plan”*, PORTA (PORTs as a gateway for Accessing inner regions) project MED Operational Programme 2007-2013 (published on line: www.porta-proejct.eu).

Ignaccolo M., Inturri G., Cocuzza E. (2013) “Ecosystem services, basis for a process of shared planning of port sustainable areas”, in *“RegioResources 21 – A cross-disciplinary dialogue on sustainable development of regional resources”.*

Kolman R. (2014), “Introducing ecosystems services for port development” in *Environment and Sustainability*, edition 62, pp. 181-183.

Schipper, C., Vergouwen, S., de Jong, M., Vreugdenhil, H., De Bel, M., Schasfoort, F., & Minderhoud, S. (2015), “*Port of the Future Exploratory Study”,* Technical Report of Project “Port of the Future”.

New York/New Jersey Harbor & Estuary Program, https://www.hudsonriver.org/estuary-program

Taljaard, S., Slinger, J. H., Arabi, S., Weerts, S. P., & Vreugdenhil, H. (2021), "The natural environment in port development: A 'green handbrake'or an equal partner?" in *Ocean & Coastal Management,* vol. 199, 105390.

The World Association for Waterborne Transport Infrastructure (PIANC) (2014), "PIANC-EnviCom Sustainable Ports. A Guide for Port Authorities", Technicals Reports, Brussels Van den Bergh J.C.J.M. (2010), "Externality or sustainability economics?", in Ecological Economics no. 69, Elsevier, pp. 2047–2052.

Wang S., Fu B., Wei Y., Lyle Clive (2013), *"Ecosystem services management. An integrated approach, Current opinion in Environmental sustainability",* Elsevier, pp. 11-15.

Zhao, D., Wang, T., & Han, H. (2020), "Approach towards Sustainable and Smart Coal Port Development: The Case of Huanghua Port in China" in *Sustainability*, vol. 12, issue 9, 3924.

Head Image: Augusta port. (Source: Port System Authority of the Sea of Eastern Sicily; ports of Augusta and Catania; https://www.adspmaresiciliaorientale.it).