Ecosystem Indicators and Landscape Ecology Metrics as a Tool to Evaluate Sustainable Land Planning in ICZM

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Abstract. In the frame of Integrated Coastal Zone Management (ICZM) planners need tools to design and assess a sustainable state for the coast. Sustainability and progress indicator have to be integrated to identify improvements in the state of coastal zones as a result of ICZM implementation [1].

There are two useful approaches in order to take into account, system property, complexity and evolution, and integrating humans and bio-geospheres: system ecology (and ecosystem health concepts, as defined in [2]) and landscape science and ecology (as defined for example in [3–7]). The holistic approach in the context of human-nature relations is the real challenge of modern landscape ecology. It regards the background of increasing environmental problems and the discussion about sustainability [4] and for sustainability planning [8].

In the paper, it is proposed a brand new synthetic ecosystem indicator suited to monitoring regeneration plans of coastal zones: the Land Eco-Biodiversity. In order to have more benchmarks in assessing the state of implementation of a strategy, the plan, as well as from an ecosystemic point of view, is measured from a landscape point of view through Landscape Ecology indexes. In fact, the fragmentation of the landscape is part of the resource efficiency indicators defined by Eurostat in the context of monitoring the main objectives defined in the Europe 2020 strategy in the Category: "Nature and ecosystems | Biodiversity".

The study area is the Delta of Po River (Italy).

Keywords: ICZM · Landscape ecology metrics · Ecosystem indicators

1 Landscape Ecology: A Paradigm for ICZM

The 2007 Integrated Maritime Policy for the European Union [9] acted as an important factor in stimulating the consolidation of coastal and marine information to support policy implementation. This approach includes the development of coastal and marine Decision-Support Systems (DSS) [10, 11]. In order to create a coastal information

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system it is needed a large amount of data and of high quality structured information. High quality coastal information systems can be organized as a set of indices and indicators. An indicator is a measured or observed parameter that provides information about a system. An index is a more elaborated and organized information that provides as a coherent view of the reality and an integration information of one (or more) qualities. It is supposed an indicator or index (or a set of them) is a model of reality [12–16] and it has a significance extending beyond what is directly obtained from observations [17].

Indices and indicators, as the system models, simplify systems, functions, forms and processes. A set of meaningful and representative indicators, however, would facilitate knowledge, decision-making, monitoring and assessment of planned interventions in terms of policy and management objectives [17, 18]. As such, they have to provide a concrete contribution to a difficult communication among stakeholders in the rationalization of multi-purpose decision-making processes. In general, sharing coastal knowledge and offering organized information (such as indicators and indices) once it is built requires also the development of useful comprehensive tools to disseminate that information, taking advantage of technologies such as models and earth observing systems to do so [19].

The development and use of indicators and indices for coastal areas and coastal zone management and planning is already worldwide done (e.g. [17]), and it is more and more comprehensive of coastal system, with increasing consideration for the geo-ecological, economic and social aspects (e.g. [20]).

The *working group on indicators and data* of the European ICZM expert group proposed two set of indicators to be used by member states and candidate countries [18, 21–23]:

- Progress indicators;
- Indicators of sustainable development.

In 2010, Marotta et al. [24] proposed a complementary set of indicators in order to integrate the Habitat Directive and to define a sustainability state for the coast using a framework based on a landscape approach.

Landscape ecology has two different approaches, both very powerful in integration of Coastal Zone Management. The two different views are rooted in the European versus North American traditions [7, 25, 26]. Both perspectives can be derived from Troll original definition of landscape ecology as “the study of the main complex causal relationships between the life communities and their environment” [27], which “are expressed regionally in a definite distribution pattern (landscape mosaic, landscape pattern)” [28].

Wu [29] describes the difference as follows: “It is true that the two traditions differ in some significant ways: the former has been characterized by a society-centered holistic view that focuses on solution-driven research, whereas the latter is dominated by a bioecology-centred spatial view that focuses on question-driven studies”. He outlines “the differences hinge mainly on the ways these anthropogenic influences are incorporated in research, ranging from treating humans as one of the factors creating and responding to spatial heterogeneity” [30] considering the landscape as a “total human ecosystem” [31]. Following the concept of landscape as total human ecosystem,

Barrett and Farina [32] presented a landscape paradigm able to integrate in landscape ecology and economy both assessment and planning. Desaigues [33] presented the socio-economic value of the ecotone also with a planning focus.

The environmental factors can be natural or cultural (anthropic). If the control is "mostly natural" it is called "Natural Ecosystem", while if it is "mostly human" controlled it is called "Cultural Ecosystem" [34]. Some of the environmental factors are Natural, others are Cultural. The majority is a mix between them. We can measure the degree of cultural control with the quantity of subsidiary energy supplied to the system [35].

The methodology for ICZM of Marotta et al. [24] is fully based on paradigm of landscape ecology. It follows several steps:

1. *Definition of homogeneous environmental management units, and analysis of spatial and temporal structure, hierarchy and dynamics over multiple scales*. This step requires the production of a habitat map based on landscape ecology.
2. *Analysis of land-use changes in the coastal system*.
3. *Implementation of spatial indices* characterizing each patch type and state.
4. *Conservation-gaps analysis*. The step is focused in the assessment of ecosystem health, cumulative impacts and habitat loss in coastal ecotones [36]. An urban and infrastructure index has been used as evaluation tool [37, 38].
5. *Assessment of coastal conflicts* using a coastal conflict index following the work of Vallega [39].
6. *Multi Criteria Analysis (MCA) in order to minimize conflicts over a set of values and constraints.*

Such a methodology is very reliable from a scientific point of view, but it has a drawback in its complexity. The framework uses maps and dashboards to share the results with decision makers and stakeholders, but indices and indicators are hard to understand for non-technicians people and harder to implement and update.

Therefore, in the paper we present a "lean" version of the methodology taking also in account the new Analytical Assessment Framework for Land System of EU [40].

2 Steps Towards a "Lean" Methodology for ICZM

2.1 Soil Consumption

Soil consumption is a phenomenon associated with the loss of a fundamental environmental resource, due to the occupation of an originally agricultural, natural or semi-natural surface. The phenomenon refers to an increase in artificial ground cover, linked to settlement and infrastructure dynamics.

It is a process mainly due to the construction of new buildings and settlements, to the expansion of cities, to the densification or conversion of land within an urban area, to the development of new infrastructures.

Therefore, soil consumption is defined as a variation from a non-artificial land (unused soil) to an artificial ground cover (soil consumed).

Land Cover refers to the biophysical coverage of the earth's surface, including artificial surfaces, agricultural areas, woods and forests, semi-natural areas, wetlands, water bodies, as defined by Directive 2007/2/EC [41].

The soil sealing, the permanent covering of part of the land and its soil with artificial materials (such as asphalt or concrete) for the construction, for example, of buildings and roads, is the most obvious and most widespread form of artificial transformation of the land. Soil sealing is the main cause of soil degradation in Europe, entails an increased risk of flooding, contributes to climate change, threatens biodiversity, causing the loss of fertile agricultural lands and natural and semi-natural areas: it contributes together with the urban sprawl to the progressive and systematic destruction of the landscape, mainly rural one [42].

2.2 Land System

According to EEA [40] "Land *systems are the terrestrial component of the Earth system, encompassing all processes and activities related to the human use of land. These include socio-economic, technological and organisational inputs and arrangements, as well as the benefits gained from land and the unintended social and ecological outcomes of societal activities. The land systems concept combines land use (the activities, arrangements and inputs associated with land use) with land cover (the ensemble of physical characteristics of land discernible by Earth Observation)*".

2.3 The Land System Assessment

In the Briefing no. 10/2018 of EEA [40] is proposed an approach for the assessment of Land Systems based on DPSIR framework:

1. Formulation of a policy-relevant question. The assessment has to be related with priorities of decision-makers.
2. Mapping pressures (land processes). The processes are "*physical, biological or chemical processes that directly influence changes in ecosystem functions and services*" [40]. In this category are included extreme weather events and biological dispersal. Data sources are products of Earth Observation (e.g. Copernicus land monitoring products) and spatially distributed statistical data on socio-economic activities.
3. Territorial assessment. "*The territorial assessment describes land systems as a state of natural capital and a socio-economic purpose of natural resources. This includes land management practices, such as the arrangements, activities and inputs people undertake across regions. From a practical perspective, this includes analysis of the spatial distribution of land use and land cover (LU/LC) patterns, the local and regional variances of land management practices, the degree of imperviousness and soil sealing and the existence of conservation and non-conservation areas. A territorial analysis results in map categories, which represent specific characteristics of land processes e.g. intensity levels of agricultural land use, forest management practices or peri-urban land take at a given time*" [40].

4. Dynamic assessment. "*Changes in the state of land systems can be measured from land cover flows from one broad LU/LC category to another. (…) However, both types of land process result in changes in the services and goods provided by land systems*" [40]. Kuemmerle et al. [43] mapped spatial patterns of changes in the extent and management intensity in Europe's agriculture, forestry and urban areas for the period 1990–2006.
5. Functional assessment. This is the step of measurement of the effects (impacts) generated by land process on the delivery of environmental functions. The "*analytical framework compares the provision of functions and services across geographical regions, taking into account that they occur within different land use types and are subject to contrasting management activities evaluated in steps 3 and 4*" [40]. Stavi et al. [44] proposed a conceptual model suited to score soil functions and ecosystem services and compare them across broad types of conventional, conservation and integrated agricultural systems.
6. Key policy message. The results of the assessment steps should provide an answer to the policy question of Step 1 and could help to formulating scenarios and policies.

3 The Land Eco-Biodiversity Index

3.1 Vegetation Series Map

The study of land use shows how the anthropic practices of recent years led the territory far away from the natural vocation of soils developing productive activities that most of the time do not respect the cycles of nature. In particular, the spread of agricultural practices in recent years, sometimes justified by the need for forms of economic incentive, has led to an excessive simplification of both the landscape and the variety of products.

In the paper, it is proposed to adopt for the territorial regeneration projects a methodology based on the recovery of the health status of the landscape. The "healthy" state of a landscape is that in which the places are in the natural vegetational state. It can be identified following the Hierarchical Classification of the Land approach [45]. The distribution models of spontaneous plant communities can be constructed using biogeography and plant ecology, i.e. the area distribution of species and the ecological factors determining their presence or absence, in particular the climate, the soil (chemism and morphology) and the availability of water. Given a biogeographic context it is possible to hypothesize what should be the potential vegetation (the one that would exist in the absence of anthropic disturbance) based on the aforementioned ecological factors.

Starting from the main ecological factors in conditioning the distribution of vegetation, the one that determines the differentiation between the large biomes, i.e. the climatic region, leads to the definition of homogeneous areas for lithological, bioclimatic and geomorphological features to the point of being able to hypothesize (and possibly verify) a certain potential vegetation for each of them.

The science of vegetation is not limited to describing the spontaneous vegetation by proposing the models of plant communities known as plant associations (fulcrum of that discipline called Phytosociology). Perhaps the most interesting viewpoint is that which leads us to investigate the successional relationships between grasslands, bushes and woods, the definition of the so-called "vegetation series" [46]. Therefore, for a given biogeographic context and an ecologically homogeneous environment (identified with the criteria dictated by the hierarchical classification of the land) it is possible to establish which is the series of reference vegetation, i.e. the potential vegetation (generally of forest type) and the communities plants dynamically linked to it based on successional relationships (grasslands and bushes) determined by recovery processes after ailments such as fires, deforestation and cultivation of the land.

From an operative point of view, in order to produce a Vegetation Series Map (only for the stage of maturity in a successional key) at the regional scale (1: 250,000) and at provincial scale (1: 50,000) it is possible to proceed by interpreting the Map of Systems of Soils. The information contained in it represents a synthesis of the pedological survey and allows recognizing in the territory of the areas (the cartographic units) homogeneous for the soils present within them, grouped in hierarchically organized containers, which describe the growth environment. In order not to create discontinuity, it is proposed not to separate urban areas.

The described methodology has been applied to the area of the delta of Po River in Veneto Region (Italy). From a climatic point of view, the Veneto region, although presenting a remarkable articulation, is entirely located in the temperate climatic region. This has determined the remarkable peculiarity of the north Adriatic coastal vegetation that is in the only strip of Mediterranean coast not having a Mediterranean climate. In the coastal sector there are soils with well-defined characteristics, consistent with a clearly differentiated potential vegetation. The area investigated consists of floodplain in which the differences in substrate, morphology and water availability are articulated on non-net gradients [47].

According to the method already described combinations of tree species have been identified according to the prevailing potential vegetation. The combinations of the tree species are representative of ecological variants with respect to the reference plant associations and the prevalent communities in the mosaics which, on the regional detail scale, are not allowed to be resolved in a single type. The elaboration led to individuation of 7 classes of potential vegetation at the 1: 250,000 scale on the north Adriatic coast which includes the coastal territories of Venice, Rovigo and Ferrara, and of 6 different classes of potential vegetation at the most detailed 1: 50,000 scale for the only area of the Po River delta. Since the soil maps produced by the Veneto and Emilia-Romagna regions are not based on a common survey and cartographic methodology, the interpretation of the information contained in them resulted in an evaluation in terms of homogenization of the classes. They have been assigned on the basis of vegetation potential for types of soil. This interpretative process has led to the identification of 7 homogeneous areas for potential vegetation.

The identification of potential vegetation makes it possible to identify the Habitats according to Directive 92/43/EEC [48], which represents one of the main regulatory instruments aimed at the conservation of biodiversity in Europe. This regulatory reference, which is the basis for identifying the sites of the Natura 2000 network, in

particular lists and codifies species of community importance, some of which are classified as priorities.

Finally, the presence of certain species corresponds to a specific code and typological description in terms of land use, according to the European standard legend Corine Land Cover. Based on these two references, it was possible to identify the theoretically corresponding Habitat and Corine Land Cover codes for each potential vegetation class.

3.2 The Land Eco-Biodiversity Index

In order to characterize the biodiversity rate of the study area, it was decided to take into consideration the species of fauna and flora of the Annexes of the two Community Directives "Birds" (79/409/CEE) [49] and "Habitat" (92/43/CEE) [48], selecting only those present in the environments that characterize the study area. For the floristic component only, the species defined as "important" by the Standard form of the ZPS (Special Protected Zone) I3270023 "Po Delta" were also considered.

Data on these species are obtained as an analytical result of the bibliography available.

Each habitat of a regeneration plan can be used by a single fauna or botanical species in a marginal or temporary way (weighted value = 1), or permanently, especially from a reproductive point of view (weighted value = 2). The presence of each species was therefore analyzed according to the concept of "species habitat", proper to the monitoring plans and to the environmental incidence assessments.

Multiplying these values by the extension of the area of each habitat according to the regeneration scenario, it is thus possible to obtain a Land EcoBiodiversity Index (LEBI) referring to the entire study area comparable with the current one [50].

We have a land divided in n Habitat H1, H2, …, Hn

The areas (in hectares) of the habitats are A1, A2, …, An

We have m indicator species S1, S2, …, Sm

We have the following matrix of the presence of the indicator species in the habitats:

		Habitat			
		H1	H2		Hn
Indicator Species	S1	P_{S1H1}	P_{S1H2}		P_{S1Hn}
	S2	P_{S2H1}	P_{S2H2}		P_{S2Hn}
	Sm	P_{SmH1}	P_{SmH2}		P_{SmHn}

Where

P_{SjHi} = 0 absence of the species in the habitat
1 presence of the species in the habitat
2 breeding site of the species in the habitat

$$\text{LEBI} = \sum_{i=1}^{n} TP_{Hi} * \frac{Ai}{\sum_{i=1}^{n} Ai} \quad (1)$$

Where

$$\text{TP}_{\text{Hi}} = \sum_{j=1}^{m} P_{SjHi} \quad (2)$$

In the following Figs. 1 and 2, Tables 1, and 2 there is the synthesis of the experimentation of LEBI in the delta of Po River (Italy) [50].

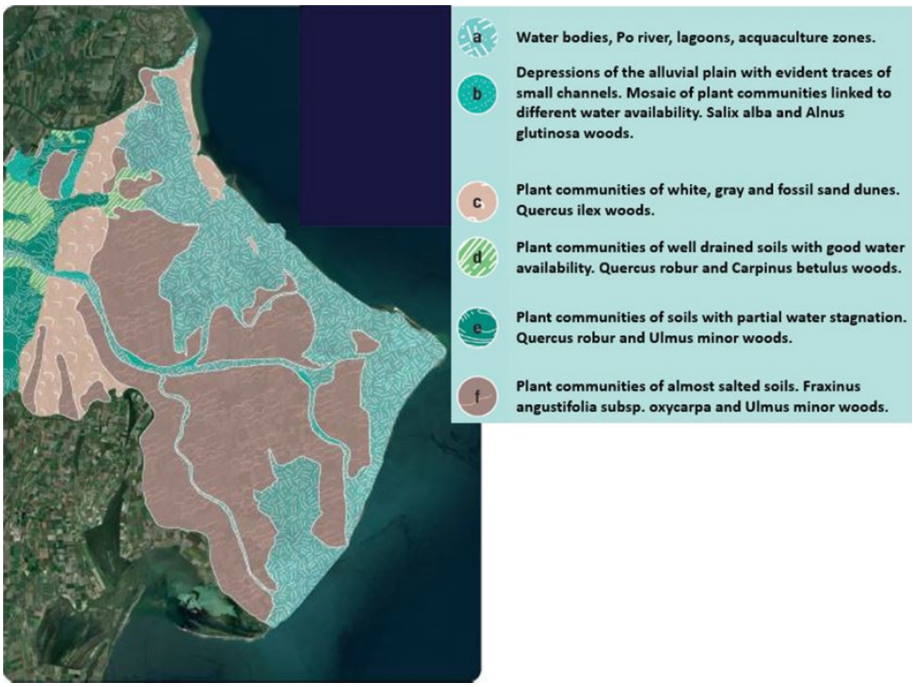

Fig. 1. Potential vegetation map (scale 1:50.000) [50]

4 Discussion

4.1 Issues Regarding Data About Indicator Species

The data on the presence of indicator species in habitats are the result of a survey conducted on several sources: the current situation does not allow access to a single national-level data source on standard bases. In fact, each Region and each Province operate with different methods: therefore, the output data is also not easily comparable. Within the Veneto Region itself, which includes the study area, there are substantial



Fig. 2. Map of places eligible for regeneration projects [50]

differences between the modus operandi in the Province of Rovigo and in the Province of Venice.

However, since numerous data are available for the study area, some of which are in the national ISPRA database, others are available by periodical publications relating to the different species, it was decided to exploit the information in order also to test the potential of the proposed Indicator. However, a standardization of the monitoring of the species should be implemented at least for a regional level.

Finally, a way to improve LEBI could be a better modelization of vegetational indicator species considering quality and conservation status and using a more detailed scale according to [51].

4.2 Landscape Value

A second point of attention is the opportunity to extend the number of indicators, in order to have more benchmarks to assess the planning scenarios and then the status of the implementation of the chosen strategy.

A first option is to use a multiplying weighing factor depending, for example, on the landscape value added to the areas subject to intervention.

In fact, current LEBI limits itself to identifying the level of general regeneration of the territory subject to interventions. By way of example only, we could use as weight linked to the restoration of typical elements of the delta landscape according to their historical presence on the territory:

LII_{Hi} = 1 (low: an element introduced by man in recent times);
2 (medium: an element present in the past and recently disappeared or significantly reduced due to the anthropic action);
3 (high: an element of the past completely or almost disappeared due to the anthropic action).

This factor (Landscape Intervention Index) would allow introducing a measure of social well-being in the model (Table 2).

Table 1. LEBI implementation in study area [50]

Environment	Indicator TP	Current scenario (surface in ha)	Potential regeneration surface (ha)	Scenario 1 (surface in ha)	Scenario 2 (surface in ha)	Scenario 3 (surface in ha)
Arable land	16	20690,02	–	20616,98	20324,8	19959,97
Wetlands	91	19820,06	13,49	19820,19	19820,73	19821,41
White & Grey dunes	90	202,58	6546,83	266,02	519,79	837
Forests	18	481,75	946,84	491,22	529,09	576,03
Total surface	–	41194,41	7507,16	41194,41	41194,41	41194,41
LEBI	–	**52,47**	–	**52,59**	**53,05**	**53,62**

4.3 Indicators of Landscape Ecology: Composition and Configuration

A second option is to evaluate the scenarios, as well as from an ecosystemic point of view, also from a landscape point of view, using indices of Landscape Ecology. It would be possible, for example, to evaluate the connectivity of a territory before and after certain interventions, thus extending the sphere of monitoring to a system of indices and indicators more complex than the LEBI alone.

Using some metrics of Landscape Ecology, we can analyze two of the main features of a landscape: composition and configuration. The composition of a landscape refers to the richness and abundance of the different elements that are part of it, without however considering their spatial distribution; even if the composition metrics are not explicitly spatial, they also have important consequences in terms of spatial effects. The landscape configuration, instead, applies to the spatial properties of the elements, such as their distribution, position, orientation and shape.

According to a methodology of ISPRA [52], we propose to adopt the following indicators:

Table 2. Weighted LEBI implementation in study area [50]

				Current Scenario				Scenario 1		
Environment	Indicator TP	Landscape Intervention Index	Weighted TP	Surface (ha)	LEBI	Weighted LEBI	Potential Regeneration Surface (ha)	Surface (ha)	LEBI	Weighted LEBI
Arable land	16	1	16	20690,02	8,04	8,04	-	20616,98	8,01	8,01
Wetlands	91	2	182	19820,06	43,78	87,57	13,49	19820,19	43,78	87,57
W&G dunes	90	3	270	202,58	0,44	1,33	6546,83	266,02	0,58	1,74
Forests	18	3	54	481,75	0,21	0,63	946,84	491,22	0,21	0,64
Total surface	-	-	-	41194,41	-	-	7507,16	41194,41	-	-
LEBI	-	-	-	-	52,47	97,56	-	-	52,59	97,96

				Current Scenario				Scenario 2		
Environment	Indicator TP	Landscape Intervention Index	Weighted TP	Surface (ha)	LEBI	Weighted LEBI	Potential Regeneration Surface (ha)	Surface (ha)	LEBI	Weighted LEBI
Arable land	16	1	16	20690,02	8,04	8,04	-	20324,8	7,89	7,89
Wetlands	91	2	182	19820,06	43,78	87,57	13,49	19820,73	43,78	87,57
W&G dunes	90	3	270	202,58	0,44	1,33	6546,83	519,79	1,14	3,41
Forests	18	3	54	481,75	0,21	0,63	946,84	529,09	0,23	0,69
Total surface	-	-	-	41194,41	-	-	7507,16	41194,41	-	-
LEBI	-	-	-	-	52,47	97,56	-	-	53,05	99.56

				Current Scenario				Scenario 3		
Environment	Indicator TP	Landscape Intervention Index	Weighted TP	Surface (ha)	LEBI	Weighted LEBI	Potential Regeneration Surface (ha)	Surface (ha)	LEBI	Weighted LEBI
Arable land	16	1	16	20690,02	8,04	8,04	-	19959,97	7,75	7,75
Wetlands	91	2	182	19820,06	43,78	87,57	13,49	19821,41	43,79	87,57
W&G dunes	90	3	270	202,58	0,44	1,33	6546,83	837	1,83	5,49
Forests	18	3	54	481,75	0,21	0,63	946,84	576,03	0,25	0,76
Total surface	-	-	-	41194,41	-	-	7507,16	41194,41	-	-
LEBI	-	-	-	-	52,47	97,56	-	-	53,62	101,57

- Composition:
  - Patch Richness (PR) describes the number of different types of land cover in the land unit of analysis;
  - Percentage of Landscape (PLAND), describes in percentage terms the composition of a given landscape;
- Configuration:
  - Patch Density (PD) indicates the degree of subdivision of a specific class of land cover typology, related to the entire extent of the landscape;
  - Mean Patch Size index (AREA_AM) expresses the average size of the elements of a given type of land cover in terms of weighted average;
  - Shape (SHAPE_AM) is a measure of the geometric complexity of the landscape elements of a given land cover category;
  - Edge Contrast (ECON_AM) measures the length of the edge shared between two types of land cover in a given landscape;

- Patch Compaction (GYRATE_AM), expresses the average distance between the various cells of a single spatial unit of the same class of land cover, reported in the total area of the land cover class;
- Contagion (CONTAG) measures the level of aggregation of the land cover classes and it is calculated at the landscape level;
- Cohesion (COHESION) indicates the tendency of land cover types to aggregate;
- Aggregation index (AI), as the previous one indicates the tendency of the types of coverage to aggregate;
- Simpson Diversity Index (SIDI) is a measure of the diversity of homogeneous spatial units.

In ISPRA methodology [52] indicators have been calculated for EU NUTS 3 administrative area units. We propose to measure indicators for the areal units of Vegetation Series Map more consistent from and ecological point of view than an administrative unit.

4.4 Indicators of Landscape Ecology: Fragmentation and Connectivity

EUROSTAT [53] considers the fragmentation of the landscape as a national level indicator in the context of monitoring the main objectives defined in the Europe 2020 strategy.

The Effective Mesh Size Index [54, 55] can be used to measure fragmentation considering the fragmenting role of the soil consumption. The index can be interpreted as the area of accessible land (without encountering physical barriers) starting from any point within the reference territorial unit.

In ISPRA methodology [52], the effective mesh size was calculated using a regular grid with the resolution of one kilometer for the whole Italy. The fragmenting element is the artificial coverage of the soil obtained from the National Soil Consumption Map [54], integrated with OpenStreetMap vector data to improve the identification of linear infrastructures (roads and railways). The level of fragmentation (effective mesh density) was assessed by 5 classes consistent with the definition of the European Environment Agency for the Landscape fragmentation indicator Effective Mesh Density (Seff).

Another way to assess the fragmentation of a territory is to analyze it in terms of connectivity. The Percolation Index [7] is capable to study whether a territory is traversable (or not) by a theoretical animal that must reach two points moving through the landscape patches. The analysis of percolation capacity, therefore, allows us to understand whether and how a landscape is connected. In other words, whether it is able to percolate, that is to allow the flow of a factor, such as the movement of animals, from one side to the other of a territorial unit of reference. This index measures, therefore, the intensity of the barrier action of highly artificialized and urbanized areas. Using some “penalty rules” we can model also the effect of soil consumption and of natural risks (landslide, flooding and seismic).

5 Conclusions

In this work, a set of indices and a methodology in the frame of Integrated Coastal Zone Management (ICZM) have been presented.

Comparing the Marotta et al. [24] methodology with the EU DPSIR approach [40] we can observe (Table 3):

Table 3. Comparison between ICZM methodologies

	Methodology for ICZM by Marotta et al. [24]	EEA DPSIR framework [40]
A		*1. Formulation of a policy-relevant question*
B	*1. Definition of homogeneous environmental management units, and analysis of spatial and temporal structure, hierarchy and dynamics over multiple scales* *2. Analysis of land-use changes in the coastal system* *3. Implementation of spatial indices* characterizing each patch type and state *4. Conservation-gaps analysis*	*2. Mapping pressures (land processes)* *3. Territorial assessment* *4. Dynamic assessment* *5. Functional assessment*
C	*5. Assessment of coastal conflicts* using a coastal conflict index following the work of Vallega [39] *6. Multi Criteria Analysis (MCA) in order to minimize conflicts over a set of values and constraints*	
D		*6. Key policy message*

1. The two approaches can be integrated in a very comprehensive workflow (A + B + C + D) or in a simpler way for local plans (A + B + D).
2. The indices and the methodology we presented can be used to implement a "lean" version of the block B of the integrated workflow.

It is a lean methodology, but focused to face the core of the contemporary dynamics of coastal systems: anthropic actions are producing soil consumption with reduction of sustainability and environmental quality and improvement of risks due to climate change. The "backbone" datasets, Land Use/Land Cover, are systematically updated using Earth Observation products and other data are coming from public bodies (thanks to INSPIRE [41] and other EU's Directives, Eurostat, etc.). Therefore ecosystemic and landscape ecology indices and indicators can be "easily" calculated (even if there are some issues regarding the data standards for indicator species in habitats) and mapped. This kind of maps and indicators and methodology are the foundation of Coastal DSS needed by decision makers and stakeholders for ICMZ. A further step in the methodology will be the exploitation of bottom-up, open and crowdsourced geo-information coming from the so-called Neo-Geography and the real-time/near real-time information of social networks in order to integrate official datasets and to collect feedbacks in a participatory ICZM process.

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