A Framework for Sustainable Land Planning in ICZM: Cellular Automata Simulation and Landscape Ecology Metrics

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Abstract. In the paper, we present a Planning Framework for Integrated Coastal Zone Management (ICZM). The points of strength of the framework are the following:

- It is an iterative and participatory process;
- It is scenario-based and model-based;
- It uses a Spatial Decision Support System (SDSS) as enabling infrastructure;
- The SDSS is "powered" by open data and data systematically updated by public bodies.

The theoretical starting point is ICZM requires decision support tools to cope with knowledge from multiple sources, interdisciplinarity and multiple scales (e.g., spatial, temporal or organizational) [1]. The 2007 Integrated Maritime Policy for the European Union [2] is a key document to understand the relationship between coastal and marine information and policy implementation. It shows that it is necessary to develop a marine-coastal Decision Support System [3, 4] based on indicators and indices (aggregations of indicators into a synthetic representation), use of Geographic Information Systems, models and multicriteria assessment of scenarios [5, 6]. The system of indices is used to describe the complexity of a coastal system: geo-ecological level, land processes, human society, economy, and coastal uses at multiple scales [5, 7]. Multicriteria assessment is a tool to support social and environmental decisions in the perspective of sustainability and strategic planning [8–11].

During the design phase of the SDSS components (basic data, indicators and models), it was performed a review of the Land Use/Land Cover change simulation models. The output of the review was the choice of SLEUTH model [12]. The framework was tested on a study area (Veneto Region - Italy). In the test we coupled SLEUTH with Fragstats [13] for the analysis of landscape ecology metrics.

Keywords: ICZM · Landscape ecology metrics · LUCC models

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1 Introduction

From a methodological point of view, the research continues the work started by two previous researches.

The PhD thesis "*Indices and indicators for Integrated Coastal Zone Management with a Landscape Approach. Application to the Adriatic Sea*" [14] by Dr. Leonardo Marotta PhD carried out at the Universitat Politecnica de Catalunya (Doctorado de Ciencias del Mar - Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos) (Supervisor: Prof. Joan Pau Sierra) shows an exhaustive analysis of the literature about ICZM and about the indicators applied to it. Marotta identified a multiscale ICZM model, based on the concepts of sustainability and landscape, to implement the resilience of the coastal socio-ecological system. The model uses a SDSS. Marotta applied his framework starting from the scale of the Mediterranean basin arriving at the detailed analysis of three sites on the upper Adriatic coast: the Venice lagoon, the Conero (Ancona) and Rimini.

The PhD thesis "*From linearity to circularity. A regenerative model applied to a coastal landscape*" [15] by Dr. Luisa Cattozzo PhD carried out at the Doctoral School in Architecture, City and Design of the IUAV University of Venice (Supervisor: Prof. Domenico Patassini; Co-tutors: Prof Leonardo Filesi, Dr. Leonardo Marotta PhD) has simplified Marotta's ICZM model by focusing it on the circular economy in the coastal area of the Po delta and introducing a new indicator of land eco-biodiversity.

The thesis of Dr. Cattozzo has highlighted it is appropriate to simplify the system of indicators in order to have an effective planning framework. It has to be exploitable at the level of a small dimension Territorial Body such as the Municipality.

This consideration led our choice of sustainability and landscape indicators with a high rate of update by Italian (e.g. ISPRA, Istat) or European (e.g. EUROSTAT, GMES - Copernicus) public bodies. The indicators are mainly available using Spatial Data Infrastructures for data sharing promoted and managed in the frame of the INSPIRE Directive (2007/2/CE) [16]. Otherwise, the indicators can be easily obtained starting from Open Data.

In reviewing the overall methodology, the EU DPSIR Model [17] was also considered as a reference. This model, in fact, places the problems of interest of the ICZM on a more general level (using the concepts of Land System and Land Process) and offers a systemic, multidimensional and integrated approach that takes into account space and time dimensions and relevant aspects of sustainability.

2 The Planning Framework

In Table 1 we compare the ICZM Methodology of Marotta *et al.* [18] with the EEA DPSIR Framework [17] using three macro-steps.

The two methodologies have wide possibilities of integration.

Since the ICZM Methodology of Marotta et al. [18] is targeted to the ICZM, it has a unique and explicit goal in the macro-step A.

The EEA DPSIR Framework [17] was set up with reference to a virtuous process of production and systematic updating of territorial information in which the Copernicus

Table 1. Comparison between ICZM methodologies

	Methodology for ICZM by Marotta et al. [18]	EEA DPSIR framework [17]
A	1. *Goal:* to implement the resilience of the coastal socio-ecological system from a sustainability perspective	1. *Formulation of goals as policy-relevant question*
B	2. *Definition of homogeneous environmental management units, and analysis of spatial and temporal structure, hierarchy and dynamics over multiple scales*. Deliverable: Map of Habitats 3. *Analysis of land-use changes in the coastal system* 4. *Implementation of spatial indices* characterizing each patch type and state 5. *Conservation-Strategies gaps analysis* 6. *Assessment of coastal conflicts* using a coastal conflict index following the work of Vallega [5]	2. *Identification of* ***Drivers*** *and mapping of* ***Pressures*** *(land processes)* 3. *Territorial assessment (****States****)* • Analysis of the LU/LC spatial distribution • Land management practices • Soil sealing and soil consumption • Existence of conservation areas and non-conservation areas 4. *Dynamic assessment (changes of state)* • LU/LC flows • Identification of hot spots 5. *Functional assessment (****Impacts****)* • Measurement of the effects of Land Processes on environmental functions
C	7. *Multi Criteria Analysis (MCA) in order to minimize conflicts over a set of values and constraints*	6. *Key policy message and* ***Responses*** *to specific pressures on the land system*

System plays a fundamental role and explicitly considers the dynamics of Land Take/Soil Sealing.

The Methodology of Marotta et al. [18] requires the Map of Habitats, a specific cartography with a high-specialized effort of production and not homogeneously available in all European countries, and it uses a scenario approach and MCA as well as a specific tool for analyzing coastal conflict dynamics.

However, both methodologies are not suitable for direct application in a planning process, as they do not include the Land Plan in their basic elements.

Macro-step B is the Knowledge Base of the Plan.

The macro-step C of the Methodology of Marotta et al. [18] is a system for the assessment of scenarios, but it is too complex to be used in a real urban-territorial planning process.

To overcome this difficulty, we have designed a Planning Framework that integrates the two aforementioned methodologies. The steps of the Planning Framework are shown in Table 2 according to the logic of the macro-steps.

The proposed Planning Framework (Fig. 1) is an iterative model. The zoning of a Plan (or the zoning of a territorially extended project intervention in the coastal area) has alternative hypotheses (Scenarios). Scenarios are evaluated using indices and indicators of fragmentation of the eco-mosaic, of soil consumption and urban sprawl/urban sprinkling.

Table 2. Planning framework steps

Step	Description	Notes
A	Goal: to implement the resilience of the coastal socio-ecological system from a sustainability perspective	Sources of sustainability goals • International conventions • EU and national regulations • Guidelines • Good practices • Scientific literature
B1	Knowledge Base. Annual-updated items. • Baseline data – Land Covermaps (EEA - Copernicus) – Soil Consumption (ISPRA) – Demographic and socio-economic statistical data (Eurostat, Istat, regional demographic offices) • Data Analysis Layers produced by processing of baseline data – Land Use fragmentation indices and indicators – Urban Sprawl/Urban Sprinkling analysis	The baseline data are cartographies and data systematically produced by national and European bodies
B2	Knowledge Base. Items with variable time interval of updating • Land Use maps produced from the Territorial and Sector Plans • Cartography of environmental constraints and protections • Geo-environmental maps • Map of Habitats	Maps and data produced by the competent bodies
B3	Analysis of the cartographies, indices and indicators of steps B1 and B2 to understand the ongoing Land Processes to support the Plan	
C1	Hypothesis of Land Plan • Land Use Scenarios (Zoning)	
C2	Analysis of the Land Cover and Land Use of Plan Scenarios using the indices and indicators of step B1 • Land Use fragmentation indices and indicators • Urban Sprawl/Urban Sprinkling analysis	
C3	Medium-term Land Use/Land Cover change simulation model starting from Plan Scenarios The simulation outputs will be evaluated using the indicators of step B1	SLEUTH model [12] with multi-criteria analysis of the constraints system (identified using the data of steps B1 and B2)
C4	Steps C1, C2 and C3 will be repeated iteratively based on feedback from the actors of the decision-making process until reaching an agreed scenario	

The assessment of the scenarios is carried out both against the configuration of the land use of the current state, and against scenarios forecasting the medium (and long-term) effects of zoning. The forecasts are the output of a simulation model of the evolutionary dynamics of LU/LC. Compared to the original Marotta model, a different modeling framework has been adopted to simulate the evolution of the Land Cover suitable for giving medium and long-term qualitative and quantitative perspectives to the scenarios of the Plan.

The Planning Framework is a methodology that produces cartographic outputs. Therefore, it is suitable for participatory planning [19].

The Actors (the Decision-makers, the Technicians, the Stakeholders and the Communities) will thus be able to evaluate the different scenarios. They will consider acceptable only a scenario verifying well-defined values of the set of indices and indicators. Such values will be obtained from good practices and from international and national guidelines about sustainability.

The Knowledge Base of the Planning Framework is made up of data and GIS layers having different frequencies of updating and elaborations carried out by the SDSS.

3 A Test for the Setup of the Planning Framework

3.1 The Overall Test Strategy

The overall strategy of the test is to verify whether the proposed indices, indicators and models are able to capture and assess the land dynamics in progress. A critical point of the test is the use of available datasets.

The study area is the coast of the Veneto Region (Italy) which extends for about 160 km, between the mouth of the Tagliamento river and the mouth of the Po in Goro. This area belongs to the provinces of Venice and Rovigo and administratively is divided into 11 municipalities from north to south: San Michele al Tagliamento, Caorle, Eraclea, Jesolo, Cavallino - Treporti, Venice, Chioggia, Rosolina, Porto Viro, Porto Tolle, Ariano nel Polesine.

3.2 Urban Sprawl/Urban Sprinkling

According to Merriam-Webster Dictionary, the definition of Urban Sprawl is "*the spreading of urban developments (such as houses and shopping centers) on undeveloped land near a city*". Urban Sprawl is a disordered and rapid growth of the city, mostly concentrated in suburban areas with low settlement density against the surrounding rural areas [20].

The concept of Urban Sprinkling was subsequently proposed in the literature to account for the pulverization of this projection of the city on the rural territory: "a small quantity distributed in drops or scattered particles" [21]. It is a typical Italian phenomenon [22], but with presence also in other European territories [23].

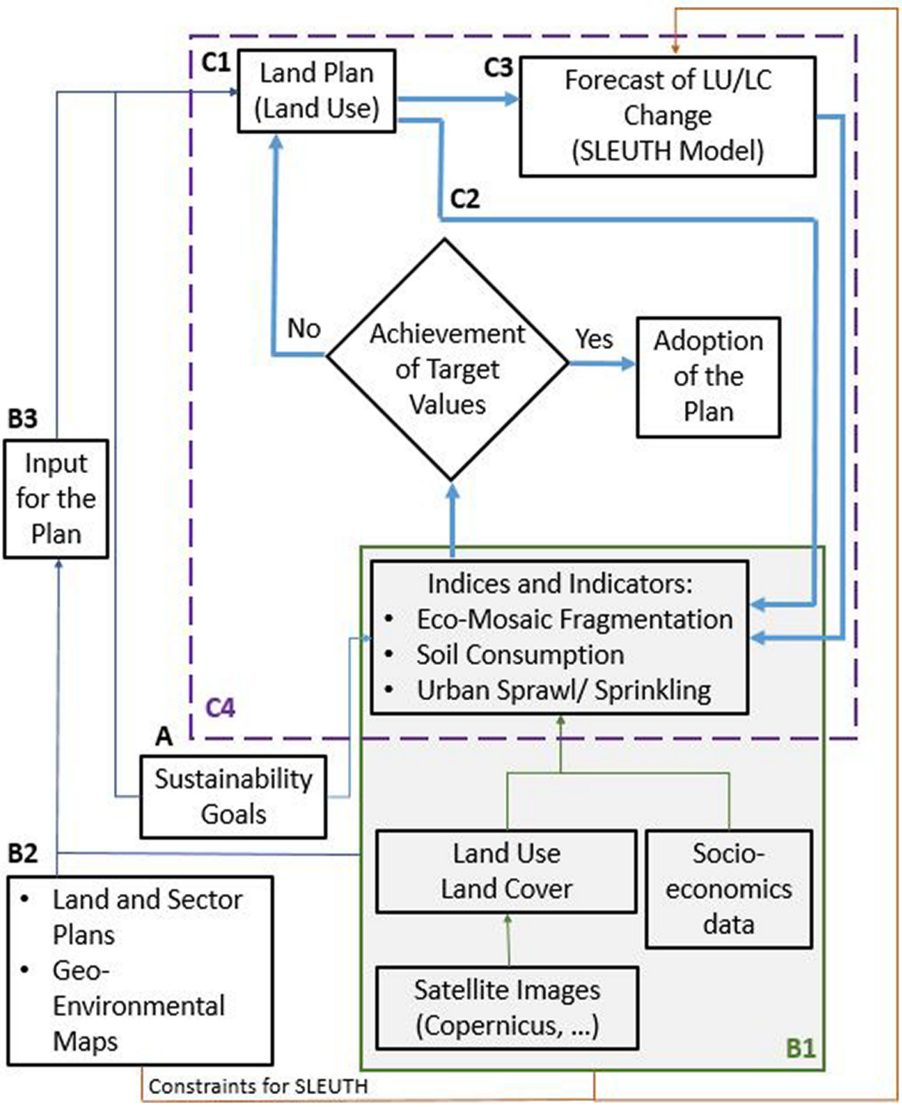


Fig. 1. Planning framework (workflow)

The two phenomena can be identified using specific indicators [24]

$$D_p = \frac{Inhabitant}{Area}\left[\frac{number}{Ha}\right] \tag{1}$$

$$D_b = \frac{Residential\ Building}{Area}\left[\frac{number}{Ha}\right] \tag{2}$$

In [24] it is proposed the following grid of criteria:

	D_b	D_p
Urban sprawl	$12 \geq D_b \geq 6$	$150 \geq D_p \geq 20$
Urban sprinkling	$0{,}8 \geq D_b \geq 0{,}1$	$2 \geq D_p \geq 0{,}2$

We have applied this methodology to the coastal municipalities of the Veneto Region. The layer of residential buildings was extracted from the Regional Vector Topographic Map (CTRN) [25]. The datasource for the area (Ha) of the municipalities is the Italian National Institute of Statistics (Istat) [26]. The result of the experimentation is shown in Table 3. With reference to the threshold values of [24], we can conclude that six coastal Municipalities of Veneto Region (cells highlighted in Table 3) are in Urban Sprinkling conditions.

Table 3. Urban Sprinkling in the coastal municipalities of the Veneto Region (Italy)

Coastal Municipality	Number of residential buildings	Area (Ha) of Municipality	Dp	Db
Caorle	8053	15359,45	0,77	0,52
Chioggia	12186	18782,72	2,65	0,65
Eraclea	7646	9533,02	1,32	0,80
Jesolo	8221	9628,68	2,55	0,85
San Michele al Tagliamento	7223	11420,43	1,05	0,63
Venezia	31984	41563,31	6,24	0,77
Cavallino-Treporti	5480	4467,38	2,99	1,23
Ariano nel Polesine	2132	8057,97	0,56	0,26
Porto Tolle	3841	25667,79	0,39	0,15
Rosolina	4373	7465,24	0,87	0,59
Porto Viro	5029	13369,20	1,09	0,38

The issue affecting this indicator is the low frequency of update of the CTRN and the strategy of not covering the whole Veneto Region at the same time stamp of update.

3.3 Land Fragmentation Indices and Indicators. Scenarios: Year 2007, Year 2012

Fragmentation is defined as "*the process that generates a progressive reduction of the surface of natural environments and an increase in their isolation: in this way, natural surfaces are to constitute spatially segregated and progressively isolated fragments, inserted in a territorial matrix of anthropic origin*" [27].

A first group of land fragmentation indices and indicators [28] is shown in Table 4.

Table 4. Land Fragmentation Indices and Indicators [28]

Denomination and Description	Formula
Infrastructural density: indicates the extension of the multimodal mobility system in relation to the size of the reference area. This extension is proportional to the action of environmental fragmentation deriving from the physical breakdown of the eco-mosaic and the associated disturbing factors (noises, pollution, vibrations).	$DI = \frac{\sum l_i}{Au}$ (m/kmq) l_i = length of the road sections Au = area of the reference land unit
Infrastructure fragmentation: the road sections, which already appear in the DI index formula, are weighted by means of a coefficient that takes into account the occlusion effect (physical interruption or disturbances) that the particular types of road network create towards potential flows of terrestrial fauna.	$IFI = \frac{\sum l_i * o_i}{Au}$ (m/kmq) l_i = length of the individual road sections (excluding discontinuities such as viaducts, bridges and tunnels) o_i = ecosystem occlusion coefficients of road types Au = area of the reference land unit
Urbanization Density: indicates the extent of the urbanized area for each square kilometer of reference area. Using the definition of Urbanized soil in [33], Aurb is modeled with the Land Use categories of the Veneto Region having first code 1.	$DUu = \frac{\sum Aurb_i}{Au}$ (mq/kmq) $Aurb_i$ = area of the urbanized surfaces Au = area of the reference land unit
Per capita urbanized surface for the year XXXX: indicates the size of the urbanized area for each resident (according to an official data source) and is aimed at providing information on local land use for urban purposes.	$SUpc = \frac{\sum Aurb_i}{Au}$ (mq/ab) $Aurb_i$ = area of the urbanized surfaces Nab = resident inhabitants (year XXXX)
Widespread Urbanization Fragmentation: it appears as a density of urbanized surface weighted through a form factor. The first term of the expression provides the incidence of urbanized surfaces in the reference surface, while the second term represents the relationship between the overall perimeter of the urbanized parts and the perimeter that urbanized parts would have if they were all concentrated in a single aggregation having circular shape.	$UFI = \frac{\sum Aurb_i}{Au} * \frac{\sum p_i}{2\sqrt{\pi \sum Aurb_i}}$ $Aurb_i$ = area of the urbanized surfaces Au = area of the reference land unit p_i = perimeters of urbanized areas
Biopermeability rate: indicates the percentage of biopermeability surfaces on the reference area. Biopermeability surfaces are those that are not affected by urbanization or intensive productive land use The classification of biopermeable land use shown in [28] has been "mapped" on the Legend of the Land Use Map of the Veneto Region.	$Tbiop = \frac{\sum Abiop_i}{Au}$ $Abiop_i$ = area of biopermeability surfaces Au = area of the reference land unit

The indices and indicators were calculated for two reference scenarios: year 2007 and year 2012. The choice is the consequence of the fact that in 2007 and 2012 an updated version of the Land Cover Map of the Veneto Region was released [25]. The Land Cover Map of the Veneto Region (scale 1: 10000), has a very detailed legend, made up of 174 classes, and provides for a classification of the territory according to the legend of the European CORINE Land Cover program deepened locally up to the fifth level.

The DBPrior10K was the datasource for the infrastructural network (roads and railways). DBPrior10K is a vector GIS dataset created as part of the Agreement between the State - Regions - Local Authorities on Geographic Information Systems ("Intesa GIS") on a scale of 1: 10000. The original dataset [29] has been updated using conflation procedures with the OpenStreetMap data [30].

The resident population (2007 and 2012) of the Veneto Region is available as open data on the website of the Statistical Department of the Veneto Region [31]. The dataset is available in various formats including MS Excel. The GIS dataset of the boundaries of administrative units for statistical purposes (reference year 2012) can be downloaded from the Istat website [32].

We can see in Table 5 coastal Municipalities with ongoing fragmentation dynamics (cells highlighted).

Table 5. Analysis of the 2007–2012 variation of the fragmentation indices and indicators for the coastal Municipalities of the Veneto Region (Italy). Comp "index X" is the difference between the delta 2007–2012 for "index X" in the municipality and the average delta 2007–2012 for "index X" in the coastal Municipalities of the Veneto Region

Municipality	Comp DI	Comp DUu	Comp UFI	Comp IFI	Comp Supc	Comp Tbiop
Caorle	1,21	-2653,33	-0,04	-3,66	30,41	0,19
Chioggia	7,28	-3585,13	0,00	-1,25	-6,57	0,14
Eraclea	-21,28	-1319,90	0,02	-9,31	21,89	0,02
Jesolo	91,99	8403,22	0,19	27,26	30,85	0,23
San Michele al Tagliamento	-19,91	-3595,55	-0,07	-11,59	-8,33	0,30
Venezia	39,48	-2309,64	0,02	32,86	-4,23	-0,15
Cavallino-Treporti	12,76	-4432,50	-0,06	-1,85	-49,51	1,03
Ariano nel Polesine	-21,46	-1702,18	0,01	-12,10	109,78	-0,58
Porto Tolle	-21,47	-5003,62	-0,06	-12,12	25,87	0,44
Rosolina	-8,12	-4216,75	-0,01	-8,29	-25,89	0,64
Porto Viro	-21,47	-4127,51	-0,16	-12,48	-4,50	0,42

3.4 Ecomosaic Fragmentation Indicators. Scenarios: Year 2006, Year 2012

A second set of fragmentation indicators of the Planning Framework originated in the disciplinary context of Landscape Ecology. "*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" [34].

The Planning Framework uses the following indicators according to a methodology of ISPRA [35]:

- "*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 indices (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*" [34].

The analysis for Veneto Region (Italy) was carried out using the CORINE Land Cover 2006 and 2012 [36] level 2 classes (Table 6). Landscape ecology indicators were calculated using the Fragstats software [13].

Table 6. Assessment of the 2006–2012 dynamics of ecomosaic fragmentation indicators in Veneto Region (Italy)

Indicator	CLC2006	CLC2012	Delta 2006–2012	Assessment
PD	0,2967	0,308	0,0113	Fragmentation increased
AREA_AM	139928,8	135888,5	−4040,2369	Weighted average patch size decreased: fragmentation increased
GYRATE_AM	17527,31	17008,72	−518,5869	Fragmentation increased
SHAPE_AM	17,7269	17,1849	−0,542	The geometric complexity of the elements of the landscape has decreased
ECON_AM	97,8449	97,8732	0,0283	Increased the contrast
CONTAG	64,0012	63,6536	−0,3476	Disaggregation of landscape elements
COHESION	99,941	99,939	−0,002	Disaggregation of landscape elements
PR	15	15	0	Constant (are the CLC classes)
SIDI	0,771	0,776	0,005	Very slight increase in landscape diversification
AI	98,8462	98,8471	0,0009	Aggregation value very high and increasing

3.5 Ecomosaic Fragmentation Indicators. Scenarios: CLC Year 2012, SLEUTH Year 2040

Understanding the processes that generate the changes in land use/land cover and their patterns at a geographical level is fundamental for the design of effective policies for the management of the lands without altering the relationships that define their structure.

The claims of precision of mathematical models for the territory of the sixties and seventies have now disappeared. The consequences of Douglas Lee's Requiem of 1973 [37] is a more realistic approach to models: the aim of the model is not the exact prediction of *how much*, but to be a stimulus for reasoning and discussion with the awareness of the importance of *where*. The model illustrates the alternatives, the effects on the complexity of the territory-environment-society system. The model does not provide the "optimal" solution: the model is the tool for the construction of scenarios and to agree a common vision.

After a survey on the Land Use/Land Cover change (LUCC) models, we chose to use the SLEUTH model [12]. SLEUTH is a representative model of cellular automata models with explicit rules and it has an extensive application in different countries of the world at different scales [38, 39]: it can be considered a model with general applicability [40].

The GIS information layers used for the model were the CORINE Land Cover (CLC), the DBPrior10K infrastructure network, and the information layers of the SDI of the Veneto Region. The simulation workflow adopted in [41] was replicated to identify two scenarios for the year 2040 of the Veneto Region (Italy). As part of the simulation, the CORINE Land Cover 2012 was rasterized with a 500 × 500 m grid and reclassified into 8 classes (Fig. 2).

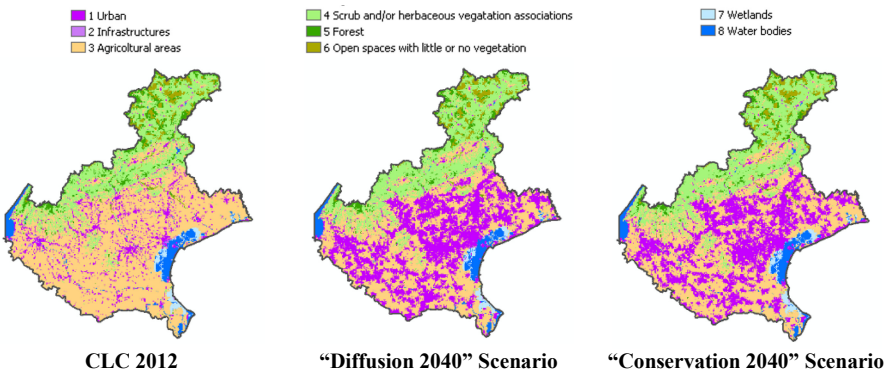


Fig. 2. SLEUTH Simulation for Veneto Region (Italy)

The landscape ecology indicators have been calculated using Fragstats [13] and applied at both landscape level (Table 7) and class level (Tables 8, 9 and 10) obtaining values consistent with a dynamic of pervasive urban expansion.

Table 7. SLEUTH 2040 simulations for Veneto Region (Italy). Landscape level fragmentation indicators

Indicator	CLC 2012	"Diffusion" scenario	"Conservation" scenario
PD	0,1439	0,1169	0,1208
AREA_AM	580814,2657	214596,151	265360,8484
GYRATE_AM	34040,9176	24989,76	27222,4472
SHAPE_AM	17,4721	14,6184	15,9773
ECON_AM	95,8565	96,4181	96,4533
CONTAG	52,9234	48,7178	49,0507
COHESION	99,0337	98,6739	98,8402
PR	9	9	9
SIDI	0,6232	0,7266	0,7227
AI	76,9824	75,5639	75,9248

Table 8. CORINE land cover 2012 of Veneto Region (Italy). Class level fragmentation indicators

TYPE	PD	AREA_AM	GYRATE_AM	SHAPE_AM	ECON_AM	COHESION	AI
1	0,06	1138,22	1415,18	2,10	99,14	74,86	45,02
2	0,01	196,47	603,66	1,35	96,68	51,49	32,10
3	0,02	912751,65	44529,78	21,90	96,54	99,72	85,76
4	0,01	299581,39	38842,37	21,52	96,77	99,23	75,66
5	0,02	1661,60	1893,44	2,31	92,71	80,71	54,11
6	0,01	2451,62	2292,26	2,26	87,78	83,70	62,69
7	0,00	5908,40	4137,15	3,09	97,95	90,44	71,17
8	0,01	20950,06	8241,47	3,59	84,41	93,06	74,86

Table 9. SLEUTH Scenario "2040 Diffusion" for Veneto Region (Italy). Class level fragmentation indicators

TYPE	PD	AREA_AM	GYRATE_AM	SHAPE_AM	ECON_AM	COHESION	AI
1	0,03	180570,80	21870,94	12,85	98,04	98,64	77,98
2	0,00	115,66	463,76	1,23	95,05	40,06	24,51
3	0,03	252627,20	27478,59	17,54	97,77	98,96	75,43
4	0,01	306920,90	36120,43	18,48	95,90	99,21	78,85
5	0,02	1307,94	1621,02	2,10	92,78	77,14	50,86
6	0,01	2479,86	2292,99	2,25	87,62	83,83	63,12
7	0,00	5178,33	3714,93	2,85	97,95	89,57	70,66
8	0,01	21577,47	8707,71	3,74	84,28	94,04	77,64

Table 10. SLEUTH scenario "2040 Conservation" for Veneto Region (Italy). Class level fragmentation indicators

TYPE	PD	AREA_AM	GYRATE_AM	SHAPE_AM	ECON_AM	COHESION	AI
1	0,03	138783,40	16778,25	10,61	98,38	98,14	76,74
2	0,00	81,67	375,19	1,11	93,87	32,00	22,31
3	0,03	379742,60	32618,70	21,25	97,78	99,28	76,85
4	0,01	354027,30	42419,47	20,26	95,74	99,34	79,53
5	0,02	1226,40	1596,60	2,03	92,66	76,17	50,30
6	0,01	2476,41	2289,56	2,25	87,65	83,80	63,03
7	0,00	5966,61	4179,04	3,06	98,11	90,67	72,08
8	0,01	21497,21	8652,60	3,65	84,17	93,81	77,33

4 Conclusions

In this work, a Planning Framework and a set of indices and indicators in the frame of Integrated Coastal Zone Management (ICZM) is presented.

The methodology identified and tested is "lean", but focused on addressing the core of the contemporary dynamics of coastal systems: anthropogenic actions are producing soil consumption with a reduction in sustainability and environmental quality and an increase in the risks due to climate change.

The "backbone" datasets, Land Use/Land Cover, are systematically updated using Earth Observation products and other data that are institutional output of public bodies. Therefore, the indices and indicators of ecosystem ecology and landscape can be "easily" calculated and mapped. This type of maps, indices, indicators and methodology are the basis of the coastal SDSS necessary for decision makers and stakeholders for the ICZM.

The path of evolution of the methodology can be identified in the following topics:

- exploitation of different implementations of the SLEUTH model;
- exploitation of a different LUCC model;
- expansion of the set of assessment models;
- exploitation of both institutional/industrial (IoT paradigm) and social and voluntary real-time data sources.

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