Supporting land use change assessment through Ecosystem Services and Wildlife Indexes

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A B S T R A C T

Biodiversity and landscape management are recognized as crucial pillars of EU policies and strategies in order to ensure the integration of environmental issues with socio-economic needs at the base of human-made changes, in structural and functional terms. Midterm EU's Biodiversity Strategy (Feb 2th 2016) highlights the importance of biodiversity protection in Europe, not only in terms of ethical behavior but also due to its intrinsic value of the biodiversity loss, estimated in EUR 50 billion a year. The study is framed into the LIFE/ENV/IT/275 Ecoremed Project, aimed to development of eco-compatible remediation protocols for polluted soils in the area of Litorale Domitio Flegreo – Agro Aversano (declared Regional Interest Priority Site).

The paper is aimed at defining potential land use change scenarios, by which positive biodiversity impacts could be provided. It entails 2 steps: definition of three LUC scenarios, through a multi-criteria approach; LUC scenarios assessment, through Ecosystem Services and through wildlife impact assessment. The study works on a physical-mathematical model, by which the multi-criteria evaluation for scenarios construction and the quantitative assessments have been integrated. The procedure allowed to identify the most LUC suitable areas and, then, the potential conflict areas between LUC scenarios and target species presence areas, with the specific identification of wildlife species more impacted, in order to calibrate mitigation interventions and strategies, through specific forms/interventions. Our evidence demonstrates an excellent land response to the LUC-LIFE protocols in terms of Ecosystem Services, while highlights the need to consider more targeted strategies with respect to wildlife impacts.

1. Introduction

1.1. Background

Land Use Change (LUC) is broadly recognized as crucial in investigating impacts on landscape alteration, and in deepening the loss of natural environment produced by human activities. LUC analysis allows to critically highlight the driving forces leading territory decline, deepening the specific condition (mostly unexpected) by which emerging new neglected landscapes, such as those generated by land abandonment and by pollution. In these cases, LUC analysis supports the assessment of the site condition for understanding the territorial potentials and for deeming planning opportunities toward more sustainable uses. Indeed, LUC analysis allows to point out selected factors by which generating a set of alternative scenarios in order to effectively compare the future changes and their impacts (Wu and Hobbs, 2002; Dormann et al., 2007; Pelorosso et al., 2009; Riccioli, 2011; Raven, 2011; Pindozzi et al., 2013, 2016; De Montis et al., 2017).

As a consequence of human development, the balance among natural resources is not always guarantee leading to a downgrade in landscape system which is often extremely simplified. It is often very difficult to predict the specific policy measures consequences on biodiversity. The awareness of LUC scenarios assessment is now achieved, in respect of international, European and national indications, directives and regulations.

1.2. Current approaches analysis

According to the need of producing more innovative knowledge of the territorial dynamics, studies on LUC involves vary research fields, (going from soil modeling to the taxonomy of spatial patterns, up to the historic land uses and of historic data set collection), by the aim of understanding causes and impacts of the future changes (Irwin and Geogheganm, 2001).

The studies in the field of Geography have demonstrated the opportunity of using more complex approaches by which stating the integration of socio-economic dynamics into the LUC territorial dynamics (Verburg et al., 2004; Rotmans et al., 2000; Verburg et al., 2008; Baker, 1989; Cialdea and Maccarone, 2012), stressing data set for generating scenarios alternatives as specific prediction support approach, where the term "scenario" is here assumed as "*a means to sketch what could happen, assuming changes in preconditions that differ in nature, course, rate, duration or place*" (Verburg et al., 2008 p.59). In this perspective, scenarios alternatives represent an effective support to deepen knowledge-oriented visions of the LUC potentials, orienting decision makers toward a more aware approach to LUC and planning.

In the framework of the LUC scenarios building, MultiCriteria Decision Analysis (MCDA) techniques have been increasingly applied. Because of their capacity at integrating mathematical models study with GIS spatial references, MCDA is a prime decision support system, guaranteeing transparency in the decision-making process. Moreover, Spatial – MultiCriteria Decision Analysis (S-MCDA) is conceptually dynamic and it allows to integrate both knowledge and contributions from different expertise within the decision framework, cross-cutting policy makers decisions and stakeholders interests (Janssen, 2001; Zhang et al., 2012; Colantoni et al., 2016; Rigillo and Cervelli, 2014; Ferretti et al., 2014; Cervelli et al., 2016a). The S-MCDA supports the construction of a set of alternative scenarios (Malczewski, 2006; Geneletti and van Duren, 2008; Lami et al., 2011; Gbanie et al., 2013; Staals et al., 2013), aimed at exploring the consequences of LUC assumed as preconditions on the observed system (Rashed et al., 2007; Verburg et al., 2008), stressing those territorial topics established as preferred by the decision makers panel (politicians, stakeholders, professionals, scientists, ecc.).

Since 1980s, scenarios evaluation and their possible effects on environment, is carried out with Ecosystem Services (ES) approach (Costanza and Ruth, 1998; MEA, 2003, 2005). The issue is particularly relevant: according to the EU Biodiversity Strategy to 2020 – Action 5 (EU, 2016), all Member States, in their territory, should evaluate and map the state of ecosystems and their services. The ES are related to land use and, therefore, are affected by its change (Foley et al., 2005; de Groot et al., 2010; Lautenbach et al., 2011; Rozas-Vásquez et al., 2016). Many of these changes have effects on landscape composition and structure (Büntgen et al., 2011; Syrbe and Walz, 2012). Different ES classifications, mapping and assessments have been developed and proposed, on global, regional, and local levels. The most widely used approach is the ES monetary value, not only to evaluate alternative strategies for land use but also to demonstrate and justify the need for biodiversity conservation (de Groot et al., 2002; Fisher et al., 2009; Cervelli et al., 2016b). Several applications have been developed, for ES modeling and evaluation such as Ecometrix, Invest, ARIES, MIMES, etc. Among others, INVEST is generally recognized as the most sensitive to assess even minor changes in ES productivity, and it is the most relevant tool to establish environmental policies and compensation/remuneration ES mechanisms (Schirpke et al., 2015).

The wildlife impact assessment is an additional element to support the decision-maker, in order to compare foreseeable effects as a result of different policies and different scenarios of LUC (de Lima et al., 2012). Midterm EU's biodiversity strategy (Feb 2th 2016) posits the importance of biodiversity protection in Europe, not only in ethical terms, but also for the intrinsic value of biodiversity loss, estimated as almost 50 billion euro a year. The wildlife impact assessment is, consequently, an additional element to support the decision-maker, in order to compare foreseeable effects as a result of different policies and different scenarios of LUC. The possible impacts can be studied through deductive or inductive models. In deductive models, the knowledge is employed to identify the most suitable regions for a given species.

1.3. Aim of the study

Starting by this, the study assumes that intense human activities (namely those concerning the development of peri-urban areas) are often not consistent with the preservation of natural resources, nor in terms of efficiency of uses, nor in terms of services provided for the territory. Especially, as consequences of such kind of LUC, extremely simplified landscapes have replaced the original and more complex habitats, producing the loss of ecosystem services and of biodiversity (Ales et al., 1992; Macdonald, 2000). Further, the study consider the LUC planning approach as key opportunity for turning negative impacts into positive ones, even in case of severely damaged areas, such as polluted areas, especially focusing on the biodiversity potential coming from the application of both LUC analysis and S-MCDA techniques.

In order to this, the study proposes the application of such prediction in the study area of SIR Agro-Aversano, located in theperi-urban context, in between the territories of the Metropolitan City of Naples and the Caserta Province. The study area is formally recognized as polluted by the inscription into the National Interest Priority Sites (NIPS) list, built by the Italian National Authority (Ministry of the Environment) in attendance of the Italian Law n. 152/06 for waste management and soils pollution. Such area – currently downgraded into Sites of Regional Interest (SIR) – has been under pressure for the assumed presence of diffuse pollution into the soils and for the practice of burning waste illegally disposed. Driven by an intensive media campaign, the supposed contamination – not fully confirmed by the soil sampling campaign – has created a crushing correlation between land degradation and the land hazard potential, especially concerning the safety of the food chain thus causing severe damages to the local economy mostly based on agriculture (Capolupo et al., 2015). Since 2012, the study area is under the attention of the EU project LIFE11/ENV/IT/275 – ECOREMED aimed at assessing the comprehensive environmental conditions of the area and at applying specific soil remediation protocols.

According to this description, the study area is very representative of the cultural assumption posit by the study, because of it maintains a number of territorial assets (i.e. agricultural landscape, cultural heritage) that encourage the approach to LUC as an opportunity for sustainable development and for reinforcing the natural assets, in contrast with the images of abandonment, marginalization, inappropriate land use, and pollution (real or perceived).

Therefore, the specific aim of the study is to build a set of LUC scenarios through the application of the MCDA methods, making them comparable in terms of the provision of ecosystem services and of biodiversity enhancement. Such objective is also aimed at understanding the re-development potential of the case study area according to different LUC alternatives. The cultural framework of the study is consistent with the EU Biodiversity Strategy to 2020. Along with this aim the LUC assessment made through ES provision together with wildlife impact evaluation can provide new insights, being of help for regional planners as well as decision makers.

Despite the study has been conceived as cross-cutting research, in which different steps dialogue together in every phase of the research, the paper has been organized as follow:

- the S-MCDA is used to analyze the complex and heterogeneous framework to create LUC scenarios;
- special attention has been given to Ecosystem Services, through two approaches: (1) monetary valuation and (2) Invest Habitat Quality module;

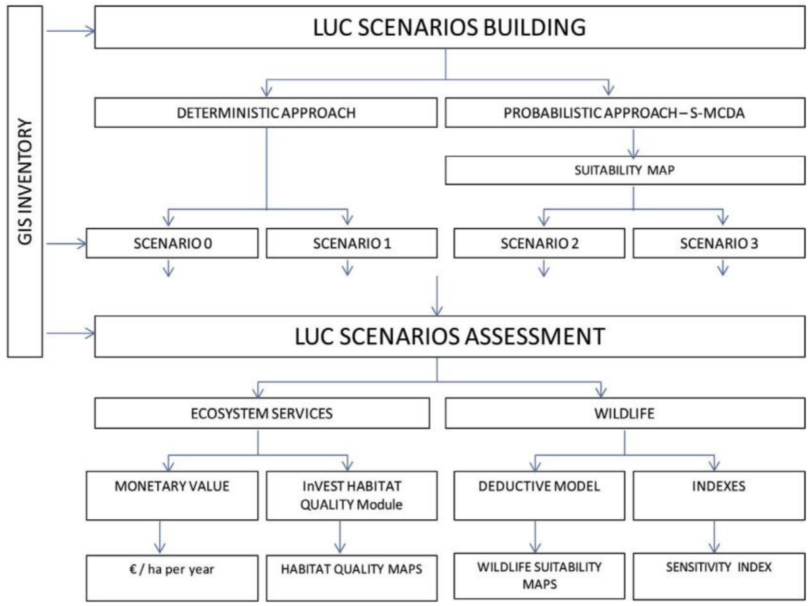

Fig. 1. Framework.

- furthermore the study focuses on the wildlife assessments with (1) deductive and (2) indexes method which differs for number of species investigated. Specifically, in the deductive model only taxa are considered in order to create spatial allocation of single species, to explore eventual conflict/overlap areas generated by land use change. On the other hand indexes approaches involves more than 300 species, providing information on which single species can be affected by LUC. The two approaches are considered as complementary for comprehension of wildlife concerns.

2. Materials and methods

General framework of the study is reported in Fig. 1.

2.1. Study area

The study area is located in Italy, in the Campania Region, in the North of Naples. The study area is known around the world for the historical-artistic and cultural heritage (the area of the ancient *Civitas Capuana*, well known in the Etrurian age and in the Roman age), and for its environment and landscape (marked by the outstanding tracks of the ancient Roman Centuriation, shaping the territorial mosaic). The area is also characterized for its agricultural productions, distinguished by the existence of a number of certificated products (EU PDO/PGI system for food) that enhance local economy.

Despite its beauty, this area has been strongly impacted by illegal activities, mostly referred to the dumping of special wastes and by the practice of burning solid urban waste illegally disposed on the territory. Both these practices lead to social riots and economic decline of local agriculture (mainly small enterprices) and have generated a strong pressure by the media so that the area is now known internationally as "Land of Fires". The study area coincides with the Regional Interest Site (ex NIPS) "Litorale Domizio-Flegreo Agro Aversano", which extends partly in the Naples province (45,000 ha) and partly in the Caserta province (112,000 ha), including 76 municipalities (Fig. 2).

To address this issue, in 2011 the University of Naples Federico II co-financed by the EU LIFE Ecoremed project, gave start to the implementation of protocols for the soil bioremediation processes, applying lab protocols on field. Such protocols will induce a relevant LUC due to the use of specific vegetation for a long term stay.

The territory is mostly flat, with small mountains in the north, close to the massive Roccamonfina Volcano. Soils typologies are organized as follow: the 62% are characterized by the presence of fall ash and pumice, the 29% are composed by alluvial soils and the 8% are dune and lagoon deposits.

Regarding the importance of the natural assets of the area, there are twenty sites of the Nature 2000 network (in attendance of the Directive 92/43/EEC) and three Special Protection Areas (SPAs); the study area also intersects three Regional Parks (Roccamonfina, Partenio, Campi Flegrei), two State Reserves (Castelvolturno; Astroni Crater), two Regional Nature Reserves (Falciano Lake, Foce Volturno – Costa di Licola) and one RAMSAR wetland (Castelvolturno Oasis) (Fig. 3).

Current land uses of the study area include mainly agricultural area (about 70% of the total area), followed by urbanized surfaces (19%) and then by natural and semi-natural areas (about 10%); water bodies and wetlands constitute the remaining 1% of the surface. Inhabitants works in industrial-manufacturing sector (24%), commerce (17%), agriculture (7%), in insurance, technical services and transport (17%), other sectors (35%). Employed in the agricultural sector increase in census of 2011, (25,333 workers in 2011), compared to the previous census (20,043 units, ISTAT 2001). The municipalities featured by the higher agricultural vocation are Cancello e Arnone (20% of the employed population works in agriculture sector), Carinola (22.2%), Cervino (22.6%), Falciano del Massico (22.5%), Francolise (34.9%), Visciano (39.6%).

2.2. LUC scenarios building

LUC scenarios building has been developed with a dual approach, namely deterministic and probabilistic. The used software were ArcGIS (ESRI, Environmental Systems Research Institute), ILWIS (52°North Initiative for Geospatial Open Source Software GmbH).

Within the deterministic approach, soils "not suitable for agro-food crops and forage" (source Ministerial Decree of February 2015), were identified as areas open to change. Such soils have been georeferenced, starting from the cadastral map extracts.

Instead, the probabilistic approach was developed through the multi-criteria evaluation. Criteria are the indicators to measure the performance or the impacts of the LUC alternatives analyzed. These criteria are part of the evaluation matrix that is crucial for the evaluation. In order to define different LUC susceptibility for the study area, the evaluation matrix was structured through a criteria-tree, which provides a hierarchical view of the data (Table 2).

The criteria-tree structure allows to distinguish "constraints" (i.e.

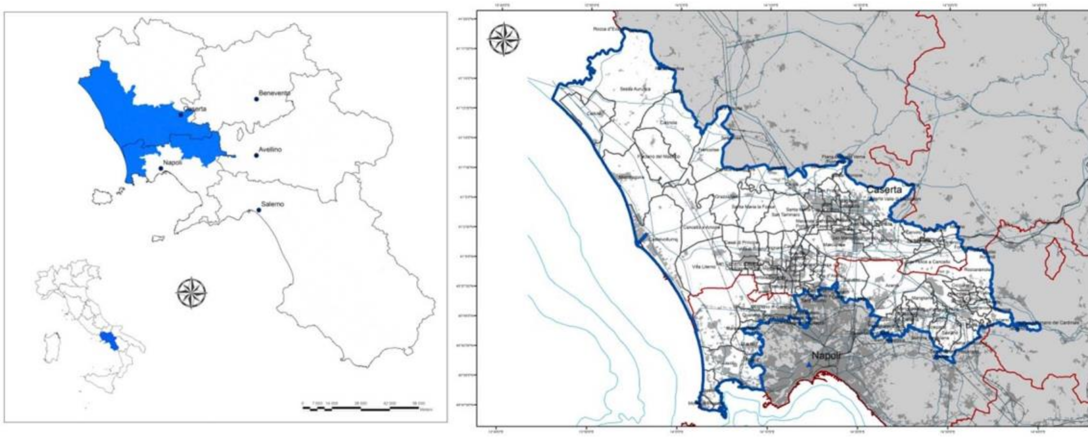

Fig. 2. Study area.

exclusion criteria) and the "factors" (i.e. criteria that contribute to determine the suitability of the area).

The organization of land knowledge process has identified criteria clusters (environmental cluster – divided into biotic and abiotic; social and economic cluster; location cluster). Each cluster is comprised of specific and individual factors (Fig. 4).

The choice of criteria was made through the contribution of an expert panel. Maps for each criterion have been carried out through the sequence of geoprocessing, projection and transformation, and operations of spatial analysis (Table 1).

All maps were converted into raster format and imported into specific software, equipped with multi-criteria evaluation module (ILWIS 3.8.5). Later, normalization supplies comparable values for all maps. Within the S-MCDA, in the standardization phase, dimensionless values ranging from 0 to 1 was assigned to each criterion (Sharifi and Retsios, 2004). The rank of the criteria importance was achieved through the following weighting phase, made in accordance with the criteria-tree matrix and with the support of a panel of experts. The weighting phase was structured through giving different values to the criteria groups and, then, to each single criteria.

In the case of a number of criteria less or equal than 3, a rating technique is directly applied by the expert panel. In the case of comparing more than 3 criteria, the pairwise comparison technique was preferred (under Analytic Hierarchy Process), because of it allows to overcome the difficulty of taking into account all the variables simultaneously.

The pairwise comparison technique is based on a comparison of two criteria at a time. The comparison is organized according to a scale of nine steps according to Saaty's scale (Saaty, 1980, 2005), reflecting the relative importance of the first variable with the second. The criteria are organized in a double-entry matrix and a checked by the Consistency Index (Okello et al., 2014).

In order to obtain a single raster, which shows the different degrees of the LUC susceptibility in the medium-short term – the "Suitability Map" – the integration of raster is produced by the application of the linear weighted combination (or WLC – Weighted Linear Combination), based on:

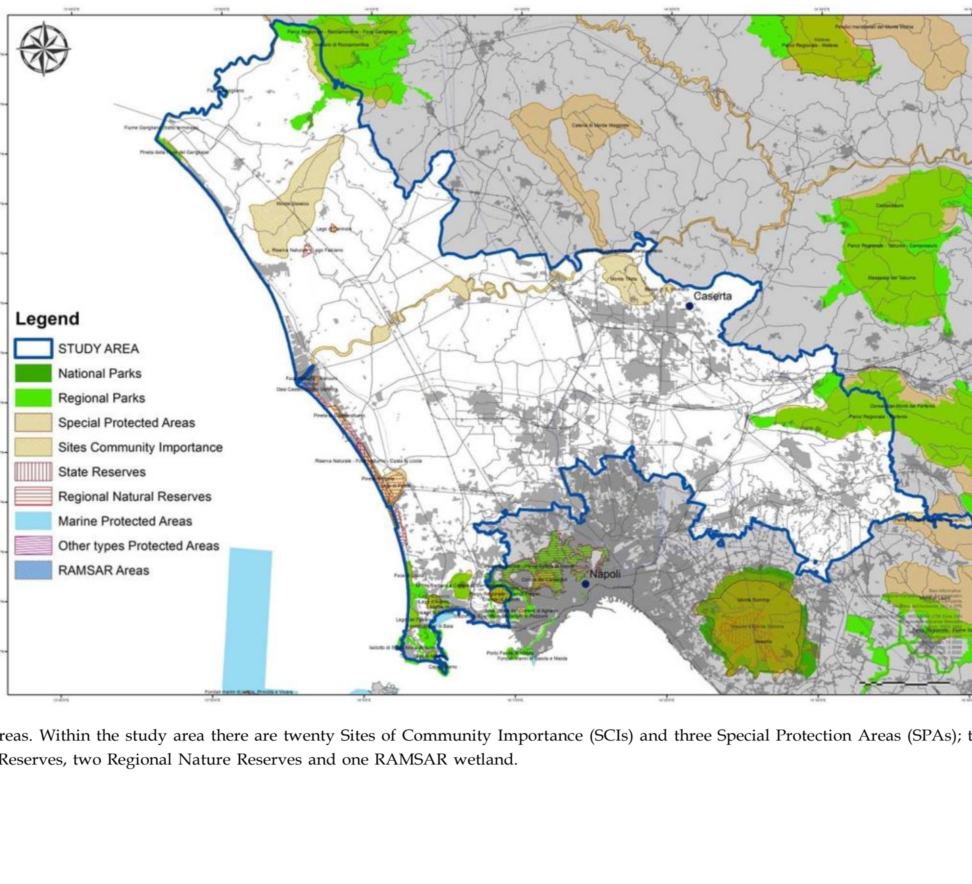

Fig. 3. Natural protected areas. Within the study area there are twenty Sites of Community Importance (SCIs) and three Special Protection Areas (SPAs); the area also intersects three Regional Parks, two State Reserves, two Regional Nature Reserves and one RAMSAR wetland.

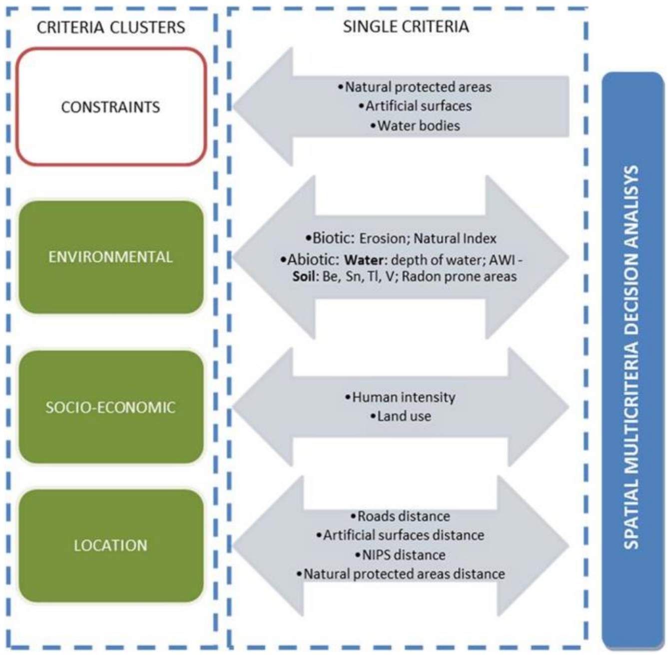

Fig. 4. Criteria definition.

$$P\ i = \sum_{j=1}^{n} (w_j * x_{ij})$$

Where: "P_i" is the resulting LUC plausibility/susceptibility value in the i-th piXel; "n" is the input variables number, "j" is the j-th variable, "x_{ij}" indicates the value that the j-th variable assumes in the i-th piXel, "w_j" is the weight assigned to the j-th variable.

LUC scenarios, previously processed, were explored in Cervelli et al. (2016b) and partially modified, because of implementation of raster map. The scenarios are:

- Scenario 0 – No Change, the scenario shows the current land use/land cover. It is assumed that the current use will not change in the short-medium term. Reference was made to the 3rd level of the Corine Land Cover 2012.
- Scenario 1 – Contaminated Soils, this scenario identifies the areas that formally are identified as "unsuitable for forage crops and agro-food crops", by means of Decree of the Agriculture Ministry 12/02/2015. Through the cadastral identification, specific soils and their buffer areas (50 m) have been identified. These areas will be subject to LUC by applying the bio-remediation protocol of the LIFE Project (Eucalyptus). In the case of contaminated soil, the main aim of the LIFE Ecoremed protocol is to avoid pollutants run-off or leaching, using bioremediation crops for energy purposes, waiting for soil remediation (Giudicianni et al., 2017).
- Scenario 2 – Fringe Areas – Abandonment, this scenario shows the LUC potential resulting from the progressive land abandonment that generates illegal uses. This scenario represents the worst condition in which the system could evolve in the lack of policies and measures targeted to the recovery of the social perception of the area and of the local productions. The fringe areas have been defined using the MultiCriteria- Spatial Decision Support Systems (Malczewski, 2006), by which results the ES – Suitability Map that identifies areas potentially suitable to LUC, because of the adverse environmental conditions and/or the raise of pollutants coming from illegal activities.
- Scenario 3 – Fringe Areas – Life Protocols. This scenario refers to the hypothesis that the same areas identified in scenario 2 will be converted into no-food crops, according to the application of the LIFE protocols (by the plantation of Poplar, Eucalyptus and Giant Reed cultures together with herbaceous ground cover in orchards).

2.3. LUC scenarios assessment

2.3.1. LUC scenarios assessment through ecosystem services (monetary approach and InVEST habitat quality module)

In order to assess the potential impacts (whatever positive) on the natural environment generated by the above mentioned scenarios, the study considers two approach:

- The evaluation of the monetary value of the Ecosystem Services (ES)
- The evaluation the ES through the InVEST Habitat Quality module.

The study points out the ES monetary value – plainly established in

Table 1
S-MCDA Criteria and main metadata and tools used for the analysis.

Multicriteria spatial analysys			
Layer	Metadata	Operations and tools	Standardization (function applied)
Artificial surfaces	CLC12	Select – Union – Conversion	EXclusion
Protected areas	GPN GPRC	Select – Union	EXclusion
Water bodies	GPRC	Select – Union	EXclusion
Erosion	Dati piogge 1939–2012 – DEM20 m – CLC12 – Sistemi di Terre Regione Campania	USLE equation – Map algebra – Reclassify	Benefit
Natural Index	CLC12 – OCS	Reclassify	Cost
Water – Depth to groundwater	Project LIFE – B1c1	Reclassify	Cost
Water – Index af Availability of water	Project LIFE – B1c2	Reclassify	Cost
Soil – Baseline value map Berillio	Project LIFE – B1b	Reclassify	Benefit
Soil – Baseline value map Stagno	Project LIFE – B1b	Reclassify	Benefit
Soil – Baseline value map Tallio	Project LIFE – B1b	Reclassify	Benefit
Soil – Baseline value map Vanadio	Project LIFE – B1b	Reclassify	Benefit
Radon prone areas	GPRC	Reclassify	Benefit
Human Intensity – urban population analysis	Population census data ISTAT 2011	Density analysis – KDE	Benefit
Land cover	CLC12	Union – Dissolve – Conversion	Class
Artificial surfaces distance	CLC12	Buffering and Euclidean Distance	Cost
NIPS distance	GPN GPRC	Buffering and Euclidean Distance	Benefit
Protected areas distance	GPN GPRC	Buffering and Euclidean Distance	Benefit

GPN = Geoportale nazionale; GPRC = Geoportale Regione Campania.

Table 2
Criteria tree framework.

AIM	Criteria types	Criteria groups	Criteria groups weighs	Criteria	Criteria weighs
LUC Suitability areas	Constraints			Protected areas	EXclusion
				Open water	EXclusion
				Artificial areas	EXclusion
				Archaeological areas	EXclusion
	Factors	Environmental characterization WATER	0.33	Depth to groundwater Map	0.50
				Index of Availability of water to the application of the Protocol LIFE	0.50
		Environmental characterization SOIL	0.33	Baseline values maps Sn	0.10
				Baseline values maps Be	0.30
				Baseline values maps Tl	0.30
				Baseline values maps V	0.30
		Environmental characterization LANDSCAPE	0.33	RUSLE erosion map	0.06
				New classification for land cover map	0.20
				Radon – prone areas	0.12
				Distance map from protected areas	0.12
				NIPS map	0.06
				Distance from NIPS areas	0.08
				Digital Elevation model – height	0.06
				Digital Elevation model – slope	0.06
				Distance map from principal roads	0.12
				Distance map from artificial areas	0.12

literature (Costanza et al., 1997; Fisher et al., 2009; Scolozzi et al., 2012; de Groot et al., 2012) – by which quantitatively compare the 3 LUC scenarios (assuming the monetary values as proposed by Scolozzi et al. (2012) into euro per hectare per year and updated to 2016). As shown in Table 2, a further element of the classification has been inserted – Herbaceous ground cover in orchards – depending on specific bio-remediation solutions developed under the LIFE-Ecoremed project (Cervelli et al., 2016b).

In order to integrate the economic evaluation of the ES, the study proposes the InVest Habitat Quality module (InVEST software, Natural Capital Project, University of Minnesota) that associates the habitat ecological value with the third level of the Corine Land Cover (McGarigal, 2015). The software synthesizes the results of the habitat assessment, expressed as one dimensionless parameter ranging from 0 to 100, representing the comprehensive habitat quality. Starting by this, a specific GIS layers have been prepared – the Habitat Quality map – showing the threats distribution in the area and their decay laws (Tallis et al., 2013). The main threats considered within the software were:

- Human Intensity (calculated using the Kernel Density, compared to urban areas and to the resident population for each municipality);
- Industrial, commercial and infrastructure areas (source Corine Land Cover, 2012);
- Infrastructure – Main road and rail routes and buffer areas of 20 m (sources Campania Region geo-portal);
- Protected crops (source Agricultural Land Use Map 2009 of Campania Region);
- Perennial crops (source Corine Land Cover 2012);
- Soil Erosion risk potential (calculated by USLE of Wishmeier and Smith).
- Each threat was mediated by four factors:

(1) relative impact of each threat on habitat (Table 3);
(2) a distance-decay function of the habitat grid cell from the threat source (Table 3);
(3) a mitigation factor that taking into account if the cell falls into a natural protected areas;
(4) relative sensitivity of each habitat to each threat.

Cell size is 20 × 20m, The Coordinate System is ETRS 1989 UTM zone 33N. The habitat values for each land use class (ranging from 0 to 1), have been assigned basing on literature data and on the wildlife consulting (IUCN web site – www.iucnredlist.org/; IUCN Italia web site – www.iucn.it/liste-rosse-italiane.php; Guarino et al., 2012; Lanza et al., 2009; Cramp and Simmons, 1977, 1980, 1983; Cramp, 1985, 1988, 1992; Cramp and Perrins, 1993, 1994a,b; Spagnesi and De Marinis, 2002).

Table 3
Decay-function and relative weight applied for each threat considered.

Max distance (km)	Weight	Threat	Decay function
5	0.8	Human intensity	exponential
3	0.8	Industrial, commercial and infrastructure Areas	exponential
3	0.5	Main road and rail routes	exponential
0.5	0.5	Protected crops	linear
2	0.5	Perennial crops	linear
3	0.5	Erosion risk	exponential

2.3.2. LUC scenarios assessment through Wildlife Indexes

Biodiversity and ecosystems services are even more crucial to support strategies for land use planning ecological oriented. The wildlife impact assessment is thus aimed at becaming an effective tool for supporting decision-making process.

In present paper, the potential impacts of LUC on the wildlife has been developed with two approaches: the first identified six target species representative of the studied area as listed in Table 4.

Templates customized for each single species have been built to describe the habitats and the interconnections with the landscape features. The maps of the target species and their distribution, were prepared following the indication of the: protection regulatory framework, species areal, home range, habitat, nesting, interaction with other species, interaction with the human activities, landscape fragmentation. Specific raster maps (wildlife suitability map) were constructed for each single species with the S-MCDA approach. Areas featured by an index of suitability greater than 0.5 are considered as high possibility presence for the species (wildlife Suitability map species index > 0.5). Areas featured by an index of suitability greater than 0.7 are areas of very high possibility presence for the species (wildlife Suitability map species index > 0.7). These maps are considered for comparison with the LUC scenarios, in order to identify the existence of possible conflict/

Table 4
Target species selected in Wildlife spatialization assessment.

	Common name Specie	Scientific name specie	Order	Family	Birds Directive Annex	IUCN Risk Category
Aves	1.0Black kite	*Milvus migrans*	Accipitriformes	Accipitridae	I	VU – Vulnerable
	2. Shrike	*Lanius collurio*	Passeriformes	Laniidae	I	VU – Vulnerable
Mammals	3. Porcupine	*Hystrix cristata*	Rodentia	Hystricidae	IV	LC – Lower risk
	4. Greater horseshoe bat	*Rhinolophus ferrumequinum*	Chiroptera	Rhinolophidae	II; IV	IUCN: VU – Vulnerable
Reptilia	5. Wall lizard	*Podarcis muralis*	Squamata	Lacertidae	IV	LC – Lower risk
Other species of interest	6. Boar	*Sus scrofa*	Artiodactyla	Suidae	–	LC – Lower risk

overlap areas.

The second approach to assess the impact of LUC scenarios on wildlife, is through the Sensitivity Index (%). This approach was extended to a substantial taxa amount present in the area (305 taxa). The complex procedure is based on the relationship between the habitat change and the change of the species permeability index and, especially, by the value of the K index, which determines the algorithm.

The Sensitivity Index (SI), expressed as a percentage (%), was obtained through four sub-indices, referred to environmental characteristics and to the relationship among individual species (US Fish and Wildlife Service, 1981; Brooks, 1997; Gibbs, 1998; Roloff and Kernohan 1999; Jaeger, 2000; Pons et al., 2003; Sandker et al., 2009; Booth et al., 2011). The sub-indices are the follows:

- Habitat Index (HI) measures the suitability of an area for the species. It is calculated through the natural logarithm of the surface (in hectares) of each environmental category (A_i) multiplied by an election factor (w_i) for the species of that particular habitat. The logarithm used to maintain the most comparable results even with large differences in area is:

$$HI = \sum_{i=1}^{n} \ln(A_i * w_i)$$

- The degree of election factor (w_i ranging from 1 to 3)of a given habitat for the species is assigned on the basis of the available literature (Guarino et al., 2012; Lanza et al., 2009; Beaman 2010; Cramp and Simmons, 1977, 1980, 1983; Cramp, 1985, 1988, 1992; Cramp and Perrins, 1993, 1994a,b; Spagnesi and De Marinis, 2002) and based on the knowledge of experts.
- Permeability Index (PI) indicates land permeability for each species. It is calculated considering the extension and fragmentation of habitats that allow greater mobility to the species, always in relation to the election factor (w_i) of that particular habitat for the species. Land fragmentation, can be measured as the ratio of the total patch perimeter (which constitute a specific environmental category) and the perimeter of a circle of area equal to its total area. Small values indicate big or branched little patches, big values indicate rather small patches scattered throughout the territory:

$$PI = \sum_{i=1}^{n} (A_i / k_i * w_i)$$

- Conservation Index (CI) represents importance of species, from the conservation point of view. It varies from one to five, depending on the species that falls within one or more categories, which indicate conservation relevance.
- Rarities Index (RI), indicates qualitatively rarity of the species on the territory ranging from one to five. The value is generally assigned according to the criteria specified below:
- for all faunal components, data from International Union for Conservation of Nature (IUCN) Italy were used; also standard templates of SCIs and SPAs area were used as the data concerning the number of species sightings;
- for the breeding birds, data from Italian Ornithological Monitoring (MITO 2000) and data from Ornitho (www.ornitho.it) were used;
- for wintering birds, data from Ornitho database and International Waterbird Census (IWC ISPRA) were used;
- for passing migrating birds, data from Ornitho database were used;
- for reptiles and amphibians, data from Ornitho database (regarding herpetofauna monitoring project and batracofauna) were used.

HI and PI are evaluated for each scenario. The ratio between HI calculated for one scenario and the HI calculated for scenario 0, expressed as a percentage, identify new values, named HDI, ranging from 1 to 7, according to Table 5. The same approach have been used for calculating PDI, starting from PI value.

The score "4" in Table 5 is representative of no LUC influence on the species habitat, or species permeability (such indexes HDI and PDI are required to calculate the advantage-disadvantage index, VSI). The VSI can be evaluated on the value of K:

$$K = (HDI - 4) + (PDI - 4)$$

Select case:

- $K < 0$, a positive impact is devoted to LUC and the VSI = HDI*PDI*(6-CI)*(6-RI)
- $K > 0$ a negative impact is devoted to LUC and the VSI = HDI*PDI*CI*RI
- K=0 and two indexes are close to 4, the LUC is not influencing, VSI is not calculated
- K=0 with HDI and PDI different from 4, VSI has to be evaluated for each single case (this situation is not common).

The Sensitivity Index (SI) leads toward the final evaluation about the comprehensive impact on the fauna components, analyzed by the balance of both advantages and disadvantages, obtained for the individual species. For the SI calculation, a numerical value, between −3 and +3, has been attributed to each species, depending on the category of the resulting VSI. The sensitivity index is the sum of all the values thus obtained:

$$SI = \sum_{i=1}^{n} (VSI_i)$$

Table 5
Categorization of the percentage changes of HI and PI in the HDI and PDI indices.

Δ%	HDI – PDI
Less than −67,3	7
From −67,7 to −34,7	6
From −34,7 to −2	5
From −2 to +2	4
From +2 to +34,7	3
From +34,7 to +67,3	2
More than +67,3	1

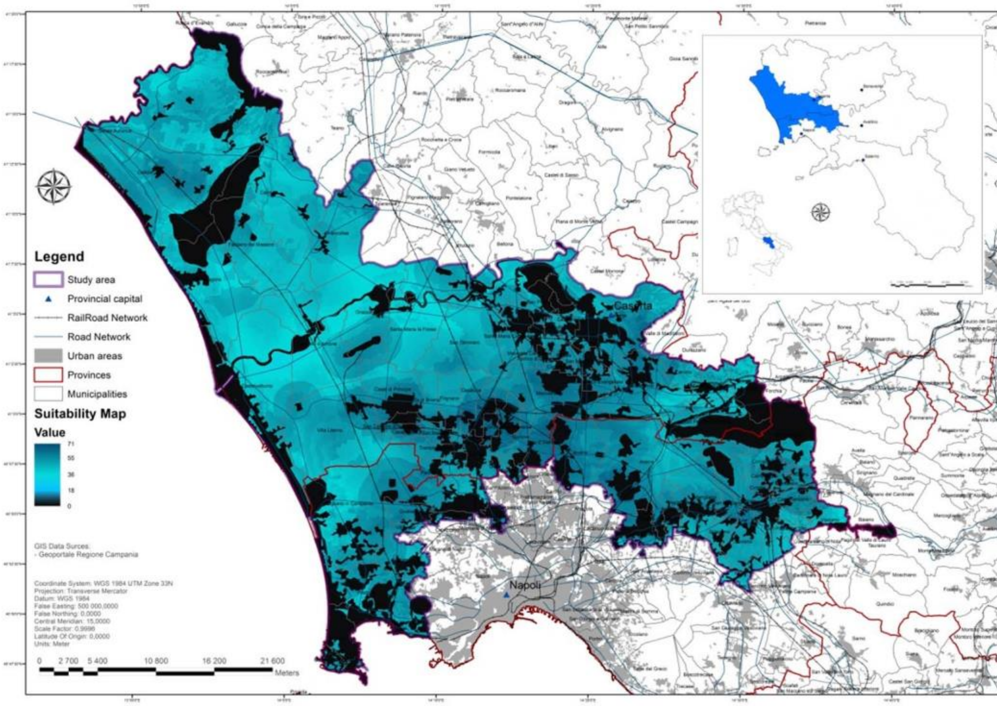

Fig. 5. Suitability Map.

where i indicates the i-th species of the N total species number analyzed.

The sum of all scores gives a value ranged between [3 ∗ the species number (N) in negative] and [3 ∗ the species number (N) in positive]. This index is obtained by transforming the result as a percentage of possible extreme scores (Percentage Sensitivity Index (SI%). Gap of such extreme scores corresponds to [6 ∗N] and the set of positive or negative values corresponds to 3N. Thus, the formula for the SI% calculation is:

$$SI\% = \left(\frac{SI + 3N}{6N} - 0.5 \right) * 100$$

where N is the number of the analyzed species.

The result provides the index difference (in percentage) compared to the original condition (IS = 0%), both in positive and negative, easy to read.

3. Results

Once suitability map (Fig. 5) was sorted out, the fringe areas were delineated (Fig. 6). The main results are the scenarios mapping and their comparison, in terms of ES monetary values, Habitat Quality Index, wildlife deductive model and indexes, with Scenario 0 (Fig. 7) which is considered as baseline.

3.1. LUC scenarios

In the Scenario 1 (titled “Contaminated Soils”, Fig. 8) a very small percentage of the whole SIR area (0.03%) is supposed to change (20.2 ha, including buffer areas). In these areas, mainly non-irrigated arable lands, the existing land cover is supposed to be converted into Eucalyptus in compliance with LIFE Ecoremed project protocols. Areas probably changed fall within 6 municipalities (Acerra, Caivano, Giugliano, Marcianise, Succivo, Villa Literno).

In the Scenario 2 (titled “Fringe areas – Abandonment”, Fig. 9), a total area of approximately 16,000 ha is subject to LUC. In these areas current non-irrigated arable lands and pastures CLC classes, were supposed to be converted in abandoned lands, whereas in the same areas, permanent crops class is supposed to be converted in arable land. LUC would affect about 40 municipalities, with biggest areas falling in the municipalities of Acerra, Caivano, Marcianise for which more than 1000 ha are supposed to be abandoned.

In the Scenario 3 (titled “Fringe Areas – Life Protocols”, Fig. 10), the same areas of Scenario 2, is supposed to be converted into Eucalyptus, Populus, Arundo donax and Herbaceous ground cover in orchards according to LIFE Ecoremed project protocols.

3.2. LUC scenarios assessment

3.2.1. LUC scenarios assessment in terms of Ecosystem Services

Table 6 reports results of ES monetary discounted value total amount, that has to be compared to Scenario 0 value (281 M€). The change in ES value for Scenario 1, is very small (about € 100,000 corresponding to a +0.03%), according to limited extension of LUC areas. For Scenario 2 the change in ES is negative and strongly relevant (- 31 M€). Even more great is ES value change for Scenario 3 (+36 M€) mainly due to the increase of the wooded area, fruit trees and complex cultivation patterns.

The second approach used to assess LUC in terms of ES variation, is through the Habitat Quality index calculation made with InVest module. The index values range from 1 to 100. The ES variation, compared to Scenario 0, is equal to + 0,03% for scenario 1; to −4% for scenario 2 and to + 5% for the scenario 3. The trends are therefore the same as those highlighted through the ES economic evaluation, even with different variation margins. Figs. 11–14 show the value of Ecosystem Services (ES) in terms of habitat quality, expressed by the different lad use/land cover classes for each scenario. Each figure enable the highlighting of areas that provide highest ES (green areas) and what are the most critical areas (red areas), in terms of habitat and related ES. These indications, along with what resulted from the wildlife impact assessments, constitute a useful reference for the design of any mitigation/compensation actions in environmental terms.

3.2.2. LUC scenarios assessment in terms of Wildlife impact evaluation

The assessment was made with two approaches, considering reduced number of target species on one hand and calculating the

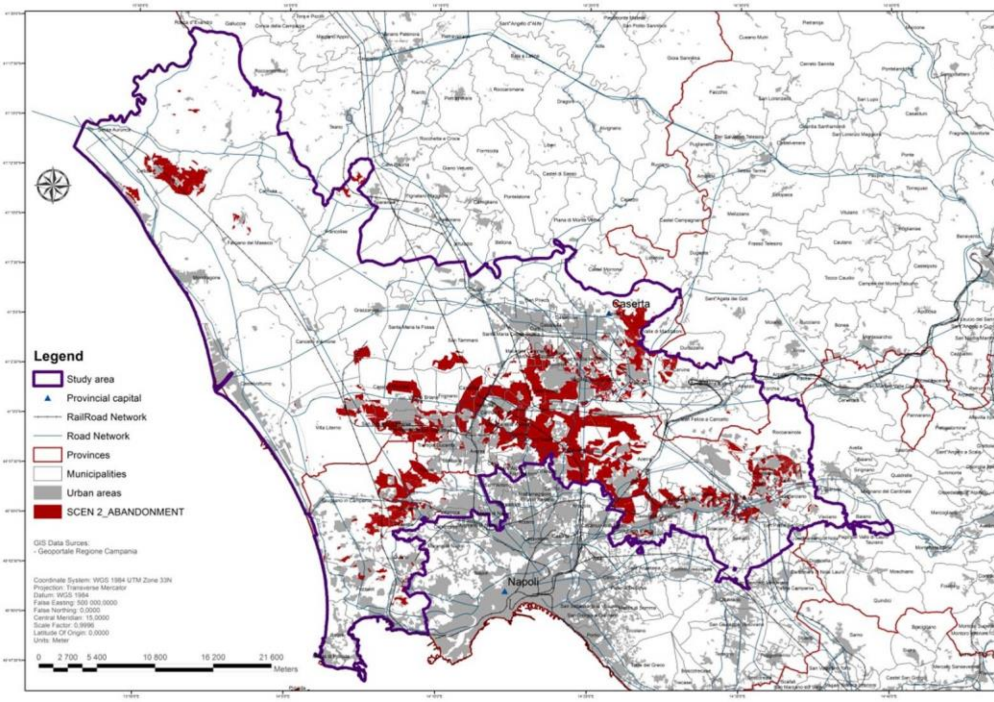

Fig. 6. Probabilistic approach – LUC areas: Fringe areas.

sensitivity index (SI) for more than 300 species on the other.

Wildlife impact evaluations for target species, allowed to highlight considerable conflict/overlap between species, in particular for birds and mammals, and the fringe areas. The assessment was conducted for scenarios 2 and 3 but not for scenario 1, due to its limited areas subjected to LUC (20 ha).

Two checks were conducted, one with a medium-high possibility presence index of species (Suitability map species Index > 0.5) and one with a higher possibility presence index of species (Suitability map species Index > 0.70). In both cases, significant interference affecting the black kite, porcupine and wild boar was assessed. Figs. 15–17 show the potential distribution of each single wildlife species. This distribution is then compared with LUC areas of scenarios 2 and 3 (fringe areas). The comparison allows to highlight the potentially critical areas for interference and overlap between LUC areas and wildlife possible presence areas.

The second approach adopted for the wildlife assessments, is with the use of Sensitivity Index, which integrates previous approach and is extended to a large species number. Results (Table 7) demonstrated a significantly positive change vs Scenario 0, only for Scenario 1:

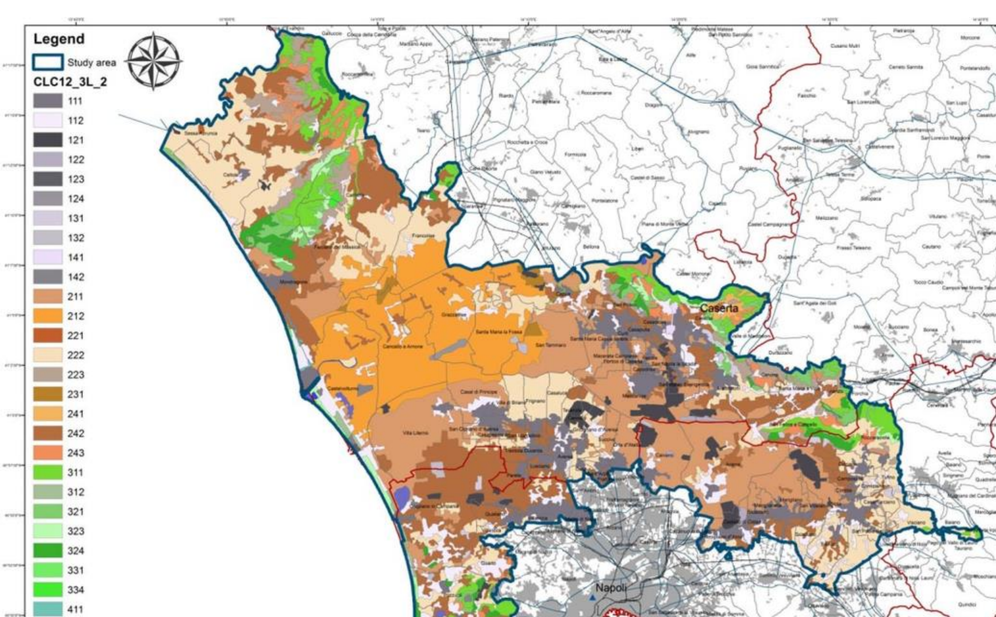

Fig. 7. Scenario 0 – No Change.

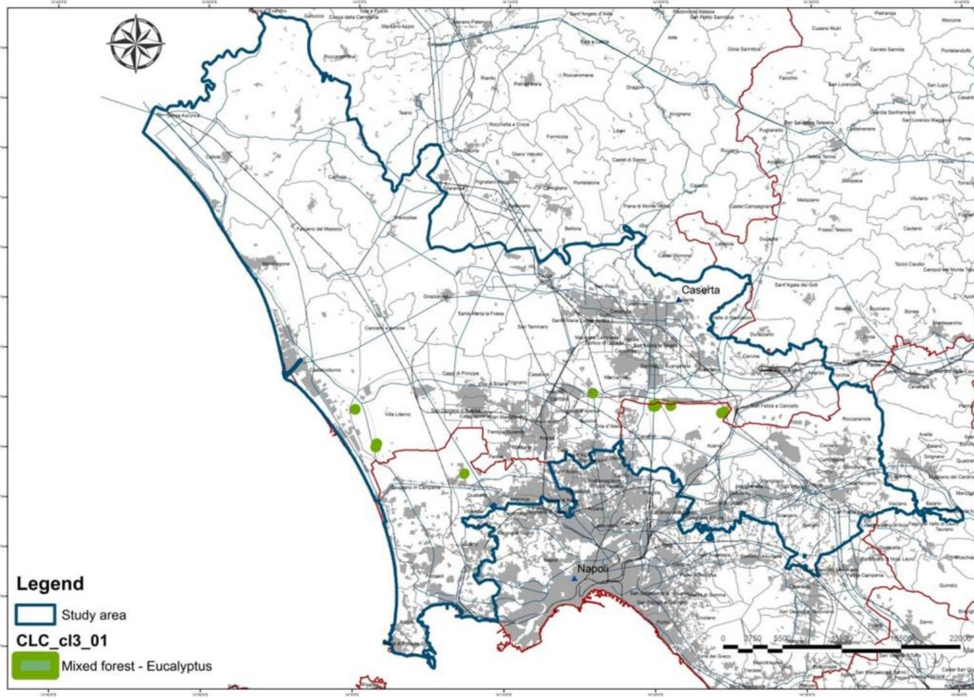

Fig. 8. Scenario 1 – Deterministic approach – Contaminated Soils.

although the LUC is expected in a few hectares, the sensitivity index is significantly positive (IS% = +12%) for the entire SIR area. The benefits are evenly distributed to all the examined animals classes (mammals, reptiles, amphibians, aves).

Scenario 2 is strongly negative (IS% = −38%), and all the wildlife classes have a strong disadvantage degree.

In particular, birds would be the most disadvantaged species (IS% = −40%), and reptiles the less one (IS% = −26%).

Scenario 3 is unfavorable too, although rather less significant (IS% = −11%). In this case, amphibians and reptiles are the most disadvantaged species.

4. Discussion

Predicted LUC areas for scenario 3, of about 16.000 ha, suitable for no-food and bio-remediation crops, are large enough to start an agro-energy production chain. The localization of the areas in a small number of municipalities, mostly very close each other would be worthy of being investigated.

The ES assessment revealed a substantial homogeneity of results for both assessment approaches, similar trends can be observed among the three scenarios, although with different percentage of variation.

The monetary approach provides an order of magnitude of the ES,

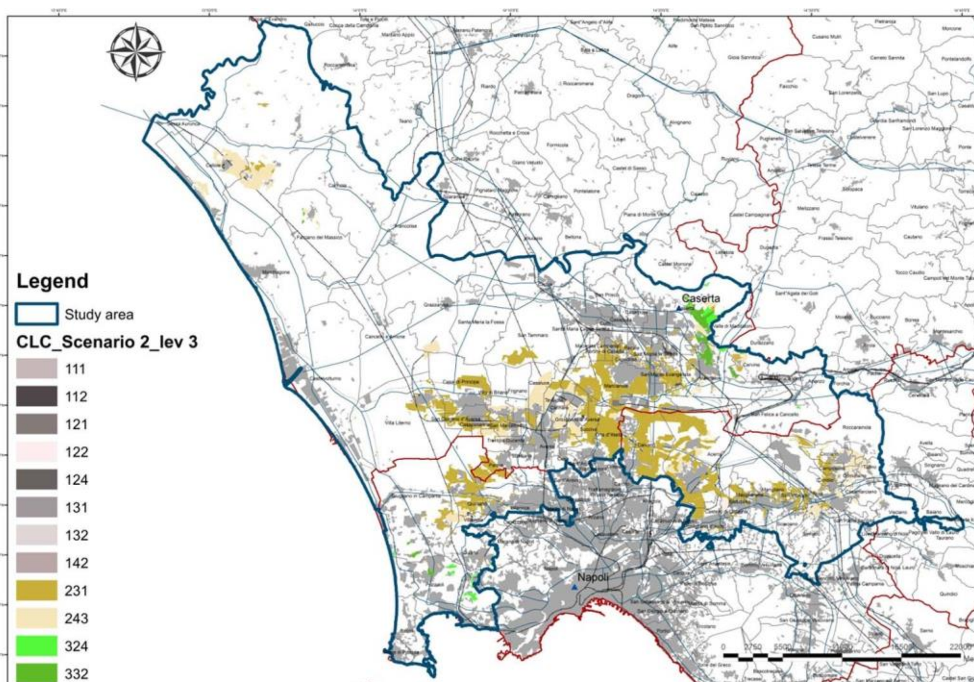

Fig. 9. Scenario 2 – Probabilistic Approach – Fringe Areas – Abandonment.

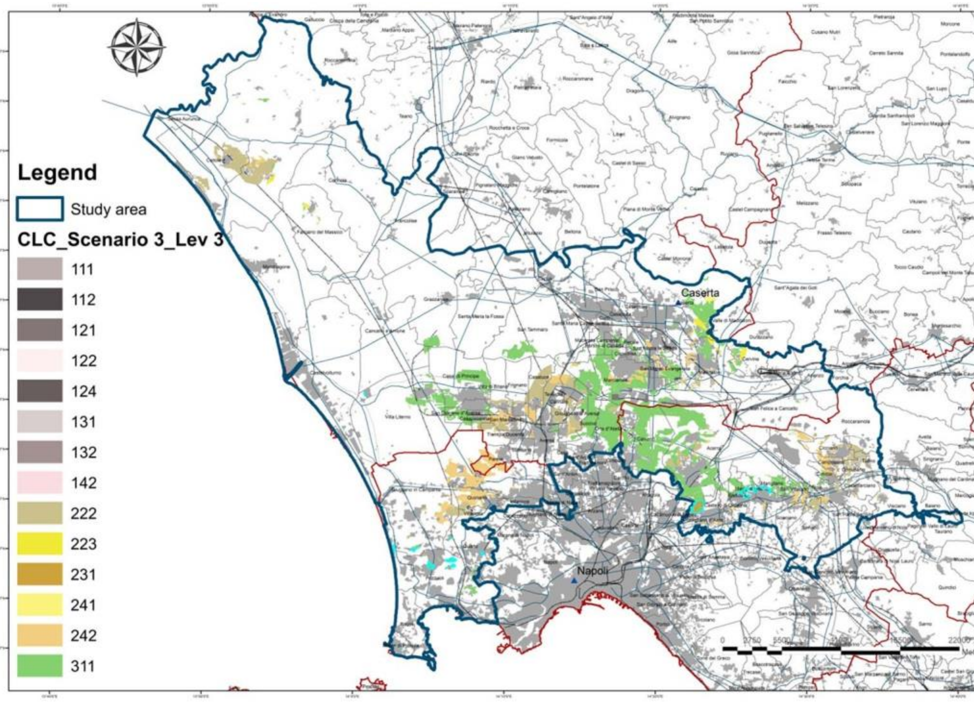

Fig. 10. Scenario 3 – Probabilistic Approach – Fringe Areas – LIFE Ecoremed Protocols.

but on the other hand when analysis are accomplished to each LU class, as in this study, it should be weighed and recalibrated on the interactions among land cover classes. For example, the recreational value of the area is certainly dependent by urban areas distance. The approach with InVEST module is user friendly. In the present study, only habitat quality index was calculated, although Invest allows a more comprehensive approach using other modules. At the same time the monetary approach is more understandable for the planner.

ES assessment, seems to support the LIFE protocols application: the bigger LUC is the higher ES value is.

Nevertheless evaluation carried out with wildlife impacts assessment, highlights some discrepancy with ES approach. As a matter of fact the wildlife index approach has emphasized, a substantial decrease in biodiversity in Scenario 2, and a moderate decrease within Scenario 3. The causes are to be found essentially in the conversion of existing not-irrigated arable land into no-food crops. A further critical factor appears the landscape mosaic loss, against a more homogeneous landscape.

About wildlife impact assessment, the two approaches proposed are complementary. The sensitivity index seems to be more rigorous and complete, regarding quite all the wildlife species in the study area. Nevertheless it does not provide spatial allocation of the species and critical areas. On the contrary the approach based on target species, apparently less detailed, delineates critical areas. Above all this

Table 6
ES monetary values and areas (classes with null values are not reported).

CLC 3rd Level	CLC12 classes – level 3	ES Value €/ha/y	ESv Scenario 0 (M€/y)	ESv Scenario 1 (M€/y)	Esv Scenario 2 (M€/y)	ESv Scenario 3 (M€/y)
141	Green urban areas	5557	0,94	0,94	0,94	0,94
142	Sport and leisure facilities	5557	2,05	2,05	2,05	2,05
211	Non-irrigated arable land	1980	55,79	55,75	39,99	40,00
212	Permanently irrigated land	1980	40,35	40,35	40,03	40,03
221	Vinyards	2106	0,25	0,25	0,25	0,25
222	Fruit trees and berry plantations	2106	58,09	58,09	50,43	58,09
223	Olive groves	2106	9,29	9,29	8,77	9,29
231	Pasture	2106	1,36	1,36	1,36	1,89
241	Annual crops associated with permanent c.	2106	1,48	1,48	1,38	1,48
242	Complex cultivation patterns	1980	51,78	51,78	46,23	51,78
243	Land principally occupied by agriculture	1980	6,83	6,83	6,67	6,67
311	Broad-leaved forest	6060	45,01	45,01	42,85	96,96
312	Coniferous forest	6060	2,93	2,93	2,89	2,89
313	Mixed forest	6060	0,00	0,13	0,34	0,00
321	Natural grassland	126	0,38	0,38	1,06	0,34
323	Sclerophyllous vegetation	126	0,21	0,21	0,34	0,19
324	Transitional woodland shrub	126	0,31	0,31	0,00	0,30
411	Inland marche	18196	1,17	1,17	1,17	1,17
511	Water corse	3290	0,45	0,45	0,45	0,45
512	Water bodies	3290	1,82	1,82	1,82	1,82
521	Coastal lagoons	3290	0,08	0,08	0,08	0,08
523	Sea and ocean	3290	0,46	0,46	0,46	0,46
	TOTAL		281,05	281,13	249,57	317,13
	Δ%			0,03%	−11%	13%

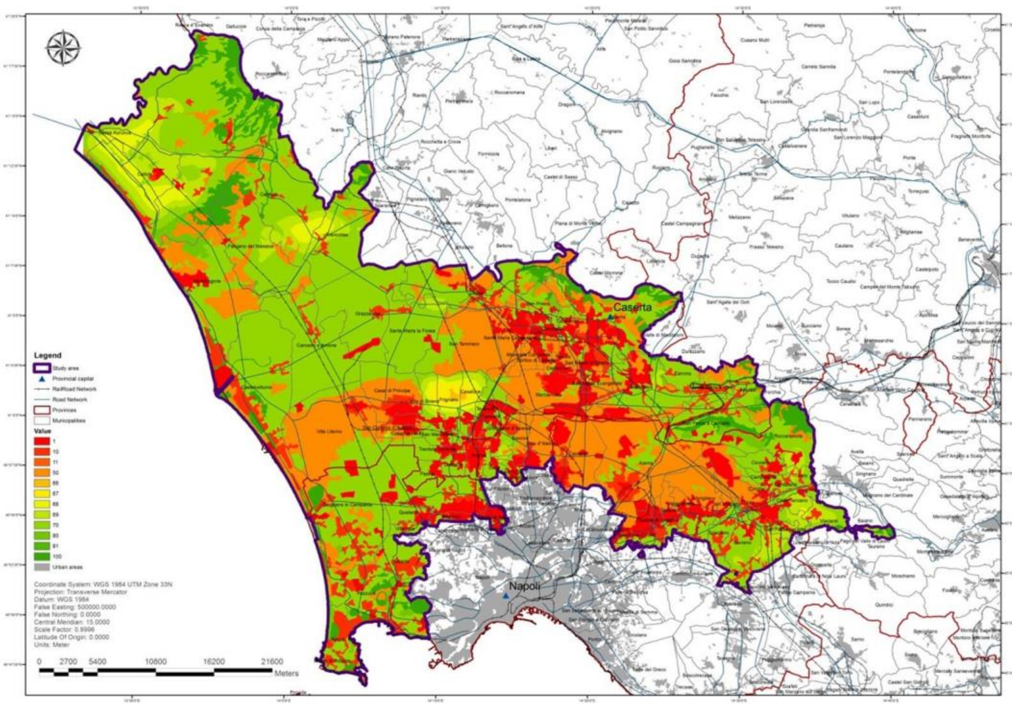

Fig. 11. Scenario 0 – ES Habitat Quality module – InVEST.

approach is useful after the SI approach, to better individuate the compensation and mitigation areas for the most impacted species.

Wildlife impact assessment as carried on in this research, is still simplified because for example do not consider major changes in species interactions such as competition or predation, or other socio-economic driving forces or extrapolations in space and time. Nevertheless, the approach followed, allows visualizing differences among alternative LUC scenarios in wildlife diversity and composition and it is based on simple and transparent relationships between land cover class types, shapes and biodiversity measures. Lastly, it generates maps and summaries that are quite easy to understand for stakeholders (Farwing, et al., 2014).

5. Conclusions

Present paper shows more different results assessments, because of different approaches and so confirms that Scenarios building helps in "thinking out of scheme", stimulating reflections about possible LUC impacts. Nevertheless scenarios do not predict exactly what will happen in the future, but support the alternatives evaluation in the long term to

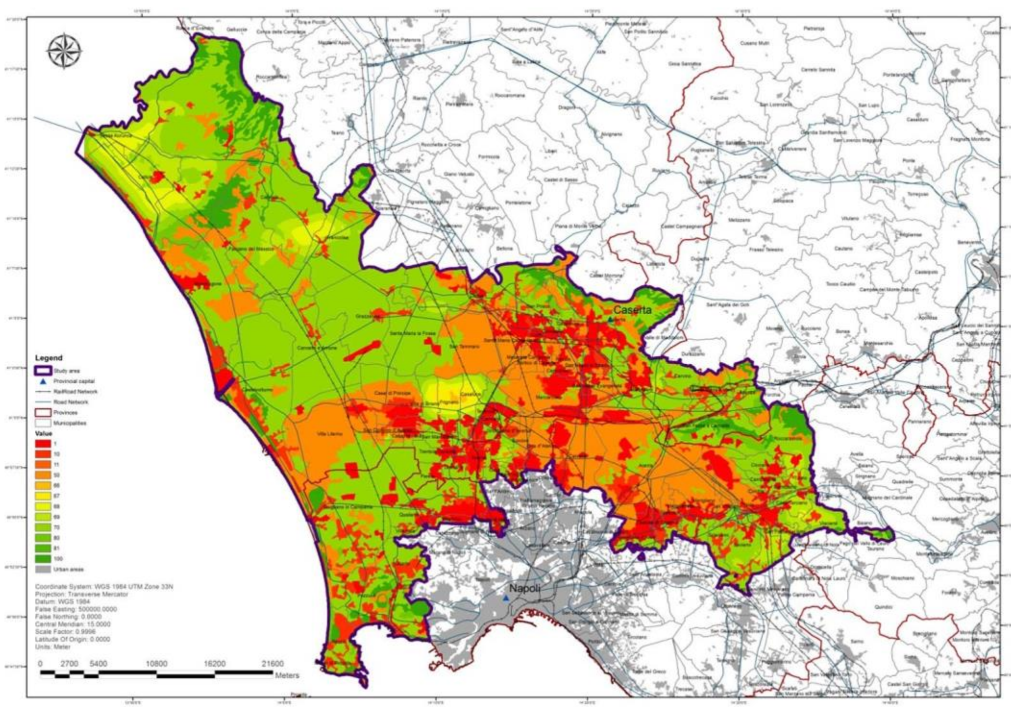

Fig. 12. Scenario 1 – ES Habitat Quality module – InVEST.

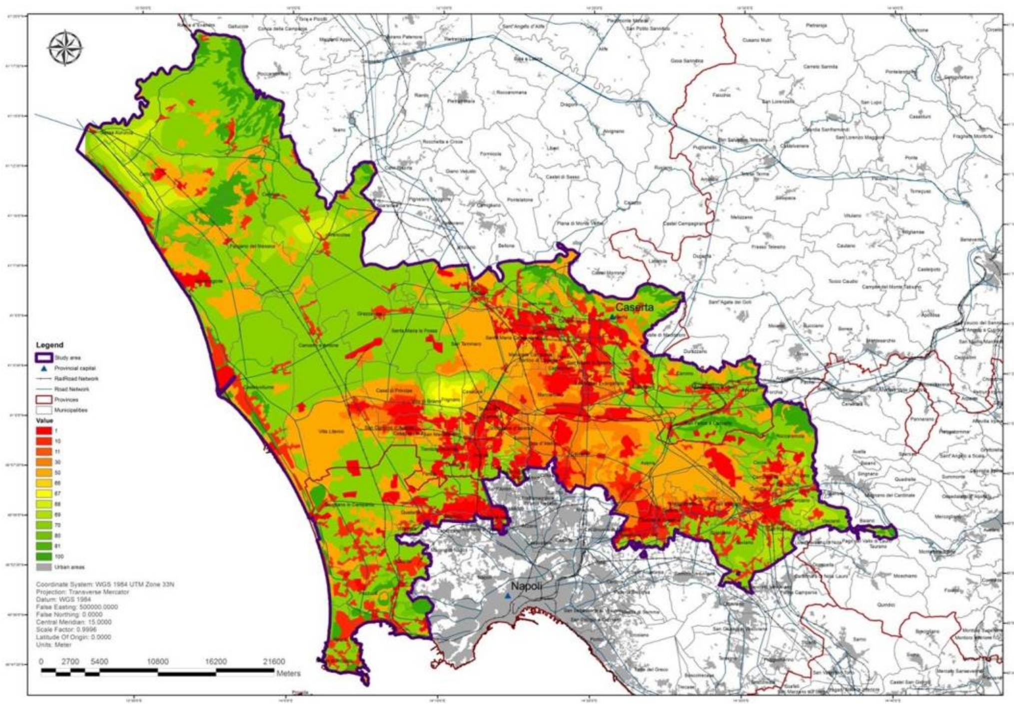

Fig. 13. Scenario 2 – ES Habitat Quality module – InVEST.

establish new planning strategies in the short-medium term period (AEE, 2009; Zhang et al., 2017).

The LUC impacts assessment through the ES appeared particularly important: LIFE protocol seems to have a positive impact on ES, i.e. on the natural capital stock of the SIR area. It is therefore possible to say that, the farmers income reduction, due to the no-food crops conversion, or the cost for conversion of abandoned land, will pay an equal compensation in terms of increased welfare for the population.

ES approach, widely used and shared in the scientific field, cannot, however, regardless of the detail and depth analysis, as demonstrated in the case of wildlife: a seemingly virtuous LUC process may correspond, potentially, negative impacts for some species of wildlife.

Combining ecological assessment with LUC scenarios buildings may provide useful input for futureregional development and conservation, facilitating an integrated approach to biodiversity conservation. It is clear the opportunity of evaluating the adequate biodiversity levels (Schneiders et al., 2012).

These reflections lead to further considerations regarding the land amount to be converted to no-food according to Life Protocols and the need to provide appropriate mitigation measures (hedges, interruptions

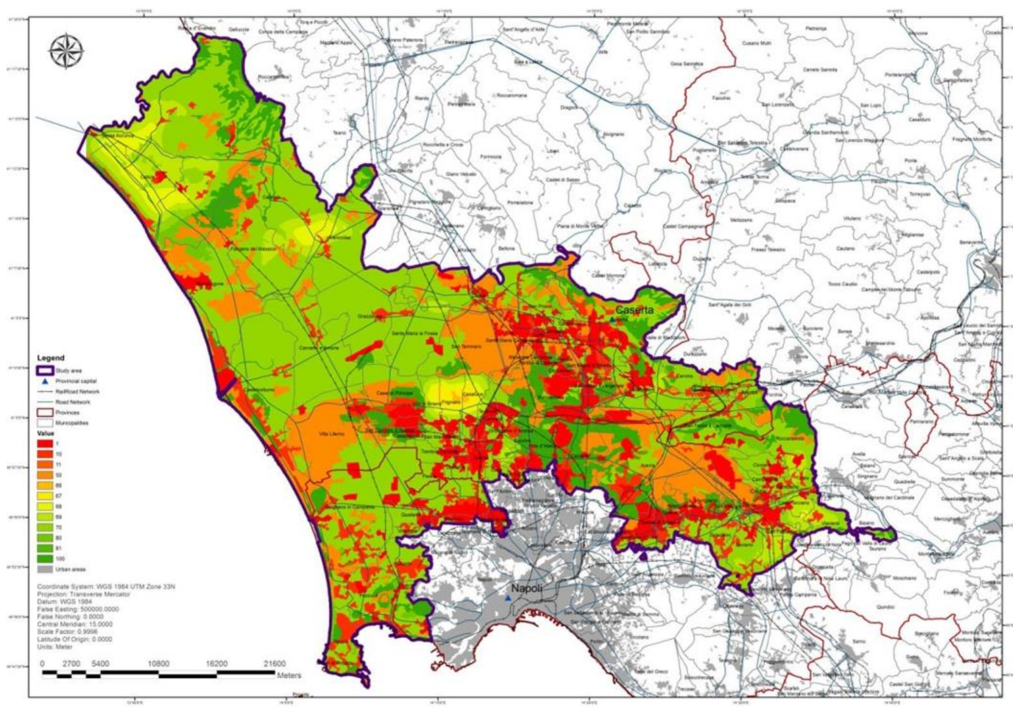

Fig. 14. Scenario 2 Corine Land Cover, 2012 ES Habitat Quality module – InVEST.

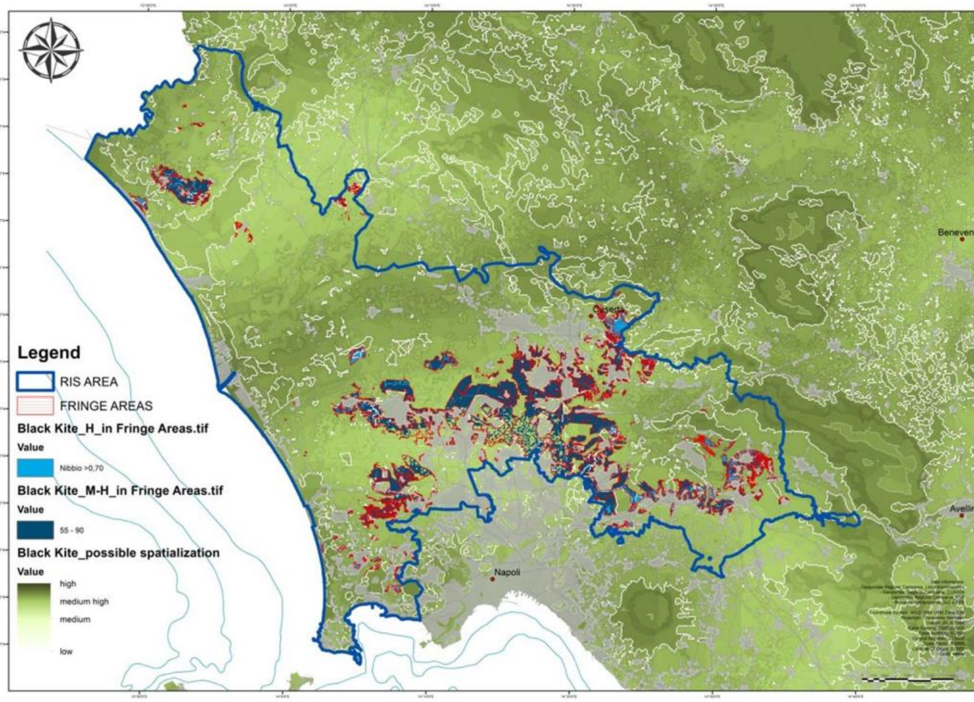

Fig. 15. Possible conflict areas between Scenarios 2 and 3 areas and suitably presence species areas: Black kite.

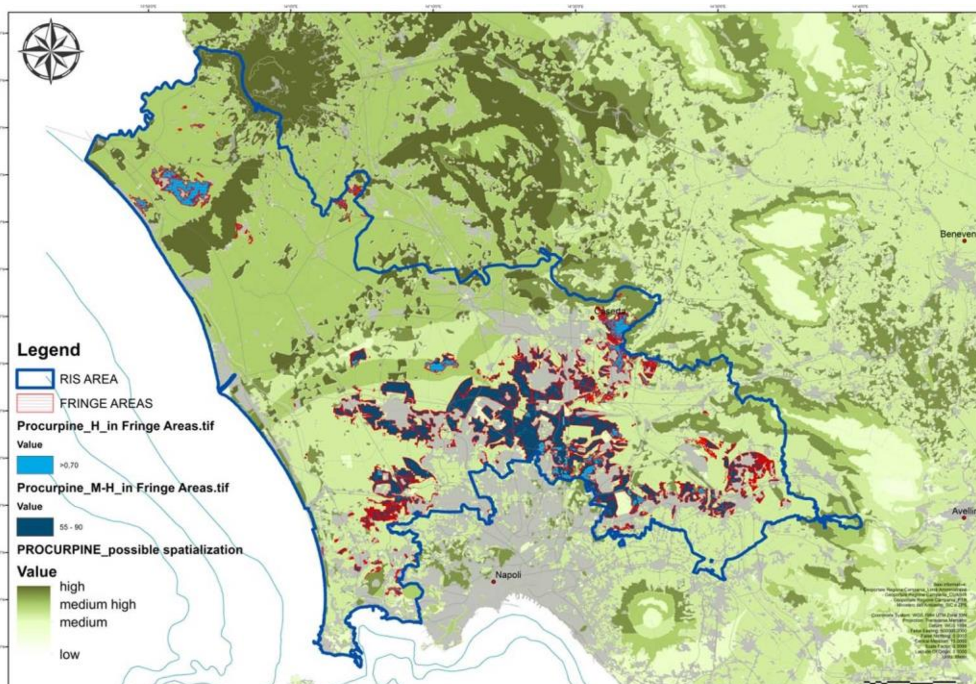

Fig. 16. Possible conflict areas between Scenarios 2and 3 areas and suitably presence species areas: Porcupine.

of crops, wildlife passages, ...) an adequate biodiversity level and to ensure that the future proposal is in fact an opportunity for implementation and improvement of the environmental quality of the study area.

Combining ecological analysis with LUC scenarios assessments may provide useful input for futureregional development and conservation, facilitating an integrated approach to biodiversity conservation thus the methodology may be a useful support to the landscape planning, about environmental quality monitoring actions and the environmental remediation for critical contexts.

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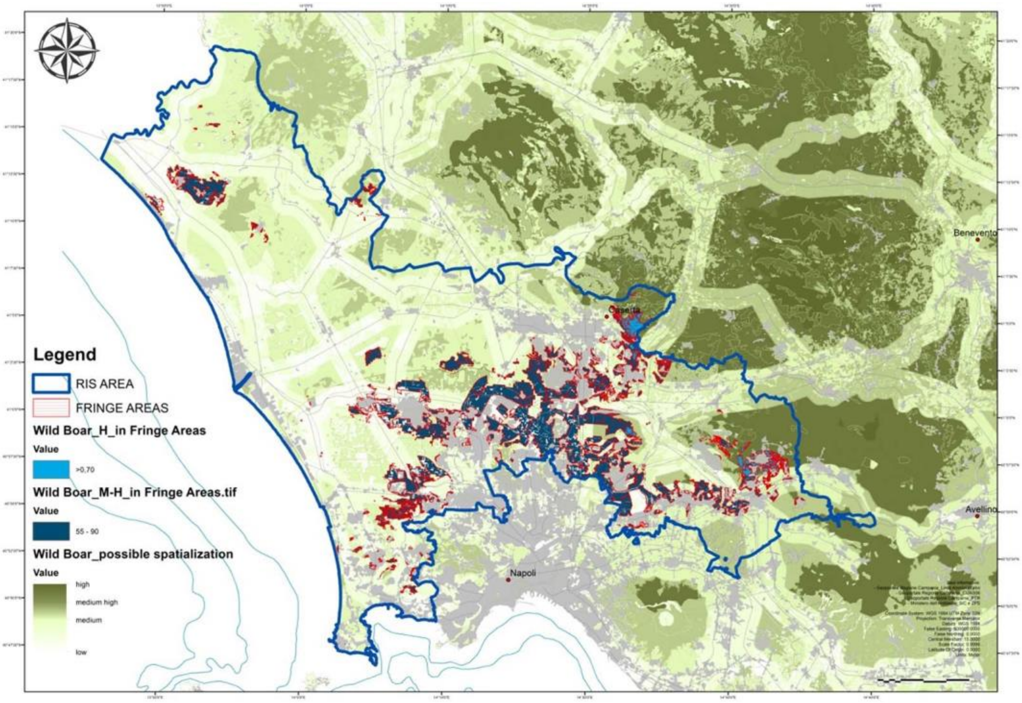

Fig. 17. Possible conflict areas between Scenarios 2and 3 areas and suitably presence species areas: Wild Boar.

Table 7
Scenarios Sensivity Index (SI%) assessment.

Group	# of species divided for advantage-disadvantage categories							total species	impacted	IS	IS%
	−3	−2	−1	0	1	2	3				
Scenario 1 vs Scenario 0											
General	1	0	0	132	52	9	1	195	63	70	11.97
Amphibians	0	0	0	8	2	1	0	11	3	4	12.12
Reptiles	0	0	0	6	5	2	1	14	8	12	28.57
Birds	1	0	0	91	25	2	0	119	28	26	7.28
wintering	*0*	*0*	*0*	*54*	*18*	*1*	*0*	*73*	*19*	*20*	*9.13*
nesting	*1*	*0*	*0*	*69*	*24*	*0*	*0*	*94*	*25*	*21*	*7.45*
Mammals	0	0	0	27	20	4	0	51	24	28	18.3
Scenario 2 vs Scenario 0											
General	49	57	33	30	40	2	3	214	184	−241	−37.54
Amphibians	2	3	1	3	2	0	0	11	8	−11	−33.33
Reptiles	4	1	3	0	6	0	0	14	14	−11	−26.19
Birds	28	46	18	26	15	2	3	138	112	−166	−40.1
wintering	*2*	*4*	*5*	*16*	*3*	*2*	*2*	*85*	*69*	*−91*	*−35.69*
nesting	*19*	*34*	*16*	*23*	*15*	*2*	*1*	*110*	*87*	*−119*	*−36.06*
Mammals	15	7	11	1	17	0	0	51	50	−53	−34.64
Scenario 3 vs Scenario 0											
General	0	92	0	21	42	42	42	239	218	−85	−11.85
Amphibians	3	3	1	0	4	1	0	12	12	−10	−27.78
Reptiles	4	2	2	0	6	1	0	15	15	−10	−22.22
Birds	23	33	13	21	45	19	4	158	137	−53	−11.18
wintering	*6*	*24*	*10*	*11*	*35*	*9*	*0*	*95*	*84*	*−23*	*−8.07*
nesting	*15*	*23*	*10*	*16*	*40*	*16*	*2*	*122*	*106*	*−23*	*−6.28*
Mammals	12	5	7	0	21	7	2	54	54	−12	−7.41

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