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Ecosystem services and bioremediation of polluted areas

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ABSTRACT

Contaminated areas represent a crucial concern in contemporary planning all over the world. The absence of shared value for such areas leads to abandonment and soil sealing specially if such areas have lost their agricultural potential. The European Project LIFE/ENV/IT/275 Ecoremed has implemented a protocol for the bioremediation of contaminated soils in Campania region. The cultivation of no food crops (Poplar and Giant reed) is proposed as buffer crops waiting for the characterization of the areas. This facilitates the uptake of the mineral contaminants and the biodegradation of organic compounds reducing the risk for leaching and the run off of harmful contaminants that would occur on bare soils.

The study discusses a new approach to land use change (LUC) assessment based on environmental and socio-economic factors, evaluated through GIS tool and decision support software (ArcGIS/ILWIS). Literature data have been used to assess the current value of the ecosystem services (ES) provided by such crops (€/ha/year) and the benefits that people obtained from ecosystems. Three scenarios have sorted out and compared through multicriteria analysis. Moving from the deep knowledge of the environmental condition of the territory the study shows the alternative ES values of the land use change starting from no-change scenario to energy crops (Poplar and Giant reed), to abandonment. Results show that is possible to asses an increase of the ES value, both in case of a private and public action, also referring to the opportunities for farmers income in the short and medium-long period.

1. Introduction

Ecosystem services (ES) are crucial for providing condition for human well-being, qualitative livelihoods and efficiency for the human habitat (Costanza et al., 1997, 1998; Millenium Ecosystem Assessment (MEA), 2005; TEEB Foundations, 2010; de Groot et al., 2012; Comino et al., 2014). Changes in ES influence all components of the human well-being (Balmford and Bond, 2005; Farber et al., 2002; Salles, 2011), so that the early assessment of the ES change may effectively support decision makers in planning (Marulli and Mallarach, 2005; Busch et al., 2012) and in programming policies for improving social well-being (Daily et al., 2009; Deutsch et al., 2003).

Further the capacity of evaluating the monetary values of ES (Costanza et al., 1997), although ignores more intangibles services (Viglizzo et al., 2012; von Haaren et al., 2014), makes the ES one of the key elements of the planning processes (Bennett et al., 2009; Frank et al., 2012) and of the decision analysis, leading towards new methodologies in terms of planning alternatives.

The Millennium Ecosystem Assessment (MEA, 2005) definition for ES describes it as the implementation of a set of effective benefits for both natural and urban environment. Thanks to the MEA studies (2003, 2005), ES has become a popular research topic and it acts as conceptual framework for many scientific projects so that various ES classification strategies, mapping methodologies and evaluations proposals have been provided at global, regional and local scales (Daily and Matson, 2008; Fisher and Turner, 2008; de Groot, 2006; Tianhong et al., 2010). Further, the evaluation of ES in economic terms became an increasingly popular approach both to assess alternative scenarios in land use change and to demonstrate the economic value of biodiversity conservation (Bayon and Jenkins, 2010; Chan et al., 2006; Costanza et al., 1997; de Groot et al., 2002; Fisher et al., 2009; Ghazoul, 2007; Ridder, 2008; Wallace, 2007; Schneiders et al., 2012).

Abbreviations: ANP, analytic network process; DEM, digital elevation model; ES, ecosystem services; LUC, land use change; MC-SDSS, Multicriteria-Spatial Decision Support Systems; NIPS, National Interest Priority Sites; PDO, protected designation of origin; SIR, Regional Interest Site; AV, added value.

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In economics, literature recognizes two broad kind of value: "use value" and "no-use value" (de Groot et al., 2010), while the ES value encompasses the state of health of a territorial system and socio-cultural values, such as cultural identity and the degree to which that is related to ES including the importance people give to (Redford and Adams, 2009.). Moreover, EU efforts are also directed towards the implementation of the Green Infrastructure in urban and rural areas of the European Regions (Mazza et al., 2011; Tratalos et al., 2007.) by the aim of arising biodiversity and of improving EU habitats.

Despite the wide acceptance of these concerns, in the scholar's community, the use of ES evaluation in landscape planning is still largely missing. However its consideration could inform regional planning authorities in finding solutions that better respond to competing social needs and demands. According to this, it is necessary to integrate ES evaluation at the early stage of regional planning and decision-making processes (Daily and Matson, 2008; Hein, 2010; Rannow et al., 2010; Koschke et al., 2012).

In this perspective a special heed is given to the global demand for energy crops that has increased all over the world, due to shared awareness of the global impacts of using of the fossil fuels, including costs (Ajanovic, 2011). In the framework of the Kyoto Protocol, Renewable Energy Directive (RED) is now addressing political strategies to foster no-food production (ATLASS Consortium, 2010; European Parliament, 2009) together with the other sustainable energy sources. Thanks to the RED recommendation and the economic and political investment done by the UE, many European Regions are going to address their land use planning towards no food production by the aim of providing more opportunities for the agriculture sector and for realizing better condition for peri-urban environment. Indeed no food crops represent a key strategy for reducing soil loss and land abandonment, for increasing soil pollution remediation and for developing, locally, new potential of economic growth. The land use change of the agricultural crops in to no-food production is a key opportunity for the local economy and for increasing the natural processes of soil formation and erosion (Recanatesi et al., 2013), but also a potential threat for rural landscape and biodiversity. Because of this, the assessment of the land use change (LUC) of the agricultural crops could use the methodologies for ES values comparison in land use change as an effective indicator of the impacts related to the LUC itself.

The Campania Region is one of the most important Italian Region due to its huge tradition in food production (one of the leading areas for PDO certificated food), for the added value (AV) of the agricultural production and because of agricultural uses shaped an outstanding traditional agrarian landscape (Pindozzi et al., 2015). Campania is now under pressure for implementing no-food production thanks to a number of driving forces such as economic incentives, the rising prices of biomass, the implementation of biomass chain, the re-organization of the supply chain, etc. (Pindozzi et al., 2013). The implementation of no food production is also pushed by the social context due to the land abandonment and of the illegal waste disposal in some rural and peri-urban areas.

Besides, Campania Region is under the media pressure due to the illegal disposal of pollutants and waste in a very wide area, almost of 110 thousand ha, named by press "Terra dei Fuochi" (Land of Fires). The media interest has damaged the perception of food safety in the area and has caused a big loss in terms of national and international products demand. The value of the agricultural crops decreased and there is a local pressure for transform the agricultural plots in new built areas.

The described condition is in some ways common to other places in the world, such as Poland, Bangladesh, China, US, and some Countries of the Central Africa (Ailshire and Crimmins, 2014; Bednarska and Stachowicz, 2013; Li et al., 2014; Seraj et al., 2014; Wang et al., 2010) where a widespread pollution are taking agricultural soils away.

Life Project Ecoremed (LIFE11/ENV/IT/275) is now under development to support Campania Region in facing soil pollution emergency. The project is funded by the EU Life Programme and it is aimed at demonstrating the potential of no-food change both in reducing environmental risk (in terms of reducing pollutant mobilization, implementing living-machine process, implementing phytoextraction) and in providing new economic incomes for farmers. The cultivation of no food crops is aimed at creating a stand by zone in which operate while the characterization of each fields will be done. No food use is here strategically merged with the specific aim of soil remediation that is the uptake of the mineral contaminants and the biodegradation of organic compounds, reducing risk for leaching and run-off of the harmful contaminants that would occur on bare soils. Bioremediation represents an effective technology for reducing the concentration of organic pollutants (EPA, 2005), aiming at reaching a target of 40% less of contaminated soils (LIFE11/ENV/IT/275 – ECOREMED, 2014). The plants species/varieties selected by LIFE Project (*Populus nigra* and *Arundo donax*), should reduce contaminant dispersion, exposure to contaminants and their transfer into the food chain (Henry et al., 2013).

The paper discusses the ES evaluation approach for assessing opportunities and constraints of no-food crops in land use change by the aim of supporting the decision process. More in deep, the study looks at the land use change of the whole SIR area, specially focusing on the polluted areas that are potentially suitable for bioremediation and on some other areas that lay in abandonment and that could be easily interested by pollution or illegal uses. Starting from this, the study is aimed at:

- implementing methodologies for selecting the most LUC suitable areas and assessing their ES values
- outlining a set of scenarios of LUC for the selected areas
- comparing scenarios by means of their monetary ES values

2. Materials and methods

2.1. The study area

The selection of the study area comes from the list of the National Interest Priority Sites (NIPS) produced by the Italian Ministry of the Environment in attendance of the Law n. 426/1998 that transpose the EU Directive (Decree of the Ministry 31/01/2006) about the waste management and soils pollution. According to this, the study area does not correspond to unique administrative boundary but respond to the definition of "part of the national territory bordered according to the site characterization, to the presence of pollutants (quantity and quality), to the environmental impacts on the adjacent areas." (Musmeci et al., 2008).

The regulatory matter is now under the control of the Campania Region that classified the study area as SIR (Regional Interest Site) in attendance to the following national laws: Decree of the Ministry of Environment n. 7 del 11/01/2013, Decree Law n.136 10/12/2013, Law n. 6 06/02/2014.

The study area (Fig. 1) is extended for 157 000 ha and covers 77 Municipalities and hosts almost 1.4 millions of inhabitants, showing a positive trend of population growth thank the migration flows. In terms of natural assets, twenty-nine Nature 2000 sites have been registered and the rural landscape is featured by the merging of traditional and modern cultivation techniques. The study area is supported by territorial infrastructures such as railways, motorways, commercial and industrial areas and it is featured by urban

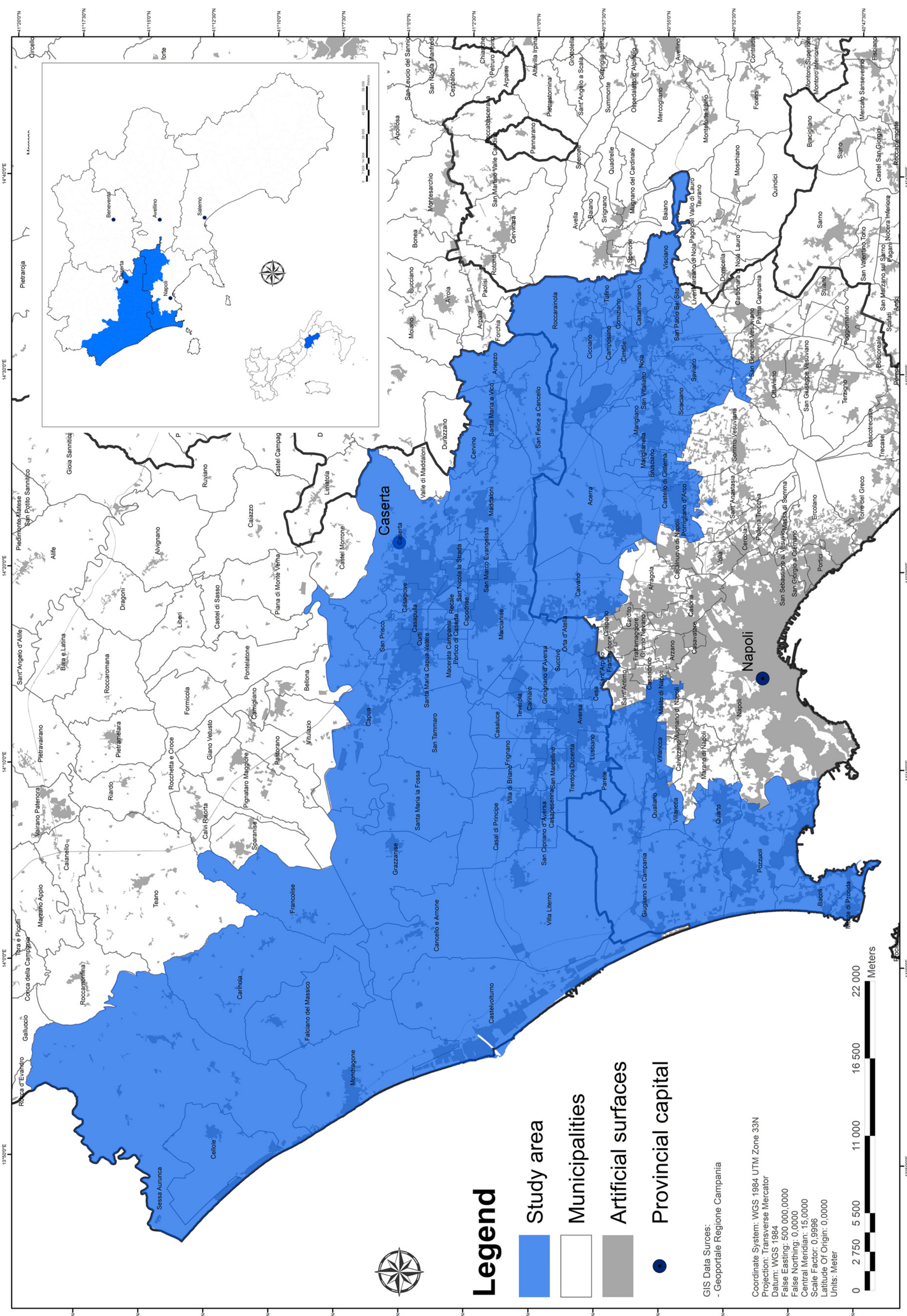

Fig. 1. Location and territorial context of the study area.

sprawl phenomenon generating soil loss, failure of valuable crops, loss of cultural landscape (Capolupo et al., 2015).

Despite the sub-mentioned impacts, agriculture still maintain its prime role and occupies a considerable surface. Agriculture also provides jobs and economic incomings, acting locally as one of the most relevant socio-economic resource: the percentage of agricultural employers is up to the regional average (Frallicciardi and Cerisano, 2013) and produce almost 8% of the National agricultural AV.

The case study area represent a good opportunity for testing effectively the results of bio-remediation application because of it is quite wide – occupying almost the 12% of the whole regional territory – and hosts 2000 drosscape's areas (Berger, 2007) registered by the Regional Authority (i.e. former industrial sites, former or closed quarries and landfills, polluted soils).

2.2. Steps in method

The interplay between ES evaluation and the bioremediation of polluted areas has developed by means of integrated approach using both GIS technologies and the Multicriteria Spatial Support System (Fig. 2)

The methodology entailed tree steps in method:

1. Multicriteria-Spatial Decision Support Systems (MC-SDSS), aimed at foreseeing LUC scenarios;
2. Recognition of scenarios alternative
3. Evaluation of the monetary values (€/ha) of ES, aimed at comparing the above-mentioned scenarios.

2.2.1. Multicriteria-Spatial Decision Support Systems (MC-SDSS)

The Multicriteria-Spatial Decision Support Systems (MC-SDSS, Malczewski, 1999, 2006) combines Geographic Information Systems (GIS) and Multicriteria Decision Aiding (MCDA) in order to provide a range of methods and tools for transforming and integrating geographic data (map criteria) and Decision Maker's preferences and uncertainties (value judgments) (Comino et al., 2014; Ferretti, 2012; Ferretti and Pomarico, 2013; Gamboa and Munda, 2007; Karnatak et al., 2007; Pindozzi et al., 2013; Tsoutsos et al., 2009).

The study area was discretized using a 20 m × 20 m grid cell size and the data sets were split in "constraints" and "general factor" (Bottero et al., 2013; Di Zio, 2009; Ferretti, 2011; Zucca et al., 2007). A thematic raster map has been done for each general factor and for each constraint. Six data classification maps (i.e. Land Cover, Nature 2000 areas, etc.) have carried out and thirteen raster maps (i.e. slope, elevation, erosion, etc.) and one point map have done as well (Table 1).

The classes and values of all the maps have been converted into a common scale from 0 to 1 - in which the standardization provides a measure of the appreciation of each class referred to a specific identified factor or constraint (Sharifi and Retsios, 2004). Once all maps were standardized, the corresponding relative importance weights have been assigned to each map. The weight mapping represents a crucial step of the study. It is managed by the adoption of the ANP technique (Saaty, 1980, 2005) and by the pairwise comparison checked by a panel of experts. Standardization and weighting have been carried out thanks to the ILWIS 3.8 software endowed with spatial multicriteria evaluation module.

Once the maps were issued and the factors weights have been established, the "Suitability Map" was carried out. This map gives the suitability range referred to the above mentioned standardization scale.

In order to achieve a concise understanding of the results, suitability values have been aggregated into five classes (Geneletti, 2007; Comino et al., 2014):

1. No relevance (value: 0–0.2)
2. Low relevance (value: 0.2–0.4)
3. Medium relevance (value: 0.4–0.6)
4. High relevance (value: 0.6–0.8)
5. Very high relevance (value: 0.8–1).

2.2.2. Recognition of scenarios alternative

Referred to the above mentioned steps, a set of alternative LUC scenarios have carried out according to the LIFE-Ecoremed protocol and mission, that is aimed at implementing bioremediation in the SIR area:

- Scenario 0 – NO CHANGE, this scenario shows the current land use as registered by the Corine Land Cover 2012
- Scenario 1 – FRINGE, this scenario shows the LUC resulting from the application of no-food changeover (Poplar and Giant Reed culture mix and herbaceous ground cover in orchard) to SIR fringe areas as derived from the application of MC-SDSS. The selection of the fringe areas was made through the application of a set of criteria (listed in Fig. 3) aimed at recognizing areas that have less favourable conditions for maintaining agriculture. In operational terms, the study has first deducted from the whole SIR area those areas that cannot be suitable to LUC due to some specific constraints (protected areas, urban areas, historical/archaeological areas, river space). Then, in the standardization step, the highest value was given to areas that have the worst environmental conditions (high concentration of heavy metals, lower levels of depth, lower availability of water in soil, high erosion risk, lower agriculture incomes, etc.). Finally, in the step of weighting, the different criteria and their corresponding standardized raster maps have been compared through pairwise comparison, giving different weight according to their different importance in order to the study aim (criteria-tree). The outcome is the Suitability Map that enables to identify SIR clusters that are potentially fit for LUC because of their negative environmental conditions and/or because of they are potentially affected by abandonment and/or illegal activities.
- Scenario 2 – DRYLAND, this scenario shows the LUC resulting from the application of no-food changeover (Poplar and Giant Reed culture mix) to a wider part of the SIR areas, including the fringe areas selected in the Scenario 1, increased by crops featured by the under 1 ha surface, agricultural land not in use, pasture, dry arable land;
- Scenario 3 – ABANDONMENT, this scenario shows the LUC derived by the abandonment of the crops featured by the under 1 ha surface, agricultural land not in use, pasture and dry arable land. Such scenario represent the condition to which the system evolves without any use support

2.2.3. ES monetary evaluation – approach

Many studies provide a monetary evaluation for ES related to specific land use/land cover (Boyd and Banzhaf, 2007; Burkhard et al., 2009; Costanza et al., 1997; Goio et al., 2005; Rein, 1999; Scolozzi et al., 2012; Willis and Garrod, 1991). Scolozzi et al. selected 63 international studies (out of above 900 reviewed) by the aim of providing monetary evaluations for the ES (euro per hectare) of land use/cover applied to the European territory. The monetary values, used in this paper, were standardized to euro per hectare per year, based on Scolozzi's study that uses 2007 as the base year (Scolozzi et al., 2012), and updated to 2014. The values are summarized in Table 2.

Table 1
General factors and constraints for the selection of LUC suitable areas – Scenario 1.

	MAP name	Map type	Map description
Constraints	Protected areas	Raster map	Binary map of protected areas: 1 for all the areas that are outside of the protected areas and 0 for those areas that are inside of it. ZPS, SIC, national and regional parks and reserves, Ramsar Areas
	Open water	Raster map	Binary map of open water bodies: 1 for all the areas that are outside of the open water bodies and 0 for these areas that are inside of it.
	Artificial areas	Raster map	From Corine land cover (artificial surfaces). Binary map: 0 for urban fabric area 1 for all the others areas.
	Archaeological areas	Point map	Map of historical and archaeological areas. Binary map: 1 for all the areas that are outside of the archaeological areas and 0 for these areas that are inside of them.
General factors	Environmental characterization	Raster map	24 Maps with environmental characterization of water-soil-air matrix, based on results of LIFE ECOREMED Project (www.ecoremed.it): 18 maps with the geochemical characterization/survey of the soils of SIR area (As, Be, Be-basic values, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, Sn-basic values, Tl, V, V-basic values, Zn) 4 baseline values maps – Be, Sn, Tl, V **Radon – prone areas** Depth to groundwater Map Index of Availability of water to the application of the Protocol LIFE
	Erosion	Raster map	RUSLE erosion map expressed by: Rainfall-runoff erosivity factor map Soil erodibility factor map Slope length- steepness factor map Cover-management factor map
	Land cover	Raster map	New classification for land cover map: agricultural lands will be explained and other areas will be combined
	Protected areas_distance	Raster map	Distance map from protected areas
	NIPS areas	Raster map	Map of NIPS
	NIPS_distance	Raster map	Distance from NIPS areas
	DEM_slope	Raster map	Digital elevation model
	DEM_height	Raster map	Digital elevation model
	Road_distance	Raster map	Distance map from principal roads
	Artificial areas_distance	Raster map	Distance map from artificial areas

Table 2
Monetary values (€/ha per Year) of ES for land-cover classes or biome. The monetary values are based on Scolozzi's study that uses 2007 as the base year and updated to 2014. "Herbaceous ground cover in orchard" is a new classification item added to verify the specific bio-remediation solution developed within the LIFE-Ecoremed project. We associate ES classes with land cover classes, specially referring to first level (5 classes, corresponding to the main categories of the land cover/land use) and to the second level (15 classes, which cover physical and physiognomic entities at a higher level of detail, such as urban zones, forests, lakes, etc.) of Corine Land Cover updates refer to the year 2012 (CLC12).

ES assessment classes	CLC12 Level 1 classes	CLC12 Level 2 classes	CLC12 Level 3 classes	ES monetary values updated to 2014 (€/ha per years)
Fresh-water	Water bodies	Inland waters Marine waters	Water corse; water bodies Coastal lagoons; estuaries; sea and ocean	3290.24
Cropland	Agricultural areas	Permanent crops	Vinyards; fruit trees and berry plantations; Olive groves	1980.02
		Arable land	Non-irrigated arable land; permanently irrigated land; rice fields	
		Heterogeneous agricultural areas	Annual crops associated with permanent crops; complex cultivation patterns; land principally occupied by agriculture; agro-forestry areas	
Pastures	Agricultural areas	Pastures	Pasture	125.61
	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Natural grassland; moors and heathland; sclerophyllous vegetation; Transitional woodland shrub	
Forest	Forest and semi natural areas	Forests	Broad-leaved forest; coniferous forest; mixed forest	6060.03
Rock	Forest and semi natural areas	Open spaces with little or no vegetation	Beaches, dunes and sand plains; bare rock; sparely vegetated areas; Burnt areas; Glaciers and perpetual snow	–
Urban	Artificial surfaces	Mine, dump and construction sites	Mineral extraction sites; dump sites; construction sites	–
		Industrial, commercial and transport units	Industrial or commercial units; road and rail networks and assocoated land; port areas; airports	
		Urban fabric	Continuous urban fabric; discontinuous urban fabric	
Urban green	Artificial surfaces	Artificial, non-agricultural vegetated areas	Green urban areas; sport and leisure facilities	5556.84
Fresh-water wetland	Wetlands	Inland wetlands	Inland marche; peat bogs	18 195.82
Herbaceous ground cover in orchard (by authors)	Agricultural areas	Permanent crops	Vinyards; fruit trees and berry plantations; Olive groves	2105.63
		Heterogeneous agricultural areas	Annual crops associated with permanent crops	

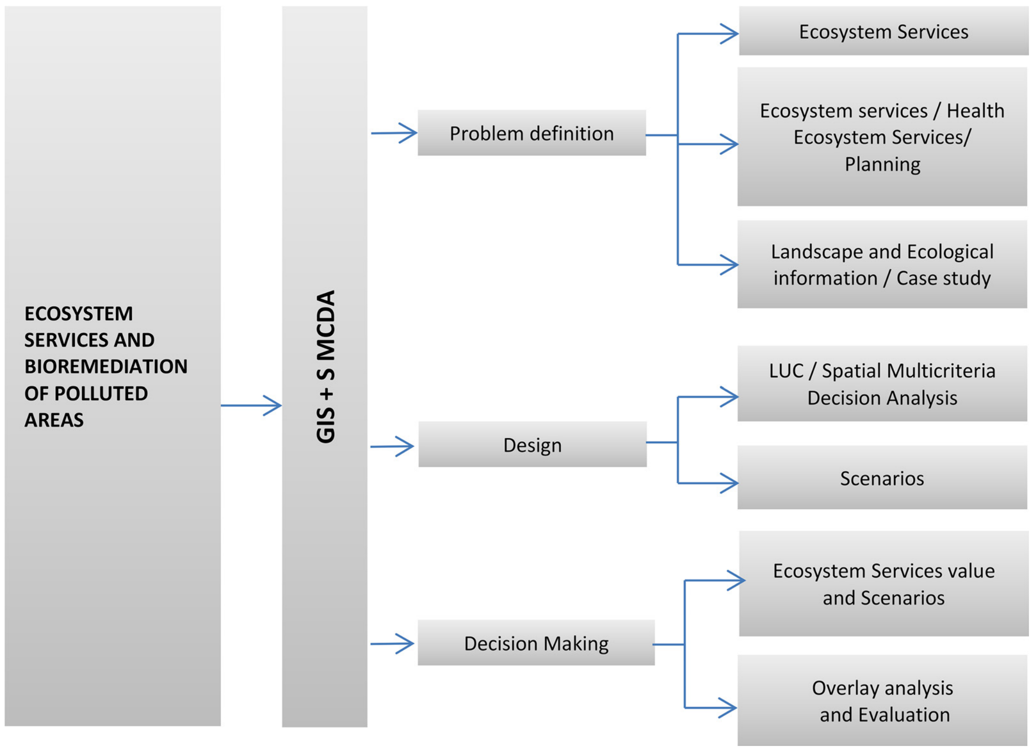

Fig. 2. Framework of planning. The framework, based on Comino et al. (2014), can be articulated in three phases.

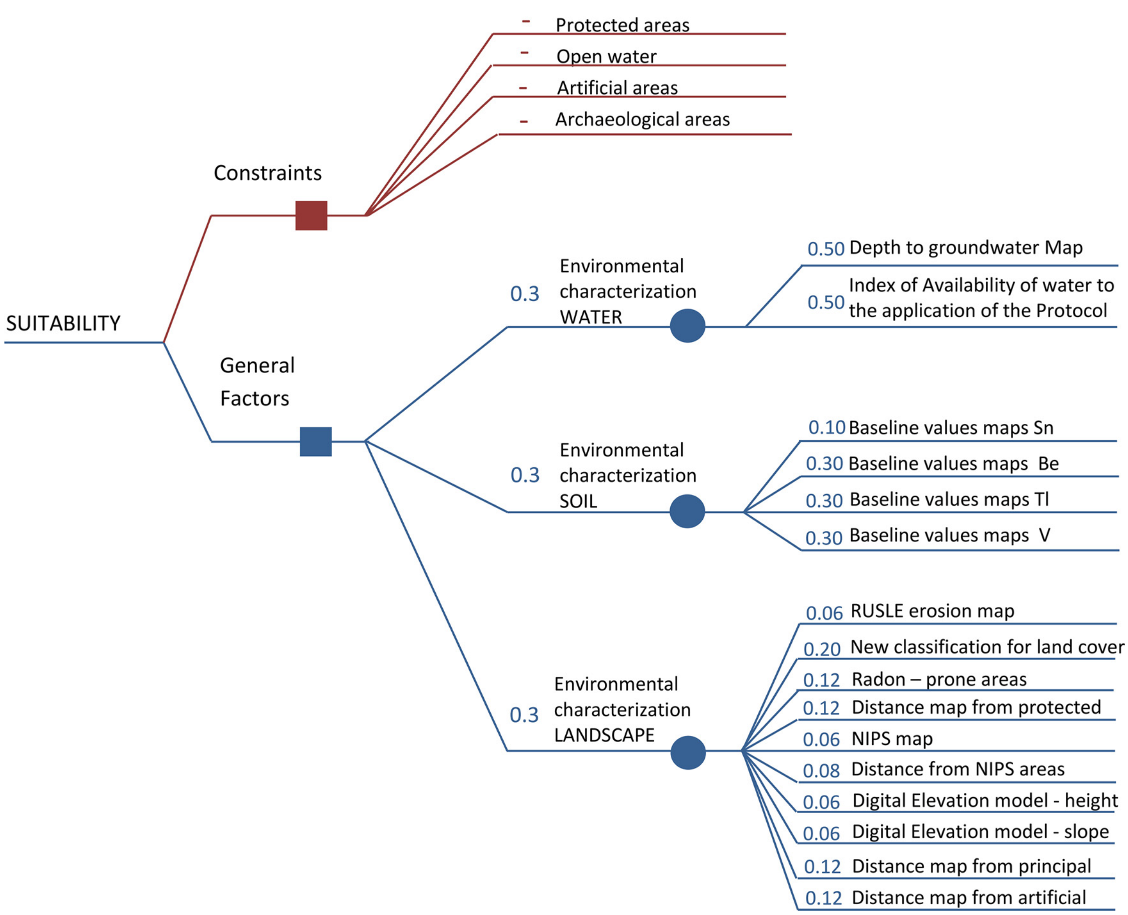

Fig. 3. Criteria tree. The criteria tree contains multiple input maps to obtain a final output raster map using Spatial Multi-Criteria Evaluation. The criteria are organized in: single criterion (factors or constraints) or groups (which define an intermediate or a partial goal; in each group, we added more factors). The criteria tree allows us to articulate the comparison for the weighting of criteria. The weights (assigned through panel of expert) are shown next to each criterion.

A new classification item – herbaceous ground cover in orchard – was added to the Table 2 due to the need of verify the specific bio-remediation solution developed within the LIFE-Ecoremed project. Such category refers to the opportunity of maintaining the present orchard use implementing herbaceous ground cover by the aim of both reducing the erosion and of facilitating the bio-remediation process. The ES monetary value of Herbaceous ground cover in orchard class is here estimated as a limited increase of the Orchard ES value (Cropland in Table 2) and it could be considered as the sum of the Orchard ES value and the Pasture ES Value.

The economic value of ES generating by the *poplar* crop has been associate, in Table 2, to forest and semi-natural areas, while the ES value of the *giant reed* crop has been associated to cropland.

The paper assumes the Costanza assessment approach (2008) as revised by Scolozzi et al. (2012) where the monetary value of the ES comes from the concern of "surrogate market" (Curtis, 2004) as hypothetical market services and benefit, for which evaluation exist. The monetary ES values have been updated first by Costanza (2008) through the analysis of a wide database where a variety of economic tools (e.g. willingness to pay, travel costs, avoided costs) have been applied. Scolozzi provides an advance of the Costanza data, founding on the bibliographic review of scientific articles.

3. Results

3.1. Recognition of scenarios alternative

3.1.1. Scenario 0 – NO CHANGE

Within the almost 157 000 ha of the SIR area, the percentage of the 17.5% is for artificial surface, the 5.3% is for forests, the 5.1% is for semi-natural areas, the 0.5% is for freshwater and wetlands, and more of 71.7% is for agricultural areas, used as arable land in the amount of 50%.

3.1.2. Scenario 1 – FRINGE

This scenario refers to the most vulnerable areas because of the limited surface and the isolated position in the territorial context could lead towards abandonment or soil sealing.

According to the MC-SDSS, "constrains" and "general factors" were arranged in a criteria tree by which the Suitability Map was generated.

In such scenario areas that may be suitable to LUC are those included in the range of suitability value in between 0.6 and 1 (classes High relevance and Very high relevance).

Water bodies, artificial surfaces, wetlands have been detracted to LUC. Forests areas and scrub and herbaceous vegetation association, have been detracted as well because of the comparison between existent land use and potential LUC is very narrow.

The Scenario 1 – fringe involves almost 10 000 ha corresponding to the 7% of the comprehensive SIR surface. The potential LUC, referred to the existing land use is described in Table 3. The main Land Use classes subjected to FRINGE are irrigated crops (33% of the total LUC surface), non-irrigated arable land (20%) and permanent crops (25%) with special reference to orchards. In the Scenario 1, all the land use change areas could be interpreted as bio-remediation potential areas because of they are polluted or abandoned areas.

3.1.3. Scenario 2 – DRYLAND

In this scenario the potential LUC surface is almost 47 000 ha and represents the 30% of the whole SIR surface. The composition of the LUC surfaces shows that the most interested areas are the non-irrigated arable land (almost 76%) and a few part of forest and semi-natural areas (almost 7%).

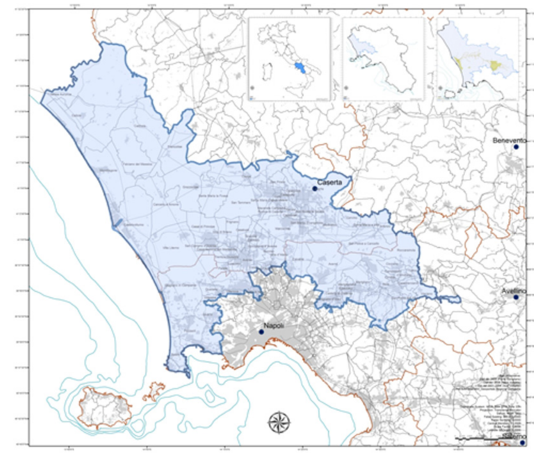

Fig. 4.1. Scenario 0 – NO CHANGE – current conditions total surface 157 000 ha.

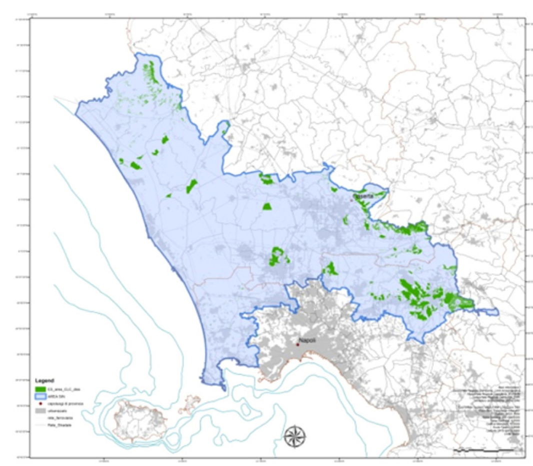

Fig. 4.2. Scenario 1 – FRINGE – fringe areas (10 000 ha) for which it is realistic to attend a LUC.

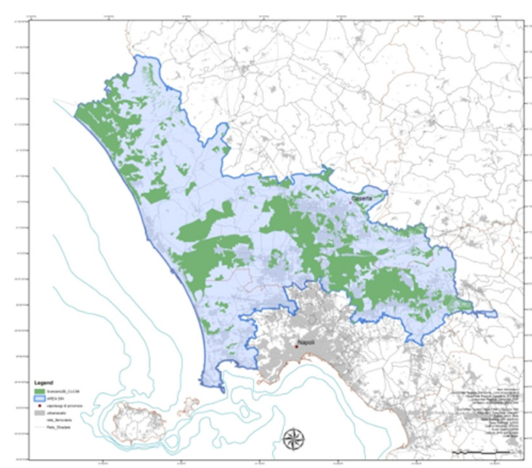

Fig. 4.3. Scenario 2 – DRYLAND – most of the agricultural areas (except intensive agricultural areas and protected areas) are converted to non-food crops (47 000 ha).

3.1.4. Scenario 3 – ABANDONMENT

The scenario comes from the hypothesis of the abandonment of the non-irrigated arable land (23% of the whole SIR surface) and of the pasture (2%). The surface classified as Abandonment is almost 39 000 ha, corresponding to 25% of the whole SIR surface (Figs. 4.1–4.4).

Table 3
Areas involved in the LUC, for each scenario.

CLC12 – Level 1	CLC12 – Level 2	CLC12 – Level 3	Total area ha	LUC Scenario 1 ha	LUC Scenario 2 ha	LUC Scenario 3 ha
Water bodies	Inland waters	Water bodies	554			
		Water courses	131			
	Marine waters	Costal Lagoons	26			
Agricultural areas	Permanent crops	Fruit trees and berry plantations	20 847	1825	1825	
		Olive groves	4423	671	671	
		Vineyards	145	0.5	0.5	
	Pastures	Pastures	713	713	713	
	Arable land	Permanently irrigated land	20 463	3332	3332	
		Non-irrigated arable land	35 925	1983	35 925	35 925
	Heterogeneous agricultural areas	Land principally occupied by agriculture, with significant areas of natural vegetation	4358	195	195	
		Annual crops associated with permanent crops	679	50	50	
		Complex cultivation patterns	24 991	874	874	
Forest and semi natural areas	Open spaces with little or no vegetation	Sparsely vegetated areas	26			
		Burnt areas	359	359	359	
		Beaches, dunes, sands	500			
	Forests	Coniferous forest	495			
		Broad-leaved forest	7834			
	Scrub and/or herbaceous vegetation associations	Natural grasslands	3002		3002	3002
		Transitional woodland-shrub	2354			
		Sclerophyllous vegetation	1694			
Artificial surfaces	Mine, dump and construction sites	Mineral extraction sites	713			
		Construction sites	25.62			
		Dump sites	27.15			
	Industrial, commercial and transport units	Airports	195.93			
		Industrial or commercial units	3 531.03			
		Port areas	82.89			
		Road and rail networks and associated land	154.87			
	Urban fabric	Continuous urban fabric	12 113			
		Discontinuous urban fabric	10 173			
	Artificial, non-agricultural vegetated areas	Sport and leisure facilities	227			
		Green urban areas	167			
Wetlands	Inland wetlands	Inland marshes	64			
Total (ha)			156 991	10 003	47 381	38 927

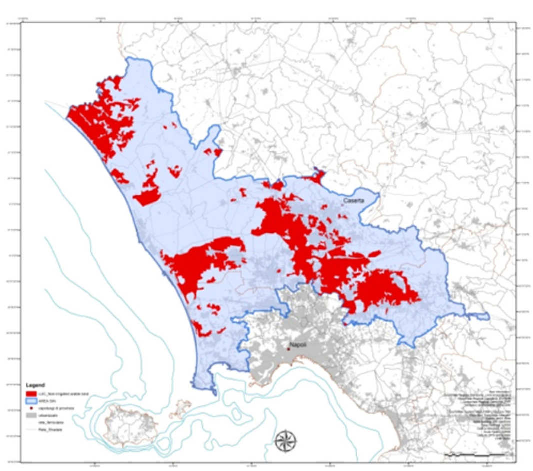

Fig. 4.4. Scenario 3 – ABANDONMENT – abandonment of non-irrigated arable land and pasture areas (39 000 ha).

3.2. LUC's scenarios and correspondent ES monetary assessment

3.2.1. ES Scenario 0 – NO CHANGE

The main ES monetary value is given by the agricultural surface in terms of 80% of the total value, generated by 72% of the total surface while the ES provided by forests (in particular: "Burnt areas" and "Natural grasslands" in CLC12 Level 3, connected with "Forest and semi natural areas", CLC12 Level 1) are 18% of the total value, generated by the 10% of total surface (Table 5).

The result shows the importance of forestry percentage in terms of ES provided because of its monetary value per hectare that is three times more than the ES provided by agricultural surfaces (Table 2).

Within the agricultural surface the main ES value comes from the arable land, then other significant ES values comes from the classes of complex cultivation patterns and permanent crops.

3.2.2. ES Scenario 1 – FRINGE

The land use change is referred to a change in the fringe areas towards poplar and giant reed mix in the proportion of 50%. The surfaces involved in the LUC are shown in Table 3. Part of these is burnt areas while the main part of LUC involves agricultural areas. The agricultural areas subjected to LUC are pastures and a little part of arable land and heterogeneous agricultural area. Moreover, in the Fringe areas, it was supposed to add an herbaceous ground cover in orchards, aimed to reduce soil losses and facilitating the bio-remediation process.

The study shows that the ES value of the 10 000 ha subjected to LUC pass from 17 M€ of Scenario 0 to almost the double, 38 M€ (Table 4).

Table 4
Monetary value of the ES.

	Total area (ha)	LUC areas (ha)	ES value LUC areas – Scenario 0 (€)	New ES value LUC areas (€)	ES value total area (€)	ES total value/total area (€/ha)
Scenario 0	156 991	0	–	–	262 796 249	1673
Scenario 1	156 991	10 003	16 768 050	37 937 530	282 859 871	1802
Scenario 2	156 991	47 381	80 525 942	178 045 860	359 346 116	2289
Scenario 3	156 991	38 927	67 462 294	4 257 168	199 591 123	1271

Table 5
New monetary ES evaluated for single classes in different scenarios.

CLC12 – Level 3	Total area (ha) ES €	Scenario 1 (LUC ha) ES €	Scenario 2 (LUC ha) ES €	Scenario 3 (LUC ha) ES €
Fruit trees and berry plantations	(20 847 ha) **3 409 000 €**	(1825 ha) **6 921 995 €**	(1825 ha) **6 921 995 €**	
Olive groves	(4423 ha) **8 262 011 €**	(671 ha) **2 545 441 €**	(671 ha) **2 545 441 €**	
Vineyards	(145 ha) **270 982 €**	(0.5 ha) **1802 €**	(0.5 ha) **1802 €**	
Pastures	(713 ha) **84 432 €**	(713 ha) **2 702 176 €**	(713 ha) **2 702 176 €**	
Permanently irrigated land	(20 463 ha) **38 223 731 €**	(3332 ha) **12 634 830 €**	(3332 ha) **12 634 830 €**	
Non-irrigated arable land	(35 925 ha) **67 106 622 €**	(1983 ha) **7 521 041 €**	(35 925 ha) **136 246 447 €**	(35 925 ha) **4 257 168 €**
Land principally occupied by agriculture, with significant areas of natural vegetation	(4358 ha) **8 140 258 €**	(195 ha) **740 494 €**	(195 ha) **740 494 €**	
Annual crops associated with permanent crops	(679 ha) **1 267 659 €**	(50 ha) **191 150 €**	(50 ha) **191 150 €**	
Complex cultivation patterns	(24 991 ha) **46 681 035 €**	(874 ha) **3 315 964 €**	(874 ha) **3 315 964 €**	
Burnt areas	(359 ha) **–€**	(359 ha) **1 362 636 €**	(359 ha) **1 362 636 €**	
Natural grasslands	(3002 ha) **355 672 €**		(3002 ha) **11 382 924 €**	(3002 ha) **–€**
Total (ha)	**–**	(10 003 ha)	(47 381 ha)	(38 927 ha)

In terms of ES value, the increase of the Scenario 1 – fringe is 8% and it is very interesting due to interests only the 6% of the whole area. This percentage refers to fringe areas that are areas with not significant agricultural value.

3.2.3. ES Scenario 2 – DRYLAND

In such scenario (Tables 4 and 5), areas subjected to the LUC are the 30% of the whole SIR surface. Because of it, the ES value of the LUC areas are quite doubled increasing the ES value of the total SIR surface from the Scenario 0: 262 M€ to the ES 360 M€ of the Scenario 2 – Dryland (Table 4).

This result mainly refers to LUC of 36 000 ha of not irrigated arable land on a whole LUC of 47 000 ha. According to this, in the comprehensive scenario assessment a part of the agricultural value of the territory is missed by.

3.2.4. ES Scenario 3 – ABANDONMENT

The LUC areas represent the 25% of the whole SIR surface. In this scenario the ES monetary values of the LUC areas decrease by almost 63 M€ (the difference between the approximately 67 M€ of the monetary ES value expressed by the Scenario 0 "No change" and the approximately 4 M€ of Scenario 3 "Abandonment"), so that the average of the ES monetary value of the SIR area decrease by 1271 €/ha (Table 4). This is the worst scenario because of the abandonment of these agricultural area leads to the ES value reduction. Further, it is plausible that some of these areas could be polluted areas and in this case the opportunity of bio-remediation is lost and the superficial run-off is increased generating environment impacts.

4. Discussion

The study shows that the current value of the ES for the SIR area (1670 €/ha) is lower than the ES reported by Scolozzi et al. (2012) for the whole areas of Naples and Caserta provinces including study area. Scolozzi refers that the ES monetary value for the Naples Province is less than 1894 €/ha and for the Caserta Province is in the range between 4265 €/ha and 8530 €/ha.

The reduced ES monetary value of the SIR area is given by the minor value of the crops referred to the other agricultural areas of the Caserta Province. Further the abandonment of part of the SIR area justifies the reduction of the average of the ES monetary value.

In planning terms, the study highlights the opportunities of agricultural and natural assets. Thanks to the introduction of the assessment of the ES monetary value, the comprehensive advantages of bio-remediation are put into evidence. Further the use of MCDA leads towards an objective process for the selection of the areas suitable to be submitted to LUC, introducing bio-remediation as a new tool for supporting decision in order to create more sustainable condition for the development of polluted territories.

In such perspective, the recovery of the polluted areas becomes consistent with the need of providing new scenarios for the territorial development and of improving a kind of social and territorial services that have not been evaluated until now:

Scenario 1 – FRINGE refers to a modest LUC consistent with the hypothesis that these areas could be directly managed by local stakeholders and oriented towards the biomass market. The ES value presents a limited increase (+8%, estimated at average value of 1800 €/ha) consistent with the amount of surface subjected to land use change (about 6.5%).

Scenario 2 – DRYLAND can be considered a scenario in which Public Bodies support bio-remediation as planning strategy. In this case, the ES value is comparable with those estimated by Scolozzi et al. (2012) for the provinces of Naples and Caserta. The new average value is almost 2290 €/ha/year, increasing of +37%, compared to the ES monetary value of the Scenario 0 – No Change.

Scenario 3 – ABANDONMENT represent what it would happen in the absence of any interference, both public and private. The ES monetary value decreases up to 1270 €/ha. This scenario presents the lowest ES value. Further, the population could be more exposed to health risk because of the soils pollutants could be easily mobilized due to run-off, wind action, leakage etc.

Last, the spatial resolution of the study is fixed to the Corine Land Cover (1:100 000) according to the correspondence with the ES classes found in literature (Bossard et al., 2000). Such spatial resolution does not allow more detailed investigation (Tianhong et al., 2010; Turner et al., 2003), but it is useful to preliminary assessment that can give interesting results consistent with the scale usually addressed for strategic planning and, notably, for the decision making support system.

5. Conclusions

The study put into evidence the benefits of bio-remediation in the management of contaminated sites located in the agricultural areas. Bioremediation techniques, integrated with policies and measures, are a key opportunity that can be site-specifically appraised as a crucial concern in planning due to it reduces human and environmental risks.

According to this, the monetary evaluation of ES helps to facilitate the social awareness of the value of maintaining vegetated soils in case of polluted areas even if it is not yet assessed the increasing monetary value of bio-remediation in risk reduction. Vice versa the study does not take into account the reduced monetary value due to the strong intensification of land use for energy crops and no food crops (such as in Scenario 2). It generally leads to a decline in biodiversity (i.e. future framework of Schneiders, 2012) so that the future development of the study could be oriented to foreseen and design mitigations actions to ensure sustainable use. More “weakness” in LUC is the change of water consumption due to the increase of permanent crops, the reducing of natural competition of non-crop plants, the increase of the phytophagous insects, etc. (Swift et al., 2004; Zhang et al., 2007).

Furthermore, the massive LUC of Scenario 2 corresponds to the significant reduction of the value of agricultural land and farmer’s incomes. Such single farmer reduction of incomes could be balanced by the social benefit of the ES monetary value, quantified by the study proposed methodology. In fact the ES monetary value increase is almost 600 €/ha that is consistent with the decrease of the farmers’ incomes.

The worst scenario is the Scenario 3 – Abandonment that is the most presumable in absence of public action. Here it will observe both the reduction of the farmers’ incomes and the reduction of the ES value.

Planning could play a crucial role in providing shared actions and strategies for integrating public and private needs. Beside, the approach can be easily replicated.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecoleng.2015.09.045.

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