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The role of the Natura 2000 Network in spatial planning policies. Ecosystem services and management plans: the question of water purification

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PhD Student: *Daniela Ruggeri*

Coordinator of the PhD Programme *Professor Roberto Deidda*

Supervisor *Professor Corrado Zoppi*

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Abstract

EU waters are under increasing pressure due to the growth of the demand for good quality water to be used for different purposes. Some ecosystems naturally provide the service of water purification, reducing costs for human society. This should be recognised with absolute priority for their strategic role, at all planning levels. Nevertheless, currently, an official disposition for the evaluation of ecosystem services is still lacking.
The Natura 2000 Network represents the vital core for several ecosystem services, including water purification. The Natura 2000 sites are often managed by specific plans (named management plans) in order to define conservation measures for habitats and species, also considering socio-economic needs. These plans do not consider the presence of ecosystem services yet.
In order to recognise the role of Natura 2000 sites for their beneficial contributions, the challenge is to build a framework aiming at integrating ecosystem services into planning decisions. Consequently, to include the evaluation and mapping of ecosystem services in management plans since the earliest phase is surely a good start in the pathway for sustainability.

Daniela Ruggeri

The role of the Natura 2000 Network in spatial planning policies.

Ecosystem services and management plans: the question of water purification

Index

Index of Figures

Index of Tables

1 Introduction

In the last decades, in Europe, the phenomenon of the development of anthropic contexts has considerably grown and the theme of the sustainable governance of these contexts is becoming increasingly important. Consequently, the issue concerning the planning of anthropized areas needs to include a broad understanding of natural processes in order to improve the urban environment and quality of life.

The protection of natural areas that still survive close to anthropized environments has become strategic and no more postponed. Therefore, it is necessary to define achievable systematic approaches to the simultaneous conservation of biodiversity in connection with planning practices.

Since the institution of the Natura 2000 Network, as ecological network of the European Union, several natural areas have been identified in the Member States, as natural sites that need to be particularly protected.

The presence of elements of the ecological network influences spatial planning and spatial planning influences the integrity of the network itself. Consequently, to conceptualise a planning model ensuring a balance between the pursuit of environmental protection and the overall socio-economic development of the territory is crucial, as well as ensuring an integrated system that allows developing a less impacting model of human activities within or near the areas that need to be protected.

The role of the Natura 2000 Network in providing ecosystem services has been recognised as essential (Maes, 2012; Bastian, 2013; EC, 2013), but the assessment of these services has not been defined in a regulative framework yet.
In this conceptual framework, a new definition of the structure of management plans of the Natura 2000 sites represents a useful step towards the integration of environmental protection into planning processes.

1.1 Research objectives

The current model of spatial planning is mainly oriented to the territorial expansion and economic growth, involving significant environmental changes, i.e. the land-taking process. This fact requires a strong answer to the question of sustainability and preservation of natural areas that still survive near urbanized contexts.
The main objective of the thesis concerns the ways in which spatial planning could be related to the management of the environmental heritage, recognized by the establishment of the Natura 2000 Network at the European level. This general objective is pursued through a methodological approach oriented to the following specific objectives: the integration between spatial planning and management of the Natura 2000 sites; the evaluation of ecosystem services, in particular, water purification service, linked to the Natura 2000 sites in planning processes.
Consequently, the thesis aims to answer the following questions:

- which relationships exist between the territorial plan and management plans of the Natura 2000 sites, and how can we improve these relationships in order to make the presence of the sites more effective in the planning process?

- which is the role of Natura 2000 sites in providing ecosystem services and how can they be considered in decision-making and planning processes?

1.2 Thesis organization

The thesis is structured in seven main chapters: Introduction, Literature, Regulative Framework, Methodology, Case studies, Discussion and Conclusions, and References.
Chapter one is the introduction of the thesis, where research objectives are stated, with reference to the assessment of the ecosystem services of the Natura 2000 sites and the role of management plans.
Chapter two defines a literature review, representing the state of the art of the two principal topics of the thesis: management plans of the Natura 2000 sites and the water purification ecosystem service.
Chapter three contains the regulative framework for the Natura 2000 Network, for management plans and the European framework for water, with a focus on nitrates issue.
Chapter 4 describes the methodology involved in the thesis, with a general description of a management plan structure proposed at European level and the description of a model aiming at evaluating water purification. Two case studies are identified: the Metropolitan City of Cagliari (in Italy) and the Flemish Region (in Belgium).
Chapter 5 contains the descriptions of the case studies, where issues related to management plans and critical questions for water are analysed. The case study of the Metropolitan City of Cagliari involves management plans, water purification and the land-taking process. The case study of the Flemish Region involves management plans, water purification and the assessment of the nitrate focus areas.

Chapter 6 is crucial to address a framework for the integration of the Natura 2000 Network into planning policies and practices. Starting from the lack of ecosystem services assessment emerged in the management plans of the case studies, a management plan structure inclusive of the evaluation and mapping of ecosystem services is suggested. This section contains also the conclusions of the thesis.

Chapter 7 contains references which have been useful in order to start and improve the thesis.

2 Literature

2.1 Management plans of the Natura 2000 sites

2.1.1 The Natura 2000 Network

In the second half of the 20th Century, there was a growing awareness of environmental problems, including the loss of species and habitats, resulting in several national and international initiatives (Evans, 2012). In particular, there was a widespread recognition that many species were in danger of extinction (Walter and Gillett, 1998) and that many habitat types were disappearing.

In 1979, the European Union adopted a directive for the conservation of wild birds (Directive 79/409/EEC, called "Birds Directive", updated by the Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009). This directive requires that Member States designate sites, called Special Protection Areas (SPAs), for a list of species considered rare and/or threatened. In 1992, the European Union adopted a directive for the conservation of natural habitats and of wild fauna and flora (Directive 92/43/EEC, called "Habitats Directive"). This directive contains measures for the protection of selected species and requires the designation of protected sites for selected habitats and species. Initially, these sites are defined as Sites of Community Importance (SCIs); after a procedure, they are designated as Special Areas of Conservation (SACs).

Sites from Birds Directive composed of sites from Habitats Directives represents the core of the Natura 2000 Network, which is established in the European territory under the Habitats Directive.

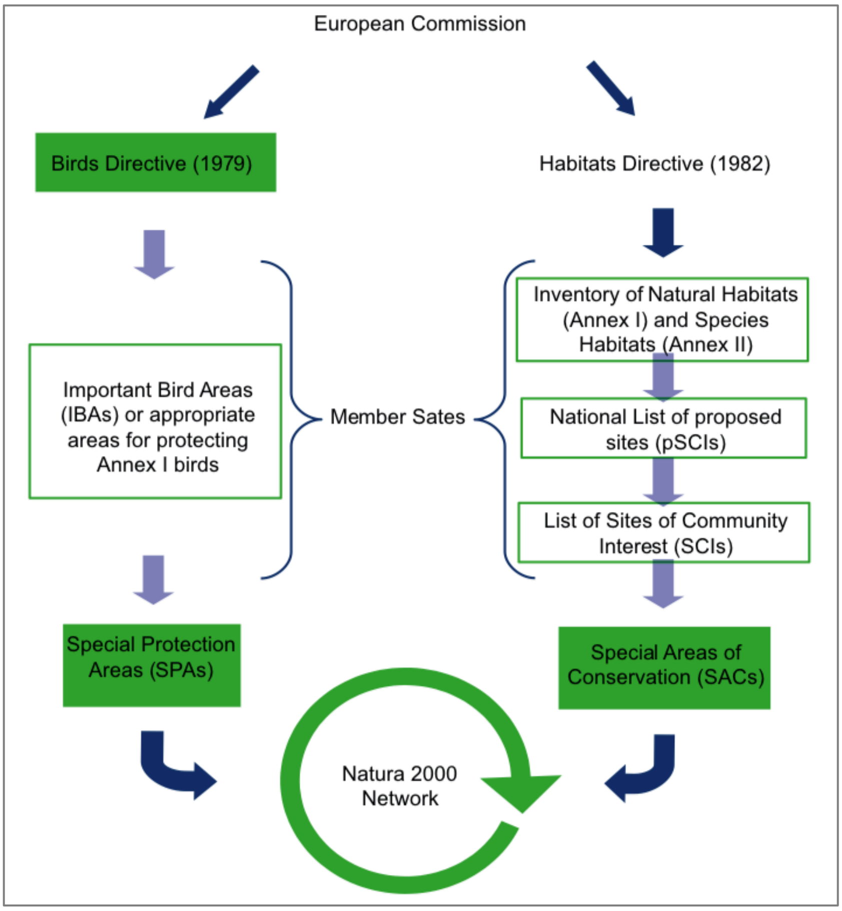

Figure 1 – The institution of the Natura 2000 Network. Source: Boivin et al. (2011).

Natura 2000 is the largest network of protected areas in the world (Sundseth and Creed, 2008) and new sites are being designated during years. With more than 29,000 sites, currently, the Natura 2000 Network covers the 18.2% of the EU territory (which amount to 4,346,742 km^2) and involves 24,127 SCIs/SACs and 5,616 SPAs[1].

2.1.2 The role of management plans

Nowadays, more and more communities are suffering due to a decline in quality of life (Portney, 2013; EEA, 2015; Streimikiene, 2015). This problem is mainly constituted by fragmentation and degradation of habitats, destruction of ecosystems caused by variation in land use, over-exploitation of resources, the presence of invasive alien species, and pollution. The model of the contemporary territorial development, which sees its expansion oriented to the economic growth, entails significant environmental changes that call for sustainability into planning questions due to several negative factors first of all soil consumption. In recent years, in Europe, the concentration of anthropized contexts is growing, and the issue of manage these territories is assuming greater importance. The debate between urban planners, sociologists, statisticians is active and dynamic, and relate to classify and interpret phenomena affecting anthropized areas; moreover, there are numerous studies and statistical analyses on large urban areas in Europe (Censis, 2014). The European Commission, in relation to the 2014-2020 cohesion policy, invited Member States to adopt an urban agenda aimed to limit soil consumption, urban renewal,

[1] Data provided by the Natura 2000 Barometer, which provides an overview on the Natura 2000 Network of sites under the Birds and the Habitats Directives, in terms of information on area and site numbers. The Natura 2000 Barometer can be consulted at: https://www.eea.europa.eu/data-and-maps/dashboards/natura-2000-barometer [last access: 15 January 2019].

transport infrastructures and sustainable mobility, and a strategy for climate and energy (EC, 2014). Increased environmental awareness is crucial to the success of conservation plans and programs, by including socio-economic and institutional factors in planning processes (Carter *et al.*, 2015). Decisions related to conservation in protected areas must be *ad hoc* and coordinated and should be guided by explicit objectives, with regional strategic priorities and clear selections between potential conservation areas and alternative management practices (Margules and Pressey, 2000). Focusing on the importance of natural processes is essential to maintain a wide perspective, to diversify management categories, to concentrate on the economy of human well-being, not ignoring opportunities that small reserves can provide (Shafer, 1999).

Planning in highly anthropized contexts is a process also involving natural elements; consequently, in agreement with McHarg (1969, 2007), planning with nature is a relevant issue. As Maldonado (1992) points out «all the questions we are asking ourselves today, no one is certainly more relevant than the following: how to meet the needs of development without affecting the quality of the environment, how to reconcile development and quality of life?». In this context, the ecological network is a model of conservation, protection and management of biodiversity within land use governance processes, through a systemic approach to planning in decision-making processes (D'Ambrogi and Nazzini, 2013), also according to an approach based on the interpretation of land use variations (Ganga *et al.*, 2015).

Planning is the intellectual component of the conservation management process, and one of the most important conservation management activities (Alexander, 2012). All sites managed for nature conservation (such as Natura 2000 sites) should have a management plan, with the main purpose to ensure the continuity and stability of management. Without an effective plan, sites are vulnerable to inconsistent management which can result in a waste of resources (both economic and natural) and in the loss of important habitats and species (NCC, 1991).

For the Natura 2000 sites, Habitat Directive includes the possibility to establish necessary conservation measures, if needed involving proper management plans, designed for sites or integrated into other development plans. These plans allow to evaluate the current quality of sites, also taking into account degraded sites in which, however, habitats maintained functional efficiency and that therefore can be restored, also by eliminating degradation causes. Eventually, if the current land use and the ordinary planning do not compromise natural functionalities, the management plan is identified only in the necessary monitoring action.
All management plans should answer some crucial questions (Alexander, 2015), like: What have we got? What is important? What are the important influences? What do we want? What must we do?
Moreover, the main functions of a management plan are:

- to identify all the legislation and policies that rule both the outcomes and the management process;
- to share decision making, whenever appropriate, and to communicate decisions to all interested individuals;
- to include all relevant information about a site and its features;
- to identify the most important wildlife and natural features;
- to identify all the relevant cultural features, as historic, archaeological, and landscape;
- to develop objectives for all important wildlife and cultural features;
- to define the range of facilities that the site provide for visitors;
- to define monitoring and surveillance programmes;
- to identify management and recording activities required to manage the site;
- to identify and justify all the resource requirements, both human and financial;
- to combine all phases in a logical, dynamic and iterative process;
- to ensure continuity of appropriate management.

A plan able to group all these functions can help to solve internal and external conflicts, to ensure continuity of effective management, can be used to bid for resources and can encourage communication between managers and stakeholders, and between sites and organisations (*ibid.*).

2.2 Water purification ecosystem service

2.2.1 The importance of clean and pure water

«Water is fundamental for life and health. The human right to water is indispensable for leading a healthy life in human dignity. It is a pre-requisite to the realization of all other human rights» (World Health Organization, 2002).
Water is essential to any civilization; human life depends on adequate water supplies to survive, but so do plants and all terrestrial and aquatic wildlife. All ecosystems, defined as a dynamic complex of plant, animal, and microorganism communities (the biotic environment) and their non-living (abiotic) environment interacting as a functional unit, depend on water.
The hydrologic cycle delivers essential water in order to maintain the life of animals and vegetation in a freshwater natural environment. It is a complex and dynamic system with three main paths of movement on the surface, which significantly affect ecosystems. They are evapotranspiration, infiltration (into soil and groundwaters), and surface water runoff (Pennington and Cech, 2010).
Water is called "universal solvent" because can dissolve so many substances. Hydrophobic are substances that do not dissolve in water (i.e. metals, fats). Rarely water is pure in nature, and even rainwater includes dust particles, dissolved materials, and other items it

collects from the air, or from the soil. After rainwater falls down, its pollution is mainly due to anthropogenic causes, since humans' activities often produce unfavourable substances to water. Natural events, like floods, erosion, landslides, and volcanoes, can harm water quality but are rarely considered as a pollution source.

Pollutants are classified in: nutrients, sediments, chemical toxic substances, oxygen depleting organics, and microbiological pathogens.

The term "water quality" is necessarily related to its intended use; therefore, water quality is relative. A drinking water standard is the most severe. For instance, the water we drink has better quality than water used for crops or lawns, because irrigation waters could have biological contaminants, that are not appropriate for drinking but not harmful for the crop. Values for these classes are usually compared to thresholds value determined reliable sources, such as the World Health Organization drinking water guidelines.

Lake and stream waters usually contain microbes and other organisms not healthy to drink, but not harmful to fish or wildlife. The majority of waters are not drinkable by humans without treatment, but most waters are not toxic, either. Instead, most freshwater found in nature is somewhere in between and can be easily used in several ways.

Natural waters consumption include water for public water supply, fishing, wildlife, recreational uses, agriculture, industry, and navigation. Physical, biological, and chemical properties of water bodies, local geographic setting, scenic values, and economic considerations are important factors to be considered, and criteria must be adopted in order to protect water quality for the intended use. These quality criteria should refer to human health, aquatic life, microbial pathogens, sediments, and nutrients.

Nutrients are one of the main pollutants currently affecting the environment. A nutrient is either an element or compound (mix of two or more elements) that is consumed by an organism to grow and create energy. Humans primarily consume the nutrients of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulphur. Nitrogen and phosphorus are the primary nutrients of plants, but their excess cause accelerated eutrophication by stimulating the plant growth and death cycle. In water, nitrogen is usually attached to

organic elements, rather than soil sediments. High levels of nitrogen reduce the amount of dissolved oxygen remaining for plants and fish, favouring algae growth and obstructing photosynthesis in beneficial aquatic plants. During the past few decades, nitrogen produced by humans has been greater than produced through natural terrestrial systems (Fowler *et al.*, 2013).
Water pollutants are defined and regulated by governments. They can be divided into two groups: point and non-point sources. Point sources of pollution can be identified as coming from a specific site (i.e., a farm, a tanker spill). Non-point sources of pollution are originated in large areas, like urban areas, agricultural areas, even entire watersheds, because runoff carries widespread pollutants through waterbodies and soil. The atmospheric deposition is considered as a non-point source too. Point source locations and accountability are quite simple to isolate and impacts of contaminants can be attributed to an owner; while non-point sources of pollution are more difficult to identify (Pennington and Cech, 2010). Both surface waters and groundwaters can be affected by nutrients.

2.2.2 The role of ecosystem services

2.2.2.1 The water purification ecosystem service

Ecosystem services are defined as the benefits that people obtain from ecosystems (MEA, 2005), and the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). The concept of ecosystem services is relevant for connecting people to nature, and it makes relevant the key role of ecosystem functioning and biodiversity to support multiple benefits to humans.
Mapping ecosystem services is attracting growing interest in urban planning processes, but their importance in decision making is still limited (Barò *et al.*, 2016). Ascribing values

to ecosystem goods and services is not an end in itself, but rather a small step in the larger and dynamic arena of political decision making (Daily *et al.*, 2009).

The Millennium Ecosystem Assessment (2005) represents the most extensive systematization of the acquired knowledge on the state of ecosystems in the world, and provides a classification of ecosystem services, subdividing ecosystem functions into four main categories: support, regulation, supply and cultural.

Supporting ecosystem services collect all the necessary services for the production of all other ecosystem services and contribute to the conservation, *in situ*, of biological and genetic diversity and evolutionary processes.

Regulating ecosystem services help to maintaining health and functioning of ecosystems and collect other services that involve direct and indirect benefits for humans, such as climate stabilization, waste recycling, which are usually not recognized until when they are lost or degraded. In many ways, these regulation functions provide the necessary pre-conditions for all other functions.

Provisioning ecosystem services include supply services produced by natural and semi-natural ecosystems (oxygen, water, food, ...).

Cultural ecosystem services contribute to the maintenance of human health through the provision of opportunities for spiritual enrichment, cognitive development, recreational and aesthetic experiences.

Among these services, particular importance is given to the water purification service, which belongs to the category of regulation services. This group of functions relates to the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems through biogeochemical cycles and other processes of the biosphere. Regulation functions maintain a "healthy" ecosystem at different scale levels and, at the biosphere level, provide and maintain conditions for life on Earth.

Water resources are located in a variety of forms, quantities, and locations across the world. Intimate relationships between water and land and the effects of land use on nature and specifically on water quality have been recognized and analysed since the ancient

Greeks (Lassen, Lull and Frank, 1952). In fact, the water purification service is a fundamental service for human well-being. Water quality has consequences for people through several ways, from drinking water to recreational purposes, to fishing activities, to aquatic ecosystems that often have a low capacity to adapt to nutrient and pollutant loads in general.

Vegetative cover, such as shrubs along river corridors, forest canopy, and groundcover on sloped surfaces, can help to regulate infiltration into soil and groundwater, slowing down the water runoff. Forest canopy and leaf cover help to reduce impacts of raindrops on the land surface and require more time for infiltration. Similarly, vegetation on sloped landscapes can trap humidity, keeping more time for infiltration into soils. Plant roots help to decrease surface water runoff reducing the speed of a potential flood event, especially on sloped landscapes, retaining soil and reducing soil erosion too. Roots improve soil quality creating a more porous structure for water infiltration during precipitation events (Pennington and Cech, 2010).

When surface water runoff flows into wetlands, acts like sponges, and gradually release it back to adjacent water systems (rivers, lakes, or groundwaters). Wetlands are natural water ecosystems that serve as filters to remove sediments and reduce some pollutants, nutrients and other impurities. Historically, wetlands have been undervalued, and many were drained out or filled with soil. Today, wetlands are more highly valued for their ability to provide valuable ecosystem benefits (*ibid.*).

In this thesis, only issues on a nutrient, the nitrogen, are discussed. Nitrogen is a key element of ecosystems and the main regulator of ecological and functional conditions of the biosphere, being the main component of the air of the earth's atmosphere. Nitrogen is defined as "nutrient" because is essential for the growth of many organisms. In the last century, due to human activities, the natural nitrogen cycle has been significantly altered, with several consequences: traces of nitrogen oxides in gaseous emissions, eutrophication in water bodies, decrease in the quality of groundwater, with negative effects on the biodiversity (Breuer *et al.*, 2008).

Nitrogen has many and complex pathways by which it is dispersed in the environment, and nutrient leaching from agricultural land is one of the major pathways. Since the industrial revolutions, the rate of nitrogen input has been doubled into the terrestrial nitrogen cycle (Vitousek *et al.*, 1997). Reactive Nitrogen is essential for agriculture, but the irregular spatial distribution of its use is remarkable. There are huge inequities in the distribution of nitrogen-containing fertilizers. Food production in some parts of the world is nitrogen-deficient while in other parts of the world its over-application results in a cascade of environmental and human health problems (Galloway *et al.*, 2008).
Nitrogen loads can be both punctual and widespread. Punctual sources can be found in farms and agriculture, as well as in food storage areas; widespread sources can be urban areas, agricultural areas or grazing areas, industrial areas. Consequently, during meteoric events, the water flow carries nutrients, as well as pollutants in general, through land surfaces, towards rivers, lakes, up to the sea.

Ecosystems provide water purification service through the removal of sediments, nutrients and pesticides from the water surface through deposition, filtration, infiltration and absorption (Zhang *et al.*, 2010); in this way, pollutants can be limited or degraded before they can reach the watercourse. There are several systems to obtain these services: vegetation can remove pollutants by binding them in the plots or releasing them in the environment in other forms; soils can trap and store soluble pollutants; the slow flow of water in humid areas allows vegetation to capture pollutants; moreover, riparian vegetation has a specific importance, representing the last barrier before pollutants can reach the stream.
Some ecosystems can naturally provide beneficial denitrification. Denitrification from biological origin consists in the conversion from nitrate (NO_3^-) to nitrogen (N); consequently, less eutrophication occurs because less nitrate enters the surface water.
Fundamental ecosystems for denitrification are, for example, poorly drained soils of forests, grasslands, in partially to fully water-saturated soils, in seepage areas and riparian

zones, in sediments of rivers, lakes and estuaries. Moisture is one of the most important factors that can positively influence denitrification.

Nitrate leaching is a complex process and is affected by a number of soils, environmental, and management conditions (Di and Cameron, 2000); it determines nitrate concentration in groundwaters. Denitrification and nitrate leaching cannot be considered separately, and the final ecosystem service consists in the improvement of soils and the surface water quality. The assessment of the ecosystem service of water quality regulation takes into account nitrate leaching and denitrification. The most relevant ecological scale for the regulation service of water purification is intended (as a breakdown of nutrients excess) is the ecosystem scale[2], with a dimension between 1 and 10,000 km^2 (de Groot, 2010).

Wetlands are important ecosystems for water purification service. Their functions can be divided into biological, biogeochemical, physical, and hydrologic. Particularly, they can (Pennington and Cech, 2010):

- process of organic matter and nutrients, nutrient cycling, and biological uptake;
- provide a diversity of habitats for wildlife, breeding, nesting, and foraging;
- help to maintain water quality by filtering sediments and contaminants and serve as natural buffers for streams, lakes, and rivers;
- attenuate floodwaters and slow the rate of flow of waters going into streams and rivers, and protect coasts from excessive erosion;
- provide a place where water can have time to permeate through the soil into an aquifer and replenish groundwaters;
- serve as nurseries and feeding areas for young fish and provide nutrients in food webs.

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[2] Other services have different scales. For example, the ecological scale of carbon sequestration is global (with dimensions > 1,000,000 km^2); the ecological scale of the service of protection against noise and dust is the plot plant (with dimensions < 1 km^2).

Protected areas are often considered as a whole as an attractive landscape or for their aggregate production of ecosystem services (Christie and Rayment, 2012; Kettunen *et al.*, 2009). They provide special areas for recreation, bird-watching, fishing, walking, photography, and offering open space and aesthetic value, and serve as educational and research areas to study the widely diverse wildlife, plants, and animals (Pennington and Cech, 2010).
The "ecological value" or importance of a given ecosystem is, therefore, determined both by the integrity of the regulation and habitat functions of the ecosystem and by ecosystem parameters such as complexity, diversity, and rarity (de Groot *et al.*, 2003). Understanding the linkages between the natural and socio-economic systems can lead to an improved and more sustainable management of ecosystems (Guerry *et al.*, 2015).

2.2.2.2 The threat of land-taking processes

There are multiple, and conflicting meanings of "nature", and it is possible to distinguish between two perspectives: the anthropocentric and the biocentric. The anthropocentric perspective places humans at the centre of the Universe, with nature at their service. From this human-centred view, nature has instrumental values. The biocentric perspective considers humans as members of an interconnected "web of life" (Marshall, 1994) and an integral part of nature, rather than its master or steward. From the biocentric perspective, nature has intrinsic values. It is an end in itself (Davoudi, 2014). Unfortunately, in the last decades, planning processes have been mainly based on the anthropocentric perspective. In anthropized areas, the relationship "built – not built" is assuming ever higher values; natural areas are reduced with negative consequences on functional parameters. Recently, these considerations started to be submitted to public opinion, in order to highlight the close relationship between "human" and "environmental" factors (Bruno, 1992).

Humans tend to modify natural cycles through two main activities: urban development and cultivation of land for crops (Pennington and Cech, 2010).

It is central to verify variations of artificial surfaces in order to identify which land use classes have been replaced by them (Abrantes *et al.*, 2016) and, in particular, the quantification of the variation in ecosystem services (Opdam *et al.*, 2015), in order to understand and improve relationships between man and nature in the framework of planning, and it is necessary to consider complex links between pressures combinations and the ecological response of ecosystems (Brown *et al.*, 2013).

Starting from the "1992 Rio Conference" up to the "European Biodiversity Strategy to 2020", natural capital is recognized as insurance for human wellbeing and health. In particular, in 2011, the European Commission put emphasis on the protection and value of ecosystem services, setting a specific target on maintaining and restoring ecosystems and their services (EC, 2011).

The assessment of benefits from natural capital, through the identification and analysis of ecosystems and their services, is one of the recent challenges for the scientific research, as well as a goal for the establishment of sustainable practices for the coming years.

In protected natural areas there is a considerable supply of ecosystem services (ISPRA, 2011). Consequently, decision-makers' information on the consequences on the provision of ecosystem services due to changes in land use is crucial.

Natura 2000 sites, designed to preserve natural values and ecosystems, provide local communities with multiple ecosystem services. The knowledge of the potential distribution of ecosystem services is crucial in the decision-making process and can lead decision makers to a new sustainable planning approach. In fact, ecosystems are complex systems that provide a multiplicity of ecosystem services interconnected by complex and non-linear relationships. Changes in land use, induced by nature management and conservation practices, affect these relationships, influencing the quantity and distribution of ecosystem services. Inadequate vegetation cover can allow precipitation to run off sloped land surfaces, causing erosion, leading to even less vegetative cover and the transport of more soil sediments into downstream watercourses.

Economic benefits of sustainable, multi-functional use of natural and semi-natural ecosystems and landscapes usually exceed the gains of their conversion to single-purpose land use types. Although this, humans continue to degrade and destroy natural habitats (De Groot, 2006).

Starting from the 1950s, in Europe, the phenomenon of soil consumption has grown unabated (Ganga *et al.*, 2015). Artificial surfaces have been developed following a dispersion model that leads to widespread soil sealing; this event involves the ecological balance alteration and natural habitats integrity (Balestrieri and Pusceddu, 2015). This phenomenon is linked to contemporary diffusion processes, which redesign the axis of urban development determining residence, services, commercial activities and industries, moving towards the medium-long distance and consequently affecting the territory in depth (Cassetti, 1992). The complexity of the dynamic phenomenon of urban expansion can be understood by analysing land use changes (Sudhira *et al.*, 2003).

The establishment of protected natural areas is a process whose dynamics tend to be in contrast against urban growth, and the constant expansion of urban sprawl tends to threaten the presence of protected sites (Hernández and Torres, 2015). Conservation policies in protected areas should prevent, or limit, the soil consumption process (Zoppi and Lai, 2015). In this context, the role of planning is fundamental, which must identify threatening situations and consequently direct local policies.

3 Regulative framework

3.1 The Natura 2000 Network

The Directive 92/43/EEC[3] on the conservation of natural habitats and of wild fauna and flora ("Habitat Directive"), on Article 3 establishes the Natura 2000 Network: «a coherent European ecological network of special conservation areas, called Natura 2000, is established. This network, consisting of the sites containing the types of natural habitats listed in Annex I and the habitats of the species referred to in Annex II, must ensure the maintenance or, where appropriate, the restoration, in a satisfactory state of conservation, of the types of natural habitats and habitats of the species concerned in their natural distribution area. The "Natura 2000" network also includes Special protection areas classified by Member States in accordance with Directive 79/409/EEC».

The Natura 2000 Network includes Sites of Community Importance (SCIs) and Special Areas of Conservation (SACs), as defined in Habitats Directive, and Special Protection

[3] Directive 92/43/EEC of 21 May 1992 is available at https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A31992L0043 [last access: 15 January 2019].

Areas (SPAs), as defined in Directive 79/409/EEC[4] ("Birds Directive", as amended by Directive 2009/147/EC[5] on the conservation of wild birds). Habitats Directive aims to contribute to the biodiversity conservation in Member States by establishing comprehensive and unitary protection of habitats and all species belonging to the flora and fauna that are persistent in a specific area to be protected. Birds Directive recommends providing for the conservation of all wild bird species through the identification by Member States of the Union of areas to be used for their conservation. SPAs' objective is the conservation of all species of naturally occurring birds in the wild, achieved not only through the protection of this specific category of fauna but also by protecting their natural habitats.

On Article 6, Habitat Directive establishes the general framework for the conservation and protection of sites and includes proactive, preventive and procedural provisions. The general framework is the key to achieving the principle of environmental integration and, finally, for sustainable development (EC, 2000). The Natura 2000 Network is composed of sites hosting natural habitat types listed in Annex I and habitats of the species listed in Annex II; it shall enable natural habitat types and species' habitats which need to be maintained or, where appropriate, restored at a favourable conservation status in their natural range. Indeed, Habitats Directive provisions have the specific objective «to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest» (Article 2, Paragraph 2).

The main objective of Natura 2000 is to oppose the biodiversity loss through the conservation of habitats and species listed in the Annexes of the Birds and Habitats Directives (Habitats Directive, Articles 2 and 3). In order to fulfil this task, the European

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[4] Directive 79/409/EEC of 2 April 1979 is available at https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:l28046&from=EN [last access: 15 January 2019].

[5] Directive 2009/147/EC of 30 November 2009 is available at https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32009L0147 [last access: 15 January 2019].

territory has been subdivided into seven biogeographical regions characterized by similar macroclimatic conditions and biodiversity (Habitats Directive, Article 1).

3.2 Management plans

Article 6 is one of the most important articles of the Habitats Directive (a specific Guide to the interpretation of Article 6 has been written (EC, 2000)) and defines how effectively the sites of the Natura 2000 network must be managed and protected. For special areas of conservation, Member States shall establish the necessary conservation measures involving, if need be, appropriate management plans specifically designed for the sites or integrated into other development plans, and appropriate statutory, administrative or contractual measures which correspond to the ecological requirements of the natural habitat types in Annex I and the species in Annex II present on the sites (Article 5, Paragraph 1).
In particular, it introduces two classes of measures: conservation measures and compensatory measures. Management plans belong to the conservation measures and could be specific or integrated into other plans. Member States establish necessary conservation measures that imply appropriate specific or integrated management plans with other development plans and the appropriate regulatory, administrative measures or contracts that comply with the ecological needs of the types of natural habitats listed in Annex I and of the species listed in Annex II present on the sites. In this context, the Habitats Directive lays a solid basis for the preparation of measures aimed at ensuring the maintenance in satisfactory conservation status of habitats and species. It leaves it up to each Member State to design and implement the type of measures that it considers most appropriate and effective for its Natura 2000 sites.

All the activities planned in a site, or outside but which affect it, are dealt with in the management plan. The management plan is configured as a tool for strategic direction and decision support, in the processes of the definition of management guidelines, planning and organization of environment-oriented planning projects towards sustainable development and the overall growth of territory. The management plans can fundamentally be of two categories: specific, i.e. specifically approved for the achievement of objectives identified by the Directive; or integrated with other development plans, then included in other planning and/or planning acts.

Member State	**Region**	**Obligatory**	**Not obligatory**	**Voluntary**
AT	Lower Austria, Salzburg, Styria		x	
	Vienna		x	
	Burgenland	x		
	Carinthia		x	
	Tyrol		x	x
	Upper Austria	x		
	Vorarlberg		x	
BE	Marine	x		
	Flanders	x		
BG	-		x	
CY	-		x	
CZ	-	x		
DE	Baden- Württemberg	x		
	Hesse	x	x	
	North-Rhine- Westfalia	x	x	
	Thuringia			
	Schleswig- Holstein			x
	Mecklenburg-Vorpommern			x

Member State	Region	Obligatory	Not obligatory	Voluntary
	Bayern	x		
	Berlin	x		
	Brandenburg			x
	Rheinland- Pfalz	x		
	Sachsen		x	x
	Sachsen- Anhalt		x	
	Marine EEZ	x (for SPA)		x
DK	-	x		
EE	-	x		
ES	-	x		
FR	-	x		
HU	-		x	
IE	-	x		
IT	20 regions		x	x (Management plans are only considered necessary for some sites)
LT		x (for new Natura 2000 sites which are not in the national protected areas – since 2010 and according to Law on Protected Areas)		x
LU		x		
LV			x	x
MT			x	x (considered a best practice approach,

Member State	Region	Obligatory	Not obligatory	Voluntary
				particularly for sites with multiple stakeholders and different land uses)
NL		x		
PL		x		
PT			x	
SE		x		
SI		x		
SK			x	
UK			x (Management plans are not obligatory under transposing legislation in any part of the UK, reflecting the fact that they are not obligatory under Article 6 of the Directive)	

Table 1 – Management plans compulsory in Member States. Elaborated from the Fact Sheets on Natura 2000 management planning, the situation in 2011 (EC, 2011).

As shown in Table 1, on 2011, for 24 Member States analysed 12 define management plans as compulsory for all the country, 2 define management plans compulsory only for some regions, 9 consider management plans as not obligatory plans.

3.3 Water regulative framework

3.3.1 The European framework for water

Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such. Waters in Member States are under increasing pressure from the continuous growth in demand for sufficient quantities of good quality water for all purposes. Water pollution, over-abstraction and hydro-morphological alterations have been denoted as the main significant pressures for the European water bodies (EC, 2015).

Good water quality will contribute to securing the drinking water supply for the population.

Member States should aim to achieve the objective of at least good water status by defining and implementing the necessary measures within integrated programmes of measures, considering existing Community requirements. Where good water status already exists, it should be maintained.

Surface waters and groundwaters are in principle renewable natural resources; in particular, the task of ensuring the good status of groundwater requires early action and stable long-term planning of protective measures, owing to the natural time lag in its formation and renewal. Such time lag for improvement should be taken into account in timetables when establishing measures for the achievement of the good status of groundwater and reversing any significant and sustained upward trend in the concentration of any pollutant in groundwater.

3.3.1.1 Directive 91/676/EEC

Directive 91/676/EEC[6] ("Nitrates Directive"), concerning the protection of waters against pollution caused by nitrates from agricultural sources, has the objective of reducing water pollution caused or induced by nitrates from agricultural sources and preventing further pollution (Article 1).

With reference to nitrates, it defines "pollution" as «the discharge directly or indirectly into the water environment of nitrogenous compounds of agricultural origin, the consequences of which are endangering human health, harming living resources and the aquatic ecosystem, compromising the attractiveness or hindering other legitimate uses of water».

Member States shall designate as "vulnerable zone" all known areas of land in their territories which drain into waters affected by pollution or which could be affected by pollution (Article 3, Paragraphs 1 and 2).

With the aim of providing a general level of protection against pollution for all waters, Member States shall, within a two-year period following the notification of this Directive (Article 4, Paragraph 1):

- establish a code or codes of good agricultural practice, to be implemented by farmers on a voluntary basis, which should contain provisions covering at least the items mentioned in Annex II A;
- set up a programme, where necessary, including the provision of training and information for farmers, promoting the application of the code of good agricultural practice.

Member States shall, for the purpose of realizing the objectives specified in Article 1, establish action programmes in respect of designated vulnerable zones, also implementing

6 Directive 91/676/EEC is available at https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A31991L0676 [last access: 15 January 2019].

suitable monitoring programmes. Action programmes shall take into account: available scientific and technical data, mainly with reference to respective nitrogen contributions originating from agricultural and other sources; environmental conditions in the relevant regions of the Member State concerned (Article 5).

Annex I define criteria for identifying waters referred to the vulnerable zone:

- whether surface freshwaters, particularly those used or intended for the abstraction of drinking water, contain or could contain, if action pursuant to Article 5 is not taken, more than the concentration of nitrates laid down in accordance with Directive 75/440/EEC (concerning the quality required of surface water intended for the abstraction of drinking water in Member States);
- whether groundwaters contain more than 50 mg/l of nitrates or could contain more than 50 mg/l of nitrates, if action pursuant to Article 5 is not taken;
- whether natural freshwater lakes, other freshwater bodies, estuaries, coastal waters and marine waters are found to be eutrophic or, in the near future, may become eutrophic if action pursuant to Article 5 is not taken.

In order to pursue these criteria, Member States shall also take into account: physical and environmental characteristics of the waters and land; the current understanding of the behaviour of nitrogen compounds in the environment (water and soil); and, the current understanding of the impact of the action taken pursuant to Article 5.

3.3.1.2 Directive 2000/60/EC

Directive 2000/60/EC[7] ("Water Framework Directive") defines a framework for Community action in the field of water policies and emphasizes that EU waters are under increasing pressure from the growth of the demand for good quality water to be used for

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[7] Directive 2000/60/EC is available at https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF [last access: 15 January 2019].

different purposes. This directive lays down a strategy against pollution of water and requires further specific measures for pollution control and environmental quality standards. Here water is defined as a not commercial product like any other but, rather, a heritage which must be protected, defended and treated.

This Directive aims at maintaining and improving the aquatic environment in Member States. This purpose is primarily concerned with water quality. The control of quantity is an ancillary element in securing good water quality and therefore measures on quantity, serving the objective of ensuring good quality, should also be established.

In cases where a body of water is so affected by human activity or its natural condition is such that it may be unfeasible or unreasonably expensive to achieve a good status, less stringent environmental objectives may be set on the basis of appropriate, evident and transparent criteria, and all practicable steps should be taken to prevent any further deterioration of the status of waters.

The objective of achieving good water status should be pursued for each river basin so that measures in respect of surface water and groundwaters which belong to the same hydrological, hydrogeological and ecological system are coordinated.

For environmental protection purposes, there is a need for greater integration of qualitative and quantitative aspects of both surface waters and groundwaters, considering natural flow conditions of water within the hydrological cycle.

The use of economic instruments by Member States may be appropriate as part of a specific programme of measures. The principle of costs recovery of water services, including environmental and resource costs associated with damage or negative impact on the aquatic environment, should be taken into account in accordance with, in particular, the polluter-pays principle. An economic analysis of water services based on long-term forecasts of supply and demand for water in the river basin district will be necessary for this purpose.

The purpose of this Directive (Article 1) is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which:

- prevents further deterioration and protects and enhances the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems;
- promotes sustainable water use based on the long-term protection of available water resources;
- aims at enhanced protection and improvement of the aquatic environment, inter alia, through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing-out of discharges, emissions and losses of the priority hazardous substances;
- ensures the progressive reduction of pollution of groundwater and prevents its further pollution;
- contributes to mitigating effects of floods and droughts.

and thereby contributes to:

- the provision of the sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use;
- a significant reduction in pollution of groundwater;
- the protection of territorial and marine waters;
- achieving the objectives of relevant international agreements.

Article 4 defines environmental objectives for surface waters, for groundwater and for protected areas (including Natura 2000 sites). It states that Member States ensure (Paragraph 5, Letter b):

- for surface water, the highest ecological and chemical status possible is achieved, given impacts that could not reasonably have been avoided due to the nature of the human activity or pollution;
- for groundwater, the least possible changes to good groundwater status, given impacts that could not reasonably have been avoided due to the nature of the human activity or pollution.

Member States shall ensure the establishment of programmes for the monitoring of surface water status, groundwater status and protected areas in order to establish a coherent and comprehensive overview of water status within each river basin district (Article 8, Paragraph 1). The European Parliament and the Council shall adopt specific measures against pollution of water by individual pollutants or groups of pollutants presenting a significant risk to or via the aquatic environment, including such risks to waters used for the abstraction of drinking water (Article 16).

Annex V defines quality elements for the classification of ecological status, including nutrient conditions, and standards for monitoring of quality elements.

Annex VIII outlines an indicative list of main pollutants, including substances which contribute to eutrophication (in particular, nitrates and phosphates).

3.3.1.3 Directive 2006/118/EC

Directive 2006/118/EC[8] on the protection of groundwater against pollution and deterioration establishes specific measures in order to prevent and control groundwater pollution. These measures include, in particular, criteria for the assessment of good groundwater chemical status, and criteria for the identification and reversal of significant and sustained upward trends and for the definition of starting points for trend reversals (Article 1).

For the purposes of the assessment of the chemical status of a body or a group of bodies of groundwater, Member States shall use the following criteria (Article 3):

- groundwater quality standards as referred to in Annex I;
- threshold values to be established by Member States.

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[8] Directive 2006/118/EC is available at https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32006L0118&from=EN [last access: 15 January 2019].

Groundwater is a valuable natural resource and as such should be protected from deterioration and chemical pollution. This is mainly important for groundwater-dependent ecosystems and using groundwater in water supply for human consumption.
Groundwater is the most sensitive and the largest body of freshwater in the European Union and, in particular, also the main source of public drinking water supplies in several regions.
Groundwater in bodies of water used for the abstraction of drinking water or intended for future use must be protected in a way that deterioration in the quality of such bodies of water is avoided in order to reduce the level of artificial purification treatment required for drinking water production. In some areas, the protection of groundwater may require a change in farming or forestry practices, which could entail a loss of income. The Common Agricultural Policy provides for funding mechanisms on support for rural development.
Member States shall use a specific procedure to assess the chemical status of a body of groundwater (Article 4). Member States shall identify any significant and sustained upward trend in concentrations of pollutants, groups of pollutants or indicators of pollution found in bodies or groups of bodies of groundwater identified as being at risk and define the starting point for reversing that trend (Article 5).
In order to achieve the objective of preventing or limiting inputs of pollutants into groundwater, Member States shall ensure that the programme of measures includes (Article 6): all measures necessary to prevent inputs into groundwater of any hazardous substances; for pollutants not considered hazardous, and any other non-hazardous pollutants not listed in that Annex considered by Member States to present an existing or potential risk of pollution, all measures necessary to limit inputs into groundwater so as to ensure that such inputs do not cause deterioration or significant and sustained upward trends in the concentrations of pollutants in groundwater.
Annex I defines the "Groundwater Quality Standards". Here limits for nitrates, classified as pollutants, are 50 mg/l. Where, for a given body of groundwater, it is considered that

the groundwater quality standards could result in failure to achieve the environmental objectives specified in Article 4 of Directive 2000/60/EC for associated bodies of surface water, or in any significant diminution of the ecological or chemical quality of such bodies, or in any significant damage to terrestrial ecosystems which depend directly on the body of groundwater, more stringent threshold values will be established in accordance with Article 3 and Annex II of this Directive. Programmes and measures required in relation to such a threshold value will also apply to activities falling within the scope of Directive 91/676/EEC.

4 Methodology

4.1 The logical framework of the thesis

The thesis involves two main issues: management plans of the Natura 2000 Network and the ecosystem service of water purification, with the aim to propose a contribute in the pathway of improvement of planning practices with reference to protected areas, particularly Natura 2000 sites. The reasoning is developed with regard to how spatial planning could integrate the management of sites protected by the EU legislation on ecological networks, pursuing policies of development and valorisation oriented towards sustainability, rather than through policies of exclusive conservation.
Planning anthropized areas involving Natura 2000 sites has to deal with plans related to sites management, with the aim of ensuring a better organization, integrating and enhancing socio-economic growth, and preserving the extraordinary heritage of biodiversity which characterizes natural contexts, in order to support a harmonious territorial and socio-economic development.

The issues of management plans and water purification are examined in the thesis firstly in separated part, and then together in the case studies.

The structure of the analyses for both management plans and water purification consists of this steps (as explained in Figure 2):

- general definitions;
- literature review;
- regulatory framework definition (with particular reference to European directives);
- analyses applied for two case studies.

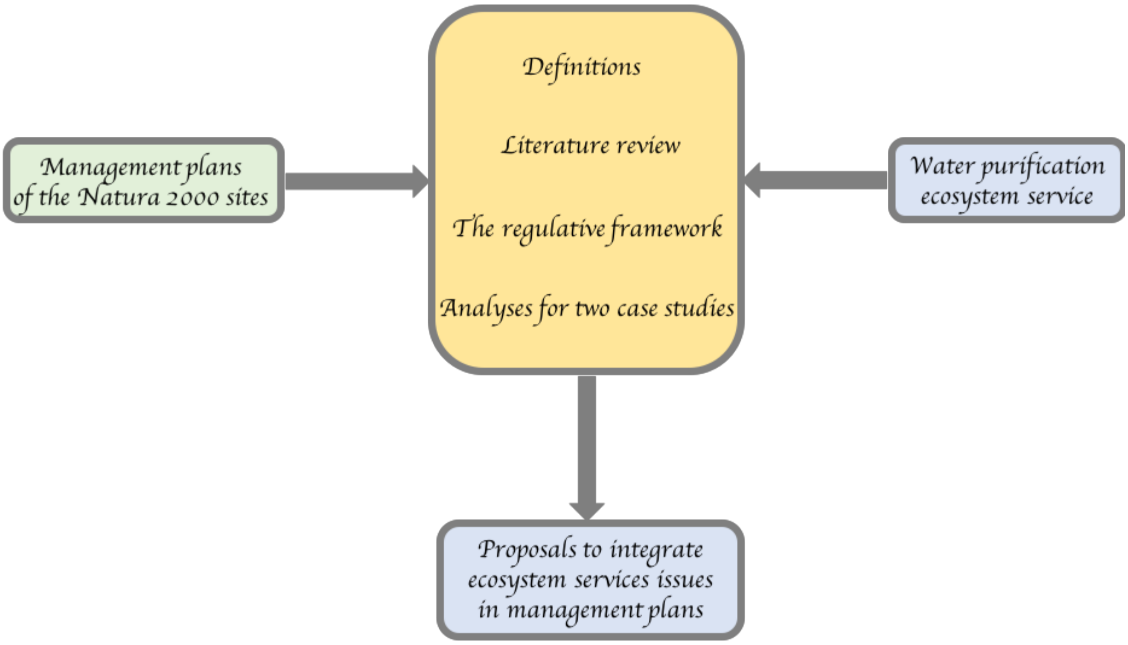

Figure 2 – The structure of the methodology applied in the thesis.

At the end of the analyses, some proposals aimed at integrating ecosystem services issues in management plans are formulated.

4.1.1 Management plans of the Natura 2000 Network

In accordance with provisions of Article 6 of the Habitats Directive, attention is increasingly focused on the issue of management, as the selection of sites for the Natura 2000 Network nears completion. The Natura 2000 Network cover almost a fifth of the EU territory, with over 26,000 sites.

The proposed management options must take into account the ecological requirements of the species and habitats, which vary significantly from one to another, and also economic, social and cultural requirements of the area concerned, as well as their regional and local characteristics.

The majority of Natura 2000 sites are likely to be in private ownership and used for other purposes than nature conservation; consequently, it is essential that stakeholders are actively involved in finding practical solutions for the long-term management sites.

The aim is not to stop economic activities altogether, but rather to set the parameters by which these can take place whilst maintaining (or restoring) the rare species and habitats present at a favourable conservation status. Indeed, many sites in Natura 2000 are valuable precisely because of the way they have been managed up to now and it will be important to ensure that these sorts of activities (e.g. extensive farming) can continue into the future. Thus, defining the ecological requirements of a species or habitat is only a part of the equation. Equally important is the process of working with stakeholders to find ways of implementing these provisions in order to achieve sustainable long-term results (Good practices in managing Natura 2000 sites, EU Environment[9]).

The management plan is an instrument of territorial governance with the function to define conservation measures necessary to guarantee the maintenance or restoration, in

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[9] Some examples of good practices in managing Natura 2000 sites are available at http://ec.europa.eu/environment/nature/natura2000/management/gp/index.html [last access: 15 January 2019].

a satisfactory state of conservation, for habitats and species under Habitat Directive. It recognizes the biotic and abiotic characteristics of the Natura 2000 sites and identifies the economic and production factors related to the system.

The management plan is therefore characterized primarily by objectives and actions for the protection of habitats and species, but also provides objectives and actions for the overall development of the territory. Furthermore, it allows to identify threats that could determine a reduction in the ecological value of the site (due to removal or fragmentation of habitat, interruption of ecological corridors, perturbations of species and habitats, …) and prepares actions for mitigation of the pressure factors (such as the anthropic load, the use of natural resources, the consumption of soil due to the urbanization process, …).

Under Habitats Directive, management plans are not compulsory, but each Member State decide if they are compulsory or not (see Table 1), and the structure for drawing up the plan.

At European level, on 2011, guidelines have been built in order to propose a framework for drawing up the management plan (Boivin *et al.*, 2011). The guidelines suggest a management structure as follow.

- Presentation report, which is made up of an ecological appraisal of the natural habitats and species of community interest and a socio-economic appraisal of human activities and their effects:
    - General information and physical characteristics: site context, site designation and management, administrative data and protection measures, abiotic data.
    - Mapping habitats and species: mapping natural and semi-natural habitats, mapping species and their habitats.
    - Ecological and functional analysis.
    - Prioritising conservation issues.
    - Socio-economic diagnosis: inventory of human activities, analysis of activities and their impacts.

- Definition of sustainable development objectives.
- Proposing measures:
  - Categories of measures.
  - Cost assessment and financing.
  - Schedule of measures.

The Presentation report represents the phase of detailed analyses of the context, as well as overall knowledge. This plays a role of identification of characteristics of the site, which need to be recognized in order to be protected. By evaluating and mapping ecosystem services provided by the Natura 2000 site should allow to improve the effectiveness of conservation measures for habitat and species and to progress towards the sustainability.

4.1.2 A model to assess the ecosystem service of water purification

These years, models to assess ecosystem services are being developed. They aim to help individuals and institutions to recognise the value of nature, in order to increase its conservation while, at the same time, fostering human well-being.

In this thesis, the case studies are analysed by using the InVEST software (Integrated Valuation of Ecosystem Services and Tradeoffs)[10] developed by Natural Capital Project (NCP)[11]. It is designed for use as part of an active and iterative pathway for integrating ecosystem services into the decision-making process.

The main peculiarity of this software is to foresee the possibility of a preliminary analysis of the input data, providing the possibility to analyse ecosystem services through models that allow to quantify and map the provision of services and to explore how the changes

[10] InVEST software is available at https://naturalcapitalproject.stanford.edu [last access: 15 January 2019].

[11] This project is founded by: Woods Institute for the Environment and Department of Biology of the Stanford University; Institute on the Environment of Minnesota University; Nature Conservancy; World Wildlife Fund (WWF).

ecosystem services affect the benefits of human health. Outputs describe ecosystem services in terms of their biophysical values and their spatial location.

4.1.2.1 The Nutrient Delivery Ratio model of InVEST

A model to investigate water purification is the Nutrient Delivery Ratio model (NDR)[12]. The NDR model refers to the retention of two nutrients: nitrogen and phosphorus and describes, through empirical relationships, the movement of nutrient masses through the space based on empirical relationships, mapping nutrient sources existing in reservoirs and transporting them to watercourses. It is based on the concept that each element of the watershed is characterized by its own nutrient load and by a transport coefficient which depends on the slope and the efficiency of soil cover retention.
Describing the movement of a mass of nutrient through space, the model uses a mass balance approach and represents the flow of nutrients through empirical relationships. Sources of nutrients across the landscape, called "nutrient loads", are determined based on a land use/land cover (LULC) map and associated loading rates. Then, nutrient loads can be divided into sediment-bound and dissolved parts, which will be transported through the flow, both in the surface and in the subsurface, stopping when they reach a stream. Delivery factors are computed for each pixel based on the properties of pixels belonging to the same flow path (in particular, retention efficiency of the land use and their slope). At the watershed/subwatershed outlet, the nutrient export is computed as the sum of the pixel-level contributions (NCP, 2015).

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[12] The NDR model is available at http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/ndr.html [last access: 15 January 2019].

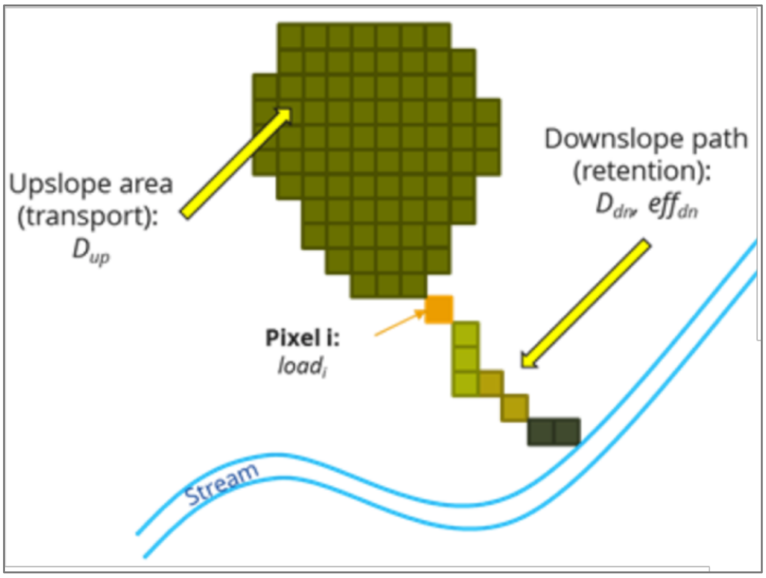

Figure 3 - Conceptual representation of the NDR model (NCP, 2015).

As described in Equation 1, each pixel *i* is characterized by its nutrient load ($load_i$), and its nutrient delivery ratio (NDR_i), which is a function of the upslope area (D_{up}), and the downslope flow path (in particular the retention efficiencies of LULC types (eff_{dn}) on the downslope flow path (D_{dn})); pixel-level export is computed based on these two factors.

$$Pixel\ export = load_i\ x\ NDR_i\ (D_{up}, D_{dn}, eff_{dn}) \qquad \text{Equation 1}$$

The surface NDR is the product of a delivery factor, representing the ability of downstream pixels to transport nutrient without retention, and a topographic index, representing the position on the landscape.

The nutrient export at the watershed level is the sum of pixel-level nutrient exports (Equation 2); for a specific area, the total amount of nutrient export is the sum of all watersheds contained in it.

$$Total\ export = \sum_{watershed} Pixel\ export \qquad \text{Equation 2}$$

4.1.2.1.1 Data needs

Data required by this model are a digital elevation model, a land use/land cover map, the nutrient runoff proxy, watersheds, and a biophysical table, as described as follows.

- Digital elevation model (DEM). A GIS raster dataset, with an elevation value for each cell. The DEM should be corrected by filling in sinks. To ensure a proper flow routing, the DEM should extend beyond the watersheds of interest, rather than being clipped to the watershed boundaries.
- Land use/land cover. A GIS raster dataset, with an integer LU/LC code for each pixel. The LULC code should be an integer.
- Nutrient runoff proxy. Consists in a GIS raster dataset representing the spatial variability in runoff potential, i.e. the capacity to transport nutrient downstream. This raster can be defined as a quick flow index or simply as annual precipitation. The raster is normalized by dividing by its average value, in order to compute the runoff potential index.
- Watershed. Consists of a shapefile of polygons. This is a layer of watersheds such that each watershed contributes to a point of interest where water quality will be analysed.

  A watershed (also called a river basin or catchment) is the entire land area draining water into a body of water (river, pond, lake, or sea). The size of a watershed is determined by the topographic relief of a region, and important factors in shaping a watershed are: land cover, geology, relief, latitude, chemistry, local biological communities, regional climate. Watersheds can include a wide variety of ecosystems and biomes and can cover multiple provinces, or countries, including both water (aquatic) and land (terrestrial) components. Watersheds, as study areas, give themselves readily to geographical delineation since boundaries are easily recognized, i.e. their boundaries can be mapped by delineating the ridges, and the delineation can be done for any body of water. Watershed are usually delineated using topographical maps to determine ridges or other high points (breakpoints) separating the different watersheds. Geographical information systems with spatial analysis software and digital elevation lines can be used to delineate watersheds quickly and accurately based on map features.

- Biophysical Table. A .csv table of land use/land cover (LULC) classes, containing data on water quality coefficients used in this tool. These data are attributes of each LULC class rather than attributes of individual cells in the raster map. Each row in the table is a LULC class while each column contains a different attribute of each land use/land cover class. The columns must be named as "lucode", "LULC_desc", "load_n", "eff_n", "crit_len_n", "proportion_subsurface_n". "lucode" is a unique integer for each land use class (i.e., urban, agriculture, forest, grassland, …), and must match the code of the land use raster. "load_n" represents the nutrient loading for each land use, given as decimal values with units of kg/ha/yr. "eff_n" is the maximum retention efficiency for each LULC class, varying between zero and 1. The nutrient retention capacity for given vegetation is expressed as a proportion of the amount of nutrient from upstream. High values (from 0.6 to 0.8) may be assigned to natural vegetation types (i.e., forests, natural pastures, wetlands, or prairie), indicating that 60-80% of nutrient is retained. "crit_len_n" is the distance (in meter) after which it is assumed that a patch of land use retains nutrient at its maximum capacity. If nutrients travel a distance smaller than the retention length, the retention efficiency will be less than the maximum value, following an exponential decay. "proportion_subsurface_n" is the proportion of dissolved nutrients over the total amount of nutrients, expressed as a ratio between 0 and 1. By default, this value should be set to 0, indicating that all nutrients are delivered via surface flow.

The model generates two main outputs: a shapefile and a tiff. The shapefile aggregates the nutrient model results per watershed, both for nitrogen and for phosphorus. The .dbf table contains nutrient loads information for each watershed. The tiff consists of a pixel level map showing how much load from each pixel eventually reaches the stream (measured in kg/pixel).

Some valuation approaches, as those relying on the changes in water quality for a treatment plant, are very sensitive to the model absolute predictions. Therefore, it is important to consider the uncertainties associated with the use of InVEST as a predictive tool and minimize their effect on the valuation step.

4.1.3 The case studies

In order to consider the most critical conditions from the planning point of view, two highly anthropized case studies have been selected. The choice of case studies is based on the following criteria:

- anthropized European contexts;
- coastal areas;
- contexts with a significant presence of inland Natura 2000 sites.

The choice of the Metropolitan City of Cagliari (Italy) and the Flemish Region (Belgium) as case studies is driven by an interest in the comparison of these two areas showing some dissimilarity, both in terms of physical condition of the territory and in terms of use of soil, which lead to different conditions for the Natura 2000 management and for the water purification process and its threats.

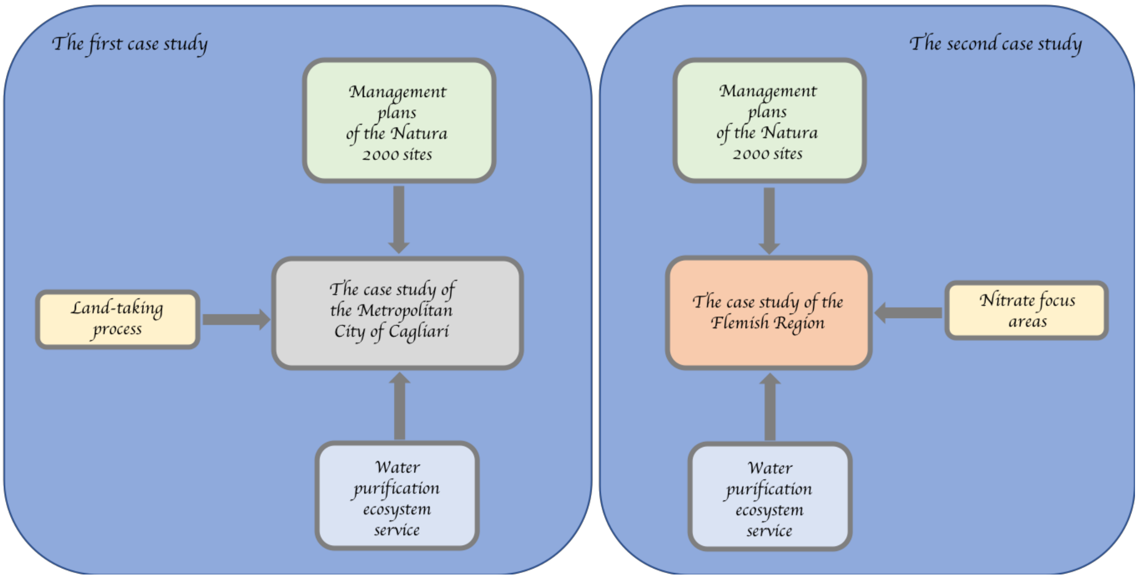

Figure 4 – The structure of the case studies analyses.

The Metropolitan City of Cagliari involves a territory with a plain in the middle position and mountains on the borders, and Natura 2000 sites are mainly threatened by the urban land-taking process. The Flemish Region is a plan for the highest part of the territory, with mountains in the southern part, and the Natura 2000 sites are threatened by agriculture (as crop production and livestock production).

These factors are an original stimulus for reflecting on the literature relating to the Natura 2000 Network and issues related to water purification.

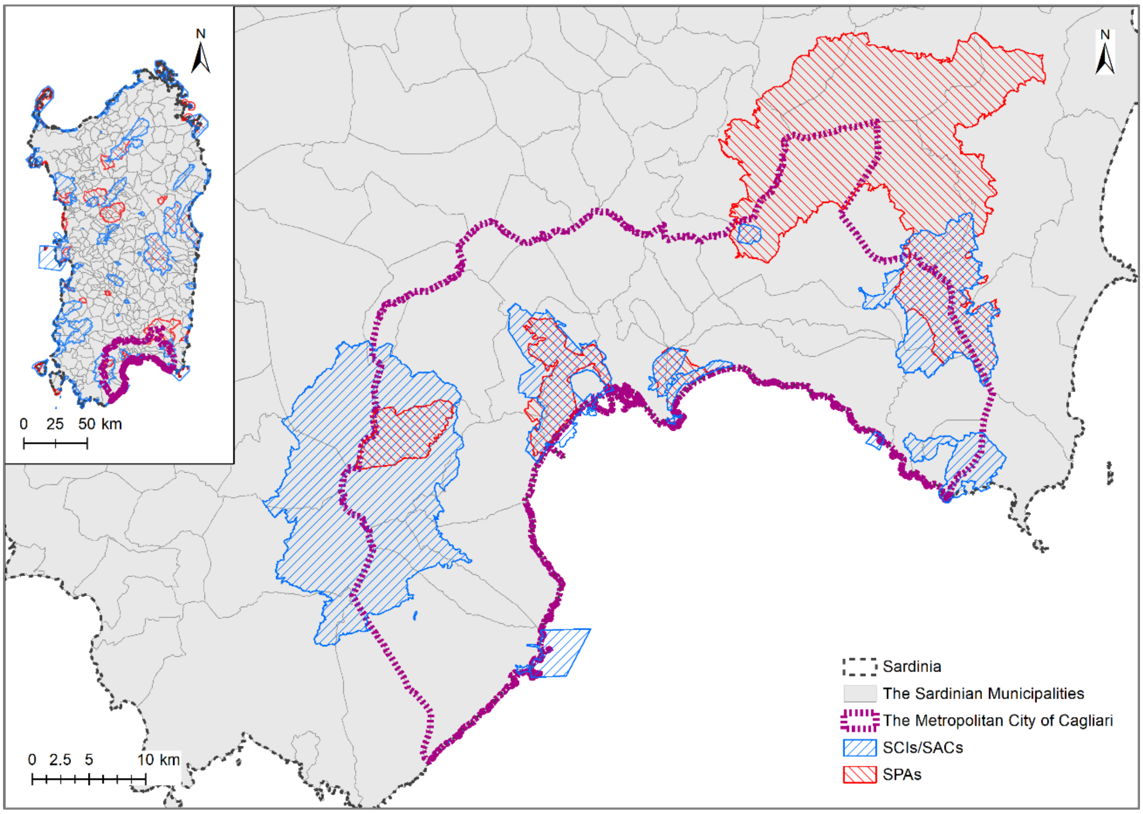

Figure 5 – The context of the Natura 2000 Network in the Italian case study. On the left, the Sardinia Region is shown; on the right, the context of the Metropolitan City of Cagliari is shown. With blue colour are SCIs/SACs; with red colour are SPAs. Elaborated from the European Environment Agency[13] *for the Natura 2000 Network and Istat sources for Regions and Municipalities*[14].

The Metropolitan City of Cagliari represents the highest anthropized area in Sardinia, with 30% of the regional population. It is located on the southern coast, in front of the gulf *Golfo degli Angeli*. The context involves several Natura 2000 sites, 16 terrestrial sites and 2 marine sites.

[13] The Natura 2000 datasets from the European Environment Agency are available at https://www.eea.europa.eu/data-and-maps/data/natura-9 [last access: 15 January 2019].

[14] The Istat database is available at https://www4.istat.it/it/archivio/209722 [last access: 15 January 2019].

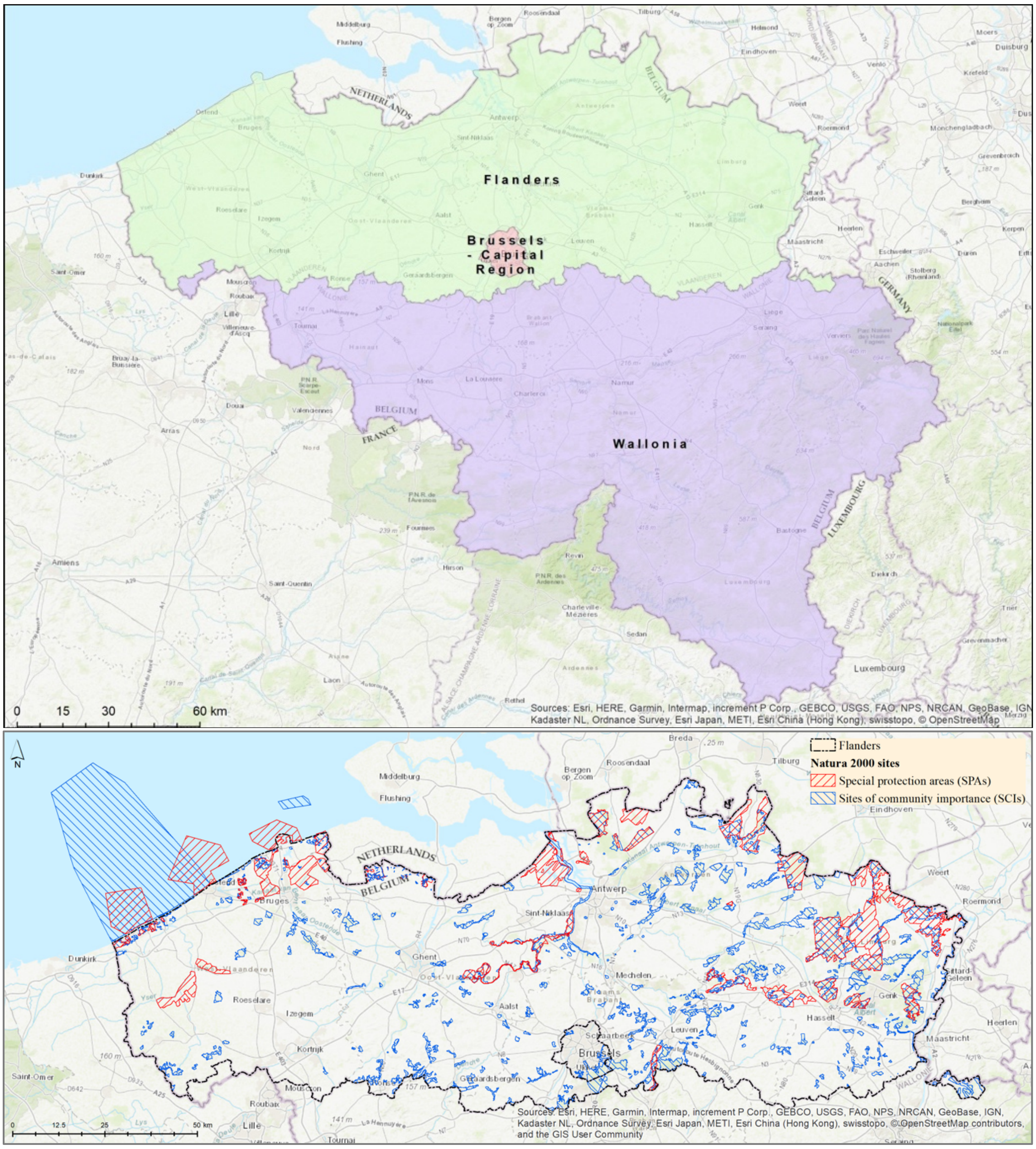

Figure 6 – The context of the Natura 2000 Network in the Belgian case study. Above, the Belgian country is shown; below, the Flemish Region is shown. With blue colour are SCIs/SACs; with red colour are SPAs.

The Flemish Region represents the highest anthropized area in Belgium, with 57% of the Belgian population. It is located in the northern part of the country, and in the western part shares its borders with the North Sea. The context involves several Natura 2000 sites, 62 terrestrial sites and 5 marine sites.

5 Case studies

5.1 The case study of the Metropolitan City of Cagliari

5.1.1 Spatial context and the Natura 2000 Network

The Metropolitan City of Cagliari, in the south of Sardinia, consists of 17 municipalities (as shown in Figure 7: Assemini, Cagliari, Capoterra, Decimomannu, Elmas, Maracalagonis, Monserrato, Pula, Quartu Sant'Elena, Quartucciu, Sarroch, Selargius, Sestu, Settimo San Pietro, Sinnai, Uta, Villa San Pietro) and a basin of about 430,000 inhabitants, mainly concentrated in the central part of the area around the Municipality of Cagliari and adjacent areas, constituting a large anthropized area. The metropolitan city surface is 1,248 km^2.

In the metropolitan context, there are some of the most important strategic transport poles for Sardinia's Island, such as ports (Marina, commercial and industrial port) and airports (the main, the secondary and the military airport), as shown in Figure 8.

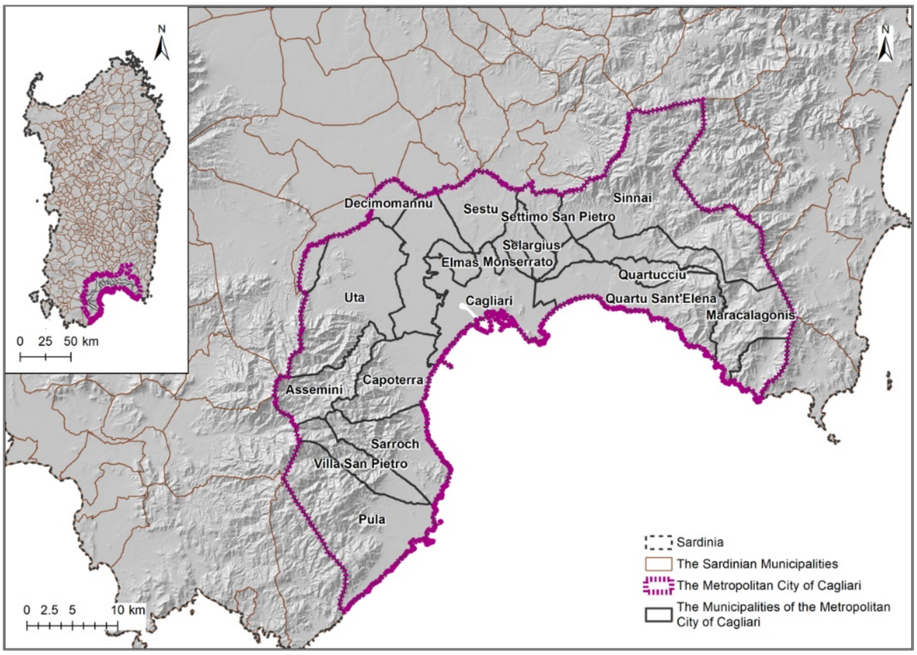

Figure 7 – The municipalities of the Metropolitan City of Cagliari.

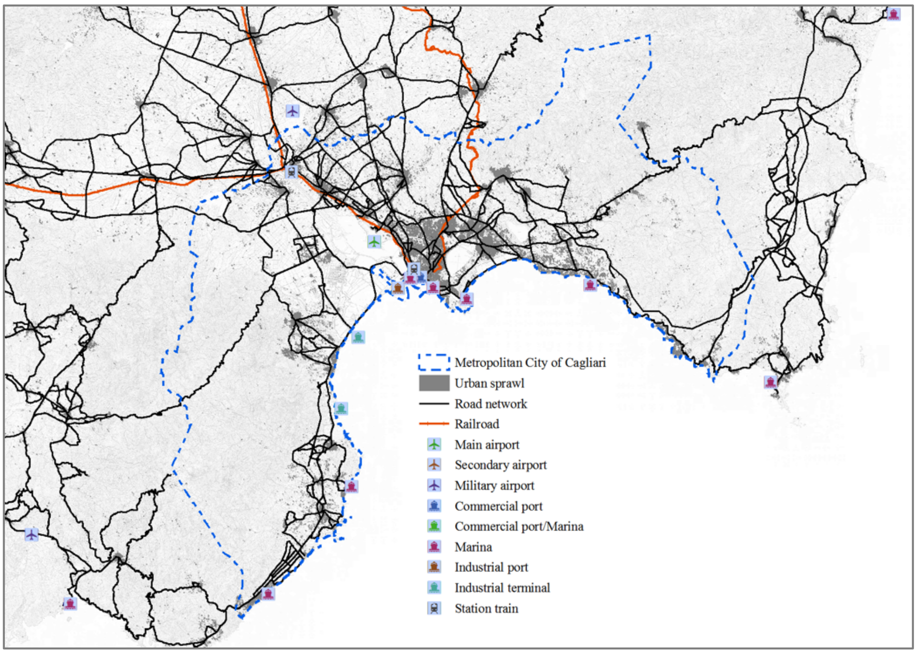

Figure 8 - Strategic points and connections in the Metropolitan City of Cagliari.

In Sardinia, the Natura 2000 Network consists in 89 SCIs (some of them are being defined as SACs), for 3642.67 km² inland and 1164.81 km² marine, and 37 SPAs, for 2433.21 km² inland and 526.05 km² marine. 6 SCIs coincide with the same number of SPAs.

The Metropolitan City of Cagliari involves 16 Natura 2000 sites (some only partially): 4 SCIs, 8 SACs and 4 SPAs (Figure 9). Some sites are partially outside the metropolitan boundaries. The metropolitan area interested by the Natura 2000 sites is 366 km², about 29% of the total.

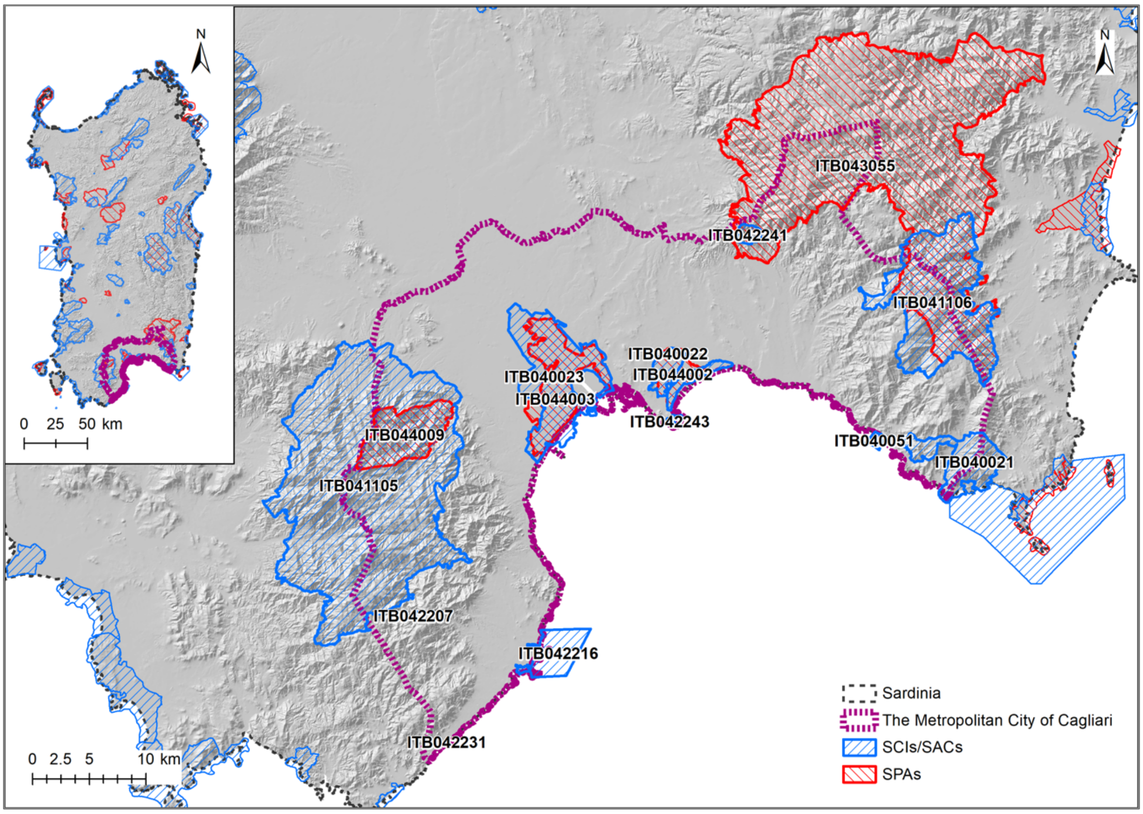

Figure 9 – The Natura 2000 sites in the metropolitan context of Cagliari (Italy). With blue colour are SCIs/SACs, with red colour are SPAs.

The land use (shown in Figure 10), based on Corine Land Cover (CLC), level 1, of the Autonomous Region of Sardinia[15], is classified in: 10.2% artificial surfaces; 31.9% agricultural areas; 52.3% forest and seminatural areas; 3.3% wetlands; 2.3% water bodies.

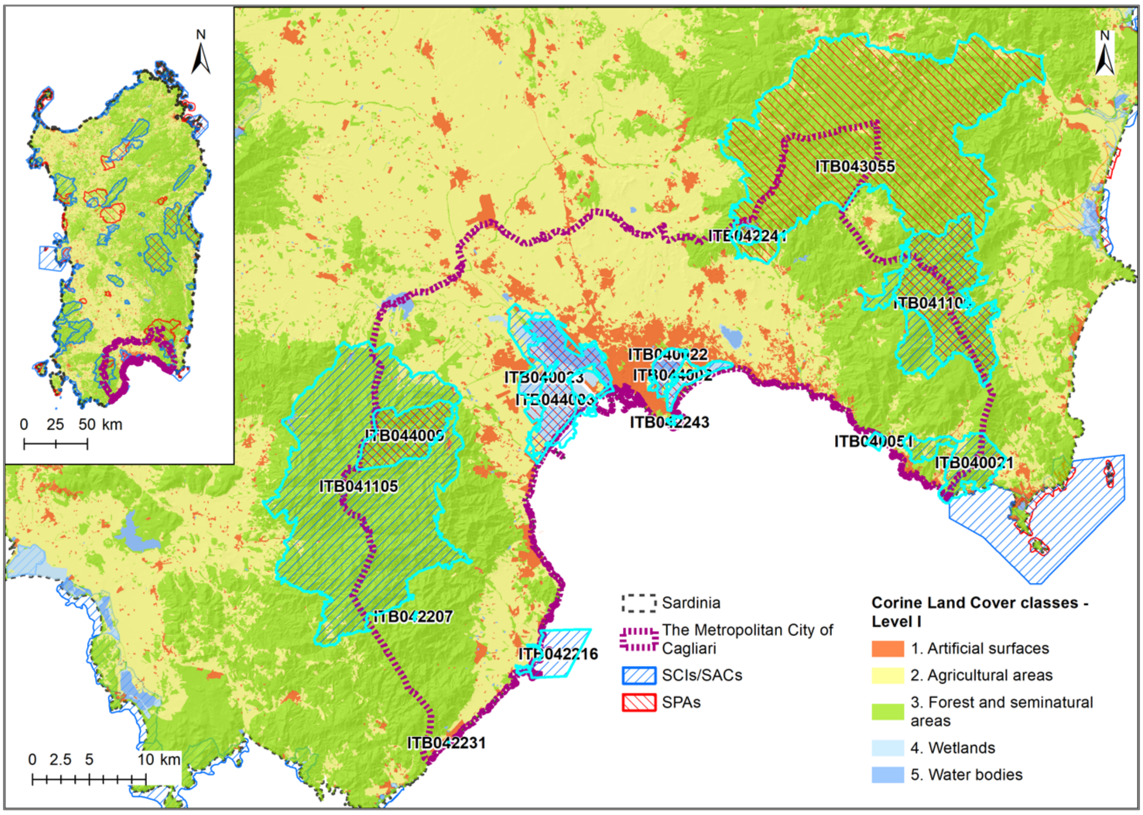

Figure 10 – Land-use in the Metropolitan city of Cagliari.

15 The land use of the Autonomous Region of Sardinia, for the year 2008, is available at http://webgis.regione.sardegna.it/scaricocartografiaETL/usoSuolo/usoSuolo2008/usoSuolo2008Areali.zip [last access: 15 January 2019].

Artificial areas, with wetlands and water bodies, are concentrated in the central part of the metropolitan area, surrounded by agricultural areas; forest and seminatural surfaces are mainly placed in two large opposed bands, one in the West part and one in the East part.
This configuration shows a clear mirror structure of the metropolitan area compared to the Municipality of Cagliari, which is located in a central position and represents the centrepiece attraction that over time has resulted to the urbanization process of the context.

5.1.2 Management plans in the metropolitan context

In Italy, Habitat Directive has been transposed with the Decree n. 357 of 8 September 1997, modified with the Decree n. 120 of 12 March 2003. The Ministry of the environment and protection of the territory and the sea committed to Regions and Autonomous Provinces the achievement and conservation of the Natura 2000 Network: conservation measures and achievable management plans of the sites, as well as measures to avoid habitat degradation and species disturbance, must be established and adopted by Regions and Autonomous Provinces. At national level, the Region is recognised as the authority that identifies and regulates the Natura 2000 Network, for its area of competence (as shown in Table 1). In some regions (e.g., Abruzzo Region) management plans are required for sites outside protected natural areas, for which there is already a management plan. If these are not considered appropriate, integrations and/or changes will be made in those plans. Regional authorities decide which Natura 2000 sites need a management plan. Sites are selected by managing authorities according to national guidelines. The management plan is relevant for sites that need effective conservation of natural resources that is not guaranteed just by conservation measures. This involves sites where conservation measures are complex and need to be defined with particular detail, and which require specific monitoring activities that cannot be included in instruments other than a management plan. In Sicily, it was decided to group 218 Natura 2000 sites (SCIs and SPAs) together in 58 management plans, according to territorial proximity and ecological similarity (EC, 2011). On 2002, a Decree[16] defined national guidelines for management of the Natura 2000 sites as an instrument for implementing Habitat Directive.

In Sardinia, with the Regional Law n. 23 of 29 July 1998[17], Regional administration transposed Habitats and Birds Directives, and, on 2012, drew up the last version of own guidelines to prepare management plans for the Natura 2000 sites.

By considering the regional guidelines for the management plans of the Natura 2000 sites, management plans should have the following structure:

- a general study, comprehending:
    - a regulatory framework;
    - a description of general characteristics of the site, like dimension, geographic information, altitude, municipalities involved, …;
    - an abiotic characterisation, as relating to physical and climatic aspects, i.e. temperature, precipitation, geology, geomorphology, hydrology and hydrogeomorphology;
    - a biotic characterisation, containing a description of habitats and species of Community interest, with reference to the Standard Dataform of the Natura 2000 sites[18];

[16] The Decree 2 September 2002 of the Ministry of the Environment and Protection of the Territory and the Sea, available at http://www.minambiente.it/sites/default/files/dm_07_02_2013.pdf [last access: 15 January 2019].

[17] The Sardinian Regional Law n. 23 of 29 July 1998 is available at http://www.regione.sardegna.it/j/v/86?v=9&c=72&s=1&file=1998023 [last access: 15 January 2019].

[18] Standard dataforms are available on the Ministry of the environment and protection of the territory and the sea website, at ftp://ftp.scn.minambiente.it/Cartografie/Natura2000/schede_e_mappe/Sardegna/ [last access: 15 January 2019].

  - an agri-forest characterisation, with reference to habitats distribution, containing the identification of pressure factors[19] and the assessment of the functional role of the agro-forestry component, with reference to the conservation status and the ecological needs of habitats and species;
  - a socio-economic characterisation, regarding all economic activities, with a focus on the demography of population, tourists, companies, …;
  - an urban and programmatic characterisation, containing the urbanistic and administrative framework of the context, analyses on municipal plan forecasts with reference to habitats, the identification of pressure factors and the assessment of the functional role of the socio-economic component, with reference to the conservation status and the ecological needs of habitats and species;
  - a landscaping characterisation, containing a list of all elements indicated in Article 6, Paragraphs 2, 3, 4, and 5, of the Technical Rules of the Regional Landscape Plan of Sardinia[20], with a synthesis of prescriptions for these elements, in order to allow a clear identification of objectives and actions for the management plan;
- a management framework, comprehending:
  - a synthesis of any impact for habitat and species identified in the general study;
  - objectives and strategies identified for the management organised as general objective (the main objective), specific objectives and expected results;
  - action data sheets;

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[19] As phenomena having a natural or anthropic origin that determine impact effects as repercussions with reference to the presence and conservation status of habitats and/or species that characterize the site.

[20] The Technical Rules of the Regional Landscape Plan of Sardinia are available at http://www.sardegnaterritorio.it/j/v/1123?s=6&v=9&c=7263&na=1&n=10 [last access: 15 January 2019].

- a monitoring plan;
- management organisation.

The management framework represents the active kernel of the management plan. The general objective represents the management plan "mission" for the site. Specific objectives express the future condition that the plan intends to pursue in terms of improving or maintaining the conservation status of habitats and species, also taking into account socio-economic and territorial aspects. Expected results express outcomes to be achieved in terms of elimination and/or reduction of pressure factors and/or impact effects on habitats and species.

Type	**Natura 2000 sites**		**Municipalities involved in the site**	**Management plans**
SCIs/SACs	ITB040021	Costa di Cagliari	Maracalagonis, Sinnai	yes
	ITB040022	Stagno di Molentargius e territori limitrofi	Cagliari, Quartu Sant'Elena, Quartucciu	yes
	ITB040023	Stagno di Cagliari, Saline di Macchiareddu, Laguna di Santa Gilla	Assemini, Cagliari, Capoterra, Elmas	yes
	ITB040051	Bruncu de Su Monte Moru - Geremeas (Mari Pintau)	Quartu Sant'Elena	yes
	ITB041105	Foresta di Monte Arcosu	Assemini, Capoterra, Decimomannu, Pula, Sarroch, Villa San Pietro	yes
	ITB041106	Monte dei Sette Fratelli e Sarrabus	Maracalagonis, Quartu Sant'Elena, Sinnai	yes

Type	Natura 2000 sites		Municipalities involved in the site	Management plans
	ITB042207	Canale su Longuvresu	Pula	yes
	ITB042216	Capo di Pula	Pula	yes
	ITB042231	Tra Forte Village e Perla Marina	Pula	yes
	ITB042241	Riu S. Barzolu	Sinnai	yes
	ITB042242	Torre del Poetto	Cagliari	yes
	ITB042243	Monte Sant'Elia, Cala Mosca e Cala Fighera	Cagliari	yes
SPAs	ITB043055	Monte dei Sette Fratelli	Burcei, Castiadas, Dolianova, Maracalagonis, San Nicolò Gerrei, San Vito, Sinnai, Villasalto	approving phase
	ITB044002	Saline di Molentargius	Cagliari, Quartu Sant'Elena, Quartucciu	no
	ITB044003	Stagno di Cagliari	Assemini, Cagliari, Capoterra, Elmas	no
	ITB044009	Foresta di Monte Arcosu	Assemini, Siliqua, Uta	approving phase

Table 2 – Natura 2000 sites and management plans in the Metropolitan city of Cagliari.

A strategic priority defined into regional strategic conservation priorities for Natura 2000 Network for the period 2014-2020, among the general conservation strategies valid for all species and habitats of the Network, is the following: completing and supporting the Natura 2000 Network management, also through the implementation of multilevel governance forms, the updating of plans, the preparation of regulatory measures and the implementation of active conservation initiatives (RAS, 2012).

The punctual management of a site can be implemented at the municipal level (if the site is completely included into a single municipality) or inter-municipal level (if the site is included within more municipalities), but the strategic vision of the network should be at the provincial and metropolitan level.
The Natura 2000 sites belonging to the metropolitan area (listed in Table 2), in some cases affect only one municipality, more municipality in others. Moreover, sometimes SCIs/SACs and SPAs are overlapped partially or totally.
Most sites have a specific management plan[21], except sites ITB042242 and ITB042243 (belonging only to the Municipality of Cagliari) and ITB042207, ITB042216 and ITB042231 (belonging only to the Municipality of Pula); ITB044002 and ITB044003 do not have a management plan yet, while ITB043055 and ITB044009 have a management plan in the approving phase.

5.1.3 Evaluation of water purification as a nutrient delivery process through InVEST

The methodology implemented to evaluate the ecosystem service of water purification is based on the use of the Nutrient Delivery Ratio (NDR) model of the InVEST software (see Par. 4.1.2.1). The NDR model refers to the retention of two nutrients: nitrogen and phosphorus, but in this case study only nitrogen is taken into account. Moreover, this

[21] Management plans of the Natura 2000 sites of Sardinia Region are available at http://www.regione.sardegna.it/index.php?xsl=611&s=18&v=9&c=14136&es=4272&na=1&n=10 [last access: 15 January 2019] for SCIs/SACs, and are available at http://www.sardegnaambiente.it/index.php?xsl=611&s=18&v=9&c=14137&es=4272&na=1&n=10 [last access: 15 January 2019] for SPAs.

model allows to investigate both surface waters and groundwaters; however, groundwaters involve uncertain data, and here only surface waters are considered.

5.1.3.1 Materials

The input data required by the NDR model and used in this methodology are the following: a digital model of the terrain; a map of land use; a shapefile containing the surface water basins; a map representing the potential outflow; a biophysical table.

5.1.3.1.1 The Digital Elevation Model

The model represents the distribution of the units of the territory in digital format, with an elevation value for each cell. The digital model is available on the Geoportal of Sardinia[22], in raster format and with a 10 m resolution.

5.1.3.1.2 Land-use map

The Land-use map of Sardinia[23], updated in 2008, constitutes a geographic database of Sardinia's land coverings, classified with the CLC codes up to the fifth level. In this analysis, the CLC classification is used up to the third level.

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[22] *Sardegna Geoportale* is available at http://www.sardegnageoportale.it/areetematiche/modellidigitalidielevazione/ [last access: 15 January 2019].

[23] The Land-use map of Sardinia is available at http://www.sardegnageoportale.it/index.php?xsl=2420&s=40&v=9&c=14480&es=6603&na=1&n=100&esp=1&tb=14401 [last access: 15 January 2019].

5.1.3.1.3 Watershed

This case study takes into account watersheds as elaborated into the Management plan of the hydrographic district of Sardinia (RAS, 2016), with a shapefile containing 64 surface water basins.

5.1.3.1.4 Potential runoff

The information layer consists of a map representing the potential outflow. Rainfall measurements to 109 rain station gauges, referred to three years data, are considered, defining a mean value for each of them. In this way, the potential runoff data is obtained. Successively, through a geostatistical elaboration with kriging model (Phillips *et al.*, 1992) the raster of the interpolations of potential outflows is obtained.

5.1.3.1.5 Biophysical table

This table correlates soil coverings with nitrogen loads, nitrogen removal efficiency and a maximum retention distance for each land cover class, developed for the context of the Metropolitan City of Cagliari, starting from Bachmann Vargas (2013) studies and NCP (2015) specific for the Nutrient Delivery model (see Par. 4.1.2.1).

lucode	**load_n**	**eff_n**	**crit_len_n**	**proportion_subsurface_n**
111	6	0.05	10	0
112	6	0.05	10	0
121	6	0.05	10	0
122	6	0.05	10	0
123	6	0.05	10	0
124	6	0.05	10	0
131	6	0.05	10	0
132	6	0.05	10	0

lucode	load_n	eff_n	crit_len_n	proportion_subsurface_n
133	6	0.05	10	0
141	6	0.05	10	0
142	6	0.05	10	0
143	6	0.05	10	0
211	5	0.2	25	0
212	5	0.2	25	0
221	5	0.2	25	0
222	5	0.2	25	0
223	5	0.2	25	0
224	5	0.2	25	0
231	5	0.2	25	0
241	5	0.2	25	0
242	5	0.2	25	0
243	5	0.2	25	0
244	5	0.2	25	0
311	1.8	0.9	300	0
312	2	0.5	300	0
313	1.8	0.8	300	0
321	5	0.4	150	0
322	1.5	0.7	150	0
323	1.5	0.7	300	0
324	1.8	0.8	150	0
331	0	0	10	0
332	0	0	10	0
333	0.8	0.6	10	0
411	0.8	0.6	10	0
421	0.8	0.6	10	0
422	0.8	0.6	10	0
423	0.8	0.6	10	0
511	1	0	10	0
512	1	0	10	0
521	1	0	10	0

lucode	load_n	eff_n	crit_len_n	proportion_subsurface_n
523	1	0	10	0

Table 3 – The Biophysical Table elaborated for the Metropolitan City of Cagliari. Each row in the table is a land use class, each column contains a different attribute of each land use class.

5.1.3.2 Results

The NDR model generates a map in which each pixel contains information on the quantity of nutrient that eventually reaches the streams, measured in kg/pixel/year, and a shapefile where the total nutrient value is aggregated per basin as a sum of the contribution of each pixel belonging to it. An important factor for the purification degree (% of removal) is the residence time of the supplied nitrate in the water-saturated zone.

In this particular case, only nitrogen loads and surface water basins are analysed. The map shown in Figure 11 represents the potential contributions of soil and vegetation to water purification through the removal of pollutants (in this case, nitrogen) from the surface runoff (so, only surface waters, not groundwaters).

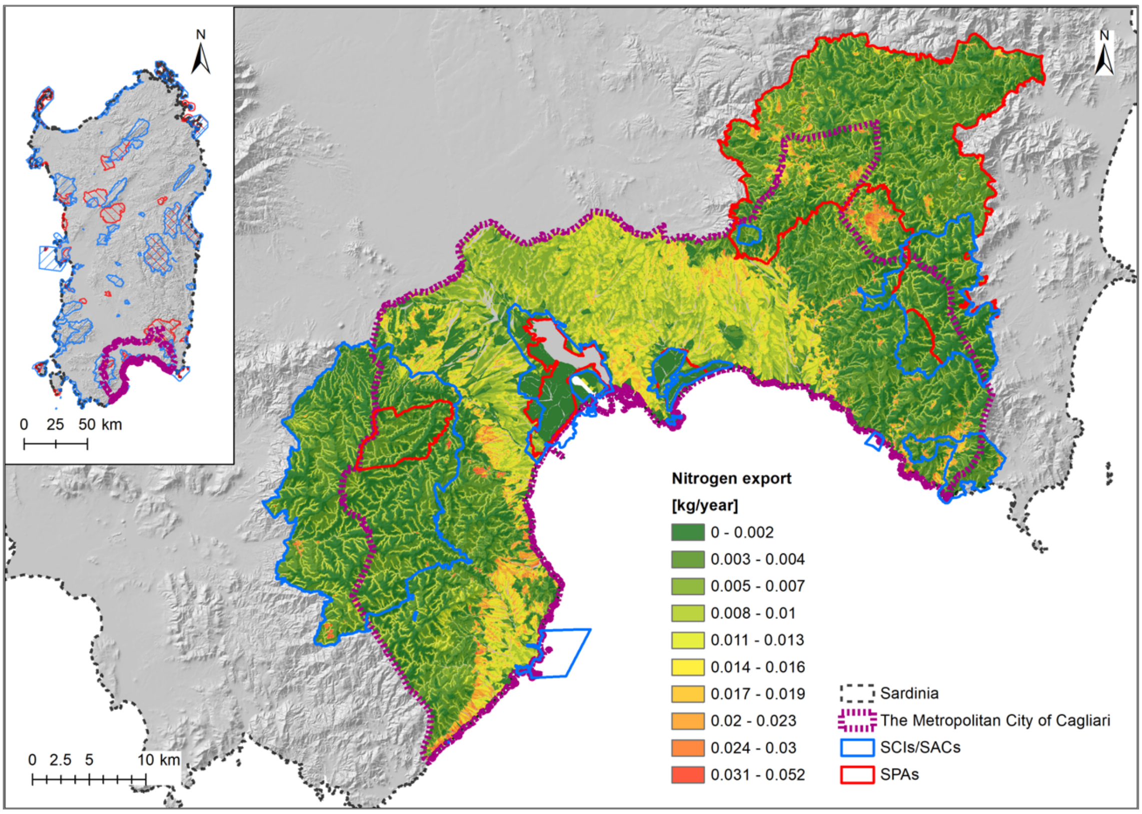

Figure 11 – Nutrient export map elaborated with NDR model of InVEST, for the context of the Metropolitan City of Cagliari. With green colours, low export and high retention; with red colours, high export and low retention.

In particular, the map shows the susceptibility of specific parts of the territory in purifying water: high nitrogen export values represent low water purification (the minimum corresponds to red colour), as large quantities of pollutants can reach the stream; low export values represent high water purification (the maximum corresponds to dark green colour), as the pollutant is caught.

The output is particularly sensitive to changes in input data. Indeed, retention efficiency values are based on empirical studies and factors based on mean values (such as intra-annual variability) and the biophysical table contains values of nitrogen loads derived from other studies and not directly measured in the context in exam.

Results summarised in Table 4 show the importance of the Natura 2000 sites in providing water purification, as nitrogen retention. For each Nitrogen export class, the corresponding percentage value of total metropolitan context and the corresponding percentage value of Natura 2000 sites are summarized.

Nitrogen export [kg/pixel/yr]	**% in the wide metropolitan context**	**% only in the Natura 2000 sites**
0.031 – 0.052	0.22	0.07
0.024 – 0.030	0.74	0.18
0.020 – 0.023	1.41	0.35
0.017 – 0.019	2.48	0.43
0.014 – 0.016	4.49	0.55
0.011 – 0.013	8.19	1.34
0.008 – 0.010	10.97	2.89
0.005 – 0.007	13.12	6.09
0.003 – 0.004	28.16	17.46
0 – 0.002	26.35	16.54

Table 4 – Nitrogen export in the metropolitan context of Cagliari and only in the Natura 2000 sites.

5.1.4 The land-taking process

In the metropolitan context of Cagliari, the dynamics of anthropized surfaces between 1990 and 2008 are analysed, focusing on the phenomenon of surfaces belonging to Natura 2000 sites. Artificial surfaces are analysed by using datasets provided by the European Environmental Agency (EEA) and the Autonomous Region of Sardinia (RAS) and classified according to the CLC classification. They are quantitatively compared in different periods, both for the whole metropolitan area and inside of the Natura 2000 sites. The analytical methodology applied in this context, based on the use of geoprocesses in GIS environment, allows detecting situations of looming threat due to the land-taking process carried out in the last twenty years.

Diachronic analyses allow identifying the Natura 2000 sites most affected by the phenomenon of land-taking, towards which planning processes should pay more attention.

The Metropolitan City of Cagliari offers one of the most significant environmental contexts among other Italian cities, where complex interaction phenomena between human activities and natural environment have taken place during years (Tanda, 2014).

The establishment of protected natural areas and urban growth are processes whose dynamics tend to be in contraposition and the continuous expansion of urban sprawl tends to continually threaten the presence of protected sites (Hernández and Torres, 2015).

5.1.4.1 Materials

In order to identify the sites most exposed to threats of anthropogenic expansion, three maps, relating to years 1990, 2003 and 2008, based on the CLC classification, from different data sources are considered. For 1990, a dataset from the EEA[24] is used; for 2003 and 2008, datasets from the RAS[25] are used.

[24] European Environmental Agency datasets are available at https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-corine [last access: 15 January 2019].

[25] Autonomous Region of Sardinia datasets are available at http://www.sardegnageoportale.it/index.php?xsl=2420&s=40&v=9&c=14480&es=6603&na=1&n=100&esp=1&tb=14401 [last access: 15 January 2019].

The 1990 dataset is available in raster format at 1:100,000 scale; therefore, it was necessary to perform a vector conversion in order to allow to perform overlay geoprocesses of polygonal elements.

The RAS provides, by downloading from the geoportal for the years 2003 and 2008, the maps relating to land use, hierarchically organized according to the CLC classification, detailed up to the third level, in some cases to the fourth and fifth level. The maps are at 1:25.000 scale, the minimum cartographed unit has a surface area of 1 hectare inside the urban area and 1.5 hectares in the suburban area, for 2003, while it is equal to 0.5 hectares inside the urban area and 0.75 hectares in the suburban area, for 2008.

The analyses are based on the polygons belonging to the CLC class “1 – Artificial surfaces”, at the second level:

1.1 – urban fabric;

1.2 – industrial, commercial and transport units;

1.3 – mine, dump and construction sites;

1.4 – artificial non-agricultural vegetated areas.

5.1.4.2 Analyses on artificial surfaces

Firstly, inconsistencies due to the different scales of the datasets used for the analyses are corrected. The artificial surfaces of 1990 (from the EEA dataset at the scale of 1:100,000) are resized, through geoprocesses, compared to those of 2008 (from the RAS dataset at the scale 1:25,000). Consequently, the analysis is affected by an error which, however, do not avoid the identification of the Natura 2000 sites most affected by the phenomenon of the artificial surfaces’ expansion.

Now, the maps of 1990, 2003 and 2008 are comparable; subsequently, the analyses are concentrated with reference to the percentage of artificial surfaces inside the sites.

By comparing the data obtained from the analyses on the CLC maps, it is evident that, between 1990 and 2008, artificial surfaces have been expanded throughout the metropolitan area.

Table 5 and related graph summarize data resulting from the analyses carried out for the periods considered for the metropolitan context: the overall area interested by the land-taking process ranges from 79 km^2, in 1990, to 127 km^2, in 2008, increasing for 61%; the variation between 1990 and 2003 is 42%, while the variation between 2003 and 2008 is 13%.

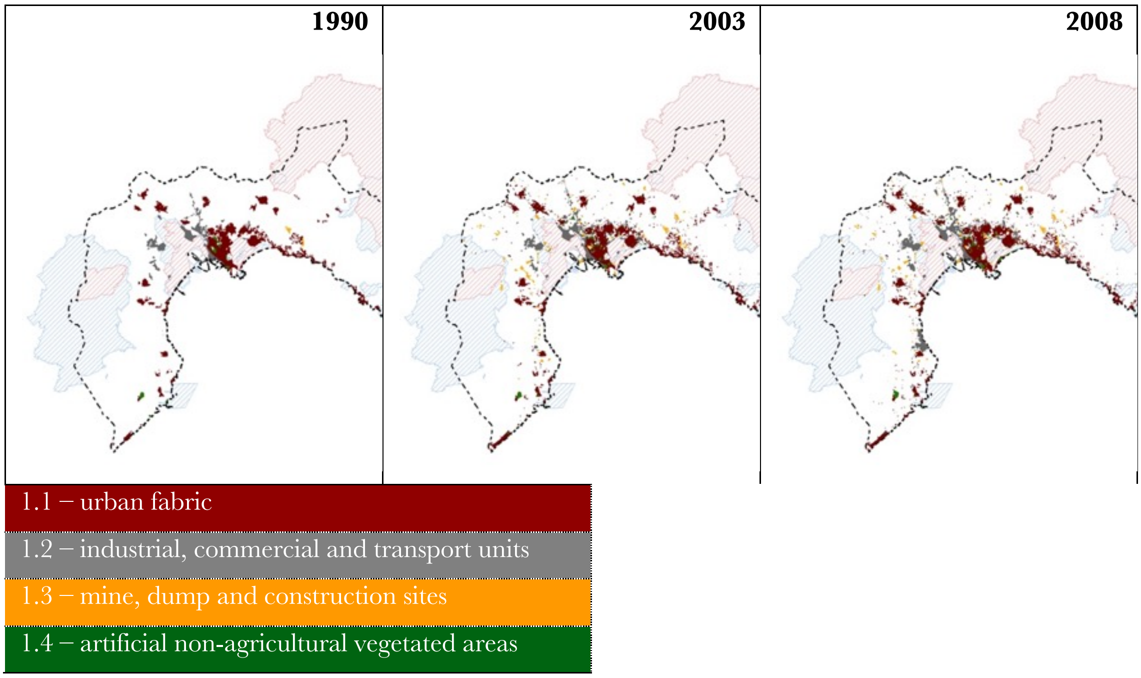

Figure 12 – The variation of artificial surfaces in the metropolitan context of Cagliari, for 1990, 2003 and 2008. Below, the four classes of the "Artificial surfaces" level.

CLC Class	1990 surface [km²]	2003 surface [km²]	2003 variation from 1990 [%]	2008 surface [km²]	2008 variation from 1990 [%]	2008 variation from 2003 [%]
1.1	57,66	69,12	19,88	74,95	29,99	8,43
1.2	17,68	26,91	52,21	34,87	97,23	29,58
1.3	0,98	11,03	1025,51	10,51	972,45	-4,71
1.4	2,84	5,71	101,06	6,93	144,01	21,37
Total	79,17	112,77	42,44	127,26	60,74	12,85

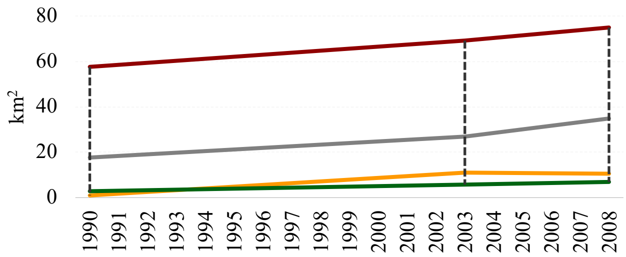

Table 5 and related graph – Artificial surfaces, grouped on 4 classes at the first CLC level in the metropolitan context of Cagliari, in 1990, 2003 and 2008.

Results are observable in graphs in Figure 13, where, from left to right, the magnitude of the phenomenon is described during the years analysed, in the whole metropolitan context and inside the Natura 2000 sites.

The analyses carried out concern the area affected by artificialization in the metropolitan city and in the Natura 2000 sites, during the 1990, 2003 and 2008. The area covered by artificial surfaces inside the sites ranges from 4.58 km², in 1990, and 8.04 km², in 2003, with an increase of 76%; while it reaches 8.27 km², in 2008, increasing, in the five-year period (between 2003 and 2008), under 3%.

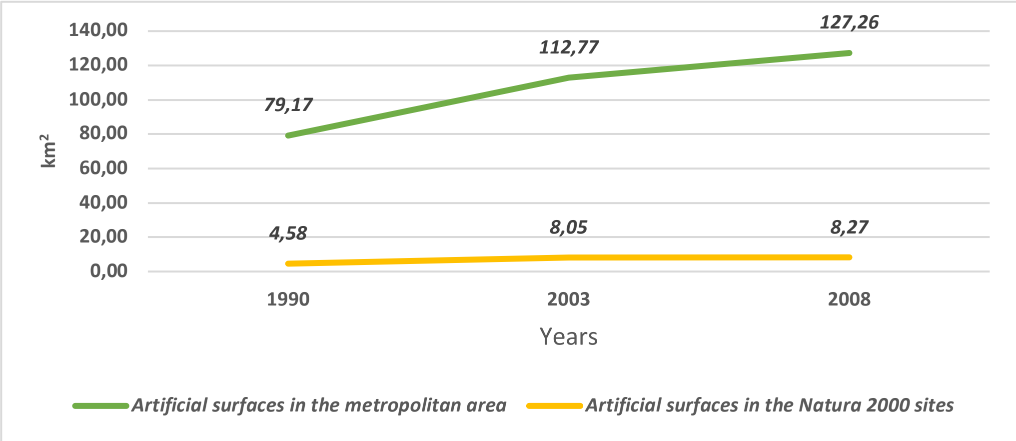

Figure 13 – Artificial surfaces in the metropolitan context, on the left; artificial surfaces in Natura 2000 sites, on the right.

5.1.5 Results concerning the Metropolitan City of Cagliari

Urbanization results in the sealing of land surfaces, mainly in presence of streets, parking lots, sidewalks, and rooftops. This increases stormwater runoff and reduces groundwater recharge. Impermeable surfaces, such as streets, allow stormwater runoff to increase speed, reducing potential groundwater infiltration. This often negatively affects groundwater levels and, in general, water availability of streams, and can prevent groundwater recharge and replenishment of wetlands and ponds, directing surface water (often polluted with urban waste) more rapidly to rivers, lakes and the sea (Pennington and Cech, 2010).
In the case study of the Metropolitan City of Cagliari, the presence of 16 sites of the Natura 2000 Network, some of which border the more urbanized area, represents a source of great interest in order to assess interactions existing between the anthropized and protected areas.
With reference to the management of the Natura 2000 sites, some critical aspects can be highlighted. In some cases, the high level of intersection and overlap of functions of

various programmatic tools and planners at different institutional levels, with the outcome of potential conflicts between dissimilar management strategies of the area, and, consequently, ineffectiveness regard to the objectives of the European directives. There is an objective difficulty of management also caused by the presence of a plurality of skills distributed over several agencies (both public and private), which sometimes pursue divergent strategies, with a consequent lack on coordinating the management; sometimes, besides, there are pressure factors linked to an obsolete and uncoordinated urban planning among neighbouring municipalities.

Some proactive aspects focus on multidisciplinary planning activities with respect to a plurality of actors with different orders of competence and scale. In fact, in several plans, the active involvement of public and private stakeholders, with wide expertise, is needed in order to create a synergy to guarantee a real restoration and integrated management of the environmental and socio-economic processes of the sites, through the definition of clear objectives, strategies and shared choices.

Since a large part of the territory belonging to the Natura 2000 Network covers private areas, the issue of public participation is surely relevant, since the early stages of the planning process.

With reference to the assessment of the ecosystem service of water purification, the metropolitan context of Cagliari is analysed by using the NDR model of InVEST. The resulting nutrient retention capacity shows areas that have both high and low retention values, in potential terms. Potential benefits and threats for nutrient retention are shown in the nutrient export map (Figure 11) in order to identify areas with high nutrient retention capacity, with particular reference to the presence of the Natura 2000 sites. In particular, the map and Table 4 indicate the role of the sites of the Natura 2000 Network, and their importance clearly emerges: especially in the eastern and western parts, as well as in the central wetlands and water bodies, the highest percentage of green values (which potentially have the highest value in supplying water purification) is contained inside the sites, or in the surrounded areas. On the contrary, outside the sites there is the highest percentage of red values (which potentially have the lowest value in supplying water purification), due to the high presence of urban and agricultural areas, intended as land use with low nutrient retention capacity and high level of nutrient loads (as defined in the Biophysical table in Table 3, for "lucode" from 111 to 244).

This confirms the fact that protected areas are a unique source of biodiversity and involve areas characterized by a high level of provision of ecosystem services (ISPRA, 2011).

In 1992, during the Rio Conference, the need for water was also recognized as quantifiable in economic terms (Pennington and Cech, 2010). The evaluation of the ecosystem service of water purification is a complex goal, as the numerous input data are hardly measured directly in the field and the model used makes several simplifications.

Moreover, to assemble the necessary data available in the time frame in which the decision-making process has to be taken is not always possible. For environmental planning, predicting nitrogen retention in surface flow is a complex task, as only a few process studies are available. In fact, models of nitrogen retention quantification are either rather complex and require a high number of input data, that often are not available during the planning period, or models simplify the involved processes to the availability of data (Trepel and Palmieri, 2002). Consequently, sometimes to make simplifications and approximations with reference to the available data is necessary.

With reference to the land-taking process, the analyses carried out for the metropolitan context of Cagliari show that, in the recent years, the artificial surface has considerably grown following a model of dispersion that leads to the widespread soil sealing. This event involves the alteration of ecological balance and the integrity of natural habitats (Balestrieri and Pusceddu, 2015).

Results elaborated in Figure 12, Figure 13 and Table 5 show a growing invariable trend for the land-taking phenomenon between 1990, 2003 and 2008 for the wide metropolitan context; on the contrary, the analysis inside the Natura 2000 sites shows a growing trend between 1990 and 2003, and a strong slowdown between 2003 and 2008. On the other hand, within the areas protected by Natura 2000, the phenomenon has been limited and the establishment of the sites has certainly contributed obtaining this result.

In fact, conservation policies in protected areas should prevent, or limit, the land-taking process (Zoppi and Lai, 2015). Evidently, in this case study, the establishment of Natura 2000 sites contributed to the contraction of the land-taking phenomenon inside the sites.

The establishment of Natura 2000 sites does not delete the possibility to carry on human activities but is an incentive towards their better sustainability with respect of habitats and species that still survive in the natural state, near a highly anthropized context.

In this context, the role of planning is fundamental, in order to identify threatening situations and consequently direct local policies.

Although the high importance of the Natura 2000 Network in providing ecosystem services and the threat of the land-taking process, current planning processes seem not to take into account these important phenomena. No management plan analysed in this case study deal with water purification (and, in general, with any ecosystem service), and this is a notable lack.

During planning processes, an adequate knowledge of these phenomena allows to make informed choices and to address objectives and strategies in a balanced and sustainable way.

5.2 The case study of the Flemish Region

5.2.1 Spatial context and the Natura 2000 Network

The Flemish Region is one of the three regions of Belgium, with the Region of Bruxelles and Wallonia Region. It is also named as “Flanders” and contains the northern part of Belgium. Its surface is approximately of 13,522 km^2, where 6,444,120 inhabitants live.
The study area concerns the Flemish region, located in the north side of Belgium. This area adjoins: to the North and North-East with the Netherlands; to the North-West with the North Sea; to the East with France.
Predominant land covers (LCs) are related to: grassland and crops, covering each one around 27% of the region; 10%, forest vegetation; around 15%, settlement; 3%, water; and the rest, around 16%, other kind of vegetation. The dominant land use is related to agriculture, concerning 46% of the region; 7% nature conservation areas; 2% recreational uses; 27% urbanized areas; and 1%, uses related to water; the remnant 17%, other kinds of land uses.
There are 62 Natura 2000 terrestrial sites, 24 SPAs and 38 SCI. The total surface covered by sites amounts to 1,686 km^2. There are also 5 marine sites, 3 SPAs and 2 SCIs/SACs (see Figure 6).

5.2.2 Water purification in Flanders

5.2.2.1 Assessing water purification with InVEST

The ecosystem service of water purification is crucial for all regions. In order to investigate this ecosystem service in Flanders, the Nutrient delivery ratio (NDR) model of InVEST (see par. 4.1.2.1) is elaborated, obtaining a Nutrient retention map, in order to identify critical conditions and potential resources aiming at provide beneficial ecosystem services. The NDR model refers to the retention of two nutrients: nitrogen and phosphorus, but in this case study only nitrogen is considered. Moreover, this model allows to investigate both surface waters and groundwaters; however, groundwaters involve uncertain data, and here only surface waters are studied.

5.2.2.2 Materials

The input data required by the NDR model and used in this methodology are the following: a digital model of the terrain; a map of land use; a shapefile containing the surface water basins; a map representing the potential outflow; a biophysical table.

5.2.2.2.1 The Digital Elevation Model

The model represents the distribution of the units of the territory in digital format, with an elevation value for each cell. The digital elevation model is obtained from European datasets[26], with a spatial resolution of 25 m.

5.2.2.2.2 Land-cover map

The land-cover map for Flanders is elaborated from European datasets[27]. This map classifies the territory in 10 classes: 1 – Agriculture; 2 – Bare soil; 3 – Forest; 4 – Grassland; 5 – Heath; 6 – Other vegetation; 7 – Swamp; 8 – Tidal flats and saltmarshes; 9 – Urban; 10 – Water.

5.2.2.2.3 Watershed

Watersheds are elaborated in a shapefile with ArcHydroTools, for the whole region, including the Brussel Region (which is completely contained in the Flemish Region), and excluding the administrative island in Wallonia (the small area on the right down in Figure 6, under the City of Maastricht), because the model needs a territorial continuity.

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[26] The digital elevation model is available at https://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem [last access: 15 January 2019].

[27] The Land-cover map is available at https://land.copernicus.eu/local/urban-atlas/urban-atlas-2012/view [last access: 15 January 2019].

5.2.2.2.4 Potential runoff

The information layer consists of a map representing the potential outflow. A raster of potential runoff is obtained, elaborated with a kriging geostatistical model (Phillips *et al.*, 1992), by using data precipitation of Belgian rain gauges[28].

5.2.2.2.5 Biophysical table

This table correlates soil coverings with nitrogen loads, nitrogen removal efficiency and a maximum retention distance for each land cover class, developed for the context analysed starting from Bachmann Vargas (2013) studies and NCP (2015) specific for the Nutrient Delivery model (see Par. 4.1.2.1).

lc_code	load_n	eff_n	crit_len_n	proportion_subsurface_n
1	50	0,5	25	0
2	0	0	10	0
3	2,8	0,9	300	0
4	8	0,7	150	0
5	1,5	0,7	150	0
6	1,5	0,7	150	0
7	2,8	0,9	10	0
8	2,8	0,9	10	0
9	20	0,05	10	0
10	1	0,7	0	0

Table 6 – The Biophysical table elaborated for the Flemish Region. Each row in the table is a land cover class, each column contains a different attribute referred to each land cover class.

[28] Data precipitation of Belgian rain gauges are available at: ftp://ftp.bafg.de/pub/REFERATE/GRDC/catalogue/grdc_stations.zip [last access: 15 January 2019].

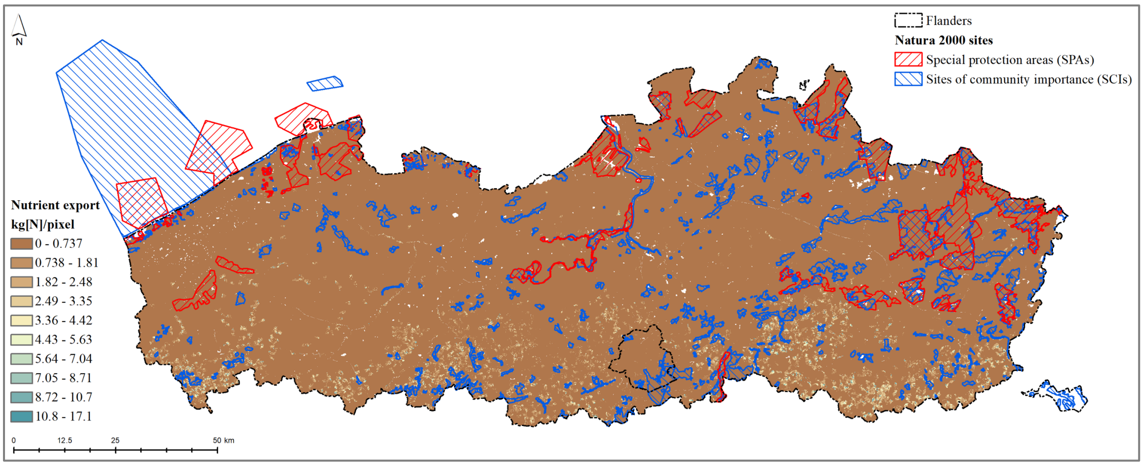

Figure 14 - The nutrient export map for the Flemish Region, with the Natura 2000 sites.

The Nutrient export map (Figure 14) indicates the potential export of nitrogen in Flanders. Due to a favourable terrain model (Flanders are mainly flat) and the presence of several waterways, the context shows a high potentiality on retaining nutrients. Inside the Natura 2000 sites there are the best performance, due to the diffuse presence of forests and waterways.

5.2.2.3 The ECOPLAN Project

For the Flemish Region, ecosystem services have been evaluating within the ECOPLAN Project[29]. The maps produced indicate where there is a high demand for certain

[29] ECOPLAN is a consortium consisting of the research group *Ecosysteembeheer* [Ecosystem Management] (University of Antwerp), the research group *Aquatische Ecologie* [Aquatic Ecology] (University of Ghent), the Department of Earth and Environmental Sciences (KULeuven), the *Aardobservatie* [Earth Observation] group (VITO), the *Ruimtelijke Milieuaspecten* [Spatial Environmental Aspects] group, and the *Instituut voor Natuur- en Bosonderzoek* (INBO) [Institute for Nature and Forest Research]. It is available at: http://www.ecosysteemdiensten.be/cms/nl/node/12 [last access: 15 January

ecosystems services, where there are zones with high production and where there is a great potential for the production of ecosystem services. All components (metadata catalogue, view and download services) are offered directly and integrated via a geographic content management system. Datasets can be also received by asking directly via website.

ECOPLAN develops spatially explicit information and tools for the assessment of ecosystem services. It designs tools for the evaluation of functional ecosystems as a cost-efficient strategy to improve land use efficiency and environmental quality. It develops open source and products for identifying, quantifying, valuing, validating and monitoring ecosystem services.

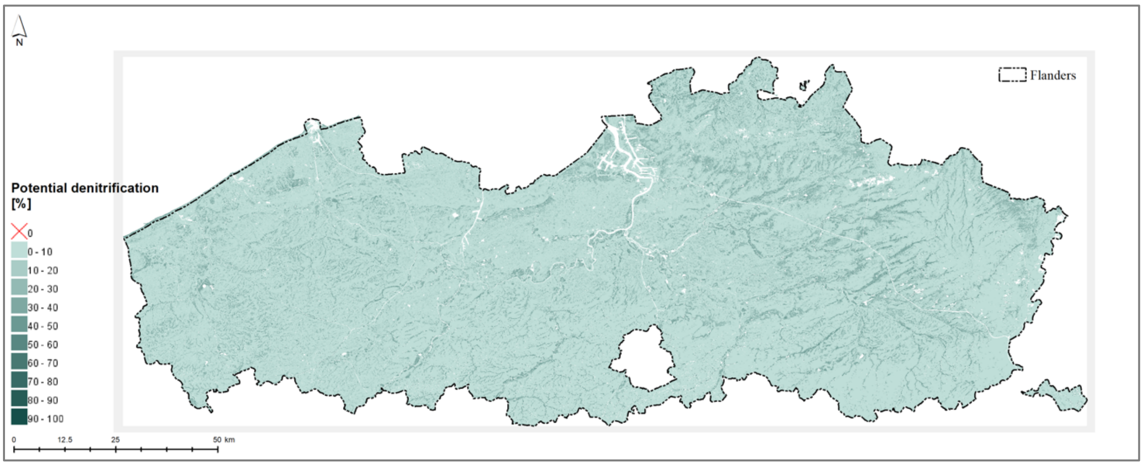

Figure 15 – Potential denitrification[30] in Flanders (%). An example of ecosystem services map elaborated by the ECOPLAN Project.

2019]. The project has been financed by the Flemish Agency for Innovation through Science and Technology, for the period 2013-2016.

[30] The map (*Potentiële denitrificatiegraad*) is available at http://www.ecosysteemdiensten.be/geoloket/ [last access: 15 January 2019].

These products can be used by administrations and consultants in project development, cost-benefit analysis, environmental impact reporting. Different end-users need different levels in complexity and detail. One of the end products is the ECOPLAN monitor that catalogues ecosystem services maps for Flanders on the basis of existing spatial data and limited data processing. Several ecosystem service maps can be consulted together and consulted with administrative boundaries and thematic background layers.

5.2.3 The nitrogen issue in Flanders

A nutrient balance describes the difference between all nutrient inputs and outputs on agricultural land. A positive balance or surplus reflects inputs that there are excess of crop and forage needs. In diffuse pollution it can result through the loss of nutrients to water bodies, decreasing water quality while promoting eutrophication. Surplus nitrogen can also be lost to air as ammonia or other greenhouse gases.

All Member States show a nitrogen surplus. However, these surpluses have declined since the mid-1980s, reducing environmental pressures on soil, water and air. The adoption of nutrient management plans and environmental farm plans has had a key role in this reduction. It is important not only to consider rates of surplus decline but also their absolute values.

Belgium and the Netherlands, for example, show significant decreases although nutrient surpluses in these two countries currently remain much higher than the average across all other countries, indicating high productivity and pressure on biodiversity. Conversely, some countries show an increase but still remain below the average (see Figure 16).

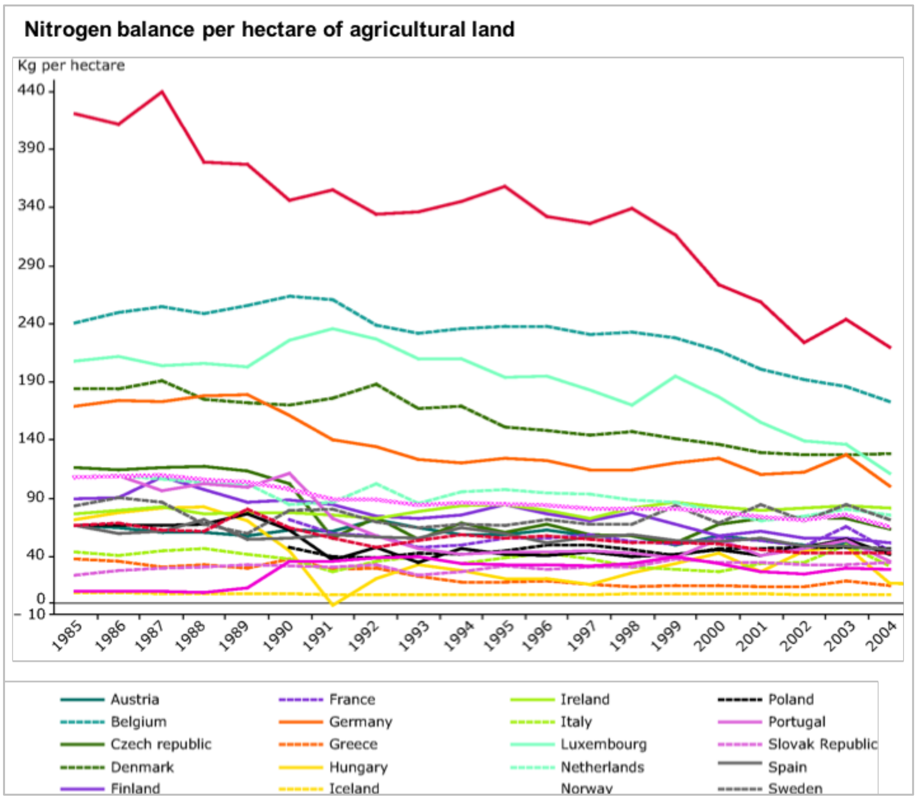

Figure 16 – Nitrogen balance in the in OECD Countries. Belgium is the second for balance per hectare of agricultural land. Source: Indicators of the European Environment Agency[31].

In most countries, national nutrient balances typically mask significant regional differences due to variation in the type and intensity of farming.

The region of Flanders is a nutrient-intensive region, due to its high population density, intensive industry and livestock production. In Flanders, crop and livestock production contribute for 49% of N, especially with fertilizer (Coppens *et al.*, 2016).

[31] Indicators of the European Environment Agency for nitrogen balance in agriculture are available at https://www.eea.europa.eu/data-and-maps/indicators/agriculture-nitrogen-balance/agriculture-nitrogen-balance-assessment-published [last access: 15 January 2019].

Agricultural activity in Flanders is dominated by intensive livestock production. Agriculture produces 23 kg N/cap/yr of crops and the main fraction of this (87% of N) is used as fodder or destined for fodder production. Nevertheless, the Flemish livestock production still relies for 37% of its N demands on imported fodder. Livestock production eventually provides 19 kg N/cap/yr and 2.2 kg of animal products such as meat, milk and eggs, while also 21 kg N/cap/yr is embedded in animal manure. Crop production, on the other hand, has a fertilizer demand of 31 kg N/cap/yr, which corresponds to 235 kg N/ha/yr. However, as the entire agricultural area of Flanders is designated as a nitrate vulnerable zone to protect the ground and surface waters from eutrophication, a legal restriction for local animal manure application of 170 kg N/ha/yr or 17 kg N/cap/yr is imposed. The high regional variation in livestock density in Flanders results in a local oversupply of manure. Consequently, 81% of the total amount of manure N produced, is applied as fertilizer for crop production, while the remaining excess of manure is destined for export or processing. Therefore, animal manure encompasses 55% of the fertilizer N demand, while inorganic fertilizers account for 32%. The remaining nitrogen demand originates from by-products from the food industry, biological N_2-fixation and atmospheric N deposition (*ibid.*).

In the last decades, in Flanders there has been an active policy aiming at reducing nitrate levels in soil, surface water and groundwater (Overloop *et al.*, 2013). Several measures are being taken to reduce nitrate concentrations. The main sources of high nitrate concentrations in ground and surface waters are the widespread leaching of nitrogen surpluses on the soil surface balance (through fertilization), point discharges in surface water (from industrial and domestic wastewater) and the atmospheric deposition of nitrogen compounds (i.e., by emissions from households, traffic, industry).

Links between emissions, concentrations, depositions, and consequences for people, nature and economy are particularly composite for nitrogen because of the many conversions that can occur.

5.2.4 Nitrate focus areas

On 2006, since the context is threatened by excesses of nitrates, a Belgian decree, concerning the protection of water against pollution caused by nitrates from agricultural sources[32], establishes to implement effective approaches to protect surface waters and groundwaters. In fact, this decree aimed to reduce water pollution due to nitrates and phosphates from agricultural sources and to prevent further pollution, according to the Directive 91/676/CEE.

On the basis of the decree, since 2012, focus areas related to water quality data are designated every year[33] (as shown in Table 7 and Figure 17).

Focus areas are surfaces where the nitrate concentration of 50 mg N/l[34] in the surface water is exceeded or where the nitrate concentration in the groundwater does not show sufficient decrements.

[32] The decree, called "Manure Decree" [*Mestdecreet*], has been updated on 2017, and is available at http://www.ejustice.just.fgov.be/cgi_loi/change_lg.pl?language=nl&la=N&cn=2006122232&table_name=wet [last access: 15 January 2019].

[33] Data related to years from 2012 to 2018 are retrieved from https://www.vlm.be/nl/themas/Mestbank/bemesting/gronden/kwetsbare_gebieden/focusgebieden/Paginas/default.aspx [last access: 15 January 2019], and they can be downloaded at http://www.geopunt.be/catalogus/datasetfolder/1ff4bb09-77a5-4ba8-ab84-a54a2f698652 [last access: 15 January 2019].

[34] As defined by the Nitrate Directive (see Par. 3.3.1.1).

	Surface [ha]			
	Focus areas with bonus	**New focus areas**	**Focus areas from previous years**	**Total**
2012	-	477466	-	477466
2013	-	69655	461247	530902
2014	89657	64407	347031	501094
2015	89412	10357	312313	412082
2016	37792	34511	314552	386855
2017	52180	50692	303936	406809
2018	50429	49987	331102	431517

Table 7 – Surface of focus areas sensitive to nitrate concentration.

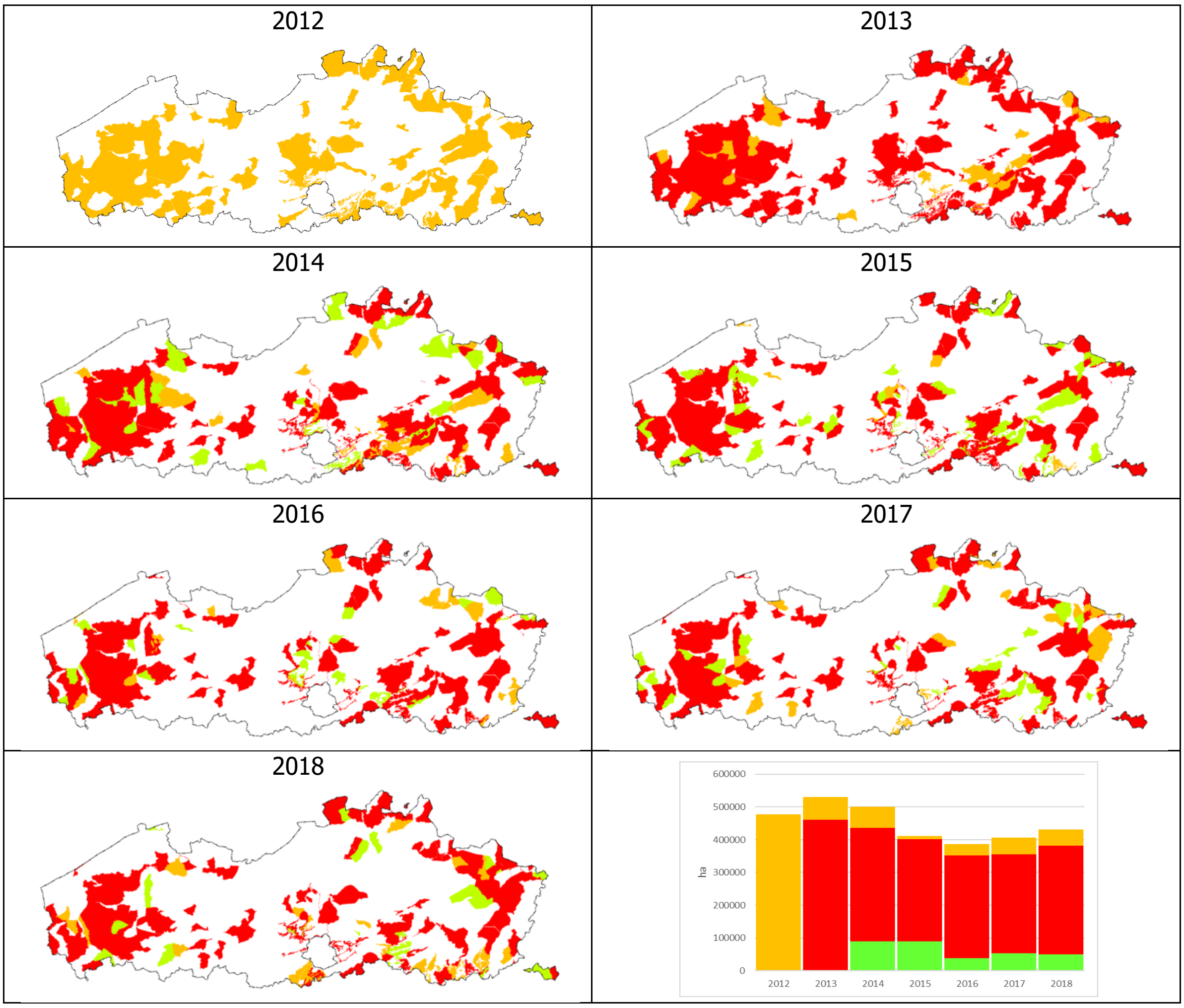

Figure 17 – Focus areas sensitive to nitrate concentration, as reported in Table 7.

Focus areas are defined each year on the basis of the following criteria: new focus areas can be classed if an exceedance of pollution limits in the surface water is measured or if groundwater measurements do not decrease sufficiently. Focus areas can be deleted if no exceedance is measured in the surface water and/or when the trend of measurements in groundwater is sufficiently low.

After two consecutive positive evaluations of both surface water and groundwater, areas can lose the focus area status. Those areas have a bonus during the previous year if exceedances do not occur in the surface water in the following winter season and if the trend of concentration in groundwater remains favourable.

5.2.5 Management plans for sites threatened by focus areas

The Natura 2000 sites are analysed with reference to the presence of focus areas. By overlapping the focus areas identified from 2012 to 2018 with the Natura 2000 Network, the sites more threatened by nitrates in water and groundwaters can be identified.

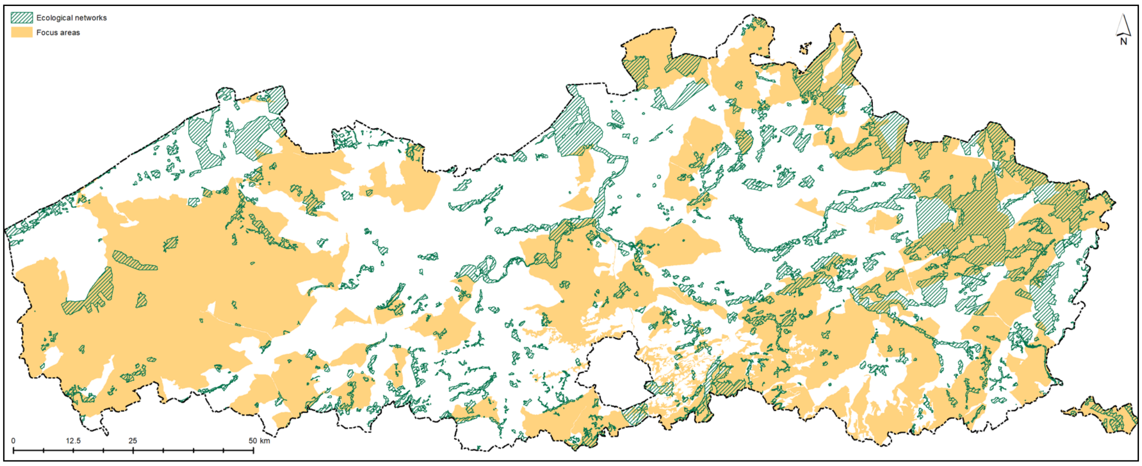

Figure 18 – The overlapping of focus areas and the Natura 2000 Network in Flanders.

sitecode	sitename	sitetype	site surface [he]	focus areas surface [he]	focus areas percentage [%]
BE1000001	La Foret de Soignes avec lisieres et domaines boisés avoisinants et la Vallée de la Woluwe. Complexe 'Foret de Soignes – Vallée de la Woluwe'	B	2076.30	1.49	0.07
BE1000003	Les zones boisées et les zones humides de la Vallée du Molenbeek au nord-ouest de la Région bruxelloise. Complexe 'Laerbeek-Dieleghem-Poelbos – Marais de Jette-Ganshoren'	B	117.18	0.02	0.02
BE2100015	Kalmthoutse Heide	B	2063.96	2049.43	99.30
BE2100016	Klein en Groot Schietveld	B	2288.04	146.99	6.42
BE2100017	Bos- en heidegebieden ten oosten van Antwerpen	B	5240.39	1741.25	33.23
BE2100019	Het Blak, Kievitsheide, Ekstergoor en nabijgelegen Kamsalamanderhabitats	B	697.37	337.53	48.40
BE2100020	Heesbossen, Vallei van Marke en Merkske en Ringven met valleigronden langs de Heerlese Loop	B	677.95	541.77	79.91
BE2100024	Vennen, heiden en moerassen rond Turnhout	B	3627.41	3144.31	86.68
BE2100026	Valleigebied van de Kleine Nete met brongebieden, moerassen en heiden	B	4884.16	2770.60	56.73
BE2100040	Bovenloop van de Grote Nete met Zammelsbroek, Langdonken en Goor	B	4306.99	172.03	3.99

sitecode	sitename	sitetype	site surface [he]	focus areas surface [he]	focus areas percentage [%]
BE2100045	Historische fortengordels van Antwerpen als vleermuizenhabitat	B	358.52	82.10	22.90
BE2100323	Kalmthoutse Heide	A	2183.35	2159.48	98.91
BE2101437	De Maatjes, Wuustwezelheide en Groot Schietveld	A	4109.84	2447.24	59.55
BE2101538	Arendonk, Merksplas, Oud-Turnhout, Ravels en Turnhout	A	7076.88	6557.29	92.66
BE2101639	Ronde Put	A	5412.33	2885.60	53.32
BE2200028	De Maten	B	535.72	331.52	61.88
BE2200029	Vallei- en brongebied van de Zwarte Beek, Bolisserbeek en Dommel met heide en vengebieden	B	8305.99	4537.96	54.63
BE2200030	Mangelbeek en heide- en vengebieden tussen Houthalen en Gruitrode	B	3767.65	3687.66	97.88
BE2200031	Valleien van de Laambeek, Zonderikbeek, Slangebeek en Roosterbeek met vijvergebieden	B	3627.14	1187.15	32.73
BE2200032	Hageven met Dommelvallei, Beverbeekse Heide, Warmbeek en Wateringen	B	1979.76	1430.52	72.26
BE2200033	Abeek met aangrenzende moerasgebieden	B	2523.19	1420.78	56.31
BE2200034	Itterbeek met Brand, Jagersborg en Schootsheide en Bergerven	B	1869.41	1319.29	70.57
BE2200035	Mechelse Heide en vallei van de Ziepbeek	B	3740.75	248.89	6.65
BE2200036	Plateau van Caestert met hellingbossen en mergelgrotten	B	132.29	3.88	2.93

sitecode	sitename	sitetype	site surface [he]	focus areas surface [he]	focus areas percentage [%]
BE2200037	Uiterwaarden langs de Limburgse Maas met Vijverbroek	B	779.24	260.60	33.44
BE2200038	Bossen en kalkgraslanden van Haspengouw	B	2603.61	1110.34	42.65
BE2200039	Voerstreek	B	1591.59	1589.91	99.89
BE2200041	Jekervallei en bovenloop van de Demervallei	B	633.45	220.97	34.88
BE2200042	Overgang Kempen-Haspengouw	B	689.39	140.68	20.41
BE2200043	Bosbeekvallei en aangrenzende bos- en heidegebieden te As-Opglabbeek-Maaseik	B	572.97	498.00	86.91
BE2200626	De Maten	A	565.59	335.29	59.28
BE2200727	De Mechelse Heide en de Vallei van de Ziepbeek	A	2344.25	200,58	8,56
BE2217310	Bocholt, Hechtel-Eksel, Meeuwen-Gruitrode, Neerpelt en Peer	A	9866.29	7794.10	79.00
BE2218311	Militair domein en vallei van de Zwarte Beek	A	8889.32	4800.28	54.00
BE2219312	Vijvercomplex van Midden Limburg	A	2563.41	666.04	25.98
BE2220313	Houthalen-Helchteren, Meeuwen-Gruitrode en Peer	A	2851.29	2705.83	94.90
BE2221314	Hamonterheide, Hageven, Buitenheide, Stamprooierbroek en Mariahof	A	13124.86	10174.32	77.52
BE2223316	De Demervallei	A	6457.00	3503.78	54.26
BE2300005	Bossen en heiden van zandig Vlaanderen: oostelijk deel	B	3376.89	1166.91	34.56
BE2300006	Schelde- en Durmeèstuarium van de Nederlandse grens tot Gent	B	8956.86	1637.08	18.28

sitecode	sitename	sitetype	site surface [he]	focus areas surface [he]	focus areas percentage [%]
BE2300007	Bossen van de Vlaamse Ardennen en andere Zuidvlaamse bossen	B	5547.90	1312.73	23.66
BE2300044	Bossen van het zuidoosten van de Zandleemstreek	B	1793.04	1012.56	56.47
BE2301134	Krekengebied	A	781.44	279.69	35.79
BE2301235	Durme en Middenloop van de Schelde	A	4190.39	1652.20	39.43
BE2301336	Schorren en Polders van de Beneden-Schelde	A	7085.47	389.34	5.49
BE2400008	Zonienwoud	B	2761.20	1037.17	37.56
BE2400009	Hallerbos en nabije boscomplexen met brongebieden en heiden	B	1831.60	678.96	37.07
BE2400010	Valleigebied tussen Melsbroek, Kampenhout, Kortemberg en Veltem	B	1445.02	365.80	25.31
BE2400011	Valleien van de Dijle, Laan en IJse met aangrenzende bos- en moerasgebieden	B	4067.67	3199.69	78.66
BE2400012	Valleien van de Winge en de Motte met valleihellingen	B	2244.41	2015.14	89.78
BE2400014	Demervallei	B	4910.40	2144.26	43.67
BE2422315	De Dijlevallei	A	1248.76	619.04	49.57
BE2500001	Duingebieden inclusief Ijzermonding en Zwin	B	3782.30	274.86	7.27
BE2500002	Polders	B	1866.19	117.37	6.29
BE2500003	Westvlaams Heuvelland	B	1878.09	1635.71	87.09
BE2500004	Bossen, heiden en valleigebieden van zandig Vlaanderen: westelijk deel	B	3063.86	2634.98	86.00
BE2500831	Ijzervallei	A	5136.05	5133.32	99.95

sitecode	sitename	sitetype	site surface [he]	focus areas surface [he]	focus areas percentage [%]
BE2500932	Poldercomplex	A	9765.84	358.68	3.67
BE2501033	Het Zwin	A	1913.90	61.79	3.23
BE2524317	Kustbroedvogels te Zeebrugge-Heist	A	498.07	0.00	0.00
60			**203280.21**	**100932.78**	**49.65**

Table 8 – Focus areas in the Natura 2000 sites of Flanders.

The Flemish Decree of 1997 for the protection of nature states that for every Natura 2000 site a "nature directive plan" must be made (Article 48). For each forest and nature reserve, it is also compulsory to prepare a management plan. These management plans are made for all forests and nature reserves, not only those in Natura 2000 sites (EC, 2011).

This case study considers management plans of sites with the highest percentage of surface threatened by nitrate focus areas, for more than 90% (see Table 8). They amount of 7 sites, 4 SPAs (sitetype A) and 3 SCIs/SACs (sitetype B). 4 sites present a definitive management plan (see Table 9). Sites BE2100015 and BE2100323 are managed in the same plan because they involve the same area.

sitecode	sitename	sitetype	management plan
BE2100015	Kalmthoutse Heide	B	complete
BE2100323	Kalmthoutse Heide	A	in progress
BE2101538	Arendonk, Merksplas, Oud-Turnhout, Ravels en Turnhout	A	in progress
BE2200030	Mangelbeek en heide- en vengebieden tussen	B	complete

	Houthalen en Gruitrode		
BE2200039	Voerstreek	B	complete
BE2220313	Houthalen-Helchteren, Meeuwen-Gruitrode en Peer	A	in progress
BE2500831	Ijzervallei	A	in progress

Table 9 – Management plans for sites with more than 90% of the surface of focus areas.

Management plans analysed show the following structure, as defined by the Agency for Nature and Forest[35] [*Agentschap Natuur & Bos*]:

- general introduction;
- task assignment;
- objectives for the Natura 2000 site;
- priority efforts with a view to achieving the conservation objectives;
- area-oriented issues for implementation;
- open task statement;
- habitats types;
- overview of the priority efforts;
- exercise matrix;
- mission statement concerning the improvement of the natural environment;
- guide card;
- situation of current habitats;
- situation of vegetations as habitat for European species to be protected;
- presence of habitat-type species;

[35] The Agency for Nature and Forest is available at https://www.natuurenbos.be [last access: 15 January 2019].

- spatial distribution of the conservation objectives;
- spatial distribution of the priority efforts;
- situation of the areas managed with a view to the realization of the conservation objectives;
- search zones;
- fields of action for the improvement of the environment;
- area-specific application of the global assessment framework for Natura 2000.

No plan underlines the nitrogen threat for the site, or any issues referred to the provision of ecosystem services.

5.2.6 Results concerning the Flemish Region

Land surface features, vegetation, and deforestation for crop cultivation can upset the hydrologic cycle in a region. Runoff and infiltration into the soil and groundwater are affected by the type of land surface. Furthermore, the extent of vegetative cover is significant. The degree of absorption and reflection of sunlight from the land surface affect evaporation rates, humidity levels, and cloud formation, land surface characteristics and vegetative cover influence precipitation patterns in a region. Frequently, conflicts exist when humans consume watershed supplies for irrigation (Pennington and Cech, 2010).
Pollution from agricultural sources has been listed as one of the leading sources of pollution in rivers and water bodies throughout the world. This pollution, which includes sediments, nutrients, and pesticides, can be transported from soil to surface waters via runoff events generated either by irrigation or natural precipitation (Zhang *et al.*, 2010).
Nutrients pollution and eutrophication of surface waters is a crucial issue for our ecosystems. All waters, both superficial and underground, have the ability to react to direct and indirect loads of pollutants. This capacity, called self-purification, includes a

complex series of mechanisms aiming at reporting water on its original state. However, if the intake of polluting substances is excessive, the self-purification capacity of water bodies is exceeded, so that negative phenomena, such as eutrophication and/or chemical and microbiological contamination, could be highlighted.

In the last 20 years, in Belgium, nitrogen balance per ha has been reduced from 240 to 173 kg/ha (Overloop *et al.*, 2013). Nevertheless, the Flemish Region is still particularly interested by the phenomenon of nitrogen excess, as a consequence of agricultural practices during the years. Consequently, in order to conform to European directives, areas with nitrogen excess have been identified and are under steady control. These focus areas involve a large percentage of the Flemish surface, also threatening areas crucial for the presence of important habitats and species, like the ecological network. In this context, the role of Natura 2000 sites in providing ecosystem services, in particular water purification, is accentuated by the physical peculiarity of the territory, mainly flat. By contrast, a negative phenomenon affects Flanders, exceeding benefits from ecosystems: the high presence of nutrients in soils and waters.

In order to evaluate the condition of the Natura 2000 Network with reference to the areas mainly threatened by nitrates and the potential nutrient retention of the context, a detailed layer of information should be built. To assess the environmental impact of nitrogen excess, more information is needed on farm nitrogen management, soil type, and climate conditions, all of which play a role in the fate of nitrogen in the environment.

With reference to the potential nutrient retention in Flanders, results demonstrate what was expected. Values within the Natura 2000 Network are favourable compared to the percentage values found throughout Flanders. The threat posed by the widespread presence of the focus areas means that the value of the natural capital constituted by the ENs is even greater than the usual considerations related to their interest from the point of view of the protection of habitats and species.

The concept of ecosystem functions, goods and services is a crucial instrument in planning processes, since it helps to identify and quantify benefits from ecosystems, and the full costs of their loss, and provides a communication tool to involve stakeholders in a constructive dialogue in this process (De Groot, 2006). In fact, when landowner decisions are based solely on market returns and their direct interests (without payments for ecosystem services), they tend to generate land use or land cover patterns with lower provision of ecosystem services and biodiversity conservation (Nelson *et al.*, 2009). In fact, human perception, choices, and actions are often phenomena that drive political, economic, or cultural decisions that lead to or respond to changes in ecological systems (Brunetta and Voghera, 2014).

By recognizing the role of ENs, the Flemish agency for nature and forests ([*Agentschap Natuur & Bos*]) defines several principles in order to protect and improve natural values which belong to ENs, like protection of existing landscape, limits for manure loads and pesticides, protection of all forests, moors, marshes, swamps, ponds and springs, and to maintain a sustainable manage of water resources.

Land use conversions that reduce the leaching of nitrogen compounds and/or strengthen ecological processes that remove nitrate from the ground and surface water can, therefore, be regarded as a benefit. In a balanced, unmissed ecosystem, virtually no nitrate will reach streams or groundwaters. The conversion of parcels with an agricultural management with fertilization to management without (or reduced) fertilization will therefore result in a reduced leaching (Overloop *et al.*, 2013).

The key to maintain the services of water purification is to protect and restore ecosystems that provide these services, so ENs, and to support proper planning that considers impacts on waterways as part of all urban, industrial and agricultural development: it is important for the current generation, and it is crucial to keep ecosystem services available for generations yet to come.

6 Discussion and conclusions

6.1 A framework to address the integration of the Natura 2000 Network into planning policies and practices: lessons from the case studies

6.1.1 The Natura 2000 sites management integrated into planning processes

Management plans belong to two categories: specific, i.e. specifically approved for the achievement of objectives identified by the Directive; or «integrated with other development plans» (Habitat Directive), therefore, included in more extensive and different plans.

The issue is that there are several conflicts all around a site, and the management plan does not sufficiently address the problem of combining nature conservation with the interest of the local community. Moreover, in some cases the high level of intersection and overlap of functions of the numerous programmatic tools and plans at the institutional levels (local, metropolitan, regional, and national) can lead to the outcome of potential conflicts between different management strategies of the area and consequent ineffectiveness with respect to the objectives of the European directives. There is an objective effort of management caused by the presence of a multiplicity of skills distributed over several entities, which sometimes pursue divergent strategies, with the consequent lack of coordination in management.

Each site should have a plan able to develop a sustainable utilization of natural resources avoiding overuse of some functions, i.e. stress on the water purification function, and specifically protecting other functions, i.e. biodiversity conservation and drinking water supply.

Although not obligatory under the Habitats Directive, Natura 2000 management plans are very useful tools, as they (EC, 2005):

- provide a complete record of the conservation objectives and ecological condition and requirements of habitats and species existing in the site, so that it is clear to all what is being conserved and why;
- analyse the socio-economic and cultural context of the area and interactions between different land-uses and existing species and habitats;
- provide a framework for open debate among all interest groups and help to build a consensus view on the long-term management of the site, as well as create a sense of shared ownership for the final outcome;
- help to find practical management solutions that are sustainable and better integrated into other land-use practices;
- provide a mean of laying down the respective responsibilities of the different socio-economic stakeholders, authorities and other organisations in implementing the necessary conservation measures identified.

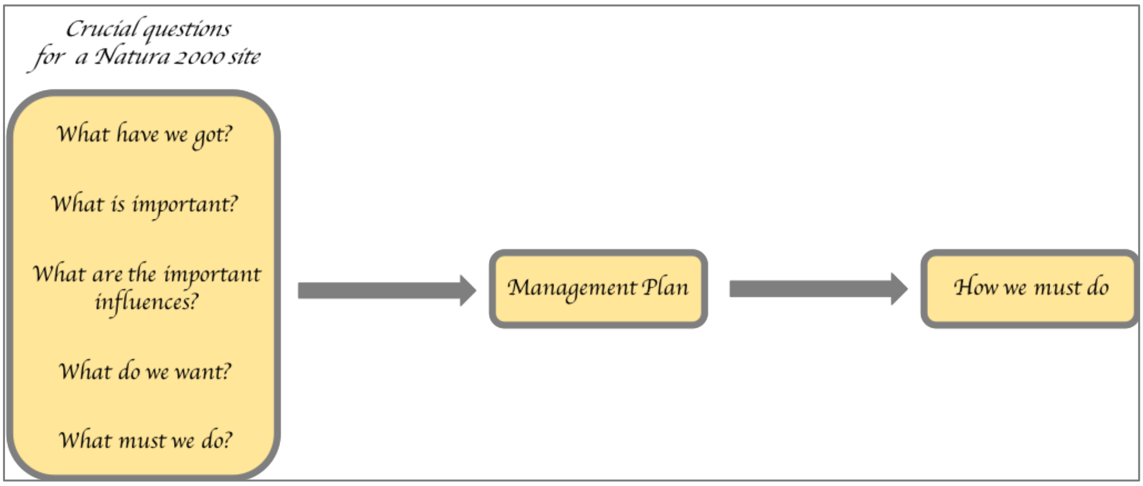

Figure 19 – The crucial role of management plans.

As shown in Figure 19, management plans have a crucial role in the conservation success of the site. The way they act is by exactly defining *how* to proceed, through a detailed set of actions. However, before defining the strategy of actions, management plans should answer five main questions, as proposed by Alexander (2015), decisive for better management of the site.

The management plan allows passing from questions and uncertainties – "what?" – related to the Natura 2000 site conditions to the strategies of actions, defining the "how" to proceed for better management of the site. It should represent an efficient framework for the implementation and the follow-up of conservation measures.

Some proactive aspects express multidisciplinary planning activities with reference to a plurality of actors with different competence, expecting the active involvement of public and private figures, in order to guarantee a tangible reorganization and integrate management of the environmental, settlement and socio-economic processes of the sites, through the definition of objectives, strategies and shared choices.

6.1.2 Measures to integrate the concept of ecosystem services in management plans of the Natura 2000 sites

Recent European conservation management strategies and policies are based on the awareness of the importance of ecosystem dynamics in changing environments and the consequences for the sustainable provision of ecosystem services (Haslett *et al.*, 2010). Several types of activities, such as agriculture, forestry, urban development, road building, produce non-point pollutants, usually removing native vegetation and altering stream courses and ecosystems. In order to solve, or at least mitigate, these problems, several best management practices have been developed (Pennington and Cech, 2010).

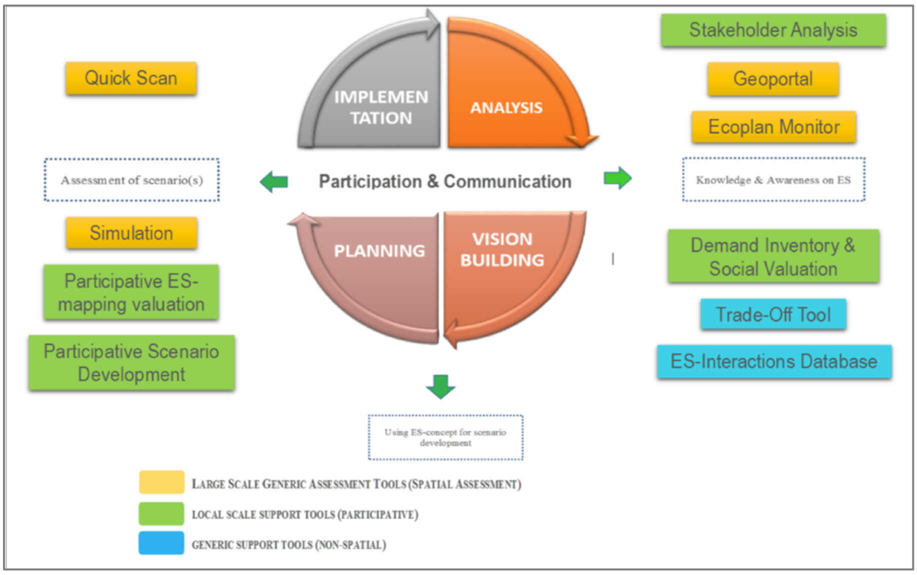

Figure 20 – A scheme to implement ecosystem services into planning. Source: ECOPLAN Project[36].

[36] The scheme is available at http://www.ecosysteemdiensten.be/cms/nl/node/533 [last access: 15 January 2019].

An important key question is: «how all the analytical assessment methods can be combined to enable effective planning and decision making, in a participative way?». In order to make well-informed decisions about consequences between different management options for Natura 2000 sites, all costs and benefits referred to a specific ecosystem service should be taken into account, including ecological, economic and socio-cultural values and perceptions.

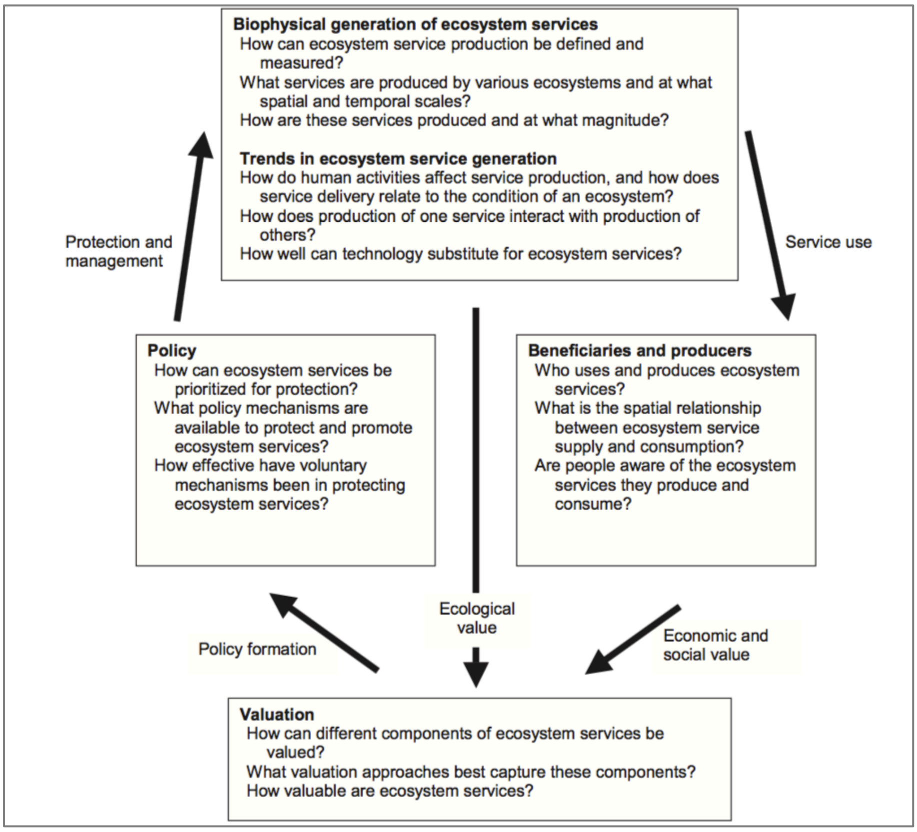

Figure 21 – Connections between ecosystem services and policy. Source: Brauman et al. (2007).

Figure 21 shows a structure of circular issues involving ecosystem services, since their definition and assessment, their interaction with human activities affecting service production, the identification of beneficiaries and producers, the valuation of ecosystem services, and possible frameworks for protection and management. Two questions are very important: «Are people aware of the ecosystem services they produce and consume?» and «How can ecosystem services be prioritized for protection?». An answer to these questions can be given by including the assessment of ecosystem services in planning processes within the whole participation of population and stakeholders.

In the case study of the Flemish Region, the presence of the ECOPLAN monitor can be taken as an example of how to start including ecosystem services into planning processes. In effect, ECOPLAN strives to develop instruments and methods that facilitate planning for ecosystem services, which is why these tools and methods are aimed at fulfilling specific needs in planning and execution of spatial planning processes, as most planning processes and projects go through phases of problem analysis, vision formation, plan layout and implementation. Although clear boundaries between phases do not exist and many alternative approaches can be developed, these products can offer an important base of information, and a flexible approach for planners and implementers who want to start by taking into account ecosystem services.

From a methodological perspective, InVEST can be defined as a useful tool, capable of map and quantify ecosystem services across broad scales, and making use of public datasets that are freely available for most of the States (Butsic *et al.*, 2017). Although this, in general, outputs can be intended only as "potential", but not exact, due to several approximations included in the model, and the lack of precision in the available data.

6.1.2.1 An ecosystem services inclusive structure for management plans

Due to the central role of the Natura 2000 Network in providing ecosystem services, the current lack of information of this important peculiarity in management plans of sites is no more acceptable.

Management plans should include the assessment of ecosystem services, as well as the other analyses on abiotic components, habitats and species, socio-economic elements.

By taking into consideration the management plan structure proposed in the guidelines in Paragraph 4.1.1, the evaluation and mapping of ecosystem services could be integrated inside the structure, into a specific section, as follows.

- Presentation report.
    - General information and physical characteristics: site context, site designation and management, administrative data and protection measures, abiotic data.
    - Mapping the habitats and species: mapping natural and semi-natural habitats, mapping species and their habitats.
    - Ecological and functional analysis.
    - Prioritising conservation issues.
    - *Evaluation and mapping of ecosystem services.*
    - Socio-economic diagnosis: inventory of human activities, analysis of activities and their impacts.
- Definition of sustainable development objectives (*by including sustainable use of ecosystem services*).
- Proposing measures.
    - Categories of measures.
    - Cost assessment and financing.
    - Schedule of measures.

The plan should also include analyses on the impacts of pressure elements on ecosystem services, likewise the assessment of impacts on habitat and species.
Real integration of these analyses into management plans needs a clear and structured procedure to be involved into the planning process, and the more the ecosystem service is fundamental and threatened, the more it needs to be monitored and participated.
With reference to the ecosystem service of water purification, since the water cycle involves the whole site and all areas outside the site in a system of energy and matter

exchange, an integrated process of participation and monitoring is necessary, by including mitigation measures.

6.1.2.1.1 Participative actions

As in most conflict situations, stakeholders see other stakeholders as opponents, and, as result, each part is concentrated on maximizing own single-function use. Conflict solving and collaborative management meeting can be very useful to present all the different stakeholder positions, and their linkages, in a quite objective and clear manner and to facilitate discussion. Function-analysis approach with analytical tools, such as spatial analysis (GIS, mapping) and models to analyse interactions between function use, are important instruments to support a participatory management approach, whereby economic analysis is crucial to create awareness about the economic costs and benefits and to develop incentives for sustainable use (De Groot, 2006). Decisive is to demonstrate the contribution of ecosystem services provided by the Natura 2000 Network to the local and national economy.

By convincing (potential) contributors that benefits of conservation and sustainable use of ecosystems and landscapes outweighs the costs and, thus, attracts investments, could better insights in trade-offs involved in land use change decisions and make their work more accessible to collaborative planning and management. By including the concept of ecosystem functions, goods and services is crucial in planning processes, since it helps to identify and quantify benefits of ecosystems and the full cost of their loss, providing a communication tool to engage main stakeholders in a constructive dialogue (*ibid.*).

It is advisable that forest managers or owners, as well as relevant other interested parties – be they representatives of local communities or other organisations for nature conservation – are actively involved in the process of identifying the necessary conservation measures and preparing Natura 2000 management plans.

For a successful management plans development, owners and managers should be involved at an early stage of the process. Their participation in planning processes and preparation of conservation measures for the Natura 2000 site allows to benefit from their expert knowledge.

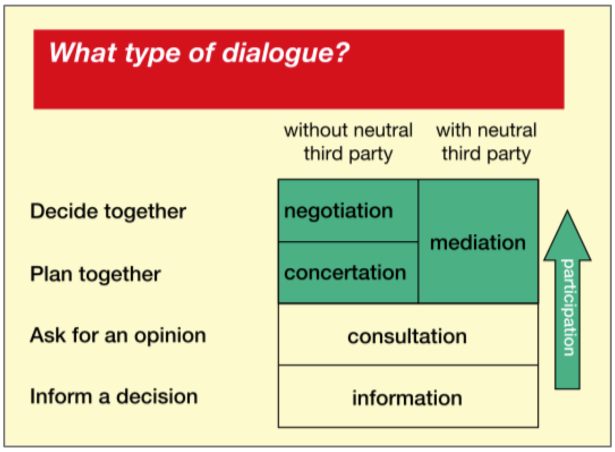

Figure 22 – An example of levels of participation in decision-making processes. Source: Boivin et al. (2011).

Currently, good practices involve ensuring the active contribution of all relevant stakeholders, e.g. by setting up steering groups or committees. Good communication from the beginning will also help finding compromises and synergies between what is already done and what can be improved. The result is likely to be a more cost-effective and less time-consuming process. It will also significantly increase the probability of success as it will encourage and enable different stakeholders to become more actively engaged in, and committed to, the management of their Natura 2000 site.

Concertation is also fundamental in the decision-making process. It can be intended as a methodical process, carried out over time, with the aim to achieve specific agreement in order to act in a collaborative way. It comprises both formal and informal aspects, enabling several institutional and local stakeholders, to meet within appropriate concertation groups to discuss and debate, eventually resulting in the development of co-constructed solutions.

6.1.2.1.2 Mitigation measures

They are intended as direct measures, consisting of material actions aimed to interrupt negative processes and create virtuous cycles, with reference to the provision of ecosystem services. For the specific threat analysed in this thesis, nitrates excess, it is crucial to understand that higher nitrogen input does not necessarily results in substantial yield increases, or at least shows a decreasing input-output efficiency (Lassaletta *et al.*, 2014). Considering the diminishing returns of increasing fertiliser application (Tilman *et al.*, 2002) and negative environmental effects of nitrogen fertilisation, such as nitrate leaching or impact on global warming potential (Erisman *et al.*, 2011), the gains from increasing fertiliser use might thus be limited in large parts of Europe (Levers *et al.* 2016).

For agricultural, silvicultural and industrial areas, best management practices can be applied by using many kinds of buffers, for many different situations. Some examples are: riparian buffers; filter strips, consisting in areas of close-growing plants; grassed waterways; windbreaks, consisting in areas of trees to provide wind protection, and cross-wind trap strips; living snow fences, consisting in shrubs and other vegetation to capture blowing snow; contour grass strip; shallow water areas for wildlife; field borders; alley cropping, consisting in crops grown between rows of trees and/or shrubs; vegetative barriers.

Buffers are crucial for mitigation: between a river, a lake or a pond, and a polluting activity, they slow the delivery of organic materials, sediments, and other pollutants produced, therefore allowing time for nutrient recycling, sediment settling and pollutant processing.

Wetlands are often included in riparian areas and represent an important means to process and clean surface water before it enters a stream.

6.1.2.1.3 Monitoring actions

Monitoring phase is crucial in all planning process. During the time, by taking into account the ecosystem service of water purification in Natura 2000 sites and analysing correlated factors inside the management plan, is possible to observe variation and identify threats since the early stage.

Services comments in the water purification process	**Ecological process and/or component providing the service (or influencing its availability) = functions**	**State indicator (how much of the service is present)**	**Performance indicator (how much can be used/provided in a sustainable way)**
Water regulation	Role of ecosystems (e.g. forests, wetlands, …) in water infiltration and gradual release of water	Water retention capacity in soils, etc. or at the surface	Quantity of water retention and influence of hydrological regime (e.g. irrigation)
Waste treatment	Role of biota and abiotic processes in removal or breakdown of organic matter, nutrients and other compounds	Denitrification (kg N/ha/y); immobilization in plants and soil	Maximum amount of chemicals that can be recycled or immobilized on a sustainable basis

Table 10 – Potential indicators for determining a sustainable use of water purification ecosystem services. Elaborated from de Groot (2010) and adapted from MEA (2005) and De Groot (2006).

An example of some indicators that could be included within a monitoring section of the management plan is shown in Table 10, with reference to the issue of water purification ecosystem service.

6.2 Conclusions

Although the consensus on a coherent and integrated approach to ecosystem service assessment and valuation is still lacking efforts to fill gaps have changed the terms of discussion on nature conservation, natural resource management, and other areas of public policy, and empirical data is still scarce.

One of the major problems of environmental systems is that they are seen as a collection of discrete and point-like elements, beyond their characteristics. The main strategy to build an environmental system at the regional level is therefore to conceiving it as an integrated system. This means connecting naturalistic and historical resources in an integrated network (Belfiore and Cassetti, 1992).

It is now widely recognized that nature conservation and conservation management strategies do not necessarily pose a trade-off between the "environment" and "development" but that investments in conservation, restoration and sustainable ecosystem use generate considerable ecological, social and economic benefits (De Groot, 2010).

In order to reconcile landscape conservation with changing and growing demands on land use and natural resources, ecological, socio-cultural and economic values of the landscape must be fully taken into account in planning and decision-making.

Why do we continue to use multi-functional, productive landscapes in an unsustainable way, and destroy our "natural capital" at the expense of our own welfare and that of future generations? Humans continue taking decisions on trade-offs between different land use options based on incomplete information. Most of the benefits of natural and semi-natural landscapes are seen as non-marketed externalities.

Benefits from land use change usually belong to private or corporate interest groups while costs (i.e. the non-marketed externalities) encumber upon a broad group of stakeholders and future generations.

Human culture is fundamental in the ecosystems of which man is a part, and therefore it is unthinkable to understand the ecology of an anthropized system without considering social and cultural components (Bruno, 1992). This can be modelled as the flow of energy and raw materials (such as water and food) and as energy balance of primary production in anthropized areas, which represents a "total environment" (Boyden and Millar, 1978). This total environment can be divided into single elements (biotic, abiotic, cultural, …) belonging to disciplines very distant from each other, but equally aimed at the evaluation (Bruno, 1992). Planning processes aim at modelling the total environment and need to understand relationships between every single element.

Humans began affecting their environment when they started accumulating in one spot and increasing population densities, planting crops, developing water delivery systems, and developing tools to support themselves. Consequently, water quality became an issue with population growth.

Several recent studies have underlined the importance of ecosystems in providing a range of valuable services for human needs (Pan *et al.*, 2013; Remme *et al.*, 2014). In particular, hydrological services, including water supply and quality, and flood regulation (Brauman *et al.*, 2007; Bruijnzeel *et al.*, 2011) have taken policy-makers interest pursuing to develop policy instruments able to protect ecosystems important in providing these services and promoting the sustainable use of natural resources (Bruijnzeel, 2002; Daily *et al.*, 2009). Despite their importance, these services are increasingly threatened (Mokondoko *et al.*, 2016).

Aquatic ecosystems (rivers, lakes, groundwater coastal waters, seas) support the delivery of crucial ecosystem services, such as fish production, water provisioning and recreation. Key ecosystem services are also connected to the hydrological cycle in the river basin, for example water purification, water retention and climate regulation. Most of these waters related ecosystem services can be directly appreciated by people and quantified, but some, especially regulating and maintenance services, are less evident (Grizzetti *et al.*, 2016).
Water use is influenced by the number of people who need to use it and how. Usually, humans tend to consume available water supplies in their local area, and then solve water scarcities (either due to water quantity or water quality problems) by transporting more water from other sources or locations (Pennington and Cech, 2010), but this is a very expensive solution, in economic and organizational terms.
EU waters are under increasing pressure from the growth of the demand for good quality water to be used for different purposes. Therefore, the water purification regulation service has a strategic role and must be protected with absolute priority, recognizing the role of Natura 2000 sites for its beneficial contributions.
Planners should identify the need to integrate the conservation of natural sites with wider sectorial and land use plans. Today, it is still perceived as a constraint rather than a method to reconcile the protection of biodiversity and development of human activities and find solutions that can favour their coexistence.
There are at least four facets that characterise the holistic ideal of ecosystem services research: (i) biophysical realism of ecosystem data and models; (ii) consideration of local trade-offs; (iii) recognition of off-site effects; and (iv) comprehensive, but critical, involvement of stakeholders within assessment studies (Staes *et al.*, 2017).
The assessment and valuation of ecosystem services at the European scale allows to address local and regional trends, identify hot spots in the delivery or degradation of services, test the effectiveness of regional policies (such as EU Directives) and conduct scenario analysis at the large scale (Grizzetti *et al.*, 2016). Many issues still remain to be

solved to fully integrate the concept of ecosystem services into everyday landscape planning, management and decision-making (De Groot, 2010).

An important change is needed: to shift from seeing nature as a threat against which anthropized areas have to be secured, to considering nature as a fundamental resource to be protected (Davoudi, 2014), with an open pathway for the transition from a protectionist policy of closed areas towards a widespread environmental protection, through the adoption of a multidisciplinary and multi-sectoral approach.

Today, the challenge is to build a framework aim to integrate ecosystem services into everyday decisions. This requires a new focus on services beyond provisioning services; an understanding of the relationships between the production of services; an understanding of the decision-making processes of individual stakeholders; the integration of research into institutional design and policy implementation; and the introduction of experimentally based policy interventions designed for performance evaluation and improvement over time (Daily *et al.*, 2009).

To achieve an integrated approach in order to recognize in decision-making and planning processes the fundamental role of the Natura 2000 Network in providing ecosystem services, many challenges, both at the levels of theory and methods, have been highlighted in this thesis.

Ecosystem services have been described from their definition in the Millennium Ecosystem Assessment, with particular reference to the water purification. The importance of pure and clean water is underlined in several European Directives, and the thesis makes a focus on the nitrate threats, which affect vast areas in several Member States, underlined the criticalities which are affecting Natura 2000 sites. Guidelines to assess and map ecosystem services have not been defined yet as a structured framework, but the European Commission suggests including them in planning policies.

Ecosystem services have been analysed for two case studies.

For the case study of the Metropolitan City of Cagliari, the ecosystem service of water purification has been evaluated and mapped in order to identify areas with high potential value in providing this service. Results show the role represented by the Natura 2000 Network, for the conservation of ecosystems which can deliver high levels in retaining nutrients.

For the case study of the Flemish Region, the ecosystem service of water purification has been evaluated and mapped in order to identify areas with high potential value in providing this service. Particular physical conditions of Flanders, mainly flat and rich of waterways, give a high potential value for a vast area, and results show the role represented by the Natura 2000 Network, for the conservation of ecosystems, such forests and wetlands, which can deliver high performance in retaining nutrients.

Management plans have been described, from their introduction in the Habitat Directive, as not compulsory but important planning instruments aiming at managing Natura 2000 sites in a sustainable way. Guidelines for drawing up management plans have been portrayed, as an example of which should be the necessary information layers. Management plans have been analysed for two case studies.

For the case study of the Metropolitan City of Cagliari, in Italy, all management plans have been evaluated in order to identify if they include analyses on ecosystem services provided by the Natura 2000 sites or the land-taking process which could threaten the context of the sites, through land-use changes. No plan has shown analyses referred to these themes.

For the case study of the Flemish Region, in Belgium, the management plans of some Natura 2000 sites have been evaluated in order to identify if they include analyses on ecosystem services provided by the Natura 2000 sites or the phenomenon of nutrient excess which is threatening the context of the sites, also affecting the water purification ecosystem service. No plan has shown analyses referred to these themes.

In the final section of discussion (Paragraph 6.1.2.1), the integration of the assessment of ecosystem services into the management plan is proposed as the introduction, in the Presentation report, of a new section of evaluation and mapping, between the assessment of habitats and species and the socio-economic analysis. Thus, this report should be intended as a framework of overall knowledge of the site context, necessary in order to identify a crucial characteristic, as well as all anthropic factors of pressure which could threaten the site.

The field of ecosystem services research is highly active, but official disposition for their evaluation is still lacking. The inclusion of analyses of ecosystem services in management plans is certainly an important step towards the wide acknowledgement of the irreplaceable role of the Natura 2000 Network in providing essential services to human health. Consequently, to include the evaluation and mapping of ecosystem services in the nearest level of planning for the sites, thus the management plans, and since the earliest phase is surely a good start in the pathway for the sustainability.

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