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The reintroduction of *Castor fiber* in Piedmont (Italy): An integrated SWOT-spatial multicriteria based approach for the analysis of suitability scenarios

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ABSTRACT

The Castor fiber or Eurasian beaver can change its habitat by building dams and creating ponds. For this reason, *Castor fiber* is known as an "ecosystem engineer" for aquatic and riparian environments. Despite its ecological importance, at the beginning of the 20th century the population was reduced to only 1200 beavers in Europe and Asia, due to uncontrolled hunting. Recently, some reintroductions and translocations have partly re-established the population. In Italy, however, the beaver disappeared in the 16th century and no action has been taken despite the recommendation of the Council of Europe to perform a feasibility study.

This research evaluates beaver reintroduction and identifies suitable areas in Italy and, in particular, in the Piedmont region. In order to achieve this, a SWOT analysis combined with a Spatial Multicriteria Analysis was performed. Firstly, the zoological and ethological aspects concerning this rodent were studied, as well as the historical reasons that led to its disappearance in Italy and near extinction in Eurasia. Secondly, Strengths, Weaknesses, Opportunities and Threats (SWOT) of the territory were identified for beaver reintroduction. The SWOT analysis was implemented, as the starting point for the spatial multicriteria analysis. Thirdly, the Multicriteria Spatial Decision Support System (MC-SDSS) was structured into two criteria, i.e. Potentials and Criticalities, representing the spatialization of strengths and weaknesses. The final result of the MC-SDSS is a map showing suitable areas for beaver reintroduction in Piedmont. This map is the weighted sum of the maps of criticalities and potentialities, performed through a set of GIS operations and weighted through a pairwise comparison of criteria by experts.

The analysis was conducted for the Piedmont region, but the integrated approach and the set of criteria can also be applied in other regions. Moreover, this mixed-method approach takes into account the characteristics necessary for the choice of suitable beaver habitats and also includes economic and social aspects. Therefore, it is an improvement on the Habitat Suitability Index (HIS), generally used in reintroductions. The aspects considered in the analysis are fundamental for the future development of a shared action plan, which considers both technical and social motivations and acts for the long-term on a wide area.

1. Introduction

The beaver is a rodent mammal belonging to the *Castoridae* family, *Castor genus*. It is classified in two species: the Eurasian beaver (*Castor fiber*), widespread in Siberia, Mongolia and almost all of Europe except for the Mediterranean areas, and the North American beaver (*Castor canadensis*), common in Canada, Alaska and most of the United States, as well as in Chile (Graells, 2015) and Argentina. *Castor fiber* and *canadensis* are very similar in appearance and behaviour, but they have a different number of chromosomes (Nolet and Rosell, 1998). Beavers live in freshwater habitats surrounded by woods but can also be found along agricultural canals or in suburban and urban areas (Taylor et al., 2017). Their diet is strictly vegetative and consist mainly of herbaceous plants, bark and branches of arboreal plants (willow, ash and alder). (Rozhkova-Timina et al., 2018). Beavers are one of the few species of mammals which intentionally transform their habitat to adapt to their needs through their life activities: cutting trees, building dams and lodges, digging dens and channels (Rosell et al., 2005; Stringer et al., 2015; Rozhkova-Timina et al., 2018). Their activities constitute a powerful environmental factor affecting the entire area (water-coastal complex) occupied by these rodents and, for this reason, they are known as "ecosystem engineers" (Rosell et al., 2005; Stringer et al.,

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2015; Rozhkova-Timina et al., 2018). The positive impact of beavers has wide consequences on the territory, including that of increasing the heterogeneity of the habitat, promoting biodiversity (Stringer et al, 2015), improving water quality (Puttock et al., 2017), lowering discharge peak in downstream river during floods (Nyssen et al., 2011), contributing significantly to the resilience of the landscape during extremely drought periods (Hood and Bayley, 2008) and generating socio-economic benefits through hunting, nature tourism (Campbell-Palmer and Rosell, 2010) and the improvement of ecosystem services (Campbell et al., 2007). Nowadays in Europe, beaver populations are stable in number with a minimum of one million beavers in at least 25 European countries. But in Asia they are considered small and need specific conservation measures (Batbold et al., 2016). At the beginning of the 20th century, however the trend was very different. At that time, in Europe and Asia only eight small populations were left with a total of 1200 individuals (Nolet and Rosell, 1998; Batbold et al., 2016). Conservation programs, numerous reintroductions and translocations were carried out in order to conserve the beaver population, protecting the remaining individuals and re-establishing the species. The measures were successful and now *Castor fiber* is classified by IUCN as "Least Concern" (Batbold et al., 2016). The main cause of the near disappearance was due to uncontrolled hunting for meat, fur and *castoreum*, chemical substances secreted by castor sacs and once used in medicine for the presence of salicin, the basis of aspirin's synthetical production (acetylsalicylic acid) (Mertin, 2003).

In the past, even in Italy, beavers could be seen along the placid waterways bordered by deciduous forests (Pratesi, 2001). However, the existence of this animal in this country, until the 16th century (Nolet, 1996), is only testified by fossil remains and by authors in the literature. To explore the potential of the Italian territory for the reintroduction of the beaver, the present paper proposes an application of the Spatial Multicriteria Analysis. Decision making, especially in nature conservation, requires the consideration of different and conflicting objectives, such as habitat protection, social needs and economic development (Orsi et al., 2011). The use of multicriteria analysis is firmly appropriate to take into account this complexity. Moreover, the analysis of geographical patterns of the different elements is fundamental in this context, since an assessment of the quality and quantity of available beaver habitats is essential in order to evaluate reintroduction, to predict population development and to avoid any beaver-human conflict. In the domain of complex spatial problems, like those in this research, the use of integrated evaluation approaches, such as Multicriteria Spatial Decision Support System (MC-SDSS), is particularly useful due to the integration of GIS and Multicriteria Decision Aiding (MCDA).

In order to support the definition of the spatial multicriteria analysis in a more structural way, a set of preliminary analysis was conducted. The Section 2 (Methods Section) of this paper illustrates the different stages of the analysis from a methodological perspective. Section 3 is devoted to the description of the application in the selected case study area. Section 4 describes the results of the MC-SDSS for the re-introduction of the *Castor fiber*. Finally, a Conclusions Section underlines the pros and cons of the applied model and future perspectives of the research.

2. Methods

For the purpose of the present research, the analysis was developed as follows (Fig. 1). Firstly, a thorough literature review of beaver habitats, its characteristics and its historical distribution was carried out, as well as an analysis of territorial impacts and benefits of the beaver

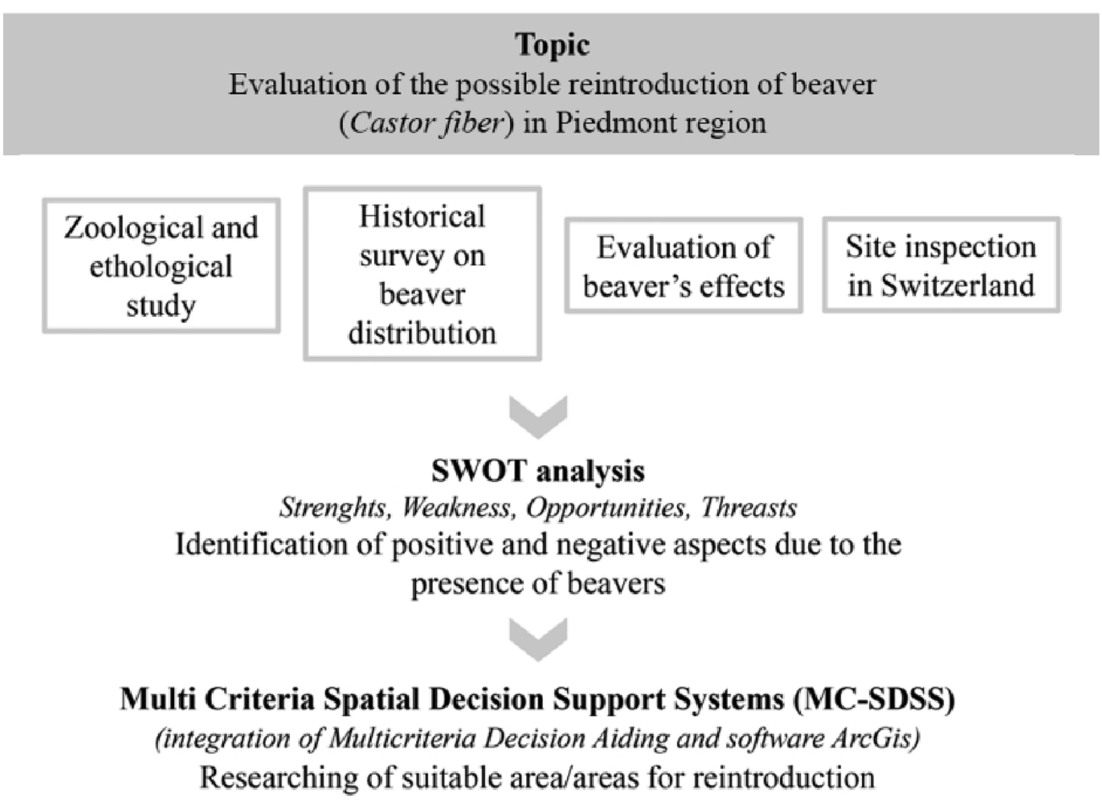

Fig. 1. Structure of the evaluation approach. Starting from the topic of the research, the different steps are illustrated: preliminary analysis (literature review and site inspection), SWOT analysis and MC-SDSS.

Fig. 2. Case study area. The study area, i.e. Piedmont region (black), is an Italian region located in the northwest of Italy. The coordinates in the box are relative to the centroid of Piedmont region.

presence on the territory. Secondly, knowledge of this species was enriched through discussions and meetings with experts and a number of site inspections in Switzerland. Thirdly, a SWOT analysis was performed to systematise all the information acquired in the previous steps and to create a clear starting framework for the spatial multicriteria analysis. Following the results of the SWOT analysis the Spatial MCDA was performed. A set of spatial criteria was defined for evaluation from the strengths and weaknesses identified. This was then clustered into a set of potentials and criticalities of the territory connected to the reintroduction of the beavers. These criteria represent the spatial indicators to perform the spatial multicriteria analysis and to obtain the final results of the evaluation of beaver reintroduction.

The methodological background of the two aforementioned approaches, SWOT and Spatial MCDA, is described in the remaining part of the present section, whereas the specific steps of the application are detailed in Section 3.

2.1. SWOT analysis

The acronym SWOT stands for Strengths, Weaknesses, Opportunities and Threats. This analysis is based on a logical procedure that allows the collection of data and information about the specific problem under investigation in order to organize the decision-making process (Humphrey, 2005).

In the context of territorial projects, the SWOT analysis is a useful tool for the definition of possible development scenarios of a given area. These scenarios can be created based on the valorization of strengths and the mitigation of weaknesses, and in light of potential opportunities and threats. The analysis distinguishes between endogenous factors of the process, that represent the internal variables, such as strengths and weaknesses, and exogenous factors, that are external from the system, such as opportunities and threats (Comino and Ferretti, 2016). It has been recognized that the SWOT analysis offers the possibility of developing an in-depth knowledge of the territorial and socio-economic context under investigation that can be useful to address design strategies (Bottero et al., 2019).

The implementation of SWOT analysis is normally performed in two steps. In a desktop phase, SWOT components are identified neutrally and objectively. This is due to a data acquisition based on literature consultation or consolidated information on the topic under analysis. In a focus group phase, experts and stakeholders are consulted for adding elements to the SWOT components. The present research follows these

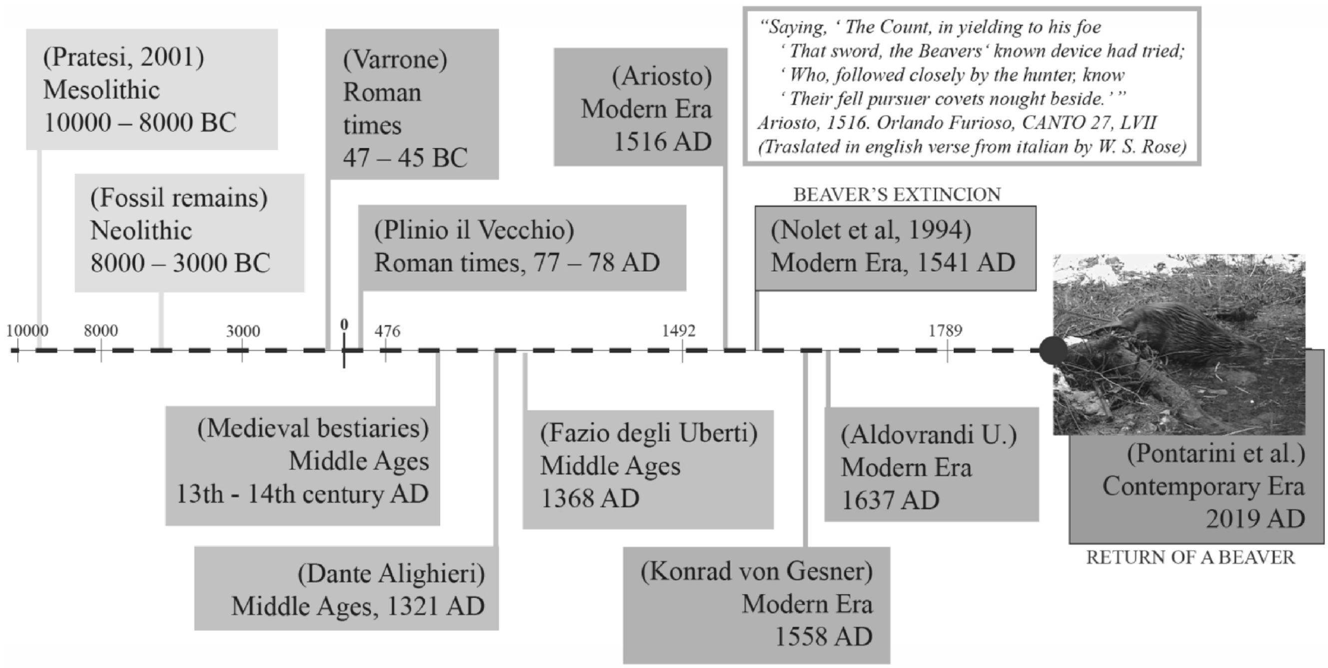

Fig. 3. Timeline of beaver presence in Italy from Mesolithic to Contemporary Era. Each Box represents a literary or historical quote that refers to Italian beaver; from left to right: Mesolithic (10000–8000 BCE) and Neolithic (8000–3000 BCE) included in Prehistory (2 million years ago – 3000 BCE), Roman Times (1st century BCE-5th century CE) included in Ancient history (3000 BCE–476 CE), Middle Ages or Post-classical history (476–1492), Modern Era (1492–1789) and Contemporary Era (1789 - Nowadays).The *Castor fiber* photo is taken from Pontarini et al. (2018).

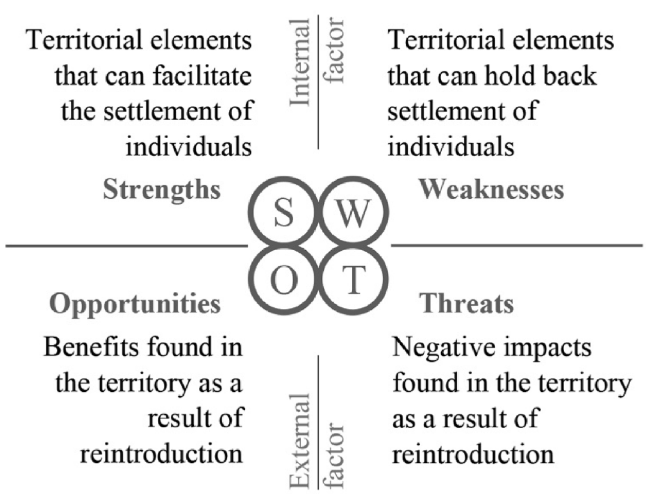

Fig. 4. Summary scheme of SWOT analysis. On the upper part of the matrix was reported and summed up the internal factors, i.e. strengths and weaknesses, instead, the lower part, the external factors, i.e. opportunities and threats.

two stages of the SWOT development, starting from an in-depth literature review and, then, adding new elements obtained from the consultation of beaver experts.

2.2. Spatial multicriteria analysis

The availability of analytical frameworks able to support spatial planning and decision-making processes is becoming increasingly relevant. Within this context, fundamental support may be provided by spatial Multicriteria Analysis (Malczewski, 1999). This type of analysis combines Geographic Information Systems (GIS) and Multicriteria Decision Aiding (MCDA) in order to provide a collection of methods and tools to transform and integrate geographic data (map criteria), and Decision Makers' preferences and uncertainties (value judgments) to obtain information for decision-making and an overall assessment of the decision alternatives.

This integrated approach is able to generate alternatives during the strategic planning phase and to compare them during the evaluation phase, and it is applicable across many scientific fields to solve different decision problem typologies (Ferretti, 2012). Spatial Multicriteria Analysis is particularly applied to land suitability analysis in the urban/regional planning, in the hydrology and water management and in the environment/ecology fields (Ferretti et al., 2015).

From the methodological point of view, the steps needed for the development of a Spatial Multicriteria Analysis, that specifically support planning and decision-making processes, can be summarized as follows. Firstly, the intelligence phase refers to the examination of the context in order to identify problems or opportunities and to structure the decision process. In this phase, the system under consideration is defined and the objectives are explored. One or more criteria, or attributes, are selected to describe the degree of achievement of each objective. Secondly, the design phase involves the development and

Table 1
SWOT matrix to analyze beaver reintroduction effects on the territory and habit features for their relocation.

References and Sources	Strengths	Weaknesses	References and Sources
Allen (1982), Baker and Hill (2003), Maringer and Slotta-Bachmayr (2006), Taylor et al. (2017)	● Presence of tree species preferred by beavers (willow, aspen, alder)	● Presence of species protected by law that would be in danger with the presence of the beaver	Deduction based on: Rozhkova-Timina et al. (2018), Taylor et al. (2017)
Allen (1982), Nolet and Rosell (1998), Stringer et al. (2018)	● Band of riparian vegetation	● Presence of landscape constraints (UNESCO sites and Regional Landscape Plane)	Deduction based on: Rozhkova-Timina et al. (2018), Taylor et al. (2017)
Allen (1982)	● Constant seasonal variation of flow rates	● Monumental trees	Deduction based on: Stringer et al. (2015), Taylor et al. (2017)
Derived from meetings with beaver experts	● Secondary river branches	● Rail and road network	Deduction based on Taylor et al. (2017) and derived from meetings with beaver experts
Dittbrenner et al. (2018)	● Optimal valley width (extensive riparian areas)	● Excessive presence/absence of predators (wolf, bear, lynx, fox)	Deduction based on: Nolet and Rosell (1998)
Allen (1982), Anderson and Bonner (2014), Maringer and Slotta-Bachmayr (2006), South et al. (2000)	● Watercourses with reduced slope	● Presence of bridles, embankments, bank defences, water intake/return structures, crossings	Deduction based on Taylor et al. (2017) and derived from meetings with beaver experts
Allen (1982), Rozhkova-Timina et al. (2018)	● Presence of wetlands	● Presence of agricultural canals	Deduction based on Taylor et al. (2017) and derived from meetings with beaver experts
Derived from meetings with beaver experts and Pollock et al. (2014)	● Presence of damaged landscapes (incised channels subject to constant erosion)	● Anthropization/urbanization	Deduction based on Taylor et al. (2017)
		● Crops and coppice wood	Deduction based on Taylor et al. (2017) and derived from meetings with beaver experts

References and Sources	Opportunities	Threats	References and Sources
Pollock et al. (2014)	● Beavers as an instrument for ecological restoration of damaged landscapes	● Impact on the landscape (felling of trees, plants and crops gnawed, construction of dams and consequent flooding of wooded areas, crops, roads)	Taylor et al. (2017)
Gorczyca et al. (2018), Stringer et al. (2015)	● Creation of basins and wet areas, branched river structure	● Degradation and destabilization of banks due to the excavation of burrows (micro and nano variations of the morphology of the place)	Gorczyca et al (2018), Rozhkova-Timina et al. (2018)
Nyssen et al. (2011)	● Variation of the water regime and flood mitigation	● Uncontrolled flooding (impact on the landscape/social and economic)	Klimenko and Eponchintseva (2014), Butler and Malanson (2005), Butler (1989)
Nummi (1989), Hood and Bayley (2008)	● Effect on the water balance of the area, droughts and forest fire risk reduction	● Damaged natural assets	Taylor et al. (2017)
Puttock et al. (2017), Martin et al. (2015), Stringer et al. (2015)	● Increase sedimentation and nutrient accumulation (decrease in speed and erosion)	● Damage to crops, fruit trees and coppice (economical damage)	Taylor et al. (2017)
Rozhkova-Timina et al. (2018)	● Changing of flora and fauna species	● Duration of the dam not predictable (variable duration from 1 to 50 years) with following management of flood waves and material presence in the riverbed (timber, mud/sediments, stones)	Rozhkova-Timina et al. (2018), Butler and Malanson (2005)
Rozhkova-Timina et al. (2018)	● Increase biodiversity of species living in or preferring conditions of humidity		
Stringer et al. (2015)	● Spatial change of forest structure (lighter at ground level and growth of species not commonly associated with riparian areas)	● Death of part of the vegetation present, depending on the type	Rozhkova-Timina et al. (2018), Thompson et al. (2016)
Stringer et al. (2015)	● Differentiation in the age of the species preferred by beavers	● Decrease in species for which the habitat created by the beavers is not favourable	Stringer et al. (2015)
Ruys et al. (2011)	● Cohabitation with nutria	● Loss of ecological continuity of species associated with old woods	Stringer et al. (2015)
Rosell et al. (2005)	● Diversified and abundant bird species more than without beavers	● Spatial redistribution of reintroduced individuals	Rozhkova-Timina et al. (2018)
Bouwes et al. (2016), Rosell et al. (2005)	● Increased areas suitable for fish reproduction and deposition, constant maintenance of the ideal water temperature	● Decrease dissolved oxygen, slow flow and reduced circulation within the ponds. Possible death of some species of fish (degenerate case)	Rozhkova-Timina et al. (2018)
Stringer et al. (2015)	● Limitation of some non-native invasive species	● Dams as barriers for moving fish (influence on some types of fish)	Rosell et al. (2005)
Elliott et al. (2017), Puttock et al. (2017)	● Improvement of water quality, pollutants retained in the sediments	● Spread of non-native invasive species	Stringer et al. (2015)

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Table 1 (*continued*)

References and Sources	Opportunities	Threats	References and Sources
Rozhkova-Timina et al. (2018)	● Influence on the nitrogen cycle, allochthonous nitrogen fixation	● Influence on carbon cycle (accumulation of carbon in beaver meadows, releases of methane in the troposphere)	Whitfield et al. (2015)
Derived from meetings with beaver experts	● Dams as an ecological corridor	● Possible spread of diseases	Taylor et al. (2017)
Nolet and Rosell (1998)	● Wildlife tourism and hunting	● Possible reduction of dissolved oxygen and creation of anaerobic conditions (degenerate case)	Rozhkova-Timina et al. (2018)
Derived from meetings with beaver experts	● Cultural growth of local populations thanks to the implementation of awareness actions and training courses (reintroduction as an educational tool)	● Possible death of beavers invested or exhausted by the current of water taken for hydroelectric	Derived from meetings with beaver experts
Derived from meetings with beaver experts	● Increase ecological knowledge on the species thanks to monitoring activities	● Consequent increase in beavers number, loss of diversity and increase of human-beaver conflicts	Nolet and Rosell (1998)

analysis of possible courses of action. Thirdly, during the choice phase, alternatives are evaluated and a set of specific courses of action is considered. Furthermore, detailed analyses, such as the sensitivity analysis, are developed in order to obtain useful recommendations. Finally, the complete set of data, information and knowledge becomes available evidence for planners, decision-makers and analysts.

3. Application

3.1. Description of the context of the research

In Italy, no action was actively performed after the beaver disappearance (Nolet, 1997). For this reason, this project considers and evaluates the reintroduction of beavers in Italy and in particular, in the region of Piedmont (Fig. 2).

The existence of this animal in Italy from the Mesolithic to the Contemporary Era, was reconstructed through a literature review and historical bibliographic research. The timeline reported in Fig. 3 summarize the literary or historical quotes of beavers in Italy.

Before the 16th century, the presence of the beaver is confirmed by various authors via the use of allegorical figures, but the identification of its distribution is more difficult. Only a few authors clearly refer to beaver location. Varrone (47–45 BC), in Roman times, and Fazio degli Uberti (1368), in the Middle Ages, respectively place the beaver in the Lazio region and in the surroundings of Ferrara. Thus, it is possible to assume that the beaver was present in the wooded marshes of Northern and Central Italy and that its distribution area gradually decreased over the centuries. Uncontrolled hunting and fragmentation of beaver habitat by human activity, such as land reclamations, led to its disappearance (Pratesi, 2001).

Nolet and Rosell (1998) dated the disappearance of the beaver to 1541, although there is not a certainty as to when the beaver really disappeared (Aldrovandi, 1637). Nevertheless, it is relevant to evidence that, at the end of October 2018, a hunter noticed some signs in Tarvisio, which could be attributable to the presence of beavers. This hypothesis was confirmed at the end of November 2018 by the presence of a specimen of *Castor fiber* captured by photographic traps (Pontarini et al., 2018). This beaver probably came from Austria and does not have conservative importance. However, it gives hope for a natural recolonization of the Italian territory.

3.2. SWOT development

The SWOT analysis was carried out in order to highlight habitat characteristics and the effects of beavers on the territory. Different sources were consulted, including several literature references on methods, indexes and models applied in the context of beavers, such as Habitat Suitability Indexes (Allen, 1982), GIS-based habitat suitability models (Maringer and Slotta-Bachmayr, 2006; Anderson and Bonner, 2014; Stringer et al., 2018), beaver habitat classification systems (Howard and Larson, 1985; McComb et al., 1990) and Beaver Intrinsic Potential model (Dittbrenner et al., 2018). These models generally consider only habitat variables needed for beaver life, such as vegetation composition and distribution, stream gradient and substrate, valley width, flow rate, water level and minimum habitat area. However, they disregard variables strictly connected to the anthroposphere with which this animal could interact, such as agricultural channels, road network and protected landscapes. These variables were explored through a bibliographic review of the effects of beavers on the ecosystem (Cazzolla Gatti et al., 2018; Rozhkova-Timina et al., 2018; Stringer et al., 2015; Ruys et al., 2011; Rosell et al., 2005), on the hydraulics and the hydrology of the area (Gorczyca et al., 2018; Rozhkova-Timina et al., 2018; Klimenko and Eponchintseva, 2014; Nyssen et al, 2011; Butler and Malanson, 2005), on climate (Rozhkova-Timina et al., 2018; Whitfield et al., 2015; Hood and Bayley, 2008) and on the socio-economic sphere (Taylor et al, 2017; Campbell-Palmer and Rosell, 2010;

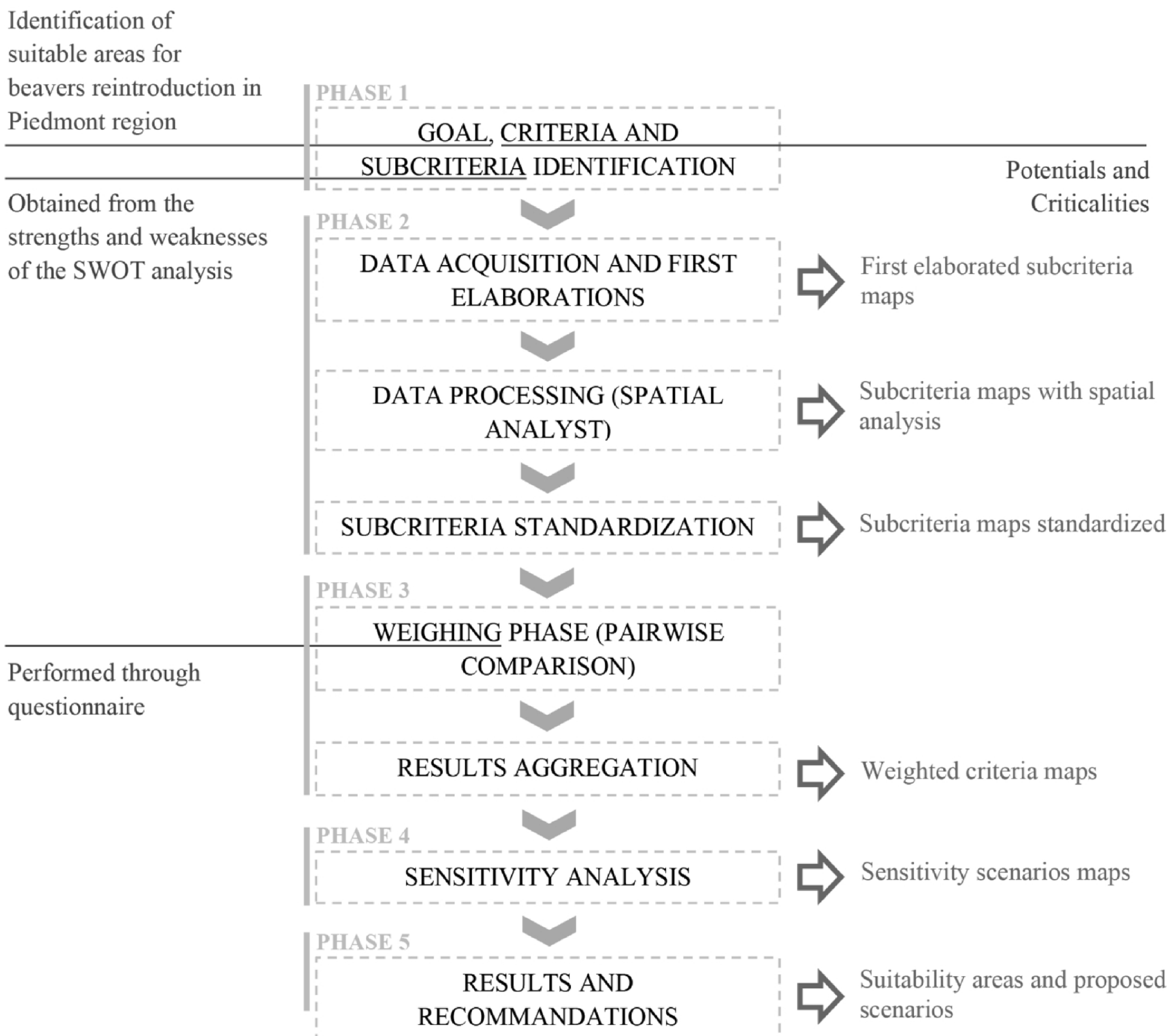

Fig. 5. Spatial Multicriteria analysis scheme subdivided into five phases and reporting the outputs obtained during each step (elaborated from Malczewski (1999)).

Table 2
List of indicators selected for the spatial multicriteria analysis. The indicators derive from the spatialization of strengths and weaknesses into potentials and criticalities.

Strengths (SWOT analysis)		Potentials (Spatial Multicriteria Analysis)
Presence of tree species preferred by beavers (willow, aspen, alder)	→	• Species composition of woody vegetation • Function of woody vegetation
Band of riparian vegetation	→	• Presence of vegetation within 20 m from the stream
Constant seasonal variation of flow rates		
Secondary river branches		
Optimal valley width (extensive riparian areas)		
Watercourses with reduced slope	→	• Stream gradient • Stream substrate
Presence of wetlands	→	• Presence of wetlands
Presence of damaged landscapes (incised channels subject to constant erosion)	→	• Level of naturalness of the territory
Weaknesses (SWOT analysis)		**Criticalities (Spatial Multicriteria Analysis)**
Presence of species protected by law that would be in danger with the presence of the beaver	→	• Protected natural areas
Presence of landscape constraints	→	• Protected landscapes
Monumental trees	→	• Distance from monumental trees
Rail and road network	→	• Distance from railways and highways • Distance from provincial, state, municipal roads
Excessive presence/absence of predators (wolf, bear, lynx, fox)		
Presence of bridles, embankments, bank defences, water intake/return structures, crossing	→	• Density of hydraulic works
Presence of agricultural canals	→	• Distance from agricultural canals
Anthropization/urbanization	→	• Level of anthropization of the territory
Crops and coppice wood		

Table 3
List of criteria and sub-criteria considered for the evaluation of beaver reintroduction. For each sub-criterion a short description, the source data and scale, the spatial analysis performed and the bibliographic sources for the standardization procedure are given.

Criteria	Sub criteria	Description	Source map	Spatial analysis	Bibliographic sources for standardization
Potentials	Species composition of woody vegetation	It subdivides tree species into deciduous trees preferred by beavers, broad-leaved trees, mixed deciduous and coniferous woods, conifers and other (all that is not woody vegetation).	Map of woodland, Geoportal of Piedmont Region (Shapefile, 2016 – scale 1:10000) and Corine Land Cover map, SINAnet (Shapefile, 2012 – Scale 1:100000)	Reclassification. Deciduous trees preferred by beavers have the highest score (100); broad-leaved trees (80); mixed deciduous and coniferous (60); conifers (40); the score is nil in the rest of the territory.	Beavers prefer to feed willow, poplar, alder and ash (Maringer and Slotta-Bachmayr, 2006). However, these varieties are not the only source of food. Different types of broad-leaved trees are regularly included in the feeding of this rodent when present in large quantities (Allen, 1982; Taylor et al., 2017). Also conifers are not excluded from the diet when deciduous trees are absent (Baker and Hill, 2003).
	Function of woody vegetation	It represents the role that forest plays, subdivided into productive, protective, tourist-recreational, naturalistic and environmental function.	Map of woodland, Geoportal of Piedmont Region (Shapefile, 2016 – scale 1:10000)	Reclassification. Naturalistic function has the highest score (100); protective (80); tourist-recreational (60); without specific function (50); productive and protective (40); productive (20); the score is nil in the rest of the territory.	Beavers prefer to live in freshwater habitats surrounded by woods (Rozhkova-Timina et al., 2018), so the optimal habitat for this animal will be given by wooded areas as natural as possible, where it can live undisturbed.
	Presence of vegetation within 20 m from the stream	It represents the strip of vegetation along the watercourse within 20 m from the banks.	Map of woodland, Geoportal of Piedmont Region (Shapefile, 2016 – scale 1:10000) and Map of riverbed types and flow rates, Geoportal of ARPA Piedmont (Shapefile, 2005 – scale 1:100000)	Reclassification. Riparian vegetation has the highest score (100); no riparian vegetation (10); the score is nil in the rest of the territory (outside of 20 m buffer zone).	Beavers prefer to live in freshwater habitats surrounded by woods (Rozhkova-Timina et al., 2018). The distance traveled by the beaver to obtain food, however, seems to depend on various factors including topography of the place, distribution and type of woody vegetation, as well as the minimum area, intended as the minimum size that habitat must have to support beaver settlement. In this case, it was considered 20 m from the waterway, minimum distance from which beaver signs have been identified (Nolet and Rosell, 1998) and often associated with the minimum size of continuous habitats (Maringer and Slotta-Bachmayr, 2006).
	Stream gradient	Inclination or degree of steepness of a watercourse or a stretch of it.	Map of riverbed types and flow rates, Geoportal of ARPA Piedmont (Shapefile, 2005 – scale 1:100000)	Reclassification. Lakes and gradient < 6% have the highest score (100); ≥6% (80); 1–16% (60); not identified gradient (50); ≥16% (10); the score is nil in the rest of the territory.	Beaver prefer water bodies with a gradient < 6% and the number of colonies decrease with the increase of gradient until to annul for gradient > 15% (Allen, 1982).
	Stream substrate	Material that constitutes watercourse's bed classified as rock, rock and/or loose materials, rock and/or alluvial deposits, alluvial deposits, unidentified.	Map of riverbed types and flow rates, Geoportal of ARPA Piedmont (Shapefile, 2005 – scale 1:100000)	Reclassification. Alluvial deposits have the highest score (100); rock and/or alluvial deposits (60); not identified substrate (50); rock and/or loose materials (10); the score is nil in the rest of the territory.	Beavers prefer water bodies characterized by soft substrates (South et al., 2000) where it can easily dig the den and building dams. Activities seem to reduce or even cancel out where there are rocky substrates or large boulders (McComb et al., 1990).
	Presence of wetlands	Presence of natural environments characterized by the presence of land and water, such as swamps and ponds, peat bogs, marshes and ponds, wet forests, lakes, riparian areas, running waters.	Map of wetlands, Geoportal of ARPA Piedmont (Lyr file, 2011 – scale 1:10000)	Reclassification. Wetlands have the highest score; the score is nil in the rest of the territory.	Beavers live in freshwater habitats surrounded by woods (Rozhkova-Timina et al., 2018) with a preference for habitats characterized by standing water (Stringer et al.,2015). Their damming activity change the environment creating unique lentic habitat (Stringer et al., 2015; Taylor et al, 2017).
	Level of naturalness of the territory	Relates natural areas, represented by wooded areas, semi-natural environments, wetlands and water bodies, and artificial/agricultural areas	Corine Land Cover map, SINAnet (Shapefile, 2012 – Scale 1:100000)	Reclassification. Natural areas have the highest score; the score is nil in artificial/agricultural areas.	Beavers live in freshwater habitats surrounded by woods, but it is possible to find them also along agricultural canals or in suburban and urban areas (Taylor et al., 2017). However, in order to identify an area suitable for reintroduction it is necessary to take into account what is the optimal habitat for the life of this animal, that meets its needs and without beaver-man conflicts that would put its safety at risk.

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Table 3 (*continued*)

Criteria	Sub criteria	Description	Source map	Spatial analysis	Bibliographic sources for standardization
Criticalities	Protected natural areas	Consisting of natural areas protected at regional, national or community level such as Parks, Sites of Regional Interest (SIR) and Sites Natura 2000 (Sites of Community Interest – SCI and Special Protection Areas – SPA)	Map of natural protected areas, Piedmont Region's web site (Shapefile, 2017 – Scale 1:10000)	Reclassification. Natural protected areas have the highest score; the score is nil in the rest of the territory.	Beavers are able to change the environment, creating a unique habitat (Stringer et al., 2015; Taylor et al., 2017). However the transformation imposed by the beaver, with the construction of dams and the consequent flooding of the adjacent areas, leads to the death of part of the vegetation due to the lack of oxygen in the soil and a change in the species of flora and fauna (Rozhkova-Timina et al., 2018). For this reason, it is good to protect those natural areas of regional, national or international importance which could otherwise be damaged by the presence of this rodent.
	Protected landscapes	Criterion consisting of the "Sites included in the UNESCO World Heritage list" and the "Rural areas of specific landscape interest"	Regional landscape plan, Geoportal of Piedmont Region (Shapefile, 2017 – Scale 1:25000)	Reclassification. Protected landscapes have the highest score; the score is nil in the rest of the territory.	Beavers are able to change the environment, creating a unique habitat and landscape (Taylor et al., 2017). For this reason, it is good to protect those areas of specific landscape and cultural interest which could otherwise be damaged by the presence of this rodent.
	Distance from monumental trees	Criterion constituted by "Sites It represents the distances from monumental trees, a common good with a naturalistic, landscape and historical-cultural value.	National list of monumental trees, Web site of Ministry of Agricultural, Forestry and Tourism Policies (Excel File, 2018)	Euclidean distance. Monotonically decreasing function that assigns the higher score to areas which are less than 20 m away from monumental trees and the lower score to areas more than 100 m away.	Beavers prefer to feed soft woody vegetation with diameter < 10 cm or at the most of 20 cm. But also, trees with diameter > 100 cm are been used by beavers (Stringer et al., 2015). The distance traveled by the beaver to obtain food seems to depend on various factors including topography of the place, distribution and type of woody vegetation, as well as the minimum area, intended as the minimum size that habitat must have to support beaver settlement. In this case, it was considered a minimum distance of 20 m from the tree - i.e. the minimum distance from which beaver signs have been identified (Nolet and Rosell, 1998) and often associated with the minimum size of continuous habitats (Maringer and Slotta-Bachmayr, 2006) - and a maximum distance of 100 m (Allen, 1982).
	Distance from railways and highways	Represents distances from railways and highways.	Map of transport infrastructures, Geoportal of Piedmont Region (Shapefile, 2004 – scale 1:100000)	Euclidean distance. Monotonically decreasing function that assigns the higher score to areas which are less than 20 m away from highway/railways and the lower score to areas more than 30 m away.	The minimum distance from which beaver signs have been identified (Nolet and Rosell, 1998) is equal to 20 m from watercourse.
	Distance from provincial, state, municipal roads	Represents distances from provincial, state and municipal roads.	Map of transport infrastructures, Piedmont Region (Shapefile, 2004 – scale 1:100000)	Euclidean distance. Monotonically decreasing function that assigns the higher score to areas which are less than 5 m away from highway/railways and the lower score to areas more than 20 m away.	Beavers could degrade and destabilize riverbanks through burrowing (Taylor et al., 2017). The burrows have a maximum length of 4 m (Rozhkova-Timina et al., 2018). At the same time the minimum distance from which beaver signs have been identified (Nolet and Rosell, 1998) is equal to 20 m from watercourse.
	Density of hydraulic works	Density of embankments, crossings fords, bank defences, spillways, bridles, collection and restitution work.	Maps of hydraulic works, SICOD Piedmont Region (Shapefile, 2009 – scale 1:10000)	Kernel density. Monotonically increasing function that assigns the higher score to areas with less density of hydraulic works and the lower score to areas with high density.	Beavers are able to obstruct pipes and bridles with wood material and dig tunnels in the banks damaging hydraulic works and bank defenses and limiting or cancelling out their function. (Taylor et al., 2017)
	Level of anthropization of the territory	It highlights the presence of artificial, agricultural and natural surfaces (wooded, semi-natural areas, wetlands and water bodies).	Corine Land Cover map, SINAnet (Shapefile, 2012 – Scale 1:100000)	Reclassification. Artificial surfaces have the highest score (100); agricultural (60); the score is nil in natural areas.	Beavers live in freshwater habitats surrounded by woods, but it is possible to find them also along agricultural canals or in suburban and urban areas (Taylor et al., 2017). However, more an area is

(*continued on next page*)

Table 3 (*continued*)

Criteria	Sub criteria	Description	Source map	Spatial analysis	Bibliographic sources for standardization
					anthropized, more beaver-human conflicts will arise.
	Distance from agricultural channels	It represents distance from agricultural channels.	Maps of channel and conduits SIBI (Shapefile, 2016 – Scale 1:10000), Geoportal and web site of Piedmont Region (Shapefile, 1993 – Scale 1:100000)	Euclidean distance. Monotonically decreasing function that assigns the higher score to areas which are less than 20 m away from highway/railways and the lower score to areas more than 30 m away.	Beavers live in freshwater habitats surrounded by woods, but it is possible to find them also along agricultural canals or in suburban and urban areas (Taylor et al., 2017). Minimum distance from which beaver signs have been identified (Nolet and Rosell, 1998) and often associated with the minimum size of continuous habitats (Maringer and Slotta-Bachmayr, 2006) is 20 m from watercourse. While the minimum buffer zone to guarantee fluvial functionality is equal to 30 m (Manuale APAT, 2007).

Campbell et al., 2007). Based on the data collected and on a direct analysis of the beaver habits in Switzerland, where this animal has been reintroduced, it was possible to develop the SWOT matrix. The two main questions at the basis of the SWOT structuring were:

1. What are the aspects of the territory that can be a strength or weakness in the reintroduction of the beaver?
2. What opportunities and threats does reintroduction offer to the territorial context?

These two questions allow the comprehension of the internal factors, i.e. the intrinsic territorial characteristics, which can help or prevent to achieve the goal, and of the external factors, able to support or threaten the project, i.e. benefits or impacts on the territory caused by the reintroduction of the beaver. Fig. 4 shows the summary scheme of the SWOT analysis: the upper part of the matrix reports the internal factors, i.e. strengths and weaknesses, instead, the lower part, the external factors, i.e. opportunities and threats.

The SWOT Analysis was fundamental to obtain a complete view of the different aspects connected to the reintroduction project. In particular, the analysis was useful to identify the territorial characteristics necessary for reintroduction and the beavers' effects detectable on the territory. It also facilitated the identification of the variables to be considered in the spatial multicriteria analysis. The SWOT analysis can be used as a starting point for the creation of a reintroduction management plan able to reduce the negative impacts and increase the benefits. The result is the 4 × 4 matrix with all strengths, weaknesses, opportunities and threats (Table 1**)**.

3.3. MC-SDSS development

Once the SWOT analysis was performed, the Piedmont area was analysed through a spatial multicriteria analysis to identify suitable areas for a possible beaver reintroduction.

The procedure can be divided into five different phases, according to the scheme shown in Fig. 5.

Phase 1 consists in the definition of the problem structure. The analysis starts from the definition of the objective of the evaluation, which in this case was the identification of one or more areas suitable for the reintroduction of beaver in Piedmont. Subsequently, a number of criteria and a set of related sub-criteria were chosen, taking into account the needs of the animal and the positive and negative effects that it could generate on the territory. In particular, the problem was broken down into two criteria, called Potentials and Criticalities, which respectively consider 7 and 8 sub-criteria. These sub-criteria derive from the strengths and weaknesses contained in the SWOT matrix and they were transformed in spatial indicators for the Spatial Multicriteria Analysis. In order to have a clearer view of the correlation between SWOT and Spatial Multicriteria Analysis, Table 2 shows the link between strengths and potentials and between weaknesses and criticalities. As can be seen in Table 2, not all the strengths and the weaknesses of SWOT were considered for two main reasons. Firstly, the lack of data related to some aspects of the territory, such as the distribution of bears and foxes, and the presence of secondary river branches. Secondly, the complexity of spatializing some of these aspects with the resolution used in this case study, such as the distribution of lynxes and wolves, the seasonal variation of flow rates, and the valley width.

In Phase 2, each sub-criterion was implemented in a geographic system through different steps. Firstly, the spatial data and information were collected from some regional open databases (SICOD, Geoportal of Piedmont Region and of ARPA Piedmont) or national databases (SINAnet and Web site of Ministry of Agricultural, Forestry and Tourism Policies) and then developed into sub-criterion maps. Depending on the specific data, some preliminary developments were implemented. A merge of some shapefiles were obtained from different sources, as applied in agricultural canals. A reclassification was performed with

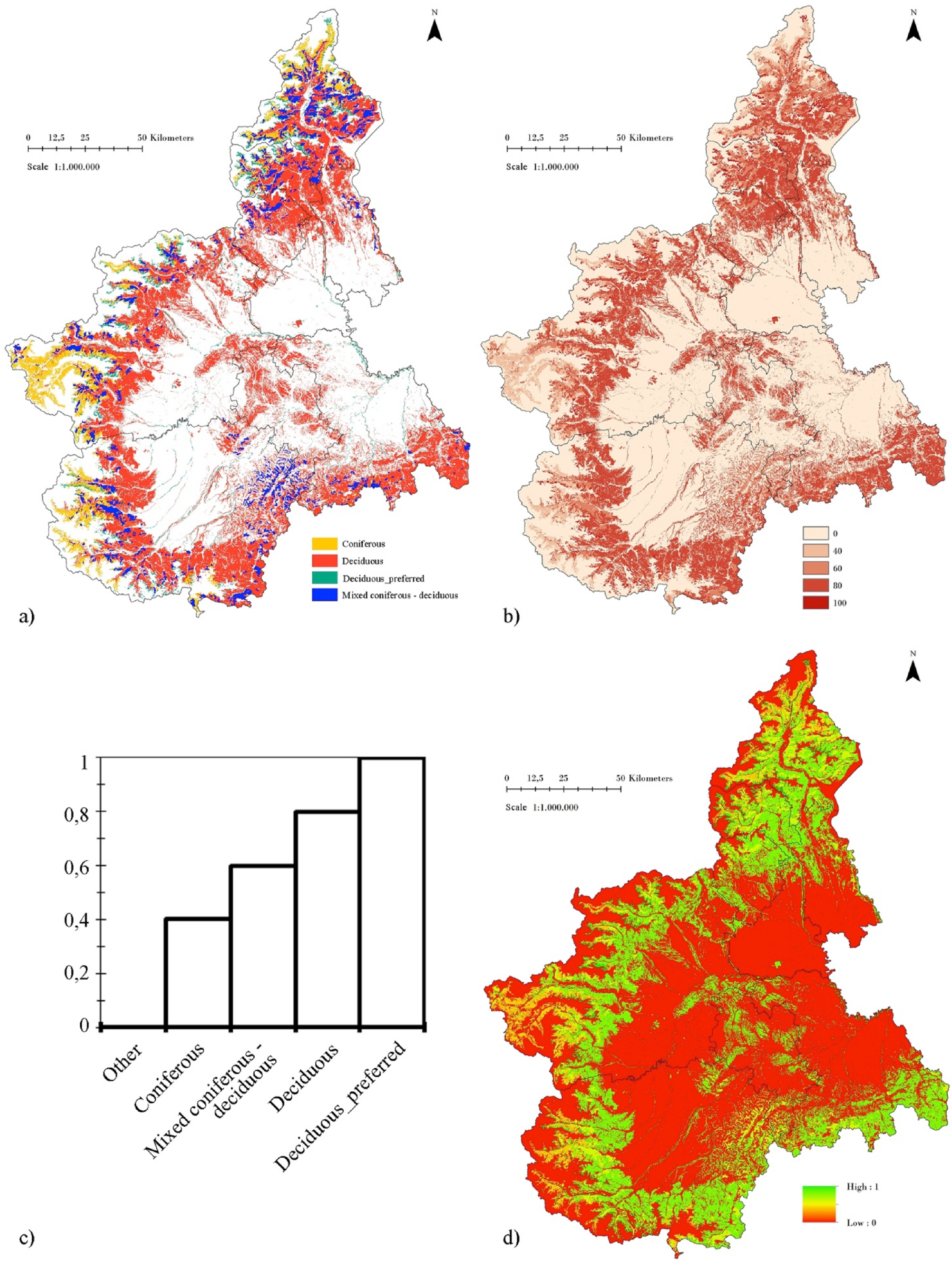
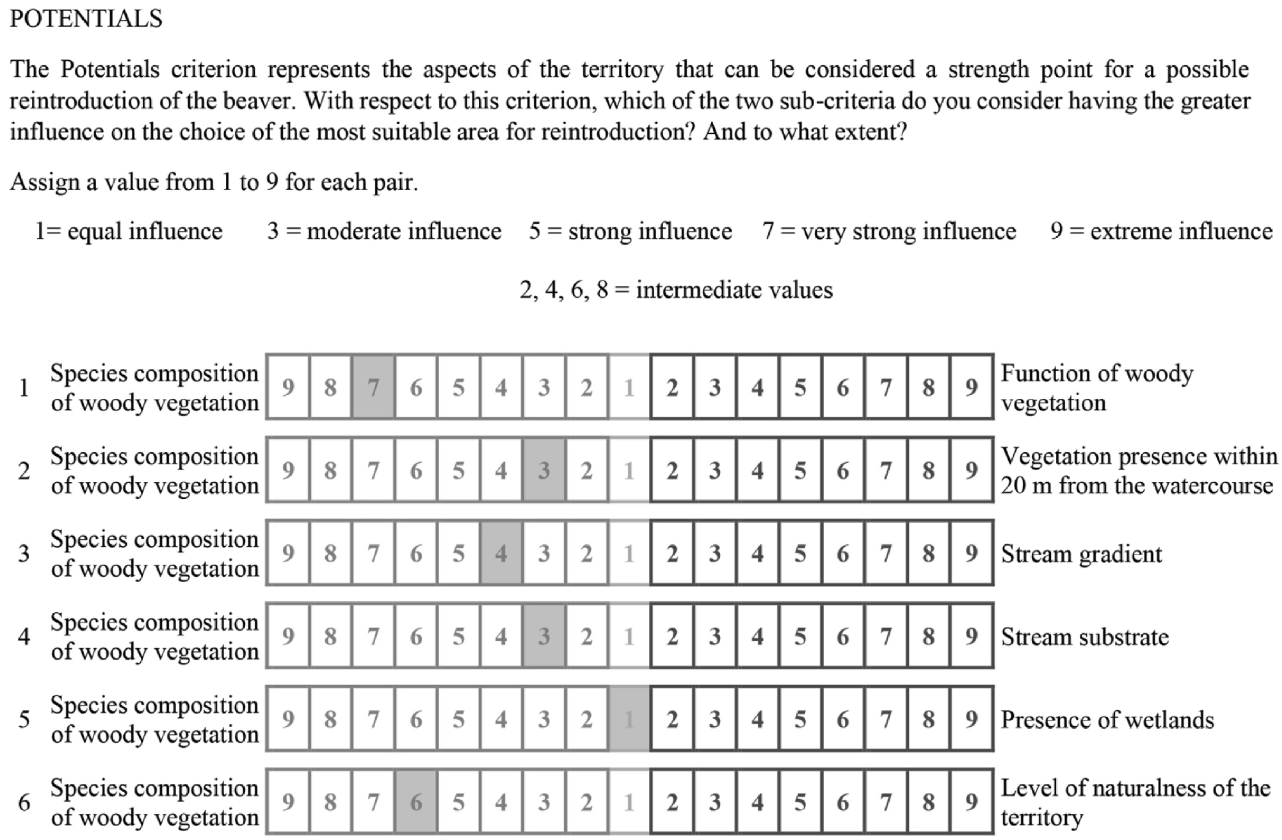


Fig. 6. Exemplary procedure for the creation of a sub-criterion map (Species composition of woody vegetation). Initial map (a), the spatial analyzed map (b), the standardization function (c) and the standardized map (d).


POTENTIALS

The Potentials criterion represents the aspects of the territory that can be considered a strength point for a possible reintroduction of the beaver. With respect to this criterion, which of the two sub-criteria do you consider having the greater influence on the choice of the most suitable area for reintroduction? And to what extent?

Assign a value from 1 to 9 for each pair.

1= equal influence 3 = moderate influence 5 = strong influence 7 = very strong influence 9 = extreme influence

2, 4, 6, 8 = intermediate values

1	Species composition of woody vegetation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Function of woody vegetation
2	Species composition of woody vegetation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Vegetation presence within 20 m from the watercourse
3	Species composition of woody vegetation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Stream gradient
4	Species composition of woody vegetation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Stream substrate
5	Species composition of woody vegetation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Presence of wetlands
6	Species composition of woody vegetation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Level of naturalness of the territory

Fig. 7. Exemplary of the questionnaire taken by one stakeholder. The sub-criterion related to the species composition of woody vegetation is compared to other six potential sub-criteria. The blackened boxes return the value assigned by the expert.

Table 4
Pair comparison matrix and its corresponding priorities obtained from expert judgments for Potentials. (A = Species composition of woody vegetation; B = Function of woody vegetation; C = Presence of vegetation within 20 m from the stream; D = Stream gradient; E = Stream substrate; F = Presence of wetlands; G = Level of naturalness of the territory).

Sub criteria	A	B	C	D	E	F	G	Priorities
A	1	7	3	4	3	1	6	0.322
B	1/7	1	1/6	1/5	1/4	1/5	1/5	0.025
C	1/3	6	1	1	4	2	4	0.182
D	1/4	5	1	1	4	3	4	0.195
E	1/3	4	1/4	1/4	1	3	2	0.057
F	1	5	1/2	1/3	1/3	1	5	0.158
G	1/6	5	1/4	1/4	1/2	1/5	1	0.061
Inconsistency	0.1							

respect to a specific attribute (as applied in the level of anthropization or naturalness of the territory). Clipping was carried out on a buffer zone, as applied in the presence of vegetation within 20 m from the stream. Secondly, different spatial analyses were conducted on the first maps in order to obtain a raster map for each sub-criterion, where each pixel represents a level of suitability. Three different types of spatial

Table 5
Priorities of Potentials and Criticalities, obtained by Expert Choice, based on the collected stakeholders' judgements. Reported in descending order.

Potentials	Priorities	Criticalities	Priorities
Presence of vegetation within 20 m from the stream	0.200	Protected landscapes	0.165
Presence of wetlands	0.199	Distance from railways and highways	0.164
Stream gradient	0.166	Density of hydraulic works	0.150
Species composition of woody vegetation	0.141	Distance from provincial, state, municipal roads	0.143
Level of naturalness of the territory	0.132	Distance from agricultural canals	0.110
Function of woody vegetation	0.090	Distance from monumental trees	0.105
Stream substrate	0.072	Protected natural areas	0.090
		Level of anthropization of the territory	0.074

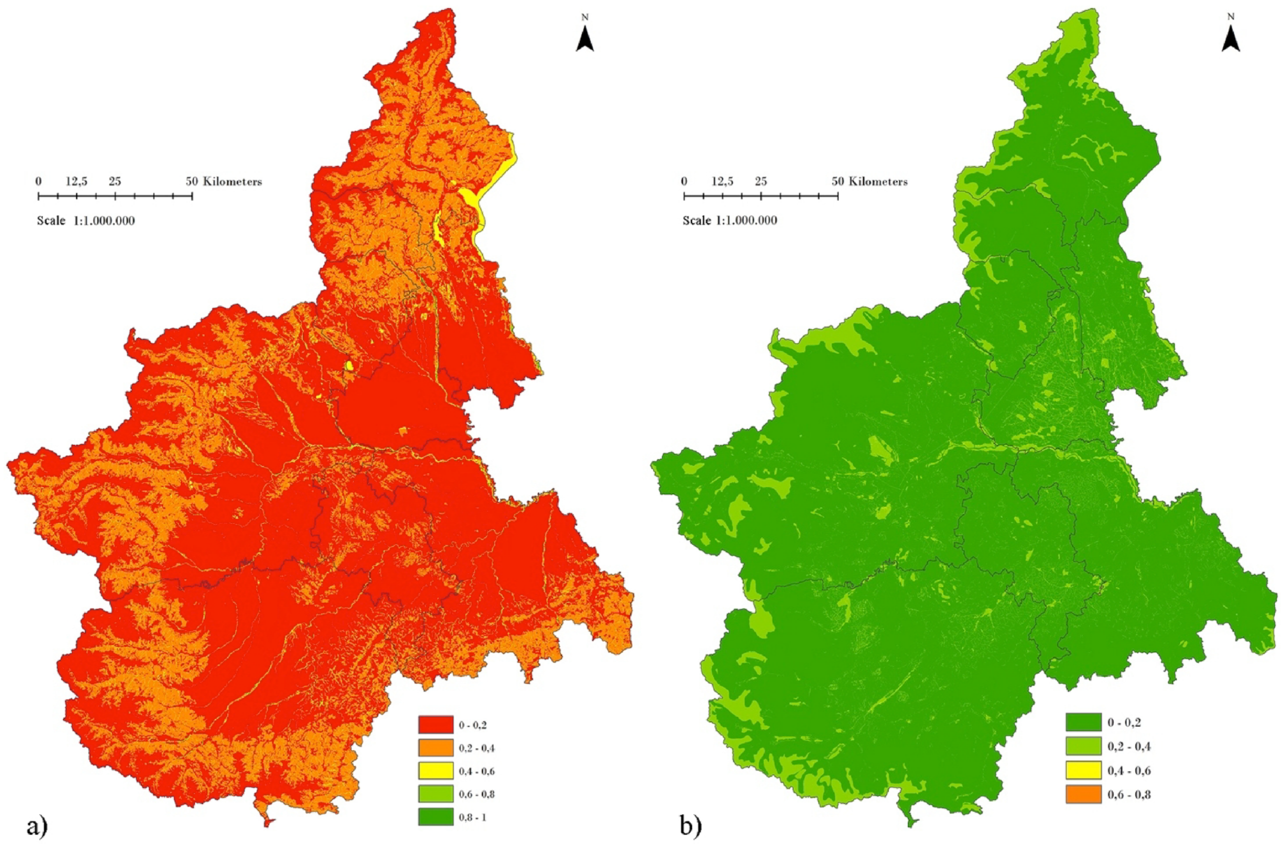


Fig. 8. Maps of Potentials and Criticalities. The Potentials (a) presents everywhere, except for water bodies, areas characterized by very low or low potentiality (red and orange range). The Criticalities (b) presents very low or low critical issues (green and light green range), excluding some areas that present medium–high criticalities. There are no very high critical areas.

analysis were performed: reclassification (used to assign a numerical value to the qualitative categories of some sub-criteria, such as species composition of woody vegetation, presence of wetlands, protected natural areas, protected landscapes), Euclidean distance (used to evaluate the distance from a certain factor, such as roads, monumental trees or irrigation canals) and kernel density (only used to obtain the density of hydraulic works, considering a 100 m radius). Thirdly, a standardization function was created for each sub-criterion, converting the different units of measures and values of each sub-criterion on a common scale, from 0 to 1 (Sharifi and Rodriguez, 2002; Beinat, 1997; Eastman, 2006). The original values were converted to 0 when the maps showed the minimum potentiality or criticality and 1 for the maximum. In the present study, the standardization was performed based on the literature. Table 3 describes the set of sub-criteria identified for the analysis for each criterion, reporting a short description for each of them, the source map used, the spatial analysis method and the bibliographic sources at the basis of standardization. To provide an illustrative example, Fig. 6 shows the procedure for the creation of a sub-criterion map. The figure reports the initial row map (Fig. 6a), the intermediary source map (Fig. 6b), the standardization function (Fig. 6c) and the standardized map (Fig. 6d) for the sub-criterion related to the species composition of woody vegetation (one of the Potentials sub-criteria).

Phase 3 is devoted to the identification of the importance of each sub-criterion to the achievement of evaluation goal. To define this importance, a variety of points of view are considered, involving different stakeholders to participate at a questionnaire. In this study, the stakeholders chosen were beaver experts, biologists, hydraulic engineers, farmers, architects and local inhabitants. In particular, each of them was asked to assign the level of importance of each sub-criterion in achieving the evaluation objective through a pairwise comparison. A ratio scale from 1 to 9 was used (the so-called Saaty fundamental scale (Saaty, 1980)), where 1 means an equal influence of the two sub-criteria and 9 an extremely importance of one sub-criteria with respect to the other. This weighting approach is used in the Analytic Hierarchic Process (AHP) methodology, one of the most common multicriteria analysis, to obtain the eigenvector of the pairwise comparison matrix which represents the synthesis of the numerical judgements established at each level of the network (Saaty, 2005). As an example, Fig. 7 and Table 4 respectively provide an exemplary questionnaire submitted to one expert and the corresponding pairwise comparison matrix with the priorities obtained for to the evaluation of Potentials.

All judgments were processed using the Expert Choice software[1]

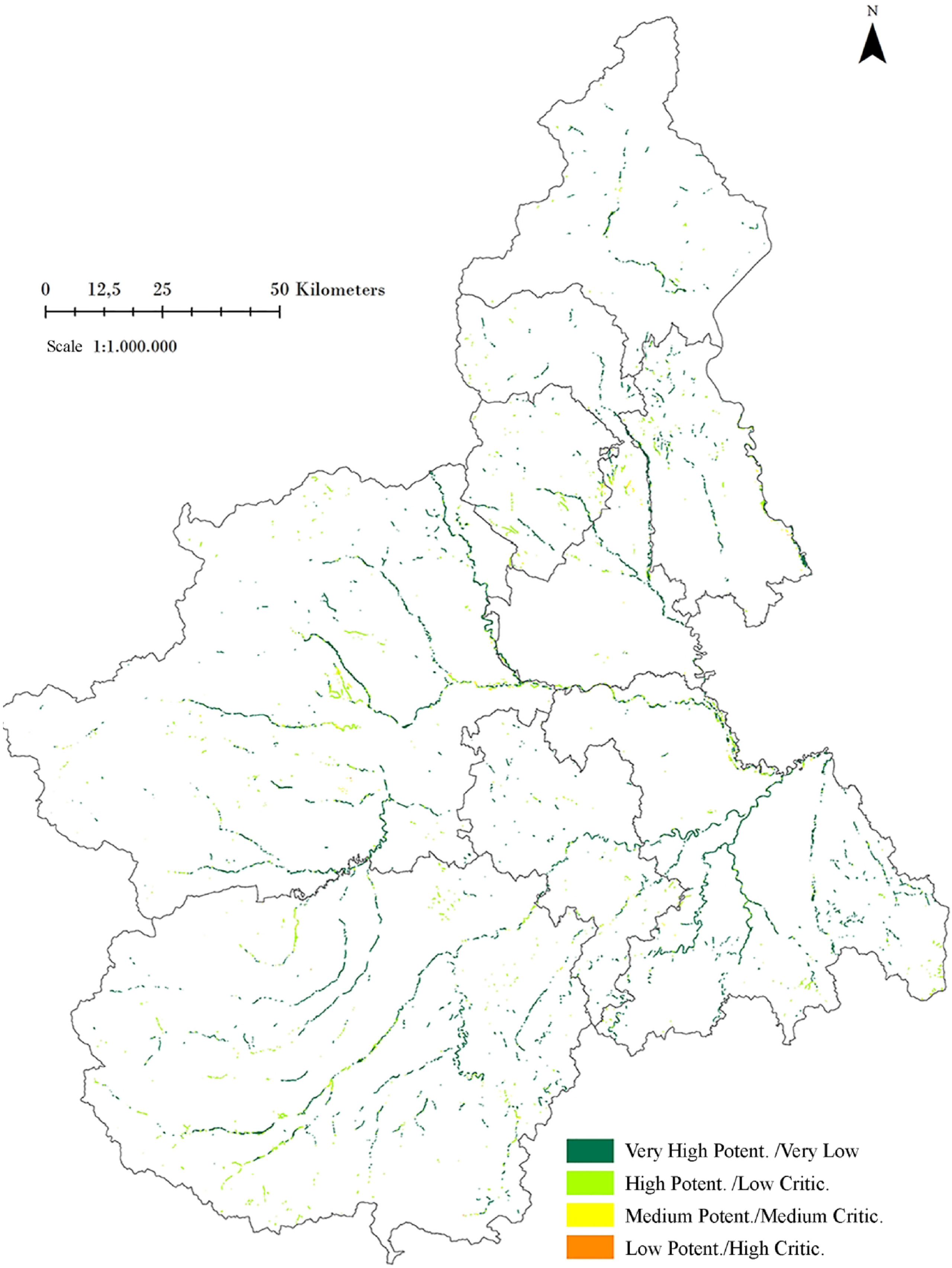


Fig. 9. Map of the areas suitable for the reintroduction of the *Castor fiber* in the Piedmont territory obtained intersecting map of Potentials and Criticalities. (Dark green = Potentials very high and criticalities very low; Light green = Potentials high and criticalities low; Yellow = Potentials and criticalities medium; Orange = Potentials low and criticalities high).

Table 6
Suitability classes obtained by intersecting Potentials and Criticalities.

Class	Suitability value	Potentials ∩ Criticalities	Colour
1	Very High	Very High P. ∩ Very Low C.	
2	High	High P. ∩ Low C.	
3	Medium	Medium P. ∩ Medium C.	
4	Low	Low P. ∩ High C.	

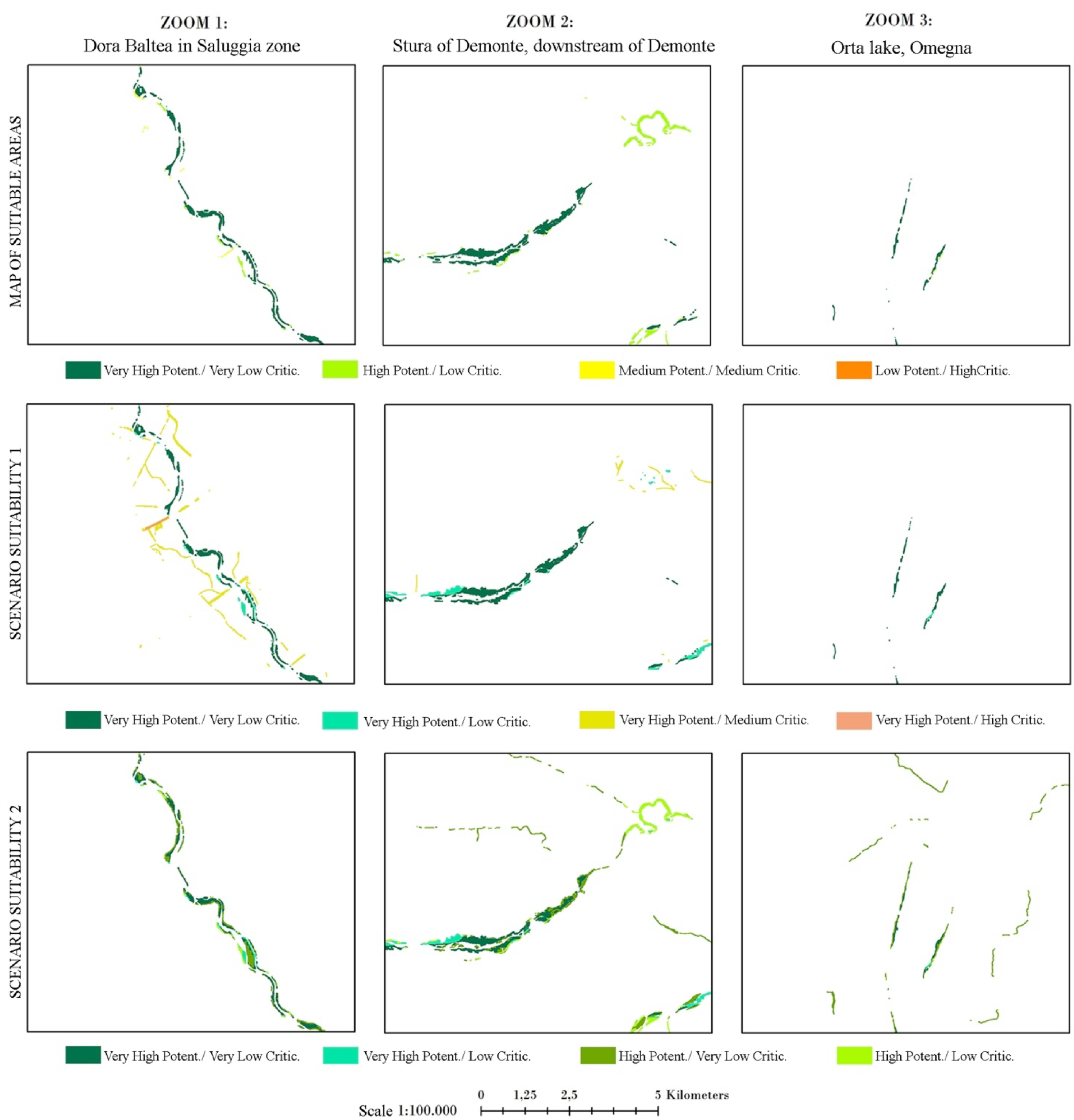


Fig. 10. Two scenarios of suitability (Scenario 1 and 2, respectively the images in the middle and below) compared with the final suitability map (images above) for three different areas.

which automatically elaborated the square matrices of the pairwise comparison. The software returned as outputs the priorities (Table 5), i.e. the weights, which represent the level of importance of each sub-criteria. The standardized maps, obtained during Phase 2 were aggregated to obtain the maps of Potentials and Criticalities (Fig. 8) through the weighted sum of each sub-criterion map.

At this stage, a Sensitivity analysis was conducted (Phase 4) by varying the set of weights assigned in order to verify the robustness of the analysis. First, the balanced scenario was developed, awarding equal importance to all sub criteria. Then, an OAT (One-At-Time) approach was implemented, raising the relevance of one criterion at a time and keeping all the other sub-criteria at the same weight. The sensitivity analysis showed similar results in the scenarios developed. This means that the evaluation was stable since the best and worst areas remained the same both for potentials and criticalities maps. As an example, the comparison between the map of Potentials and the balanced scenario of the sensitivity analysis is reported in the Appendix.

In Phase 5, the two maps of Potentials and Criticalities were intersected in order to obtain the map of the suitable areas for the reintroduction of the *Castor fiber* in the Piedmont territory (Fig. 9). This result is discussed in detail in the Results and Discussion section.

4. Results and discussion

The previous section described in detail the application of the integrated approach performed, SWOT and Spatial Multicriteria Analysis, to evaluate beaver reintroduction in Italy and to identify suitable areas in Piedmont. This section describes the results of analysis base on the Map of suitable areas previously obtained.

The Map of Suitable Areas (Fig. 9) is characterized by four suitability classes (Table 6) obtained through the intersection of the two maps of Potentials and Criticalities criteria.

The highest class, identified with Very High, includes areas with typical features of beaver habitat, such as riparian vegetation within 20 m from the stream, wetlands, low stream gradient, and very low criticalities, where human-beaver conflict is the lowest. By contrast, the suitability value class called Low includes areas with few beaver habitat characteristics and many critical elements, such as protected landscape, railways and streets or agricultural canals.

Overall, it is possible to highlight the presence of:

- numerous areas of very high suitability, interspersed with areas of medium–high suitability, distributed more or less continuously along the main waterways in foothill and in plane zones; these areas have maximum suitability (very high potential and very low criticality) for beaver reintroduction;
- most of the areas with very high suitability but very fragmented are in mountain zones;
- a limited number of areas (about ten) with low suitability for *Castor fiber* can be found throughout the territory.

Apart from the Map of Suitable Areas, which represents the final result of the analysis, two maps were created, Scenario Suitability 1 and 2 with a zoom on three different areas in Fig. 10. In particular, Scenario 1 shows areas with very high potential and high criticality where beaver settling after a natural redistribution could create conflict with humans with great probability. Scenario 2 highlights a greater number of areas suitable for the reintroduction, i.e. those areas with a very high suitability surrounded by buffer areas. Buffer areas are those characterized by high potential and low or very low criticality, without any problems for beavers or humans.

5. Conclusions

The present paper has illustrated the combination of SWOT analysis and Multicriteria Spatial Decision Support System (MC-SDSS) for the construction of a map of suitable areas for the reintroduction of the beaver in Piedmont. These areas are characterized by typical features of beaver habitat, such as riparian vegetation, wetlands, low stream gradient, and they present a very low level of criticality, since the risk of beaver-human conflict is very limited. The results show that the most suitable areas are mostly located along the main watercourses in foothill and in plane zones. At the same time, the model allows the identification of a number of buffer zones, characterized by lower potential than optimal habitats and by low or very low criticality. These zones further restrict human-beaver conflict in the event of a natural beaver redistribution. Overall, the results obtained are significant and in agreement with expectations, and the innovative approach proposed support the complex problem of localization, in line with national and international guidelines for reintroduction. Findings identify the suitable areas in terms of potentials for the beaver habitat and avoid conflicts with men and their settlements. These areas are usually determined using the Habitat Suitability Index models, which estimate the ability of a given habitat to support a specific species based on species-habitat relationships (United States Fish and Wildlife Service, 1981). The integrated procedure applied in this research combines SWOT analysis and MC-SDSS. Therefore, it is able to take into account not only the territorial characteristics necessary for the identification of a suitable habitat, but also economic and social aspects, useful for the elaboration of a shared action plan. In this way, environmental and technical characteristics, as well as socio-economic factors, can be considered simultaneously, and a long-term plan of action can be proposed for a wider area of the territory under consideration.

Moreover, the methodology proposed in this paper can usefully support both an investigation of beaver reintroduction in other territorial contexts or, more generally, the assessment and management of the potentialities and criticalities of habitats where some species have been already reintroduced or located. Regarding beaver reintroduction in other territories, the methodology and list of indicators could be used as a whole since it is consistent with the main national and international studies on the beaver benefits and impacts. However, to fit in with the specificities of a given territory, this list may need to be improved or changed slightly. As an example, in Northern European countries, such as Norway, Sweden or Finland, wood production is a leading sector of the economy, and the presence of beavers is often harmful because of the serious tree damage they cause (Parker et al., 1999). The model presented partially considers the damage to loggers in the sub-criterion level of anthropization. For Northern European countries, a higher level of attention would be necessary to this damage, for example by using an additional sub-criterion – and therefore a map – which would consider the presence of forests exploited for profit. On the contrary, some sub-criteria, such as the distance from monumental trees or protected areas, would be eliminated. The specific socio-economic and cultural policies of each country could be a reference to fix the list of relevant indicators.

For what concerns the maintenance of other species, the proposed methodology can be used both for guiding their reintroduction and for the management of those already present (Ovenden et al., 2019; Tosi et al., 2015). The present research could represent a valuable methodological framework where the indicators are necessarily adapted to the specific characteristics of the species considered. Moreover, the management of existing species is a relevant aspect both at a local and wider scale, and the methodology proposed can help public administrations in the definition of a plan of action.

For the specific area analysed, some reflections could be proposed as a guide for future research on this field.

Firstly, it should be noted that this study did not consider the entire territory of Northern Italy, where this animal could probably live. This is due to two main issues: (i) it is unfeasible to perform a single analysis on such extensive area, since details would be lost in the wider scale; (ii) standardization of the data based on the different regulations of each single regional body could cause an oversimplification of the final results. However, the proposed process is completely reproducible for other regions using the same set of indicators, which derives from a national and international research of suitable and unsuitable habitats for the beaver.

Secondly, the final map obtained, i.e. the Map of Suitable Areas, represents a good starting point for choosing the best place in which to reintroduce the beaver. However, further studies should be performed, in particular on the size, distribution and ecological continuity of the areas. In fact, due to the great adaptability of this animal and its tendency to move (Rozhkova-Timina et al., 2018), it is essential to evaluate the surface size and a buffer zone in order to avoid possible conflict generated by over-distribution.

Thirdly, the method performed to identify suitable areas for reintroduction should be coupled with an adequate management plan able to structure all the steps of the intervention and to manage all its aspects.

The result could be an instrument to analyse all aspects of this complex context but would not be a definitive answer to the question "Reintroduction - yes or no?". In fact, even if the final maps show many suitable areas in the Piedmont region with many benefits (Rozhkova-Timina et al., 2018), three fundamental aspects must be taken into account:

1. The beaver, which disappeared more than 500 years ago from our territory, could be seen negatively by the population as occurred with the natural return of wolf in the territories where it lived in the past.
2. Once reintroduced, beavers will probably migrate and settle to other areas, including suboptimal areas due to the great adaptability of this animal.
3. The probability of conflict between man and beaver is very high, so costs for the recovering should be taken to account (Campbell et al., 2007; Taylor et al., 2017).

If reintroduction is chosen, an information and training campaign will be necessary to raise the population's awareness of the benefits and impacts of the beaver in the territory. Moreover, a management program should be defined in advance both for the reintroduction of animals and for management of the damage/conflict. At the same time, it should be defined the rules at the basis of the reintroduction, such as who will intervene and how, and possible monetary compensation where damages occur. Management costs are not easy to estimate since they depend strictly on the studied area, the type of conflict, the solutions adopted, the possible compensation measures for damage to different goods and whether these actions are performed in the short or the long term. Nevertheless, an advance plan of actions would reduce costs to a minimum; instead, if plans are made only after beaver colonies have been already established, management could be more difficult and expensive (Taylor et al., 2017).

A future perspective of this research could consider the value of beaver reintroduction with respect to the provision or reduction of ecosystem services. According to Campbell et al. (2007), the only attempt to assess the role of beavers in the context of ecosystem services indicates that benefits are high. In fact, the wetlands created by beaver activity can offer and improve a wide range of ecosystem services, in particular by reducing erosion, improving water quality through the regulation of sediment retention, the level of nutrients and dangerous chemical components, reducing flood peaks after intense rainfall and storing water in the aquifer. The topic of ecosystem services and their evaluation has intensively increased in the last twenty years. More recently, the study of the benefits and impacts of wildlife has begun, the role of bees in crop production has been recognised, as well as the importance of the presence of a variety of species for biodiversity (Dee et al., 2019; Leroy et al., 2018). However, there is still little awareness at the political level on the role of animals in generating spin-off effects on a territory. The reintroduction of the beaver, as well of many other species, can strongly contribute to the restoration of the ecological and natural balance of an area. The present research could represent a first step in the direction of increasing consciousness of decision-makers, by guiding them in the definition of a strategic plan for increasing a variety of ecosystem services in their territory.

CRediT authorship contribution statement

Anna Treves: Conceptualization, Methodology, Validation, Data curation, Writing - original draft. **Marta Bottero:** Methodology, Validation. **Caterina Caprioli:** Methodology, Validation. **Elena Comino:** Conceptualization, Methodology, Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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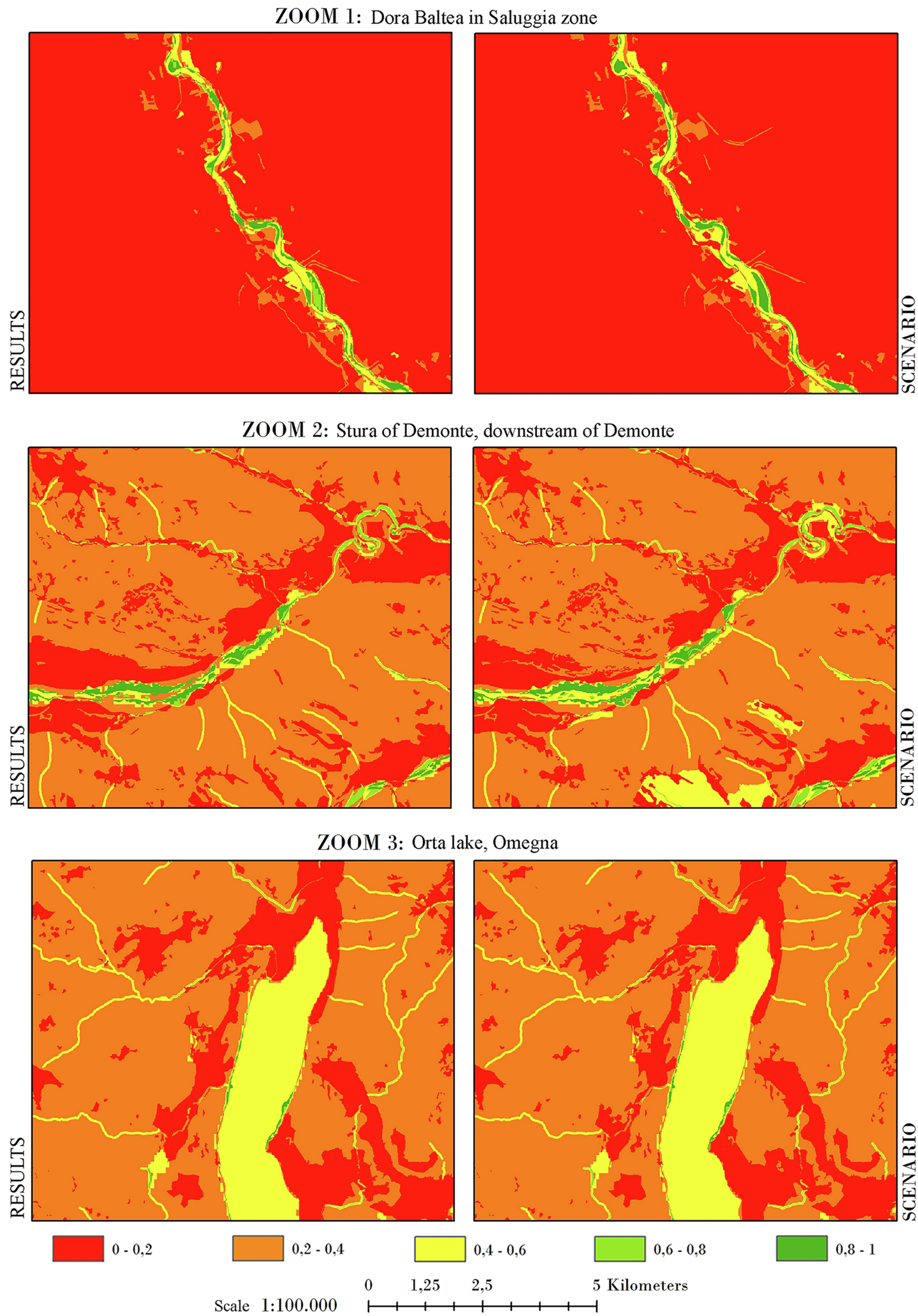
[1] https://www.expertchoice.com/2020.

Appendix A


ZOOM 1: Dora Baltea in Saluggia zone
RESULTS
SCENARIO
ZOOM 2: Stura of Demonte, downstream of Demonte
RESULTS
SCENARIO
ZOOM 3: Orta lake, Omegna
RESULTS
SCENARIO
0 - 0,2
0,2 - 0,4
0,4 - 0,6
0,6 - 0,8
0,8 - 1
0
1,25
2,5
5 Kilometers
Scale 1:100.000

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