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ORIGINAL PAPER

Management of grazing Italian river buffalo to preserve habitats defined by Directive 92/43/EEC in a protected wetland area on the Mediterranean coast: Palude Frattarolo, Apulia, Italy

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Abstract

Modern investigation through botanic, vegetation and soil analyses allowed us to establish, for the first time, the maximum herd size of grazing Italian river buffalo that would allow the preservation of habitats defined by Directive 92/43/EEC in a coastal area of the Mediterranean basin. The study was funded by project LIFE09 NAT/ITI000150 ("Humid coastal habitat conservations actions inside SIC - Zone umide della Capitanata"), and focused on an Italian wetland area called Palude Frattarolo in the Apulia region included in a SAC IT9110005 (Zone umide della Capitanata). Ten habitats defined in Habitat Directive 92/43/EEC were identified in the study area—six more than reported in the LIFE technical report, and only one (1150*) of the four habitats (1150*, 1510*, 2250*, 2270*) reported in the LIFE technical report was confirmed to exist in the study area. The most important buffalo grazing habitats were found to be 1410, 3170*, and 3290, none of which had been reported in this area previously.

Keywords Botanical · Habitats of Directive 92/43/EEC · Buffalo grazing load · Palude Frattarolo · Soil · Vegetation

Introduction

Europe has a long history of land use that has had a major impact on nature; it has resulted in the creation of diverse cultural landscapes that are home to a rich fauna and flora. However, human land use has also resulted in widespread degradation or destruction of the natural world, particularly during the twentieth century. From 1900 to the mid-1980s, Europe lost two-thirds of its wetlands and almost three-fourths of its sand dunes and heaths through land-use changes, infrastructural development, pollution, and urban expansion (European Commission 1995).

Part of the Mediterranean region has been European for a very long time. The wetlands around the Mediterranean Basin have long provided essential services to the people in this region and have played a very important role in their social and cultural activities. Recently, and especially in the first part of the twentieth century, humid areas in the Mediterranean were destroyed to prevent waterborne diseases, create new agricultural lands, and to generate areas suitable for housing, industry, and tourist facilities (Maiorca et al. 2002, 2020; Giusso del Galdo et al. 2008; Tomaselli et al. 2008, 2012; Silva et al. 2009; Farantouris 2009; Perrino et al. 2014; Cano et al. 2017; Spampinato et al. 2017, 2019; Quinto-Canas et al. 2018; Sciandrello et al. 2019). In the last few decades, this degradation of Mediterranean wetlands has resulted in the loss of some functions that they once provided free of charge: sediment and erosion control; maintenance of water quality and pollution reduction; maintenance of surface and underground water supplies; support for fisheries; areas for grazing, agriculture, and outdoor recreation; and habitats for flora and fauna that can also educate humans about the natural world (Poff et al. 1997; Postel et al. 1998; Baron et al. 2002; Millennium Ecosystem Assessment 2005; Hobbs et al. 2006; Finlayson et al. 2011; Cano-Ortiz et al. 2013).

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Because of the degradation of Mediterranean wetlands, it became clear that they had to be protected. This objective was first clearly expressed at the MAR (Marshes, Marecages, Marismas) Conference held in the Camargue, France, in 1962 (Daubercies 1963). Later, as the loss of wetlands became more extensive, remedial actions were stepped up. In 1995, the Barcelona Convention adopted new protocols that gave much greater attention to Mediterranean wetlands and coastal areas (Farantouris 2009). The goal of the MedWet (Mediterranean Wetlands) initiative is to stop and reverse the loss and degradation of Mediterranean wetlands, thus contributing to the conservation of biodiversity and to sustainable development in the region (Finlayson and Davidson 1998). The Ramsar Convention on Wetlands, adopted in 1993, has a program, a well-endowed budget, and a sizeable permanent secretariat that assists in the day-to-day operation of the treaty (Matthews 2013). Italy currently has 55 wetland sites, totaling 72,337 hectares, that are included in this convention. Three of those 55 sites occur in Apulia: Saline di Margherita di Savoia, Torre Guaceto, and Le Cesine (Ramsar Convention Secretariat 2017).

Recently, the European Commission approved funding for 84 new environmental innovation projects in 24 countries within the framework of the LIFE+ Nature & Biodiversity Programme 2009 (European Commission 2009a). These projects will demonstrate new methods and techniques for dealing with a wide range of Europe's environmental problems. The projects are led by "beneficiaries," or project promoters, who are based in several countries, including Italy. Italy has participated in 56 of these projects. One of them (LIFE09 NAT/IT/000150 "Zone Umide Sipontine—Conservation actions of habitats in the coastal wetlands of SCI wetlands of Capitanata") (European Commission 2009b) was assigned to the Apulia region with the following objectives: to conserve rare or endangered habitats of the Bosco dell'Incoronata Regional Natural Park and to increase the biodiversity of the Valle del Cervaro—Bosco Incoronata SCI (Site of Community Importance) within the Natura 2000 network. The short- to medium-term objectives were to restore and improve the SCI habitats 92A0, 6220*, and 91AA*; and to increase the individual abundances of species that are typical of these habitats (raptors, amphibians, reptiles, and bats). Among the longer-term objectives of the project, raising public awareness and increasing local community participation in order to improve habitat and species protection should play important roles in ensuring sustainable environmental management (European Commission 2009b).

Within the framework of the above mentioned project, the objective of the present study was to determine the maximum herd size of grazing Italian river buffalo (*Bubalus bubalis* L.) in some areas of the Zone umide della Capitanata (SAC IT9110005) using sustainability criteria, with a view to identifying the main actions required to preserve priority habitats (as defined in Directive 92/43/EEC) in this region. Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (informally known as the Habitats Directive) and the Birds Directive are collectively termed the Nature Directives. The Habitats Directive requires national governments to specify areas that are expected to ensure the conservation of flora and fauna species, so this directive has resulted in the creation of a network of protected areas—Special Areas of Conservation, SACs—across the EU. Together, the SACs and the preexisting Special Protection Areas comprise the so-called Natura 2000 network, which was established to protect species and habitat.

The research work described in this paper was carried out in 2013 as part of the A4 measure "Drafting of the pasture management" of the LIFE09 NAT/ITI000150 project (European Commission 2009b). The area studied here is currently mainly used as grazing land for a herd of 400 Italian river buffalo (henceforth "buffalo") (Rosati and Van Vleck 2002). Other animals (goat and sheep) also graze on this land, but in smaller numbers. Some of the study area has also been cultivated and urbanized. The parts of the SAC Zone umide della Capitanata considered in this work include the mouth of the Candelaro River, some of the coastal region, and the wetland area known as Palude Frattarolo, which covers 1485 hectares.

Study area

The study area is located in the municipality of Manfredonia, in the province of Foggia, Apulia region, southern Italy (Fig. 1). From a geomorphological point of view, the area is moderately flat, with slight depressions, bumps, and hills that become more pronounced upon moving from the coast to the hinterland, which includes Holocene and Quaternary terraces incised by rivers (the Candelaro and the Ofanto) that tend to meander to the sea. There are also many permanent and temporary ponds (the remnants of ancient coastal lakes).

Materials and methods

The methodology used in this work is important, as this study represents the first time that pedological and botanical data have been used together to determine a pasture plan. The methodology can be divided into four steps, as explained later. We chose to apply the aptitude assessment methodology used by the FAO (1976, 1991), which establishes a single crop evaluation methodology. It is based on the following rules: (a) the territorial suitability must refer to a specific use; (b) the assessment must compare various

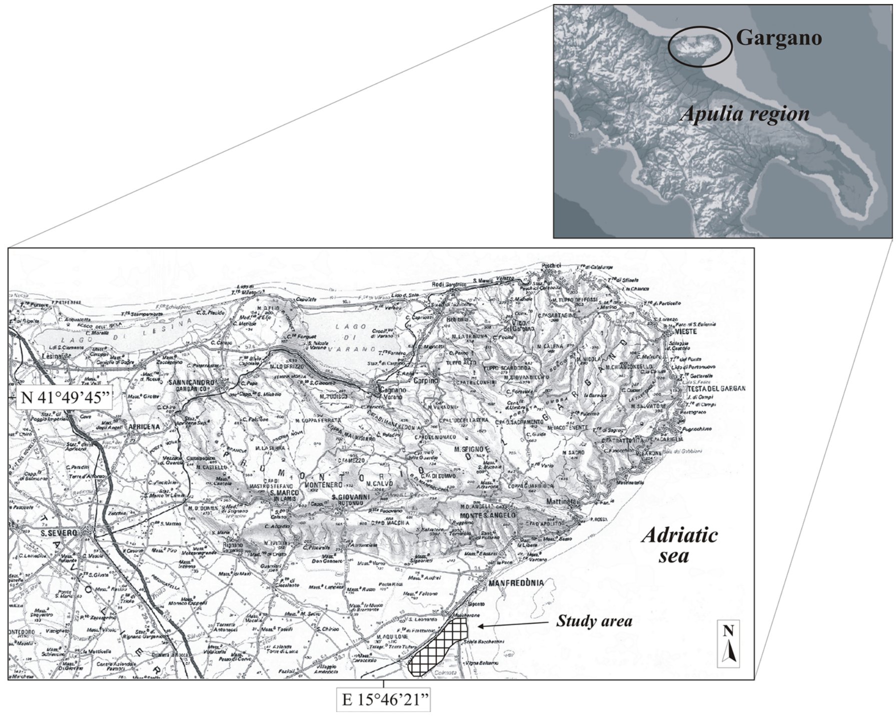


Fig. 1 Study area

alternative uses; (c) the suitability must account for the costs of preventing soil degradation; and (d) the assessment must be based on a multidisciplinary approach. The basic concept of the method is that of sustainable use; i.e., that the land can be used for an indefinite period without causing severe or permanent deterioration of the biodiversity, environmental quality, and therefore of the habitats in the region of interest.

Climate analysis

The climate analysis followed Rivas-Martínez (2004) in that it utilized the bioclimatic indices for 30 years (1963–1992) of thermopluviometric data extracted from the Annals of the Hydrological Basin Service of the Italian Ministry of Public Works (Protezione Civile Puglia 2018). The monitoring station was Manfredonia, the closest thermopluviometric station to the study area. The results of this analysis were only used to establish the general climatic framework for the study area.

Soil surveys

Soil surveys were performed based on existing data (ACLA 1 1999) as well as six soil profiles that were obtained in 2013 and fully analyzed for 20 physical and chemical parameters using official methods, namely methods 1, 2, 3, 5, 7, 8, 9, 10, 15, 26, 27, 29, and 30 of MUACS (1999), as described by the Institute for Agrobiology and Soil Science of Florence. The results of these analyses will be published in the near future.

Vegetation and habitat surveys

In total, 65 vegetation surveys were conducted according to the Zurich–Montpellier methodology (Braun-Blanquet 1932), which was used to build up a syntaxonomical scheme. The relevant phytosociological tables will be published in a subsequent paper. The Zurich–Montpellier methodology is widely applied to grazing, agricultural, and protected areas of the Mediterranean to probe the composition of the vegetation and the texture and chemical composition of the soil in a particular region (Spampinato 2001; Cano-Ortíz et al. 2005, 2009a, b, c, 2010, 2014; Cano et al. 2007; Mendes et al. 2015). The habitats defined in Council Directive 92/43/EEC (Annex I) were identified via phytosociological data, the Italian Interpretation Manual of the Directive 92/43/EEC Habitats (Biondi and Blasi 2009), and the Interpretation Manual of European Union Habitats (version EUR27) (Directorate-General for Environment 2007).

Suitability assessment and buffalo herd size

In the first step of the suitability assessment (FAO 1976, 1991) for the studied area, a landscape unit map was obtained by integrating information interpreted from aerial photographs with holistic morphological information, land use information, and lithological data. A soil map (1:5,000 scale) was then created using preexisting data as well as information obtained by extracting a number of soil profiles that were fully analyzed in terms of their physicochemical parameters. The soil data were entered into a database that formed the basis for subsequent attitudinal assessments. Data on the vegetation, 92/43/EEC habitats, and livestock-relevant herbaceous and shrub species present were been added, allowing the development of soil and vegetation maps at 1:5000 scale. These detailed data were used to generate pasture maps for buffalo, sheep, and goats living in the area of interest.

Land-use and vegetation characteristics relating to the sustainability of soils under pressure from grazing and the suitability of soils for grazing (based on vegetation typology, species cultivation, and reference values for the climatic, morphological, hydrological, and soil requirements) were evaluated, allowing land uses to be rated for grazing suitability. Five classes of land-use suitability were defined: S1—suitable, with rating values between 85 and 100; S2—moderately suitable, with rating values between 60 and 85; S3—unsuited, with rating values between 40 and 60; N1—temporarily unsuited, with rating values between 25 and 40; N2—permanently unfit, with rating values between 0 and 25. Seven limiting factors were identified: Is - marginally suitable, with limitations relating to internal and external drainage, texture and permeability of soils; Isf - temporarily unsuitable, with limitations relating to internal and external drainage, useful depth at the root, permeability of soils and content of soluble salts; Vf - suitable, with limitations relating to herbaceous vegetation cover, the palatability of herbaceous species and the organic carbon content; Vif - Marginally suitable, with limitations relating to herbaceous plant cover, palatability of herbaceous species, external and internal drainage, organic carbon content; Vis - Marginally suitable, with limitations relating to herbaceous vegetation cover, internal and external drainage and soil permeability; Visf - Marginally suitable, with limitations relating to shrubby vegetation cover, the palatability of herbaceous species, internal and external drainage of soils, permeability of soils and exchangeable sodium content; Vsf - marginally suitable, with limitations relating to the herbaceous plant cover, the palatability of the herbaceous species, the organic carbon content and the skeleton content.

Database processing yielded a thematic map that could be used to assess the areas of the region of interest that were most suitable for grazing, as well as environmentally fragile areas and necessary or recommended conservation practices. The general scheme that was used to determine the suitability of each plot for grazing is shown respectively in Table 1 and in Fig. 2.

Assessing the suitability of soils for use as livestock pasture necessitates some specific considerations that are not included in other soil aptitude evaluations: (a) territorial requirements depend on the grazing system used, which ranges from extensive to intensive, and (b) soil surveys and subsequent evaluations for extensive grazing practices are usually less rigorous than those performed for intensive grazing practices. Grazing suitability evaluations must consider (i) the predicted primary production (the capacity of the pasture land to produce feed for grazing); (ii) the predicted secondary production (the amount of livestock product produced); (iii) changes in the number of livestock that are grazing per unit area due to spatial and temporal variations in the amount of forage available; and (iv) the nutritional needs of the cattle (food and water), which remain relatively constant across the seasons.

Therefore, for all types of pasture, there are four aspects that must be considered: (1) the growth and composition of pabulum flora for primary production; (2) the type of cattle that are to be bred (species, race, etc.) for secondary production; (3) territorial characteristics that may affect the breeding of the cattle; (4) land conservation through sustainable management of grazing.

It was decided that a GIS (geographic information system) would be utilized for grazing management in the drained areas of Lago Salso (Salso Lake) and Palude Frattarolo (Frattarolo Swamp), which cover 1007.0 hectares. These areas were chosen based on botanical surveys that identified as many pabular species as possible and soil surveys that evaluated the suitability of the plot for grazing. Particular attention was paid to map units 1–12, which were generally categorized into the S2 and S3 suitability classes (corresponding to soils that are suited and are marginally suitable for grazing, respectively); see Figs. 3 and 4. Surveys indicated that the entire coastal area (map unit 13) was characterized by a high level of urbanization and intensive horticulture, so it contained few areas that were suitable for extensive grazing.

Ungrazed, these environments are characterized by the presence of many plant species. Grazing causes environmental erosion because only a few plant species can withstand the load exerted by the livestock. To prevent environmental degradation, which is often irreversible, it is necessary to develop a grazing plan that includes a demographic model which accounts for the motivation of animals to find food and plant species-specific grazing intensities. The grazing area was divided into 13 plots (Fig. 5) delimited by temporary paddocks. These plots had different surfaces in terms of the palatabilities of the plant species present, the suitability of the soil for grazing, and the accessibility of the plants for grazing, considering that the grazing season lasts from March to October.

The maximum permissible buffalo load depends on the season (spring, summer, or autumn), and was calculated using the general formula

$$\text{Maximum buffalo load} = \frac{\text{ACUha/month} \times \text{ha}}{30\ \text{days}} \times \text{dayslivestock},$$

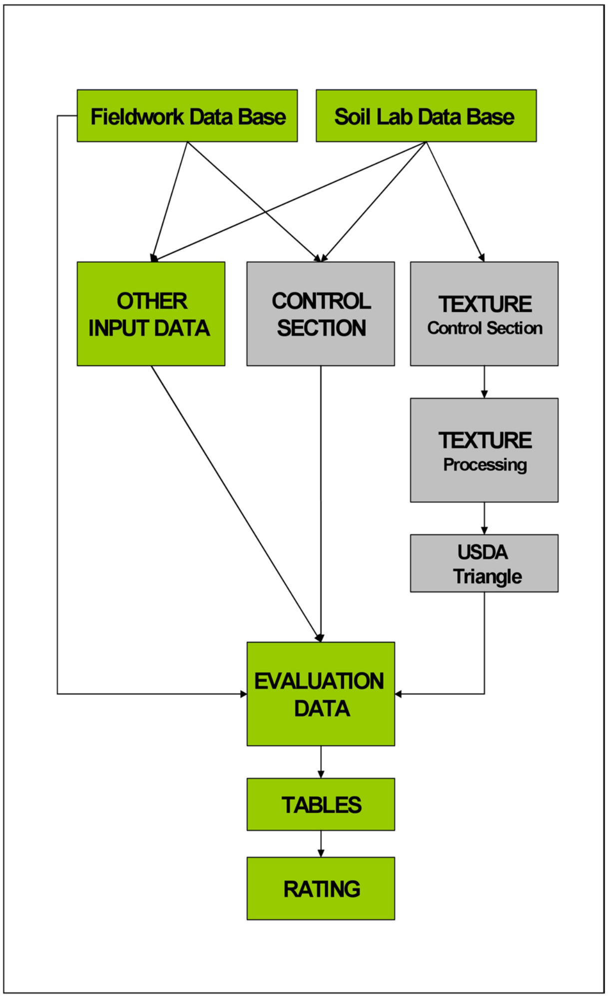


Fig. 2 Flow diagram for suitability processing

Table 1 Suitability class of the soil in each map unit (see Figs. 9 and 10) for grazing by cattle and buffalo and by sheep and goats

Suitability for cattle and buffalo grazing			Suitability for sheep and goat grazing		
Map unit	Suitability class	Limiting factors	Map unit	Suitability class	Limiting factors
1	S3	vsf	1	S3	v
2	S2	vf	2	S2	vf
3	S2	vsf	3	S2	vf
4	S3	visf	4	S3	visf
5	S3	vsf	5	S3	vsf
6	S3	vis	6	S3	vis
7	S3	is	7	S3	is
8	S3	vis	8	S3	vis
9	N1	isf	9	N1	if
10	N1	vsf	10	S3	vsf
11	N2	visf	11	N1	visf
12	N2	visf	12	N2	visf

where ACU stands for adult cattle unit. The GIS for grassland management yielded information relating to the soil, plant species palatability, and maximum cattle load during each of the three seasonal periods. This information from the GIS allowed us to evaluate the load and the maximum residence time in each of the 13 plots, any changes in species composition over time, soil conditions (waterlogging, drought, etc.), and the timing of grazing, which affected the maximum buffalo load during each of the three seasonal periods. Table 2 shows the management plan, obtained from the GIS, for each of the 13 plots in the study area, including recommended and discouraged practices, the best season for grazing, and other detailed information.

The maps were created in a GIS using two layers of information: a 1:25,000 scale IGM (Military Geographic Institute) map and aerial photos. The results of interpreting the photos to identify the plant community types present were validated using phytosociological samples and by checking for the presence of pabular species. In the editing step, a numeric value and/or alphanumerical value related to area (ha), vegetation (I, II, and III), habitats (I, II, and III), taxon (I, II, and III), and plot area was/were assigned to each polygon. It was necessary to be able to indicate the presence of many types of vegetation, habitats, and plant species in a single polygon because a plot often included a complex mosaic of vegetation. Therefore, multiple maps of vegetation (I, II, and III: Figs. 6, 7, and 8, respectively) were generated to visualize the prevailing vegetation (in terms of coverage) in a particular polygon. Vegetation map II (Fig. 7) presents species with lower specific coverages than those presented in vegetation map I (Fig. 6), while vegetation map III (Fig. 8) presents species with lower specific coverages than those in vegetation maps I and II. The same approach to mapping was applied for the habitats (Figs. 8, 9, and 10) and for taxa of conservation interest. Note that no maps of taxa of conservation interest are presented here because these plants were only found (except for *Asparagus officinalis*) in plots 12 and 13 (Fig. 5)—the only plots where buffalo do not graze (Fig. 3).

Results and discussion

Climate

The Manfredonia thermopluviometric station indicated that the annual rainfall was low (429 mm) in the region of interest. The region exhibits a pluviometric regime of the autumn solstice type (137 mm), with the absolute winter maximum (50 mm) occurring in November. The rainfall is well distributed throughout the year, although the low rainfall during the summer period (75 mm) and the stunted recovery in rainfall during the spring (101 mm) can favor dry conditions.

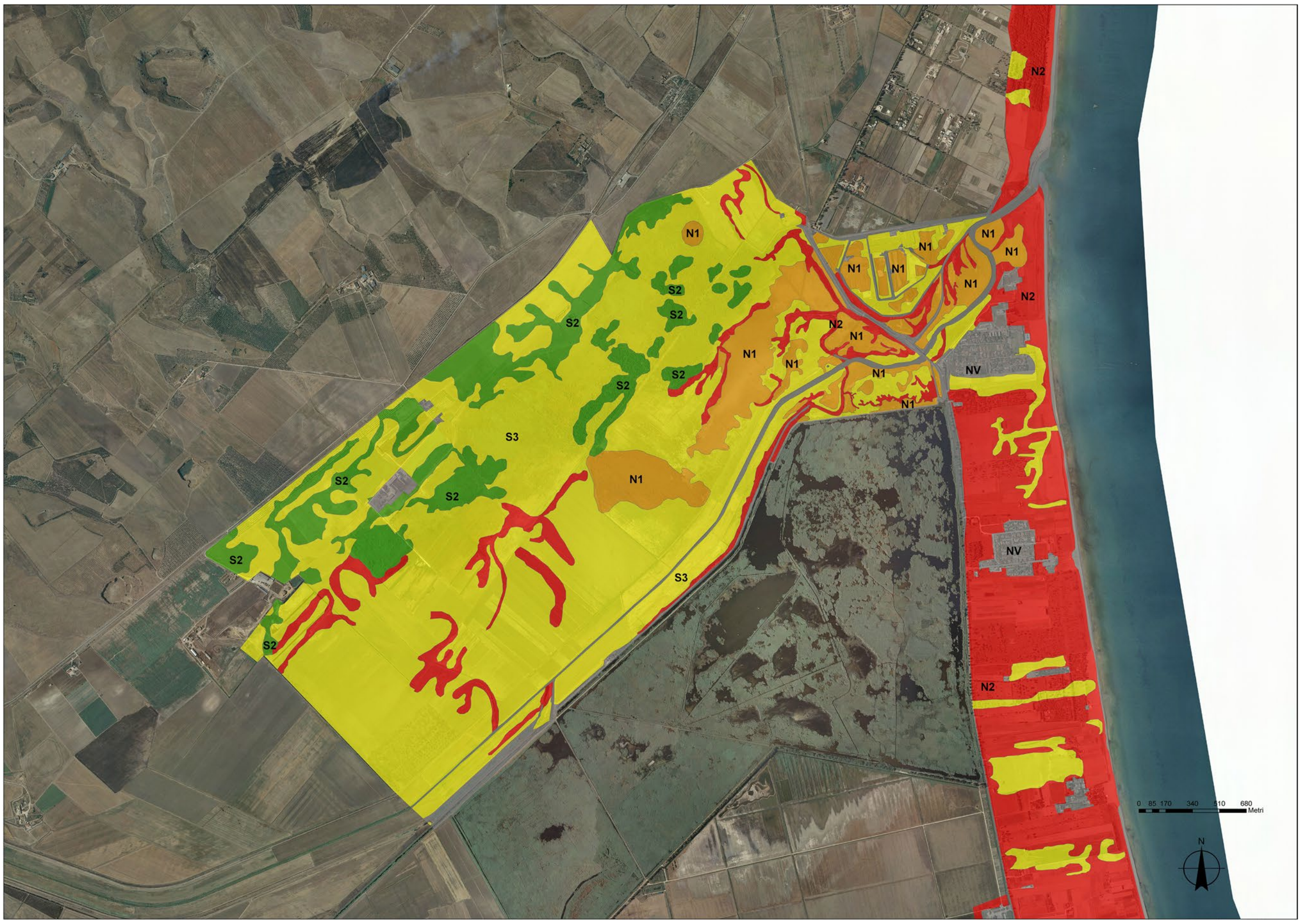


Fig. 3 Map showing the suitability for buffalo grazing of the soils in various areas of the region of interest. *NV* (not evaluable; *gray*), *N2* (permanently unfit; *red*), *N1* (temporarily unsuited; *orange*), *S3* (unsuited; *yellow*), *S2* (suitable; *green*)

The average annual temperature is 15.5 °C, with a temperature range between the hottest month (July) and the coldest (January) of 16.1 °C. According to the bioclimatic classification of Rivas-Martínez (2004) and the relative bioclimatic indices (the continental index $I_c = 16.05$; the ombrothermic index $I_o = 2.31$; the summer ombrothermic compensated indices $I_{os2} = 0.98$, $I_{os3} = 1.08$, $I_{os4} = 1.20$; the thermicity index I_t and the compensated thermicity index $I_{tc} = 314.9$) in the context of a Mediterranean macrobioclimate, we found that the region of interest has an oceanic bioclimate with seasonal rains as well as a mesomediterranean thermotype and dry ombrotype, both with low horizons (Perrino et al. 2013).

Vegetation analysis

Phytosociological surveys allowed us to identify 16 plant communities (shown in *italics* and **bold** in the syntaxonomical scheme presented below) that are shown in three maps (Figs. 6, 7, and 8). It was possible to attribute Directive 92/43/EEC habitats (Figs. 9, 10, and 11) to some plant communities. The coastal habitats 1210, 2110, and 1310 are not of interest to buffalo, whereas habitats 1410, 3170*, and 3290 are the most relevant because they have high coverages of some important pabular species for livestock. Since habitats 3170* and 3290 always form mosaics and have similar coverages, they are presented together in the maps. It should be noted that habitat 1150* is not reported in the syntaxonomical scheme because it does not have typical vascular vegetation due to its limited size and because of the strong anthropic pressure in the coastal part of the studied region.

Syntaxonomical scheme and correspondence with habitat types:

Cakiletea maritimae R. Tüxen & Preising in R. Tüxen 1950 [**1210: Annual vegetation of drift lines**].

Euphorbetalia peplis R. Tüxen 1950.

Euphorbion peplis R. Tüxen 1950.

Salsolo-Cakiletum maritimae Costa & Manz. 1981 corr. Rivas-Martínez et al. 1992.

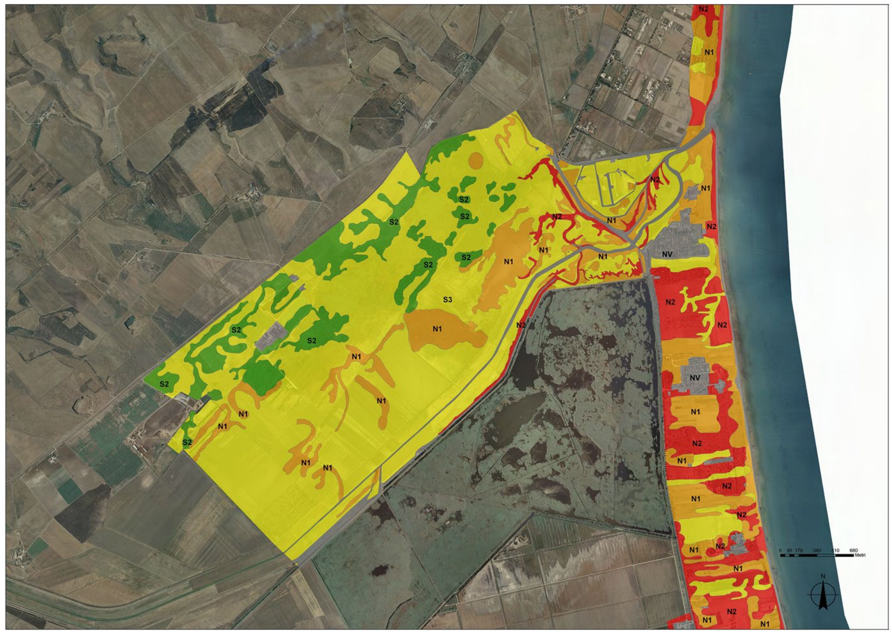


Fig. 4 Map showing the suitability for sheep/goat grazing of the soils in various areas of the region of interest. *NV* (not evaluable; *gray*), *N2* (permanently unfit; *red*), *N1* (temporarily unsuited; *orange*), *S3* (unsuited; *yellow*), *S2* (suitable; *green*)

Ammophiletea Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946 [**2110: Embryonic shifting dunes**].

Ammophiletalia Br.-Bl. 1933.

Ammophilion australis Br.-Bl. 1921 em. Géhu, Rivas-Martínez & R.Tüxen in Rivas-Martínez, Lousã, T.E. Díaz, Fernández González & J.C. Costa 1990.

Agropyrenion farcti Rivas-Martínez, Costa, Castroviejo & Valdés Bermajo 1980.

Cypero capitati-Agropyretum juncei (Kühnholtz-Lordat 1923) Br.-Bl. 1933.

Stellarietea mediae R. Tüxen, Lohmeyer & Preising ex Rochow 1951.

Thero-Brometalia (Rivas Goday & Rivas-Martínez ex Esteve 1973) O. Bolòs 1975.

Echio plantaginei-Galactition tomentosae O. Bolòs & Molinier 1969.

Carpobrotus edulis community.

Hordeion leporini Br. Bl. in Br. Bl., Gajewski, Wraber & Walas 1936 corr. O Bolòs 1975.

Hordeum murinum subsp. *leporinum* community.

Helianthemetea guttati (Br. Bl. in Br. Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963 em. Rivas-Martínez 1978.

Brachypodietalia distachyi Rivas-Martínez 1978 [**6220* (subtype 3) Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea].**

Hypochoerion achyrophori Biondi & Guerra 2008.

Hypochaeris achyrophorus community.

Stipa capensis community.

Saginetea maritimae Westhoff, Van Leeuwen & Adriani 1962 [**1310: Salicornia and other annuals colonizing mud and sand**].

Frankenietalia pulverulentae Rivas-Martínez ex Castroviejo & Porta 1976.

Hordeion marini Ladero, F. Navarro, C. Valle, B. Marcos, Ruiz & M.T. Santos 1984.

Hordeum marinum community.

Isoëto-Nanojuncetea Br.-Bl. & R. Tx. ex Westhoff et al. 1946 [**3170*: Mediterranean temporary ponds**].

Isoëtetalia durieui Br.-Bl. 1936.

Isoëtion durieui Br.-Bl. 1936.

Juncus pygmaeus community.

Molinio-Arrhenatheretea Tüxen 1937.

Holoschoenetalia vulgaris Br.-Bl. ex Tchou 1948 [3290: **Intermittently flowing Mediterranean rivers of the Paspalo-Agrostidion**].

Paspalo distichi-Agrostion semiverticillatae Br.-Bl. in Br.-Bl., Roussine & Nègre 1952.

Paspalum distichum community.

Juncetea maritimi Br.-Bl. in Br.-Bl., Roussine & Nègre 1952 [**1410: Mediterranean salt meadows**].

Juncetalia maritimi Br.-Bl. ex Horvatić 1934.

Juncion maritimi Br.-Bl. ex Horvatić 1934.

Juncenion maritimi Géhu & Biondi 1995.

Juncetum maritimo-acuti Horvatić 1934.

Sonchus maritimus L. subsp. *maritimus* community.

Artemisietea vulgaris Lohmeyer, Preising & Tüxen ex von Rochow 1951.

Onopordenea acanthii Rivas-Martínez, Báscones, T.E. Díaz, Fernadéz-Gonzáles & Loidi 2002.

Carthametalia lanati Brullo in Brullo & Marcenò 1985.

Onopordion illyrici Oberdorfer 1954.

Silybum marianum and *Carduus pycnocephalus* subsp. *pycnocephalus* community.

Table 2 Grazing management plan for buffalo in the region of interest, considering each of the 13 plots (map units) in turn

Plot	Net surface area (ha)	Land use and main natural vegetation present	Dominant soils	Maximum permissible number of livestock grazing days	Maximum buffalo load (head/particle)			Recommended and discouraged management practices
					Spring	Summer	Autumn	
1	87.6	Arable, with *Stellarietea mediae* vegetation	UC 1, 2, and 6 Lithic Haploxerolls, fine loamy, mixed, thermic Typic Calcixerepts, coarse silty, mixed thermic Aquic Haploxererts, fine, mixed, thermic	42	98	49	40	Favor the diffusion of palatable species such as *Sonchus maritimus* and *Paspalum distichum* Reduce arable land Avoid grazing during the summer due to poor grass cover Avoid deep machining due to the presence of compact substrates and accumulations of secondary carbonates
2	106.3	Arable, with *Stellarietea mediae* vegetation	UC 6 and 8 Aquic Haploxererts, fine, mixed, thermic Typic Haploxererts, fine, mixed, thermic	50	177	89	58	Favor the diffusion of palatable species such as *Sonchus maritimus* and *Paspalum distichum* Reduce arable land Perform surface machining to suppress crepe formation Avoid grazing during the summer due to poor herbaceous coverage and cracking phenomena Promote the diffusion of palatable halophytic species
3	108.8	Arable, with *Stellarietea mediae*, *Juncetum maritimo-acuti*, *Sarcocornion alpini*, and *Phragmitetum australis* vegetation	UC 1, 2, 3, and 4 Lithic Haploxerolls, fine loamy, mixed, thermic Typic Calcixerepts, coarse silty, mixed thermic Sodic Haploxererts, fine, mixed, thermic	50	145	73	31	Favor the diffusion of palatable species such as *Sonchus maritimus* and *Paspalum distichum* Reduce arable land Avoid grazing during the summer due to poor grass cover Avoid deep machining due to the presence of compact substrates and accumulations of secondary carbonates Thin rushes when necessary in the central portion of the particle Promote the diffusion of palatable halophytic species

Table 2 (continued)

Plot	Net surface area (ha)	Land use and main natural vegetation present	Dominant soils	Maximum permissible number of livestock grazing days	Maximum buffalo load (head/particle)			Recommended and discouraged management practices
					Spring	Summer	Autumn	
4	71.2	Arable, with *Stellarietea mediae* vegetation	UC 6 Aquic Haploxererts, fine, mixed, thermic	38	90	45	30	Favor the diffusion of palatable species such as *Sonchus maritimus* and *Paspalum distichum* Reduce arable land Avoid grazing during the summer due to poor grass cover Thin rushes when necessary in the central portion of the particle Avoid grazing during the wet autumn and spring periods Prevent soil compaction
5	49.8	Arable, with *Stellarietea mediae* vegetation	UC 1, 2 Lithic Haploxerolls, fine loamy, mixed, thermic Typic Calcixerepts, coarse silty, mixed, thermic	25	33	21	7	Favor the diffusion of palatable species such as *Sonchus maritimus* and *Paspalum distichum* Reduce arable land Avoid grazing during the summer due to poor grass cover Avoid deep machining due to the presence of compact substrates and secondary carbonate accumulation
6	79.4	Arable, with *Stellarietea mediae* and *Juncetum maritimo-acuti* vegetation	UC 4 Sodic Haploxererts, fine, mixed, thermic	37	32	29	29	Thin rushes when necessary to check their spread Promote the diffusion of palatable halophytic species
7	69.2	Arable, with *Stellarietea mediae* and *Hordeion marini*	UC 6, 9 Aquic Haploxererts, fine, mixed, thermic Sodic Endoaquents, clayey over sandy, mixed, thermic	36	83	66	27	Favor *Hordeion marini* and palatable halophytic species Avoid grazing during rainy months to suppress soil compaction and subsidence Remove arable crops Avoid surface processing that encourages salts to rise to the surface
8	65.5	Arable, with *Stellarietea mediae*, *Hordeion marini*, and *Scirpetum compacti*	UC 6, 9 Aquic Haploxererts, fine, mixed, thermic Sodic Endoaquents, clayey over sandy, mixed, thermic	33	94	43	22	Favor *Hordeion marini* and palatable halophytic species Avoid grazing during rainy months to suppress compaction and subsidence Remove arable crops Avoid surface processing that encourages salts to rise to the surface

Table 2 (continued)

Plot	Net surface area (ha)	Land use and main natural vegetation present	Dominant soils	Maximum permissible number of livestock grazing days	Maximum buffalo load (head/particle)			Recommended and discouraged management practices
					Spring	Summer	Autumn	
9	62.8	Arable, with *Juncetum maritimo-acuti* and *Phragmitetum australis*	UC 3, 4 Sodic Haploxererets, fine, mixed, thermic	30	31	19	31	Thin rushes when necessary Promote the diffusion of palatable halophytic species Remove arable crops
10	60.6	*Scirpetum compacti*, *Juncetum maritimo-acuti*, and *Hordeion marini*	UC 9, 10 Sodic Endoaquents, clayey over sandy, mixed, thermic Aquic Calcixererts, fine, mixed, thermic	30	48	24	18	Favor the spread of *Scirpetum* species and the most palatable halophytic plants to improve soil coverage Thin rushes when necessary to avoid uncontrolled diffusion Avoid grazing during rainy periods to suppress soil compaction and encourage herbaceous coverage of the soil
11	34	*Juncetum maritimo-acuti*	UC 7 Typic Haploxererts, fine, mixed, thermic	21	8	3	7	Thin rushes when necessary to avoid uncontrolled diffusion Promote the diffusion of palatable halophytic species Avoid grazing during rainy periods to suppress soil compaction and encourage herbaceous coverage of the soil
12	53.9	Arable, with *Stellarietea mediae*	UC 10 Aquic Calcixererts, fine, mixed, thermic	28	40	25	17	Favor the diffusion of palatable species such as *Sonchus maritimus* and *Paspalum distichum* Reduce arable land Avoid grazing during the summer season due to poor herbaceous coverage Avoid deep machining due to the presence of compact substrates and accumulations of secondary carbonates
13	66.3	Urbanizzed	Not evaluated					
Total				420	881	486	318	

Fig. 5 Subdivision of the region of interest into map units to facilitate buffalo grazing management, and points (in red) of water intake to realize

PHRAGMITO-MAGNOCARICETEA Klika in Klika & V. Novák 1941.

PHRAGMITETALIA W. Koch 1926 em. Pignatti 1954.

PHRAGMITION COMMUNIS Koch 1926.

Phragmitetum australis (W. Koch 1926) Schmale 1939.

Typhetum angustifoliae (Allorge 1921) Pignatti 1953.

SCIRPETALIA COMPACTI Dahl & Hadač 1941 corr. Rivas-Martínez, Costa, Castroviejo & E. Valdés 1980.

SCIRPION COMPACTI Dahl & Hadač 1941 corr. Rivas-Martínez, Costa, Castroviejo & E. Valdés 1980.

Scirpetum compacti Van Langendonck 1931 corr. Bueno & F. Prieto in Bueno 1997.

SARCOCORNIETEA FRUTICOSAE Br.-Bl. & R. Tüxen ex A. & O. Bolòs 1950 em. O. Bolòs 1967 [**1420: Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornietea fruticosi)**].

SARCOCORNIETALIA FRUTICOSAE Br.-Bl. 1933 em. O. Bolòs 1967.

SARCOCORNION ALPINI (Rivas-Martínez et al. 1990).

Sarcocornia alpini community.

NERIO-TAMARICETEA Br.-Bl. & O. Bòlos 1958 [**92D0: Southern riparian galleries and thickets (Nerio-Tamaricetea and Securinegion tinctoriae)**].

TAMARICETALIA Br.-Bl. & O. Bòlos 1958.

TAMARICION AFRICANAE Br.-Bl. & O. Bòlos 1958.

Tamarix africana community.

The first pabular species grows behind dunes and must be referred to *Echio plantaginei-Galactition tomentosae* (not a 92/43/EEC habitat) (Biondi and Blasi 2015) as *Brassica tournefortii*, *Hypochaeris radicata*, and *Orobanche canescens*. Several species in *Hypochoerion achyrophori* meadows (habitat 6220*) (San Miguel 2008) are potentially good: *Hypochaeris achyrophorus*, *Brassica tournefortii*, *Trifolium scabrum* subsp. *scabrum*, *Trifolium campestre*, and *Trifolium stellatum*. The *Paspalum distichum* (habitat 3290) and *Juncus pygmaeus* (habitat 3170*) communities (Ruiz 2008), which are very common in the areas grazed by buffalo, contain many pabular species such as *Paspalum distichum*, *Lythrum hyssopifolia*, *Bolboschoenus maritimus*, *Ranunculus trichophyllus*, and *Sonchus maritimus* subsp. *maritimus*. The latter species is also common in *Juncetum maritimo-acuti* vegetation (habitat 1410) (Attorre et al. 2004), and is one of the most important wild species used as food by livestock, including buffalo. *S. maritimus* subsp. *maritimus* is a halophyte that blooms (with yellow flowers) during late summer, from June to September, so the achenes (seeds) ripen in autumn. Measurements have shown that the phenological stage preferred by buffalo is the period corresponding to anthesis (spring), when this species is unlikely to bloom or produce fruit. Therefore, it is possible that the strong coverage of this species (in some micro areas) is favored by various factors, as follows: (1) It is a hemicryptophyte (a perennial species), which allows it to survive under grazing pressure without changing its growing cycle, unlike many therophytes—including many congeners—that adopt an annual cycle as an adaptation to this pressure; (2) It probably has a higher degree of tolerance than other grass species; (3) There may be a geographic aspect where seeds (achenes) ripen in zone 1 (where there is no grazing) and are transported by north winds (still dominant in the Mediterranean) in a southeasterly direction into area 3.

The vegetation and pabular species data were recorded in a database for use in grazing aptitude assessment.

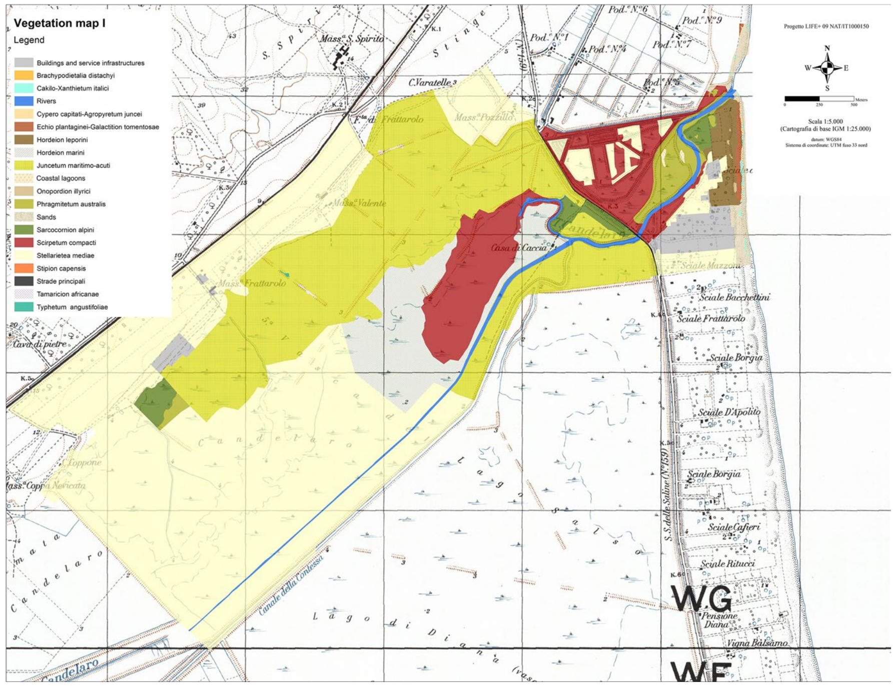


Fig. 6 Vegetation map I

Combining vegetation and soil data made it possible to obtain a map of soil suitability for buffalo and sheep grazing; this map was also used to prepare the GIS for grazing management.

Based on the floristic surveys and the palatability of the species present, particularly *Sonchus maritimus* subsp. *maritimus* and *Paspalum distichum*, it was decided to favor buffalo grazing in the region of interest rather than sheep and goat grazing, as the eating habits of buffalo allow the maintenance of greater plant biodiversity. In addition, *Asparagus officinalis* is a palatable species that is mainly found in *Juncetea maritimi* communities (habitat 1410). It is very rare at the regional level, and populations comprising a few individuals were found in the buffalo grazing area.

Species of conservation interest in the Palude Frattarolo, except for *Asparagus officinalis*, were always located in the coastal area, where there are no buffalo. *Melilotus albus* is a subcosmopolitan species that was reported in Apulia for the first time—in the Salento peninsula—by Beccarisi et al. (2007), and then also found in the northwestern sector of this region, near Celenza Valfortore, Carlantino, and San Marco la Catola (Foggia) (E.V. Perrino, unpublished data). *Puccinellia festuciformis* subsp. *convoluta* is a rare species (Pignatti 1982) that is found mainly in *Sarcocornia alpini* communities (habitat 1420). Finally, *Triglochin bulbosum* subsp. *barrelieri* (habitat 1420) is a taxon of great interest that was detected in the region of interest.

Impact of grazing on the soil

According to Lal (1997), "the debate on global soil degradation, its extent and agronomic impact, can only be resolved through understanding of the process and factors leading to establishment of the cause-effect relationships for major soils, ecoregions and land uses."

We are aware that the issues of soil degradation and regeneration and soil resilience are very important considerations when attempting to improve the management of ecosystems. We are also well aware that rangeland soil quality, soil resilience, and soil erosion depend on several interacting factors: (1) the landscape and climate; (2) current disturbances, and (3) the recent and historical disturbance history of the region (Herrick et al. 1999).

Bearing in mind that there is a need to develop and standardize techniques for measuring soil resilience, we hope to be able to identify indicators of soil quality and soil

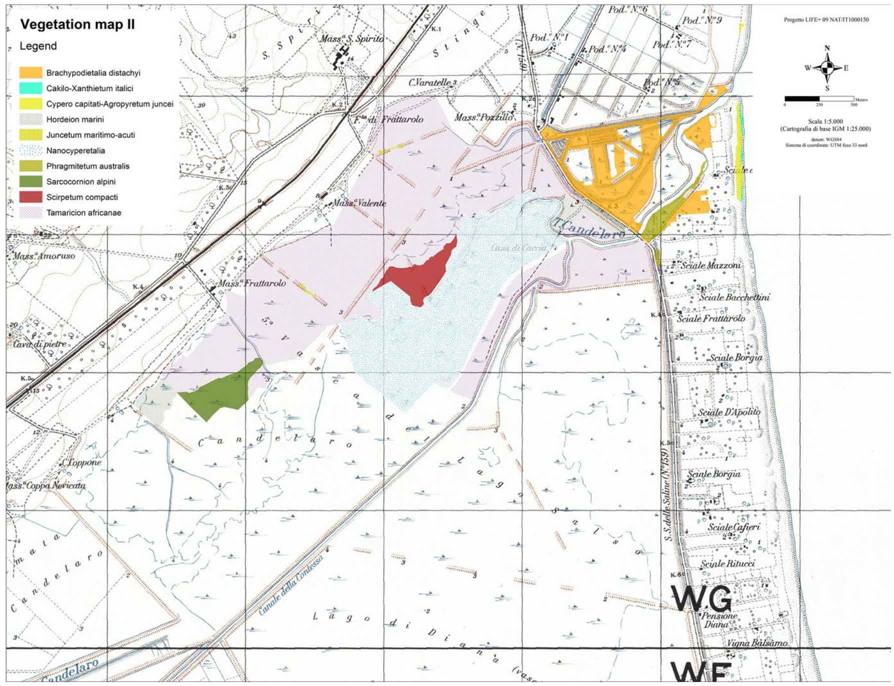


Fig. 7 Vegetation map II

resilience, and to establish critical limits of properties that are relevant to soil degradation and soil resilience.

Regarding soil degradation in the study area, the main problem at present is the overcharge of buffalo grazing, which leads to very high soil compaction and strongly reduced soil structure and permeability, resulting in considerable waterlogging on the surface during the wet season. If the proposed sustainable level of buffalo grazing is implemented in this region, vegetation will spread across currently bare areas, and the resulting organic matter will quickly (in 2–3 years) improve soil structure and permeability, thus reducing waterlogging.

At the moment our data do not allow further discussion of the results because our work is one of the first examples of a multidisciplinary approach to this topic, so further research is needed. Even so, the data already make it possible to develop a model that we hope will be improved in the future through the inclusion of other data from research carried out by other specialists in different sectors, especially data relating to animal feeding and pasture land management in dry areas, and information from agroecologists.

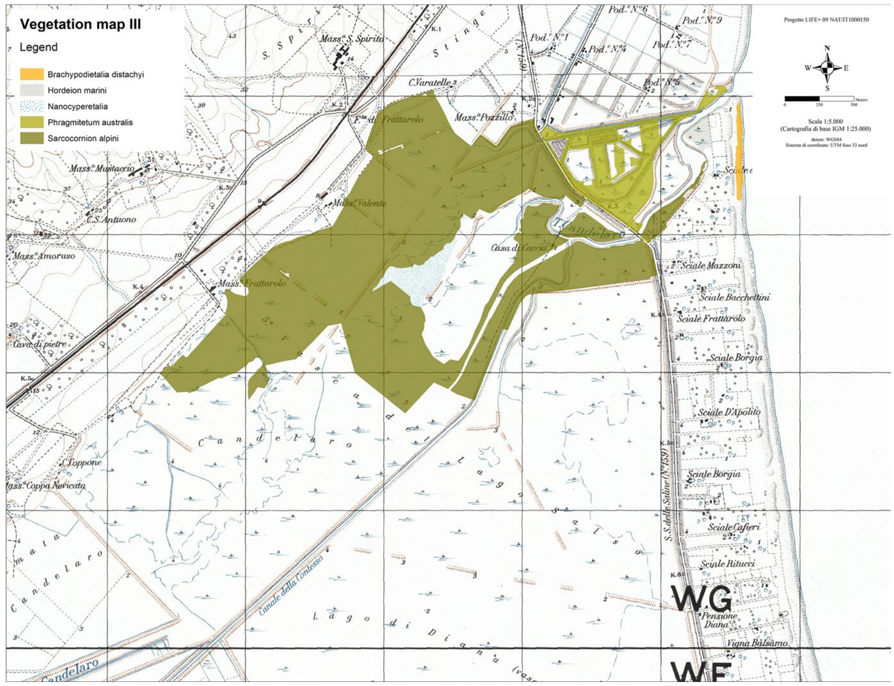
Some suggestions and/or recommendations derived from the data collected and briefly discussed in light of our experiences are summarized in the following section, although we are aware that what we propose is only a basic plan that should be adjusted from time to time according to the results of targeted monitoring to account for the natural evolution of the investigated wetland area.

Conclusions

The present research addressed the issue of establishing, for the first time through botanical, vegetation, and soil analyses, the maximum herd size of grazing Italian water buffalo in a coastal area of the Mediterranean Basin that will allow the preservation of Directive 92/43/EEC habitats in this region. The results of this study will provide useful scientific data for future studies in this field.

At present, the available data (which will be reassessed in years to come) suggest that it could be possible to use at least six plots simultaneously for a period of 3 months during the spring, which could support a maximum total load of about 200 buffalo. In the summer, this maximum load would be even higher, since the same six plots can easily satisfy the feeding requirements of 400 buffalo (the maximum load already present in the area), whereas the region can only support a maximum of 150 grazing buffalo, spread across

Fig. 8 Vegetation map III



6–8 plots, in autumn. After a year of grazing, it should be possible to automatically reassess the maximum load for each plot in the project area based on accumulated monitoring data on the plant species and soil conditions present.

Therefore, using sustainability criteria and pasture suitability maps, we have shown that it is possible to achieve an important goal: a GIS for buffalo pasture planning in a humid area. It was also possible to identify ten habitats in the studied region that are defined in the Habitats Directive 92/43/EEC—six more habitats than reported in the LIFE technical report. Indeed, only one (1150*) of the four habitats (1150*, 1510*, 2250*, 2270*) reported in the LIFE technical report was identified in the present work, again highlighting the importance of sampling vegetation directly in the field, especially in coastal areas of Apulia. It should be noted that habitat 1510* was wrongly reported to exist in Apulia and in all Italian regions (Biondi and Blasi 2009).

In order to improve the proposed paradigm, we feel that further studies are needed, and our work could provide a good starting point for those investigations. Further studies should account for links between the wetland and both the agroecology and the human exploitation of the natural resources in the geographical area considered, since the evolution of the wetland is naturally linked to the anthropic activities in the region. Wetland environments are very rare and are at risk in southern Italy, and it is crucial to maintain a balance between herd size and the conservation of 92/43/EEC habitats without neglecting the effects of urbanization and horticulture, which were not scientifically quantified in this study.

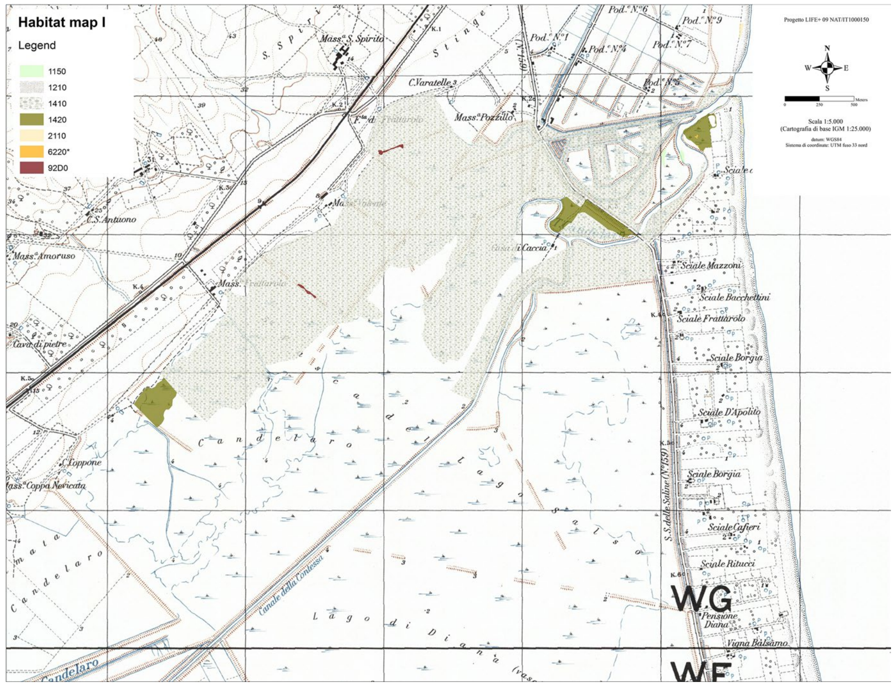


Fig. 9 92/43/EEC habitat map I

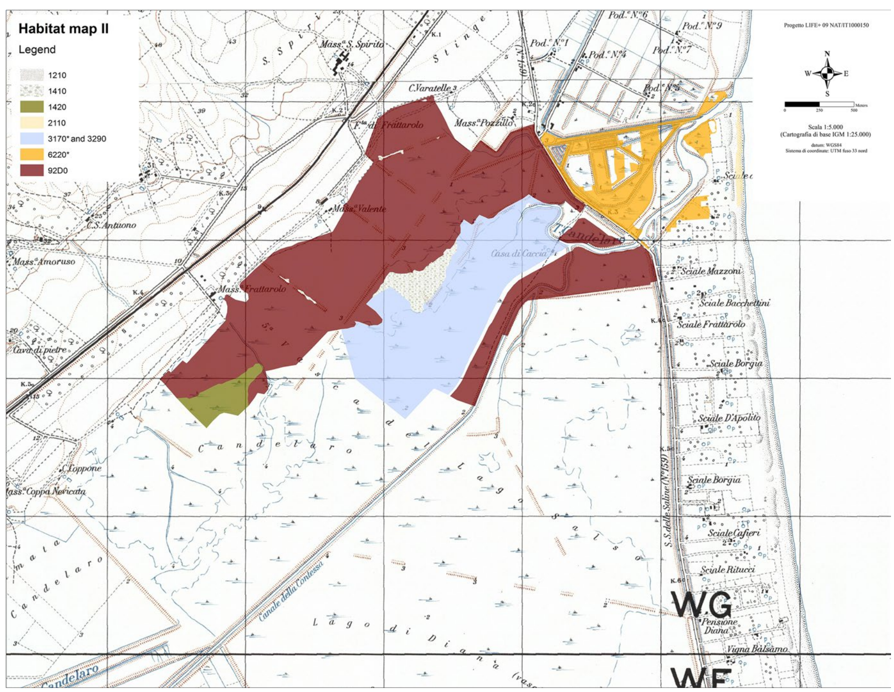
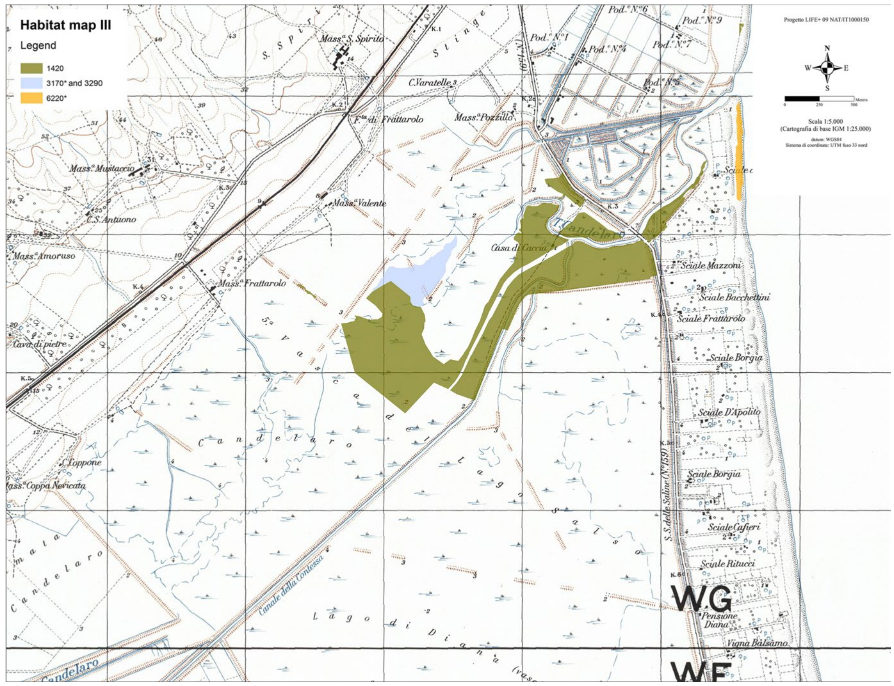


Fig. 10 92/43/EEC habitat map II

Fig. 11 92/43/EEC habitat map III



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