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Perdita di Aree Umide nella Pianura Veneta Meridionale: una Prospettiva Geo-Storica

Loss of Wetlands in the Southern Venetian Plain: a Geo-Historical Perspective

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Riassunto

La protezione delle zone umide è diventata parte importante nella pianificazione degli ecosistemi nella maggior parte delle nazioni. In alcuni paesi il ripristino delle zone umide perdute o anche la creazione di nuove zone umide è considerato essenziale per i servizi ecosistemici che esse forniscono. Il primo passo nella pianificazione delle zone umide e degli ecosistemi è la loro mappatura sia nel presente sia, ove possibile, nell'ambito storico. Il censimento e la mappatura delle zone umide su aree estese sono eseguiti attraverso l'analisi di immagini telerilevate, come immagini aeree o satellitari. Il censimento e la produzione di carte riguardanti le zone umide del passato sono più difficili poiché il telerilevamento da piattaforme aeree esiste solo dalla prima metà del XX secolo. Tuttavia, alcuni prodotti cartografici storici includono aree umide o caratteristiche del territorio che possono essere interpretate come aree umide e che possono fungere da *proxy* per le ricostruzioni storiche della distribuzione delle zone umide. In questa ricerca, sia le carte storiche sia foto aeree recenti sono state utilizzate per cartografare la distribuzione geografica delle zone umide nella provincia di Padova nel nord Italia. Un'analisi diacronica del cambiamento delle zone umide ha rivelato un'importante perdita di zone umide in tale provincia. Le zone umide attuali rappresentano solo il 3,4% delle zone umide presenti nel 1882. L'attuale distribuzione di zone umide è, in gran parte, diversa dalla distribuzione storica in quanto, ad oggi, pochissime delle zone umide storiche rimangono ancora nel territorio, mentre le nuove zone umide sono sparse e sporadiche, perlopiù risultato di processi antropici.

Parole chiave

Aree umide, perdita, carta storica, Pianura Veneta

Abstract

The protection of wetlands has become an important part of ecosystem planning in most countries. In some countries the restoration of lost wetlands or even the creation of new wetlands is considered essential for ecosystem functions. The first step in wetlands and ecosystem planning is mapping the present and, hopefully, the historic geographic distribution of wetlands. For any large area mapping wetlands today is performed through the analysis of remotely sensed imagery, such as airborne or satellite-based imagery. Mapping historic wetlands is problematic as remote sensing from airborne platforms has only existed since the early part of the 20th century. However, some historic cartographic products do contain wetlands or wetland-like features that can serve as a proxy for historic wetlands distributions. In this research, both historic maps (1882) and recent (2015) aerial imagery were used to map the geographic distribution of wetlands in the Padova province in northern Italy. A change analysis of wetlands revealed a dramatic loss of wetlands in this province. The present-day wetlands amount to only 3.4% of the wetlands present in 1882. The current distribution of wetlands is, in large part, very different from the historic distribution as few historic wetlands remain today, while scattered new wetlands are a result of anthropogenic processes.

Keywords

Wetlands, Loss, Historic map, Venetian Plain

1. Introduction

1.1 Context, Goals, State of the Art

Historical landscape and habitat reconstruction can be an important tool for regional habitat mitigation, conservation and restoration (NRC, 1992; Swetnam *et Al.*, 1999; Steiner, 2000). Among landscapes and habitats, wetlands play an important role in providing ecosystem services for a variety of reasons (see Tiner, 2003; Ramsar Convention Secretariat, 2013; Singh, 2015). Any loss of wetland areas may cause serious and sometimes irreparable environmental and habitat damages within a landscape (Soule, 1991). The goals of this research were to produce an updated wetlands database for the Padova province (Venetian-Po Plain, northeastern Italy) and to provide a first estimation of wetlands change in this study area by comparing contemporary and historical wetlands data through the analysis of remote sensing and historical maps. Before describing the present understanding of wetlands in the study area, a brief review on wetlands classification, mapping and wetlands change is provided. One of the earliest and certainly the most well-known work on developing a standardized method of wetland classification and mapping was conducted by Cowardin *et Al.* (1979). This wetland classification system was subsequently adopted in a slightly modified form by the US Fish and Wildlife Service (USFWS) in their long-term National Wetlands Inventory (NWI), which is now a nationwide wetland inventory in a Geographic Information System (GIS) format. Similar versions of wetland classification systems and mapping have been adopted by other large non-US projects such as the GReek INventory (GRIN) (Zalidis, Mantzavelas, 1996), the Romanian Wetland Inventory (Török, 2002), the Island Wetland Inventory in Croatia (Sučić *et Al.*, 2018) and the wider Pan Mediterranean Wetland Inventory[1] (PMWI) (Hecker *et Al.*, 1996). Starting from present-day wetland inventories, many diachronical comparisons aimed at estimating the wetland changes for localized areas have been conducted. Wetlands inventories at global and continental scale are based on collections of inventories performed at national, regional or local scales. For example, Spiers (1999) provided a comprehensive review to quantify "the global wetland resource by compiling and reporting on existing wetland areal estimates and studies of wetland loss and degradation". This work was based on data provided by information sources including regional inventories, global atlases for particular wetland types, journal and conference papers, books and web pages. Perennou *et Al.* (2012) assessed the existing wetlands in the 27 Mediterranean countries around the year 2000 and provided an evaluation of the changes in wetland extent at the national scale through the 20th century.

At the local scale, analyzing trends of wetlands loss is possible by the use of single or combined geo-historical methodologies such as remote sensing, analysis of stratigraphical records, or analysis of historical maps and GIS technologies. For example, Gong *et Al.* (2010) provided a national-wide comparison of wetlands in China between 1990 and 2000 using Landsat imagery. Coleman *et Al.* (2008) studied the loss of wetlands in 14 deltas around the world between the early 1980s and 2002 using satellite images provided by a NASA-project. In their study on the Mississippi delta plain, Morton *et Al.* (2005) offered an example of an integrated approach between imagery analysis and stratigraphic coring techniques to demonstrate that subsidence is the most dominant cause of wetlands conversion to open water (e.g. a wetlands 'loss'). However, the use of photography and remote sensing technologies for the study of wetland loss, although highly accurate, is limited because of the almost absence of aerial photography prior to the 1930s (e.g. Bromber, Bertness, 2005). The use of historical cartography can, in this sense, help to map wetlands in the past. For example, Gimmi *et Al.* (2011) analyzed the wetland collapse in the Swiss lowland between 1850 and 2000 from historical and current maps. Sprague *et Al.* (2007) used one hundred year old topographic maps in a GIS environment to analyze rice field persistence in Japan.

Georeferencing historical maps with many techniques, both for environmental and urban studies, is very common. For example, using 1950s era maps, Salerno *et Al.* (2008) studied the surface area changes of a glacier in the Nepalese national park of Sagarmatha

1 https://medwet.org

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through the second half of the 20th century. Affek (2013) used Austrian military survey maps to study the evolution of the Polish territory of Galicia in the 18th and 19th centuries; the same territory was studied by Harvey *et Al.* (2014) through a time period of 150 years using cadastral maps. San-Antonio-Gómez *et Al.* (2013) studied the Spanish territory of the Real Sitio de Aranjuez from the 18th century to present times. This historical approach with older maps is very common in Italy as well (Lo Rè, Terrana, 2005; Brovelli, Minghini, 2012; Brigante, Radicioni, 2014).

However, the georeferencing process of historical maps may be problematic when the original documentation is missing and the projection or datum of the map is unknown (Balletti, 2000, 2006; Baiocchi, Lelo, 2005; Podobnikar, Kokalj, 2006; Bitelli *et Al.*, 2013); this is especially true for small scale (large area) maps. For smaller areas this problem is greatly diminished as the cartographic base is a rectangular coordinate system and thus, compatible with an affine transformation. Identifying the original map projection is very important for small scale maps; others have proposed methods for identifying the missing map projection information (Triplat Horvat, Lapaine, 2015; Bayer, 2016).

The study area for this research is the province of Padova administrative unit, located in the Veneto region between the Lagoon of Venice and the Prealps piedmont. Our study used large scale (small area) maps. In the paradigms of map georectification methods our approach may be considered as a piecewise rectification, since we used localized ground control points, independent for each of the map sheets.

Historical literature and maps provides information on the presence of large wetlands in the past within the Padova provincial study area. A significant change in both climate and anthropogenic management of waters occurred within the Late Ancient-High Medieval period. According to others (Bertolani Marchetti, 1966; Panizza 1985; Veggiani, 1994), there was a deterioration of climatic conditions which, in coincidence with the progressive abandonment of the lands after the decline of the Western Roman Empire, produced disastrous environmental effects in the Southern Venetian and Emilia Romagna plains (Cremaschi, Gasperi, 1989). From a hydrographic point of view, long rainy periods resulted in a series of important floods and coincidentally supraelevated rivers avulsions, which led to the flooding of large morphologically depressed areas. As a result, the most depressed areas of the Southern Venetian plain became hosts to large lakes and swamps, such as Vighizzolo and Anguillara (Marcolongo, Zaffanella, 1987; Vigato, 1997). Many of those wetlands remained, partially human-managed, until the large land reclamation at the end of the nineteenth century (Zuccagni-Orlandini, 1844; Stefani, 1854; Mozzi, 1927).

Many former natural wetlands, which later became human-managed, consisted of rice fields and irrigated meadows (Sereni, 2004; Vigato, 1997). For the Ramsar Convention, rice fields are classified as agricultural wetlands (Ramsar Information Paper no. 1[2]). As noted by Verhoeven, Setter (2010), "rice cultivation has been a labour-intensive activity in fields that were kept under water for a major part of the year. Rice fields can therefore be classified as 'agronomically managed temporary wetland ecosystems'." In 1993, Hook found that 57% of rice fields were located on wetlands or former wetlands. Irrigated fields, wet meadows and flooded fields are terms usually associated with the practice of flooding fields with very shallow waters for crops cultivation (Leibundgut, 2004; Sereni, 2004; Peck, Lovvorn, 2001). The Ramsar Convention included "seasonally flooded irrigation land" as wetlands[3].

Nowadays, the largest and most important wetland areas of the Veneto region are the Po River Delta located in the province of Rovigo and the Lagoon of Venice located partially in the province of Venice and the province of Padova (in its southern part, see Figure 1). These two larger wetlands (or their smaller parts) have been the focus of biochemical and ecosystem research (Serandrei-Barbero *et Al.*, 2011; Pappalardo *et Al.*, 2017). Others have studied these two large wetlands from a socio-economical condition related to the vast land reclamations and the historical human-water relationship (for example, Bertoncin, 2004; Novello, 2009; Morin, Scola Gagliardi, 1993 (eds.); Pasa, 1999).

2 https://www.ramsar.org/sites/default/files/documents/library/info2007-01-e.pdf

3 https://www.ramsar.org/sites/default/files/wwd14_leaflet_en.pdf

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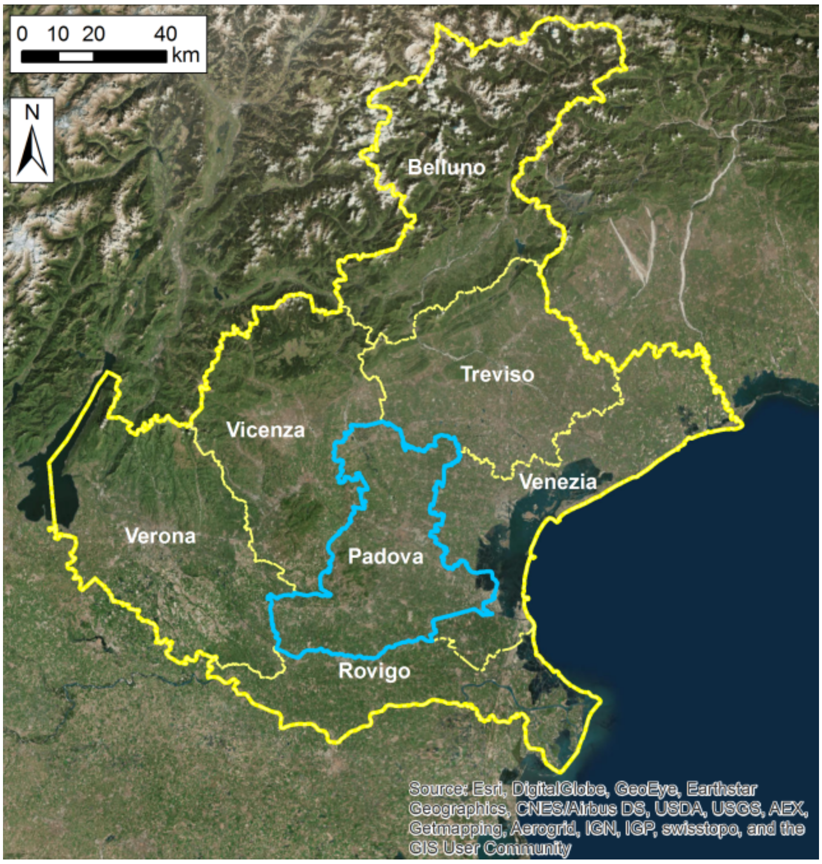

FIGURE 1
The Veneto region and the borders of its provinces (in yellow). In blue, the study area of the Padova province (Graphics by Silvia E. Piovan)

Despite numerous works on local wetlands in the Veneto region (primarily in the Lagoon of Venice), there is still poor knowledge of the amount, the extension and the type of inland wetlands in this area. The Regione Veneto provides an online database[4] purported to represent wetlands conforming to the Ramsar definition ("Zone umide ex D.Lgs. 42/2004, art.142"); however, at the current date, there are no (0) wetlands reported for the province of Padova. In 2004, ARPAV[5] published a census of the "minor natural areas in the Veneto region"[6]. This report includes both natural wetlands and other types of environments such as minor natural forested areas. For the Padova province, the Regione Veneto (2004) reported a total of 31 minor natural areas (28 areas in the alluvial plain zone and three areas in the lagoon) for a total of 3,117 ha. This report seems to include many of the inland wetlands but it does not officially categorize which areas correspond to wetlands versus other types of natural areas. Furthermore, it does not include anthropogenically created wetlands. From a visual analysis of satellite imagery and contemporary cartography, the Veneto region seems to have many more inland wetlands than what is reported by the official data, which only includes wetlands protected by special regulations (see paragraph 1.2).

Another possible source of mapped wetlands is the land cover database created and maintained by the Re-

4 https://idt2.regione.veneto.it/idt

5 Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto,

6 http://www.arpa.veneto.it/arpavinforma/pubblicazioni/censimento-delle-aree-naturali-minori-della-regione-veneto

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Figure 2 – The pond and surrounding wetlands, missing from Natura 2000, located almost at the western border of the Bassa Padovana, close to Montagnana, as an example of semi-natural wetland in the province of Padova
(Photo by Silvia E. Piovan)

gione Veneto[7]. This database was created in 2009 on the base of orthophotos taken in 2007, and contains four types of water bodies: inland wetlands, coastal wetlands, inland waters and coastal waters. Coastal wetlands and coastal waters are related to the Adriatic Sea and the Lagoon of Venice and are not considered in this paper, since we are interested only in inland wetlands. In the legend of the Regione Veneto database, inland wetlands are defined as wet areas referring to fluvial, lacustrine and peat bog environments; inland waters are instead defined as rivers, canals and waterways, and water basins. We examined this database for possible inclusion. However, a comparison (i.e. direct intersection) between our data and all the inland waters and inland wetlands in the Regione Veneto land cover database shows only a 53% correspondence. Thus, 47% of inland wetlands are missing from the Regione Veneto database (e.g. Figure 2). In this study we excluded rivers and canals (free flowing water bodies) and included all wetlands, including geographically isolated wetlands/ water bodies that belong to the inland context.

Many of the wetlands that appear in our visual analysis seem to fall into the European Pond Conservation Network (EPCN) (EPCN, 2008; Ewald *et Al.*, 2010), where the definition of "pond" is "a temporary or permanent standing waterbody between one m^2 and five hectares in surface area". The EPCN also defines an "Important Areas for Ponds" (IAPs) as "a geographical area which supports a pond site or network of high biological, social or economic importance". The concept of an IAP could also fit for some ponds in the study area.

7 https://idt2.regione.veneto.it/geoportal/catalog/search/resource/details.page?uuid=r_veneto:c0506021_CopSuolo

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This research in our study was focused on providing an updated inventory of inland wetlands for the Padova province from a remote sensing survey of 2015 orthophotos in the spirit of the Pan-Mediterranean Wetland Inventory (PMWI): to "include as many wetlands as possible in each Mediterranean country" (Tomàs-Vives, 2008). After collecting the 2015 wetland polygons in a GIS database, the comparison with wetland-type polygons obtained from the Orazio Morelli (1882) historical map provided a good estimate of wetland loss in the study area. This work was based, in part, on the contributions of unpublished University of Padova bachelor thesis works (Zandonà, 2015; Benolich, 2016) focused on wetlands inventories in portions of the study area.

1.2 European and Italian regulation on wetlands

To ensure the protection and/or the restoration of wetlands, whenever possible, the Ramsar Convention (1971) has provided a cooperative framework for the conservation and wise use of wetlands and their resources in every country that adheres to the treaty. As of January 2013, 163 nations have joined the Convention as Contracting Parties, and more than 2,060 wetlands around the world, covering over 197 million ha, have been designated for inclusion in the "Ramsar List of Wetlands of International Importance" (Ramsar Convention Secretariat, 2013). The Ramsar Convention also provided an official definition for wetland areas, adopted for the purpose of this work as well: "Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters".

In response to the Ramsar Convention, the European Union decided to add two different guidelines to ensure the protection of wetlands within the borders of every member state:

- the "Birds" directive (1979) for the preservation of aquatic birds, along with their nesting and feeding areas;
- the "Habitats" directive (1992) for the preservation of natural and semi-natural habitats.

This lead to the institution of a network of protected areas throughout the entire European Union, called "Natura 2000", which resulted in the creation of Special Protection Areas (SPAs) and Special Areas of Conservation (SACs), based on the Birds and Habitats Directives, respectively (ISPRA, 2011). Italy hosts 53 Ramsar Sites, for a total of 62,016 ha. The Veneto region alone has only three of the Ramsar designated wetland sites: "Valle Averto" in the Lagoon of Venice (500 ha, Venice province), "Palude del Brusà – Le Vallette" (171 ha, Verona province) and "Vincheto di Cellarda" (99 ha, Belluno province), for a total of 770 ha. No Ramsar defined wetlands are present in the Padova province.

The Veneto Region database hosts 12 SCAs/SPAs for the province of Padova, for a total of 106,368 ha. Within these protected zones, there are large areas, such as most of the Euganei Hills zone that are not wetlands.

2. Geomorphological setting

The study area for this research is located in the Central-Southern Venetian Plain and is contained in the administrative unit of the province of Padova, an area of 2,143 km^2 (Figure 1). The Central-Southern Venetian Plain lies in the eastern part of the foreland basin of the Southern Alps. This part of the larger Venetian Plain is composed, to the north, by the alluvial megafan developed by the Brenta River and, to the south, by the Adige-Po sedimentary system, both developed during the Late Quaternary (Fontana *et Al.*, 2008; Piovan *et Al.*, 2012). The study area can be divided into three geographical regions, which are characterized by quite different geomorphological and hydrographical processes and forms.

The northernmost portion, here called Alta Padovana (561 km^2), is defined by the border of the Padova province to the north and, to the south, by the Brenta River and minor hydrography (Figure 3). The Alta Padovana lies on the medium-grained sector of the Brenta River megafan (Mozzi *et Al.*, 2010). The northern part of the Alta Padovana marks the transition zone between the so-called "high plain", characterized by

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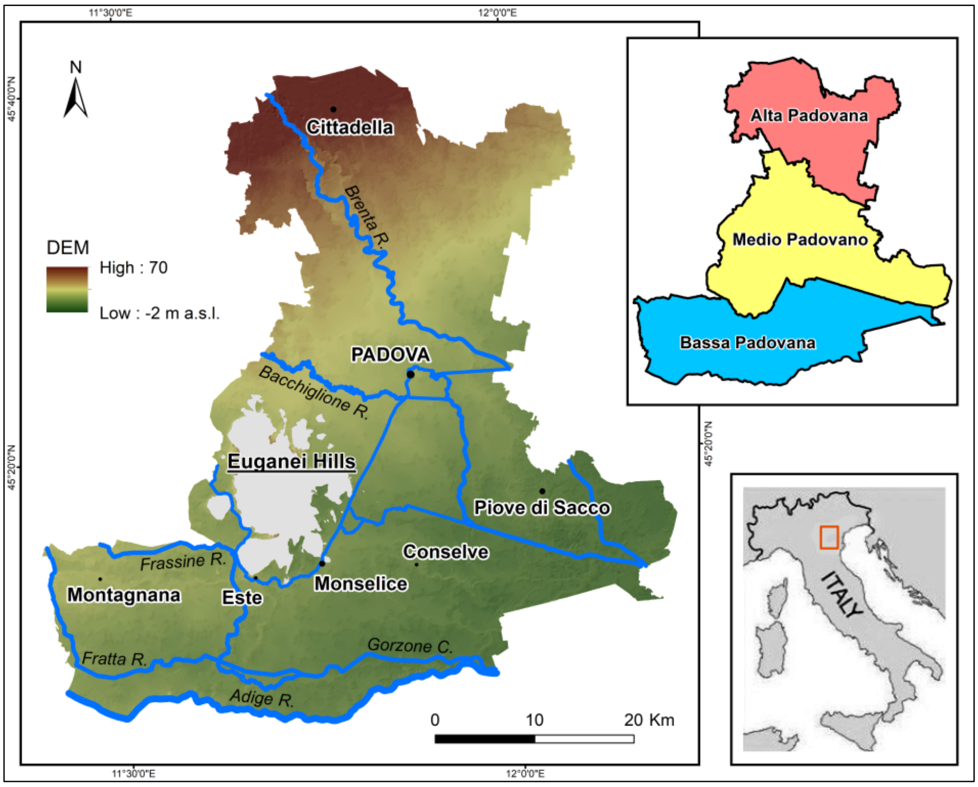

FIGURE 3
Terrain map of the three areas considered in this work. From north to south: Alta Padovana, Medio Padovano and Bassa Padovana (Graphics by Silvia E. Piovan)

coarse gravel beds in the piedmont plain, and the medium-fine-grained sedimentary sequence, forming the so-called "low plain".

In the transition zone between the high plain and the low plain the water table intersects the topographic surface and the groundwater emerges on the plain as numerous springs called "fontanili" (Vorlicek *et Al.*, 2004; Piccinini *et Al.*, 2017). The major river is the Brenta and, in the Alta Padovana, its course changes from braided to meandering.

The central area, here called Medio Padovano (813 km^2), is mostly defined by the border of the Padova province and also by minor hydrography, especially to the south: proceeding from west to east the Frassine River, the Bisatto, the Vigenzone and Cagnola canals and the Bacchiglione River. The Medio Padovano includes the Euganei Hills in the southwestern area and a small portion of the Venice Lagoon in the eastern part (Figure 3). The hydrography of the Medio Padovano is mainly related to the Bacchiglione system, since many of the canals crossing this area were dug hundreds of years ago (mostly in the 12th century) for navigation and water-strategy purposes (Genio Civile, 1879).

The southernmost portion, called Bassa Padovana (770 km^2), is completely included in the so-called "low plain", composed by fine sediments (sandy and silty-clayey). The major rivers in the Bassa Padovana are the Adige and the Fratta-Gorzone ones. The Bassa Padovana is characterized by a dense network of alluvial ridges created mostly by the Adige River. In the western part of the Bassa Padovana there are geomorphological and stratigraphical evidences of ridges intersections that are a product of the interaction between the Po and the Adige rivers sedimentary activities during the Bronze Age. The geomorphologically depressed basins formed between the alluvial ridges are generally silty-clayey, although they frequently show accumulations of peat, results of extensive swamps and

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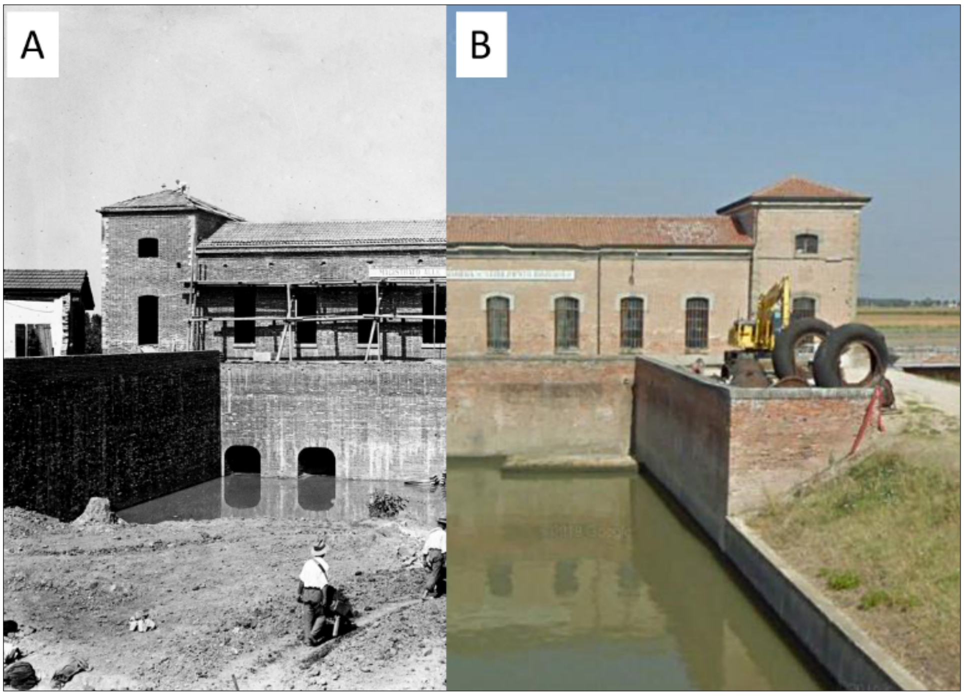

FIGURE 4

a) Vighizzolo d'Este, August 18th 1922. Final stages of the construction of the pumping station building in the Colonna locality along the Fratta River (see also Figure 5) (modified from Piovan 2014b);

b) the same pumping station today (Google Earth, 2019)

organic deposition occurred in the past (Piovan *et Al.*, 2012). Many historical documents (for a review, see for example Valandro, 1980) and maps (e.g. Lai, 1593) show the Bassa Padovana occupied by large wetlands, ponds and lakes, and drained by a long land reclamation process. The first important hydraulic work aimed at draining the southeastern portion of the Bassa Padovana was the "Taglio del Gorzon" (i.e. the digging of the Gorzone canal). The Gorzone is an artificial canal excavated in 1572 by the Padova rulers to discharge the waters of the Fratta, Santa Caterina and other minor watercourses. Prior to the creation of the Gorzone canal, the waters of the Bassa Padovana flowed into a large marshy area (called Lago della Griguola), in the northwest area of Anguillara (Piovan, 2014a). Other important land reclamation works occurred during the first decades of the 20th century (Piovan, 2014b), primarily through the construction of drainage canals and pumping stations (Figure 4). Pumping stations are necessary in the Bassa Padovana area to move the water from the drainage canals (low waters) to the major rivers (such as the Adige and the Fratta-Gorzone) as their courses are supraelevated on the alluvial plain.

3. Data Sources and Methods

3.1 Data Sources

Our inventory of present-day and historical wetlands was based on two sources – recent orthophotography and historical maps. The study of present-day wetlands was based on a visual analysis of digital aerial orthophotos for the province of Padova, produced by AGEA (*AGenzia per le Erogazioni in Agricoltura* – "Agency for Agriculture Supply") in 2015 with a resolution of 20 cm/pixel. Both panchromatic and color-infrared versions of these orthophotos were used. The color-infrared version allowed an easier recognition of smaller water bodies because of the sharp contrast between water features and other land cover.

The inventory of historical wetlands was based on a map dated back to 1882 and drawn by Orazio Morelli, a Venetian cartographer. The map is titled "*Carta Idrografica Stradale Amministrativa Consorziale della Provincia di Padova e dei terreni che si estendono fino alla sinistra sponda del fiume Adige e della Laguna di*

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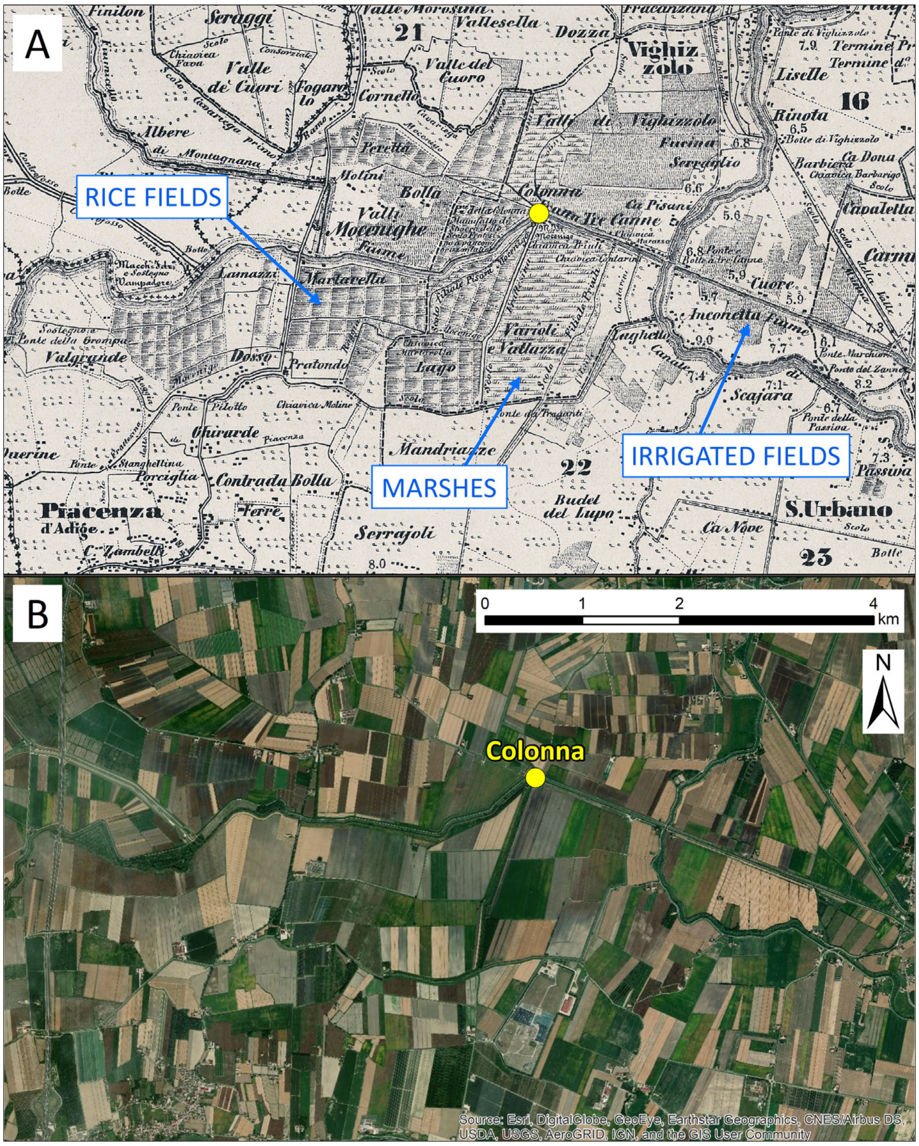

FIGURE 5
Detail of the Valli Mocenighe area from the 1882 map by Orazio Morelli (A, modified by the original map provided by courtesy of Biblioteca di Geografia, University of Padova) and the same area today (B, ArcGIS Online basemap) at the same scale. The three types of historical wetlands in 1882 are shown
(Graphics by Marco Filippini)

Chioggia. Delineata da Orazio Morelli. 2° edizione ridotta alla scala di 1/50000; riveduta, corretta e completata colla indicazione delle coltivazioni e delle altezze del piano campagna sul livello del mare, e colle piante dei Capoluoghi distrettuali. Dedicata alla Deputazione provinciale di Padova che incoraggiò l'opera, 1882"[8]. The 1882 Morelli 'map' is actually composed of twelve sheets, numbered from I to XII. Eleven map sheets were required (I to V and VII to XII) to cover the study area; sheet VI was not used because it barely covered the area of the Padova province. Each map sheet was a subset of the entire map with an original scale of 1:50,000. Wet-

8 "Map of hydrography, roads, government and consortiums of the Province of Padova, of the territories on the left side of the Adige River and of the Chioggia Lagoon. Drawn by Orazio Morelli. 2nd edition reduced to a scale of 1:50,000; revised, corrected and completed with indications of cultivations and elevation of ground surface above sea level, with plans of district capitals. Dedicated to the Government of the province of Padova, which encouraged the production of this work, 1882"

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lands were depicted in three different land cover categories – marshes ("paludi e canneti"), irrigated fields and meadows ("prati irrigui o naturali e pascoli"), and rice fields ("risaie") (Figure 5). The term "irrigated field" was used in the past to indicate fields (usually cultivated with grasses for hay production) that were covered by water at least during part of the year (Di Filippo conte Re, 1815). We decided to include the "irrigated fields and meadows" category in our analysis because the Ramsar Convention defines wetlands also as areas temporarily covered by water (Ramsar Convention Secretariat, 2013). However, since the use of irrigated fields and meadows as a wetlands category may be argumentative, we summarized the results for each category of wetland separately. The use of the 1882 historical map is justified as most of the land reclamations in the study area were performed in the 20th century; thus, it was necessary to go back at least as far as the 19th century to gain a proper understanding of how the wetlands environment has changed. To define the areas of study, three different boundary files were created and used to delineate the areas of the Alta Padovana, Medio Padovano and Bassa Padovana.

3.2 Methods

3.2.1 Georeferencing

Georeferencing of the historical map sheets was based on the feature linking ground control point technique, using the AGEA 2015 orthophotos as a reference basemap[9]. To minimize distortions endemic to large study areas, a separate rectification was conducted for each of the three study regions. Each sheet was georeferenced separately; also, if a sheet covered parts of two different areas, it was georeferenced twice with control points unique to each specific region. As one of the goals of the georeferencing process was to obtain a historical basemap for the province of Padova, the control points were spread as much as possible throughout each sheet. The first order polynomial transformation (i.e. affine transformation) resulted as the best approximation, as other kinds of transformations provided unsatisfying results. In particular, the spline transformation was originally expected to result in greater accuracy with control points located around wetland areas, but produced unsatisfying results around the borders of the sheets.

A target spatial error for all sheets was maintained below 100 m (RMSE), varying by map sheet from 29.78 m to 85.06 m. The final step was to merge all sheets for each study region and clip the resulting raster of the historical map using the boundary files of the study area as a mask.

3.2.2 Polygonization of wetland areas

Polygonization of wetlands from the 1882 map was interpreted from the legend (thus, separating irrigated fields/meadows, marshes and rice fields in three different layers). Although Morelli (1882) did not specify his minimum mapping unit, our observation of his recorded polygons indicates that a minimum mapping unit of about 0.0017 km^2 (0.17 ha) was used, because 0.17 ha was the smallest extension of the mapped wetlands.

Polygonization of wetlands from the 2015 orthophotos was instead based on the Ramsar Convention's guidelines, thus identifying not just the areas where water was clearly visible, but also those with a thick aquatic vegetation. In addition, as suggested by the PMWI manual (Tomàs-Vives, 2008), we digitized as many wetlands as we were able to confidently recognize at the working scale. Although the Ramsar definition of wetlands also includes rivers and canals, in this work rivers and canals as wetlands were not mapped, neither in the Morelli map nor in the 2015 orthophotos. The digitizing of wetlands from the orthophotos was conducted at a scale of 1:500. The minimum mapping unit for the survey using 2015 imagery was 0.0001 km^2 (0.01 ha). We did not attempt to map the same three categories as in the 1882 Morelli map as there seem to be no rice fields nor irrigated fields (in the sense discussed in the paragraph 3.1) in the three study areas today. In the last thirty years the irrigation of fields in the study area has been performed mostly by spray and sprinkler techniques and not by flooding.

9 All operations shown in this work were performed with the software ArcGIS (v. 10.5.1).

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4. Results

4.1 Survey of historical wetlands and comparison with the present day

Polygonization of 1882 wetlands allowed us to create three different feature classes for all three areas of the province of Padova, thus separating irrigated fields and meadows from marshes and rice fields, as they were at the end of the 19th century (Figure 6, Figure 7, Figure 8). The areas for each type of wetland in 1882 were calculated for each region and summarized for all wetlands in that region (Table 1). A similar analysis was obtained for the 2015 wetlands, but in this case the type of wetlands was not differentiated (Figure 6, Figure 7, Figure 8, Table 2). Finally, the total wetland areas for all regions were calculated and compared (Table 2).

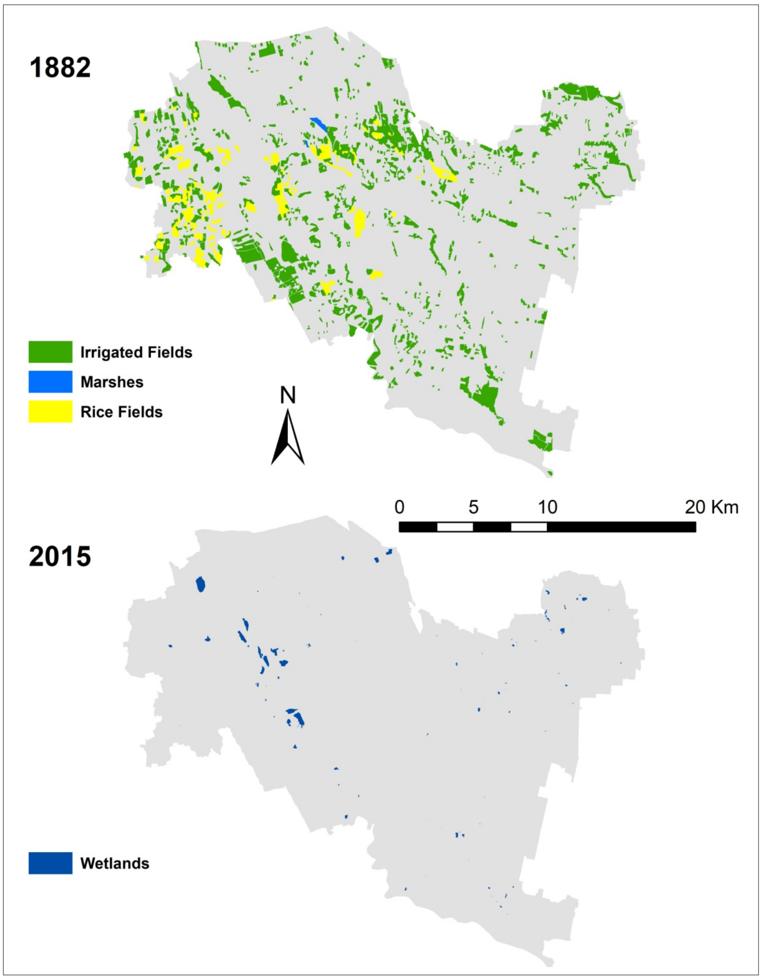

FIGURE 6
Comparison between 1882 and 2015 wetlands in the Alta Padovana area
(Graphics by the authors)

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Figure 7
Comparison between 1882 and 2015 wetlands in the Medio Padovano area (Graphics by the authors)

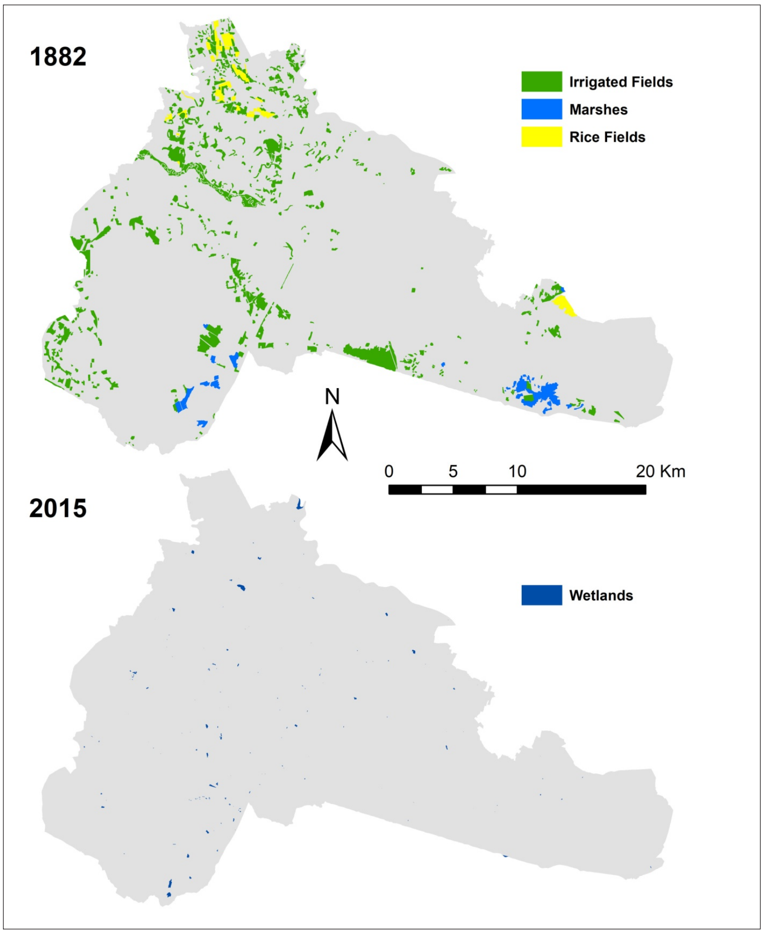
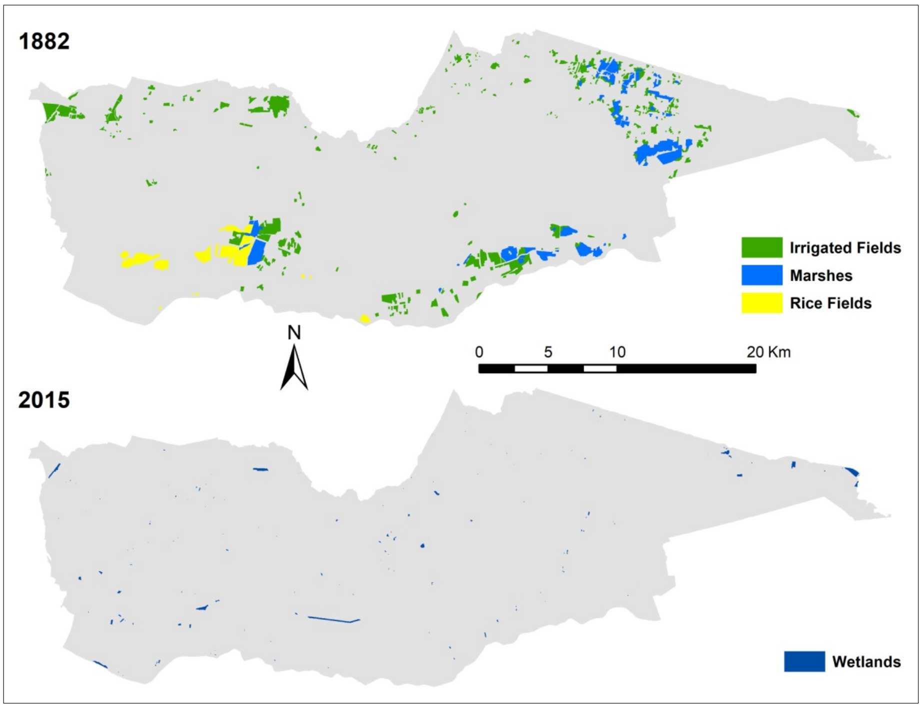


Figure 8
Comparison between 1882 and 2015 wetlands in the Bassa Padovana area (Graphics by the authors)



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4.2 Data analysis

4.2.1 Wetlands Statistics

The creation of digital representations of all wetland areas allowed us to summarize and analyze individual changes in wetlands for each region. In 1882, a total of 205.12 km^2 of wetlands was present in the entire province. Of this total, 22.82 km^2 were marshes, 152.36 km^2 were irrigated fields and meadows and 29.94 km^2 were rice fields. Table 1 shows the amount in km^2 and percentage of the total area for that region by types of wetland.

The totals and the percentages of wetlands for each region and date were also derived (Table 2). The results show a dramatic decrease in wetlands for all regions. More precisely:

- In the Alta Padovana, in 1882 there were 86.28 km^2 of wetlands, corresponding to 15.38% of all the Alta Padovana area (16.44 km^2 excluding the irrigated fields and meadows, corresponding to 2.93% of the Alta Padovana area); in 2015, only 3.16 km^2 were present, corresponding to 0.56% of the entire Alta Padovana area;
- In the Medio Padovano, in 1882 there were 70.69 km^2 of wetlands, corresponding to 8.70% of all the Medio Padovano area (13.84 km^2 excluding the irrigated fields and meadows, corresponding to 1.70% of the Medio Padovano area); in 2015, only 1.49 km^2 were present, corresponding to 0.18% of the entire Medio Padovana area;
- In the Bassa Padovana, in 1882 there were 48.15 km^2 of wetlands, corresponding to 6.25% of all the Bassa Padovana area (22.48 km^2 excluding the irrigated fields and meadows, corresponding to 2.92% of the Bassa Padovana area); in 2015, only 2.45 km^2 were present, corresponding to 0.32% of the entire Bassa Padovana area;
- In the entire province, the total area of wetlands was 205.12 km^2 in 1882 and 7.09 km^2 in 2015. Even excluding the irrigated fields and meadows, the total wetland area in 1882 was 52.76 km^2, over seven times greater than in 2015.

4.22 Diachronic comparison

It was also of interest to note the specific changes in wetlands throughout the study region. For instance, we wanted to know what areas were consistently wetlands from 1882 to the present versus what are-

TABLE 1 – Total area of wetlands in 1882 and the percentage area in each study region

	Marshes	Irrigated Fields and Meadows	Rice Fields	TOTAL BY REGION*
Alta Padovana	0.46 km^2 0.08%	69.83 km^2 12.45%	15.98 km^2 2.85%	86.28 km^2 15.38%
Medio Padovano	7.27 km^2 0.89%	56.85 km^2 7.00%	6.57 km^2 0.81%	70.69 km^2 8.70%
Bassa Padovana	15.08 km^2 1.96%	25.68 km^2 3.33%	7.39 km^2 0.96%	48.15 km^2 6.25%
TOTAL BY WETLAND TYPE	22.82 km^2 1.06%	152.36 km^2 7.11%	29.94 km^2 1.40%	205.12 km^2 9.57%

* Values in the tables are rounded independently

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as were wetlands in 1882 and were transformed into non-wetland areas (or vice-versa). The intersection geoprocess was used to calculate the wetland presence in both years (i.e. wetland persistence) and wetland change, as well as the percentages of these areas covered in wetlands (Table 3). For this calculation, we considered the two cases in which the irrigated fields and meadows are either considered as wetlands or not. More precisely:

- In the Alta Padovana, the total area consistently wetland in both time periods was 0.61 km^2, corresponding to only 0.71% of the historical wetlands (0.18 km^2 without I.F.&M., corresponding to 1.08% of the historical wetlands);
- In the Medio Padovano, the total area consistently wetland in both time periods was 0.26 km^2, corresponding to only 0.36% of the historical wetlands (0.01 km^2 without I.F.&M., corresponding to 0.08% of the historical wetlands);
- In the Bassa Padovana, the total area consistently wetland in both time periods was 0.43 km^2, corresponding to only 0.90% of the historical wetlands (0.02 km^2 without I.F.&M., corresponding to 0.07% of the historical wetlands).

In the entire province, the total area consistently wetland in both time periods was 1.30 km^2, corresponding to only 0.63% of the historical wetlands (0.20 km^2 without I.F.&M., corresponding to 0.39% of the historical wetlands).

TABLE 2 – Total area of wetlands and the percentage area in each study region for 1882 and 2015. I.F.&M. implies the irrigated fields and meadows

	Alta Padovana	Medio Padovano	Bassa Padovana	TOTAL*
1882	86.28 km^2 16.44 km^2 without I.F.&M.	70.69 km^2 13.84 km^2 without I.F.&M.	48.15 km^2 22.48 km^2 without I.F.&M.	205.12 km^2 52.76 km^2 without I.F.&M.
	15.38% 2.93% without I.F.&M.	8.70% 1.70% without I.F.&M.	6.25% 2.92% without I.F.&M.	9.57% 2.46% without I.F.&M.
2015	3.16 km^2	1.49 km^2	2.45 km^2	7.09 km^2
	0.56%	0.18%	0.32%	0.33%

* Values in the tables are rounded independently

TABLE 3 – Areas of wetlands in 1882 that remained as wetlands in 2015. I.F&M. implies the irrigated fields and meadows

Alta Padovana	Medio Padovano	Bassa Padovana	TOTAL*
0.61 km^2 0.18 km^2 without I.F&M.	0.26 km^2 0.01 km^2 without I.F&M.	0.43 km^2 0.02 km^2 without I.F&M.	1.30 km^2 0.20 km^2 without I.F&M.
0.71% 1.08% without I.F&M.	0.36% 0.08% without I.F&M.	0.90% 0.07% without I.F&M.	0.63% 0.39% without I.F&M.

* Values in the tables are rounded independently

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5. Discussion

The data collected from the Morelli (1882) map (Table 1) shows that the Alta Padovana was the region with the larger area of wetlands (15% of its area contained wetlands) while the Bassa Padovana was the region poorer in wetlands (6% of its total). However, if irrigated fields and meadows are not considered as part of the wetlands (Table 2), the Bassa Padovana was the region richest in wetlands by extension (22.48 km^2, corresponding to 2.92% of the total surface of this region) and similar in percentage with the Alta Padovana (2.93%, corresponding to 16.44 km^2). The most common type of wetland was the irrigated fields and meadows (152.36 km^2, corresponding to 7.11% of the total area of the Padova province), followed by rice fields (29.94 km^2, corresponding to 1.40%) and marshes (22.82 km^2, corresponding to 1.06%).

It is interesting to note the influence that the different geomorphological features have on the locations of wetlands within each of the three regions (Alta Padovana, Medio Padovano and Bassa Padovana). In general, the wetlands distribution and type are correlated with the location of water bodies (Figure 9). In the Alta Padovana, wetlands in 1882 were almost uniformly distributed, while in 2015 the few remaining ponds are mostly located near the course of the Brenta River. In the Medio Padovano, the historical wetlands are located in three particular areas: the area between the Brenta and Bacchiglione rivers, the so called "peri-euganeean" belt around the Euganei Hills and the northern side of the Bacchiglione River. In 2015 most of the ponds are instead located in the "peri-euganeean" belt. The wetlands in 1882 in the Bassa Padovana were located especially in the intrabasinal depressed areas between the alluvial ridges and the rivers embankments. In 2015 there was no particular relationship between the distribution of wetlands and rivers or other geomorphological features in the Bassa Padovana.

In 1882 the marshes were more common in the Bassa Padovana, where the alluvial ridges intra-basin conditions may have contributed to the difficult drainage of water, facilitating the formation of natural swamps and marshes. In the Alta Padovana, where the sediments are coarser (highest gradient in elevation) and the drainage better, there were almost no marshes in 1882.

Statistics from Table 2 and Table 3 show that the province of Padova has lost a huge amount of wetlands during a time period of only 133 years. In fact, if in 1882 there were a total of 205.12 km^2 of wetlands (including the irrigated fields and meadows), in 2015 there were only 7.09 km^2. From the diachronic comparison it is also possible to notice that, thanks to the intersection between the two wetlands polygons layers (1882 and 2015), only 1.30 km^2 of wetlands are located in the same place in both dates; the remaining 5.79 km^2 of the present-day wetlands are located in completely different positions. This is the result of the land reclamations that were performed especially during the first decades of the 20th century, which have radically changed the landscape of the province and its economy. The original classification by Orazio Morelli (irrigated fields, marshes and rice fields) does not apply anymore, as the present-day wetlands have a completely different origin and purpose and the irrigation techniques are different. Most of the wetlands are in fact abandoned clay or sand pits or oxbow lakes, sometimes reinvented as ornamental water bodies or containment tanks. As shown in Table 2, even when the irrigated fields and meadows are excluded as wetland, the loss of wetlands between 1882 and 2015 was substantial.

A final consideration regarding the minimum mapping unit and the amount of wetlands mapped is given. Using a MMU of 0.17 ha, Morelli mapped 205 km^2 of wetlands in the three regions. If Morelli had mapped wetlands of smaller size than 0.17 ha, then his estimate of total wetlands would have obviously been larger and the loss of wetlands from 1882 to the present day would have been even larger. One assumption that could be made is that the percentage of wetlands not mapped by Morelli (because of his larger MMU of 0.17 ha instead of 0.01 ha that we used for 2015) was the same proportion (1.67% of total) of what we mapped for 2015. Using a minimum mapping unit identical to what was used in 2015 (0.01 ha) then Morelli's estimate would have been approximately 1.67% greater, resulting in a total wetlands area of circa 208 km^2. Thus, the resulting wetland loss is substantial regardless of the smaller MMU used in 2015. In summary, the total wetlands in 2015 is only 3.4% of the total wetlands present in 1882. This dramatic loss of wetlands in the three regions of the province of Padova would have substantial impacts on the avian habitat as well as other species.

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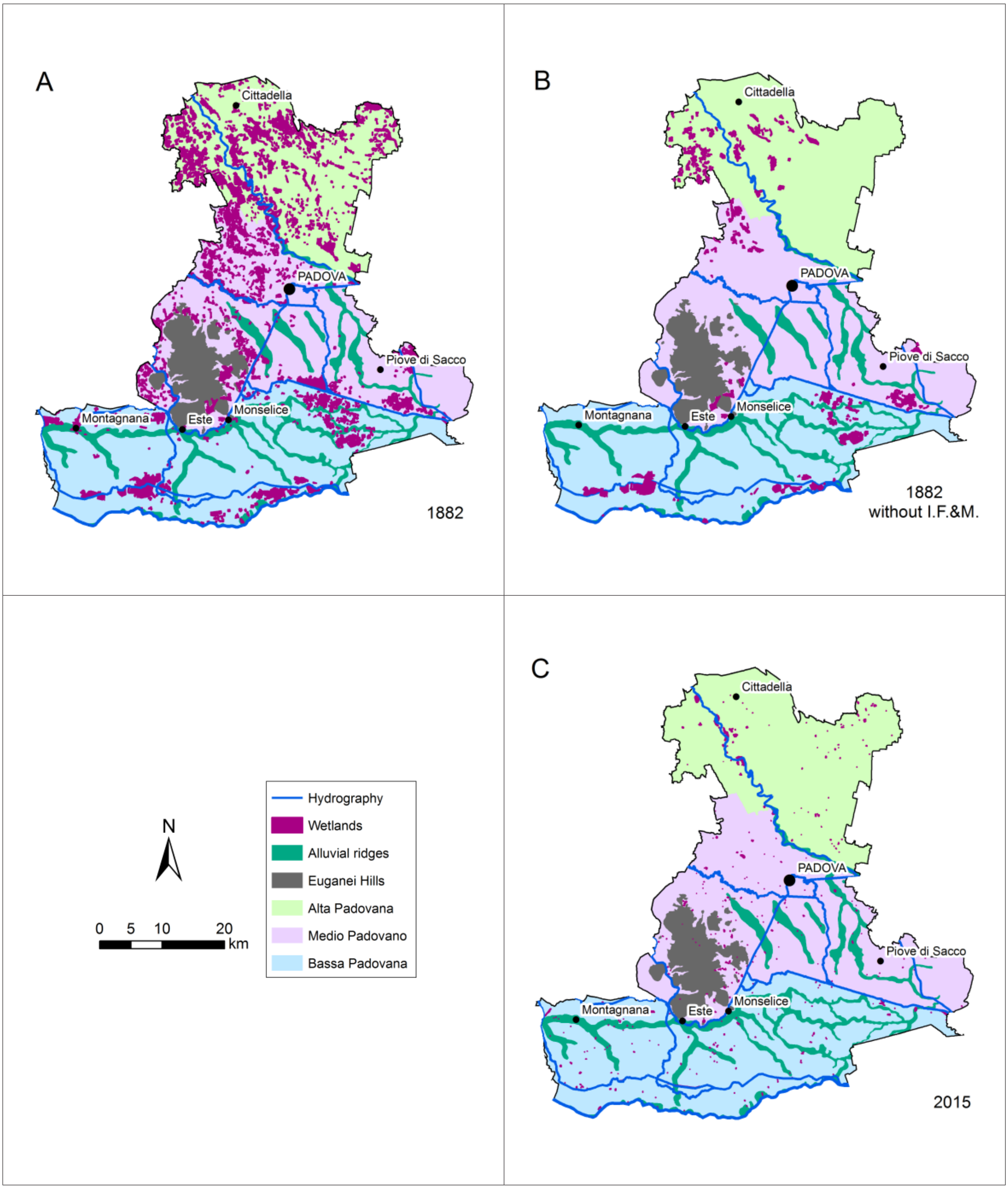
FIGURE 9 – Comparison of location and distribution of wetlands between 1882 (A, including I.F.&M.; B, without I.F.&M.) and 2015 (C) (Graphics by the authors)



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6. Conclusions

The two main objectives of this work were: 1) to perform a survey of wetland areas for the Padova province, taking in consideration two different periods (19th century and present-day), and 2) to make a diachronic comparison between the two periods representing the change in total areas and positions of wetlands. During this work the historical map of Orazio Morelli (1882) was georeferenced and analyzed, while aerial orthophotos were used to survey the entire Padova province for the present day (2015).

An analysis of the location and the distribution of wetlands was conducted. This research improves our knowledge on historical and present-day wetlands in the Veneto region and shows how great the impact of the reclamations of the 20th century have been for the Padova province. The observations on the distribution of wetland polygons in the two studied years seem to confirm that the original subdivision of the province of Padova into three areas was justified. The Alta, Medio, and Bassa Padovana regions appear to have experienced different causal factors for the distributions of wetlands in 1882 on the base of their different geomorphological conditions. No major conclusions can be proposed for the present-day wetlands distribution, since their few numbers, small sizes, and what seems to be their artificial origin, limit a quantitative correlation. In this sense, a field survey to improve the knowledge on the origin and purpose of the present-day wetlands could help in the understanding of their apparent non-geomorphological influenced distribution.

Another future prospective for this work could be to expand the current knowledge of the wetlands in the Polesine area, corresponding to the Rovigo province, located south of the Padova one. The Polesine area, as suggested by historical maps and documentation, seems to have also lost a huge amount of wetland environment, due to land reclamation processes. Furthermore, the Polesine seems to have a similar geomorphology as the Bassa Padovana and this could help confirm our thesis on the distribution of historical wetlands in the intrabasinal depressions between the alluvial ridges.

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References

Affek A. (2013), "Georeferencing of historical maps using GIS, as exemplified by the Austrian Military Surveys of Galicia", *Geographia Polonica*, 86 (4), pp. 375-390.

ARPAV (2014), *Censimento delle aree naturali "minori" della Regione Veneto, Servizio Comunicazione ed Educazione Ambientale*, Padova.

Baiocchi V., Lelo K. (2005), *Georeferencing the historical maps of Rome between the seventeenth and eighteenth centuries*, CIPA 2005 XX International Symposium, 26 September – 01 October, 2005, Torino, Italy.

Balletti C. (2000), "Analytical and quantitative methods for the analysis of the geometrical content of historical cartography", *International Archives of Photogrammetry and Remote Sensing*, 33 (B5).

Balletti C. (2006), "Georeference in the analysis of the geometric content of early maps", *e-Perimetron*, 1 (1), pp. 32-42.

Bayer T. (2016), "Advanced methods for the estimation of an unknown projection from a map", *Geoinformatica*, 20, pp. 241-284. DOI: 10.1007/s10707-015-0234-x.

Benolich V. (2016), "Le aree umide del Medio Padovano: censimento e prima analisi", Bachelor Thesis, Corso di Laurea Triennale in Geografia dei Processi Territoriali, Dipartimento di Scienze Storiche Geografiche e dell'Antichità, Università degli Studi di Padova.

Bertolani Marchetti D. (1966), "Vicende climatiche e floristiche dell'ultimo glaciale e del postglaciale in sedimenti della laguna veneta", *Mem. Biogeogr. Adriatica*, 7, pp. 193-225.

Bertoncin M. (2004), *Logiche di terre e di acque*, Cierre Edizioni, Verona.

Bitelli G., Cremonini S., Gatta G. (2013), "Analisi metrica in ambiente digitale di due carte pregeodetiche coeve condotta con metodologie non convenzionali", *Bollettino Associazione Italiana di Cartografia*, 149, pp. 27-40.

Brigante R., Radicioni F. (2014), "Georeferencing of historical maps: GIS technology for urban analysis", *Geographia Technica*, 9 (1), pp. 10-19.

Bromberg K.D., Bertness M.D. (2005), "Reconstructing New England Salt Marsh Losses Using Historical Maps", *Estuaries*, 28 (6), pp. 823-832.

Brovelli M. A., Minghini M. (2012), "Georeferencing old maps: a polynomial-based approach for Como historical cadastres", *e-Perimetron*, 7 (3), pp. 97-110.

Coleman J.M., Huh O.K., DeWitt B. (2008), "Wetland Loss in World Deltas", *Journal of Coastal Research*, 24, pp. 1-14. DOI: 10.2112/05-0607.1.

Cowardin L.M., Carter V., Golet F.C., LaRoe E.T. (1979), *Classification of wetlands and deepwater habitats of the United States*, U.S . Department of the Interior, Fish and Wildlife Service, Office of Biological Services, Washington D.C.

Cremaschi M., Gasperi G. (1989), "L'alluvione alto-medioevale di Mutina (Modena) in rapporto alle variazioni ambientali oloceniche", *Mem. Soc. Geol. It.*, 42, pp. 179-190.

Di Filippo conte Re (1815), *Nuovi elementi d'agricoltura*, Volume 2, Per Giovanni Silvestri, Agli Scalini del Duomo, Milano.

EPCN (2008), *The Pond Manifesto*, EPCN, www.europeanponds.org.

Ewald N., Nicolet P., Oertli B., Della Bella V., Rhazi L., Reymond A.-S., Minssieux E., Saber E., Rhazi M., Biggs J., Bressi N., Cereghino R., Grillas P., Kalettka T., Hull A., Scher O., Serrano L. (2010), *A preliminary assessment of Important Areas for Ponds (IAPs) in the Mediterranean and Alpine Arc*, EPCN.

Fontana A., Mozzi P., Bondesan A. (2008), "Alluvial megafans in the Venetian–Friulian Plain (north-eastern Italy): Evidence of sedimentary and erosive phases during Late Pleistocene and Holocene", *Quaternary International*, 189(1), pp 71-90. 10.1016/j.quaint.2007.08.044.

Genio Civile (1879), *Giornale del Genio Civile. Parte non ufficiale*, Serie Terza, Anno V, Tip. e Lit. del Genio Civile, Roma, p. 71.

ISSN 2282-572X (online)
ISSN 0044-9733 (print)

Gimmi U., Lachat T., Bürgi M. (2011), "Reconstructing the collapse of wetland networks in the Swiss lowlands 1850-2000", *Landscape Ecol*, 26, pp. 1071-1083.

Gong P., Niu Z.G., Cheng X. *et Al.* (2010), "China's wetland change (1990-2000) determined by remote sensing", *Science China Earth Science*, 53, pp. 1036-1042, DOI: 10.1007/s11430-010-4002-3.

Harvey F., Kaim D., Gajda A. (2014), "Analysis of historical change using cadastral materials in the Carpathian foothills", *European Journal of Geography*, 5 (3), pp. 6 -21.

Hecker N., Costa L.T, Farinha J.C., Tomàs-Vives P. (1996), *Mediterranean Wetlands Inventory: Data Recording.* MedWet/Wetlands International/ Instituto da Concervaco da Natureza Publication, Volume II.

Hook D.D. (1993), "Wetlands: history, current status, and future", *Environmental Toxicology and Chemistry: An International Journal*, 12 (12), pp. 2157-2166.

ISPRA (2011), Contributi per la tutela della biodiversità delle zone umide, Rapporto ISPRA, 153/11, ISPRA, Roma.

Lai G. (1593), *Regolarizzazione delle acque del torrente Chiampo nei territori di sua percorrenza*, DAVR, Digital Archive Verona, Prefettura di Verona/ Mappeedisegni/ PrefetturadiVerona/ 014.

Leibundgut C. (2004), "Historical meadow irrigation in Europe. A basis for agricultural development". *IAHS PUBLICATION*, 286, pp. 77-87.

Lo Rè A., Terrana M. (2005), "Evoluzione spaziale dell'area industriale di Trieste: applicazione di tecniche GIS ad una serie di carte antiche", *Bollettino Associazione Italiana di Cartografia*, 123-124-125, pp. 213-222.

Marcolongo B., Zaffanella G.C. (1987), "Evoluzione paleogeografica della Pianura veneta Atesino-Padana", *Athesia*, 1, pp. 31-67.

Morin G., Scola Gagliardi R. (eds.) (1993), *Un territorio e le sue acque: profilo storico dell'idrografia e del paesaggio agrario fra Adige e Tregnon*, Consorzio di bonifica valli grandi e medio veronese, Verona.

Morton R.A., Bernier J.C., Barras J.A., Ferina N.F. (2005), *Rapid Subsidence and Historical Wetland Loss in the Mississippi Delta Plain: Likely Causes and Future Implications*, U.S. Department of the Interior, U.S. Geological Survey.

Mozzi P., Piovan S., Rossato S., Cucato M., Abbà T., Fontana A. (2010), "Palaeohydrography and early settlements in Padua (Italy)", *Il Quaternario*, 2bis, pp. 409-422.

Mozzi U. (1927), *I magistrati veneti alle acque ed alle bonifiche*, Zanichelli, Bologna.

National Research Council (1992), *Restoration of Aquatic Ecosystems*, National Academy Press, Washington, DC.

Novello E. (2009), *Terra di bonifica: l'azione dello Stato e dei privati nel Veneto dalla Serenissima al fascismo*, CLEUP, Padova.

Panizza M. (1985), "Schemi cronologici del Quaternario", *Geogr. Fis. Dinam. Quat.*, 8 (1), pp. 44-48.

Pappalardo S.E., Ibrahim H., Saad M., Cerinato S., Borin M. (2017), "Assessing the water-purification service in an integrated agricultural wetland within the Venetian Lagoon drainage system", *Marine and Freshwater Research*, 68, pp. 2205-2215.

Pasa M. (1999), *La creazione dei Consorzi ed il grande sviluppo industriale dell'800*, in Pasa M. (ed.) *Acqua terra e uomini tra Lessinia e Adige*, Verona.

Peck D.E., Lovvorn J.R. (2001), "The importance of flood irrigation in water supply to wetlands in the Laramie Basin, Wyoming, USA", *Wetlands*, 21 (3), pp. 370-378.

Perennou C., Beltrame C., Guelmami A., Tomas Vives P., Caessteker P. (2012), "Existing areas and past changes of wetland extent in the Mediterranean region: an overview", *Ecologia Mediterranea*, 38, pp. 53-66.

Piccinini L., Fabbri P., Pola M., Marcolongo E. (2017), "An example of aquifer heterogeneity simulation to modeling well-head protection areas", *Italian Journal of Engineering Geology and Environment*, Special Issue (2017), pp. 103-115. DOI: 10.4408/IJEGE.2017-01.S-10.

Piovan S. (2014a), *Anguillara e la Bassa padovana, l'assetto geomorfologico ed idraulico del territorio*, in: Franceschi S., Lazzari A. (eds.), *I cippi di confine della Veneranda Arca del Santo di Anguillara Veneta. Atti delle giornate di studio, Anguillara Veneta 10-11 Ottobre 2013*, Alberto Brigo Editore, Rovigo, pp. 17-20.

Piovan S. (2014b), *Bonifiche, alluvioni e lavori sui fiumi*, in: Selmin F. (ed.), *Atlante Storico della Bassa padovana. Il primo Novecento*, Cierre Grafica, Verona, pp. 17-33.

Piovan S., Mozzi P., Zecchin M. (2012), "The interplay between adjacent Adige and Po alluvial systems and deltas in the late Holocene (Northern Italy)", *Géomorphologie: relief, processus, environnement*, 4, pp. 427-440.

Podobnikar T., Kokalj Z. (2006), "Triglav National Park historical maps analysis". https://www.researchgate.net/profile/Toma_Podobnikar/publication/228426319_Triglav_National_Park_historical_maps_analysis/links/09e4150efe78089ffc000000.pdf. Accessed online on 13 February 2020.

Ramsar Convention Secretariat (2013), *The Ramsar Convention Manual: a guide to the Convention on Wetlands (Ramsar, Iran, 1971), 6th ed.*, Ramsar Convention Secretariat, Gland, Switzerland.

Salerno F., Buraschi E., Bruccoleri G., Tartari G., Smiraglia C. (2008), "Glacier surface-area changes in Sagarmatha national park, Nepal, in the second half of the 20th century, by comparison of historical maps", *Journal of Glaciology*, 54 (187), pp. 738-752.

San-Antonio-Gómez C., Velilla C., Manzano-Agugliaro F. (2013), "Urban

ISSN 2282-572X (online)
ISSN 0044-9733 (print)

and landscape changes through historical maps: The Real Sitio of Aranjuez (1775–2005), a case study", *Computers, Environment and Urban Systems*, 44, pp. 47-58.

Serandrei-Barbero R., Donnici S., Madricardo F. (2011), "Supratidal foraminifera as ecological indicators in anthropically modified wetlands (Lagoon of Venice, Italy)", *Ecol. Eng.*, 37, pp. 1140-1148.

Sereni E. (2004), *Storia del paesaggio agrario italiano, Laterza*, Roma-Bari.

Singh M. (2015), "Isolated wetlands: assessing their values, functions", *Journal of Aquatic Science*, 3 (1), pp. 6-13.

Soule M. E. (1991), "Land Use Planning and Wildlife Maintenance: Guidelines for Conserving Wildlife in an Urban Landscape", *Journal of the American Planning Association*, 57 (3), pp. 313-323.

Spiers A.G. (1999), *Review of international/continental wetland resources*, in Finlayson C.M. and Spiers A.G. (eds.) *Global review of wetland resources and priorities for wetland inventory*, Supervising Scientist Report, 144, Wetlands International Publication, Supervising Scientist, Canberra, 63-104.

Sprague D. S., Iwasaki N., Takahashi S. (2007), "Measuring rice paddy persistence spanning a century with Japan's oldest topographic maps: georeferencing the Rapid Survey Maps for GIS analysis", *International Journal of Geographical Information Science*, 21 (1), pp. 83-95, DOI: 10.1080/13658810600816433.

Stefani G. (1854), *Dizionario corografico-universale dell'Italia.* Volume Primo Parte Seconda. Provincie Venete, Stabilimento Civelli Giuseppe e c., Milano.

Steiner F.R. (2000), *The Living Landscape, 2nd Edition*, McGraw-Hill, New York.

Sučić I., Talaja M., Štih A., Burić I., Zadravec M., Koren T., Lauš B., Vujanović M., Popović Dujmović I. (2018), Water pearls of the Adriatic Islands - 1st systematic Island Wetland Inventory in Croatia. Poster at the 9th European Regional Meeting, 19- 23 March 2018, Olomouc, Czech Republic 10.13140/RG.2.2.32494.72005.

Swetnam, T.W. Allen, C.D. Betancourt, J.L. (1999), "Applied historical ecology: using the past to manage for the future", *Ecological Applications*, 9 (4), pp. 1189-1206.

Tiner R. W. (2003), "Estimated extent of geographically isolated wetlands in selected areas of the United States", *Wetlands*, 23 (3), pp. 636-652.

Tomàs-Vives P. (2008), *Inventory, assessment and monitoring of Mediterranean wetlands: The Pan-Mediterranean Wetland Inventory Module*, MedWet publication, TdV, (Scientific reviewer Nick J Riddiford).

Török Z. (2002), The Romanian Wetland Inventory Project, *Scientific Annals of the Danube Delta Institute for Research and Development, Tulcea, Romania*, 30, pp. 161-173.

Triplat Horvat M., Lapaine M. (2015), "Determination of definitive standard parallels of normal aspect conic projections equidistant along meridians on an old map", *International Journal of Cartography*, 1 (1), pp. 32-44. DOI: 10.1080/23729333.2015.1055645.

Valandro R. (1980), *Un libro per la Bassa: recensioni, informazione culturale e storiografica sul Padovano negli anni Settanta*, Libreria editrice Zielo, Padova.

Veggiani A. (1994), "I deterioramenti climatici dell'Età del Ferro e dell'Alto Medioevo", *Boll. Soc. Torriceliana di Scienze e Lettere*, 45, pp. 3-80.

Verhoeven J.T., Setter T.L. (2010), "Agricultural use of wetlands: opportunities and limitations", *Annals of botany*, 105 (1), pp. 155-163.

Vigato M. (1997), *Il monastero di S. Maria delle Carceri, i comuni di Gazzo e Vighizzolo, la comunità atestina trasformazioni ambientali e dinamiche socio-economiche in un'area del basso padovano tra medioevo ed età moderna*, Comune di Carceri, Carceri (Padova).

Vorlicek P.A., Antonelli R., Fabbri P., Rausch R. (2004), "Quantitative hydrogeological studies of the Treviso alluvial plain, NE Italy", *Quarterly Journal of Engineering Geology and Hydrogeology*, 37, pp. 1-7.

Zalidis G.C., Mantzavelas A.L. (1996), "Inventory of Greek wetlands as natural resources", *Wetlands*, 16, pp. 548-556.

Zandonà G. (2015), "Le aree umide della Bassa Padovana: censimento e prima analisi", Bachelor Thesis, Corso di Laurea Triennale in Geografia dei Processi Territoriali, Dipartimento di Scienze Storiche Geografiche e dell'Antichità, Università degli Studi di Padova.

Zuccagni-Orlandini A. (1844), *Corografia fisica storica e statistica dell'Italia e delle sue isole*, Volume Sesto, Presso gli Editori, Firenze.

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