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# MAPPING OVER 80 YEARS OF WETLAND SENSITIVITY TO HUMAN INTERVENTION. THE SPATIAL DYNAMICS OF THE LAKES AND WETLANDS OF THE JIJIA-IAȘI WETLANDS RAMSAR SITE IN 1935–2018

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**Highlights**

- Wetlands are top of the list in terms of valuable ecosystem services.
- The spatial dynamics of the wetland areas and lakes in the Jijia-Iași Wetlands Ramsar Site were analysed using historical cartographic materials.
- A timeline is used to put into perspective the resulting maps and synthesised findings.
- This paper complements the scientific work focusing on "the Delta of Moldavia".

**Abstract.** Wetlands are at the top of the list in terms of valuable ecosystem services, at the same time being one of the most sensitive ecosystems that are subject to human-induced changes. The delicate balance between their ever-changing waterlogged and dry areas, together with the associated rich flora and fauna, are easily disturbed by human drivers, which are also responsible for long-term land use conversions. This paper aims to 1) document the spatial dynamics of the wetland areas and lakes in the Jijia-Iași Wetlands Ramsar Site, using historical cartographic materials and modern land use data, and 2) pinpoint the anthropic drivers that shaped these dynamics, via a literature review. This Ramsar Site constitutes an eloquent example of a wetland landscape that was mainly shaped by human intervention. A timeline is used to put into perspective the resulting maps and synthesised findings, and several inferences regarding the past, present, and future sensitivity of the wetlands in the study area are formulated. In 1935–2018, the two analysed elements followed opposite trends: while the wetland areas decreased from 10.61% of the study area to 4.79%, the lake features increased in size, from 0.68% of the Jijia-Iași Wetlands to 10.84%. In order to explain these changes, anthropogenic interventions were divided into three types of management (detrimental high human pressure, beneficial high human pressure, and beneficial low human pressure). In the long term scientific works, the unbalanced dynamics proved to be beneficial to the environment, as the construction of water collections determined a biodiversity boost and the designation of the study area as a Ramsar Site. This paper complements the scientific work focusing on "the Delta of Moldavia", highlighting the practical implications of the management strategies applied during the reference period.

**Keywords:** wetlands, wetland sensitivity, wetlands spatial dynamics, Jijia-Iași Wetlands, Ramsar.

## Introduction

Scientific research concerning wetlands has become more and more focused on the human-driven changes of these ecosystems (Maltby & Acreman, 2011; Zariņa et al., 2018), especially in areas where the climatic and hydrological conditions that favour their development are also subject to variation. Human communities modify the environment to their benefit, mainly pursuing two goals: to ameliorate undesirable situations (e.g., to compensate for potential water shortages, to reduce flood risk via hard or soft adaptation options), and/or to acquire material or abstract wealth. Often times, land use changes prove to undermine the pursuit of these

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targets in the long term, when ecosystem services are negatively affected.

The "wetland" term supports many definitions, depending on the field of study and the particularities of the environment (e.g., climate, hydrologic regime, geomorphologic setting, pedogenesis) that dictate wetland taxonomy. Wetlands include swamps, marshes, and bogs, but also environments that are temporarily wet; in summary, areas with prolonged soil saturation conditions that favour the development of hydrophytes and that may be permanently or periodically subject to flooding (Tiner, 2017). Also, wetlands have an abundant fauna component, mainly represented by birds and aquatic species (Arias-García et al., 2016). The specific ecosystem services refer to water supply, water purification, aquifer regeneration, nutrient and sediment retention, carbon sink, flood control, and climate moderation (Maltby & Acreman, 2011; Mitsch et al., 2015; Tanislav, 2014). The Millennium Ecosystem Assessment (2005) divided these services into four categories (provisioning, regulating, supporting, and cultural services), with wetlands providing ecosystem services from all aforementioned taxonomical units. Reputable scientific sources cite wetlands as the most valuable ecosystems in terms of provided services (Costanza et al., 1997; De Groot et al., 2012; McInnes, 2013; Mitsch et al., 2015). Maltby and Acreman (2011) present a well-documented study of how society's relationships with wetlands have evolved from Antiquity to the present. This history highlights that their high value and productivity have not sheltered them from the impact of human intervention (Gâștescu & Ciupitu, 2014; Maltby & Acreman, 2011; Zariņa et al., 2018), until their importance was acknowledged via the IUCN's MAR Project in the 1960s and the Ramsar Convention in 1971 (Matthews, 1993).

Understanding how wetlands are shaped by anthropogenic factors is of primary importance to their conservation, implying to ensure that the specific ecosystem services remain functional. This is especially important in developing countries, where economic development appears to be winning the battle against nature conservation.Multi-temporal mapping of wetland spatial dynamics is useful in determining which drivers were harmful or beneficial to the thriving of these ecosystems. Taking into consideration that "Wetland loss and degradation has proceeded at least in part due to the poor understanding of their functioning and of their role in providing benefits to people through delivery and maintenance of ecosystem service" (Maltby & Acreman, 2011), it becomes clear that sound scientific research on wetlands represents a prerequisite for the avoidance of past mistakes and for the elaboration of improved close to nature management plans. These goals appeared on the international agenda at the end of the last century, taking the form of protection conventions like Ramsar or Natura 2000.

In Romania, wetlands cover about 2882.06 km$^2$, representing 1.2% of the national territory; the percentage increasing to 2.61% if inland water bodies are added (Corine Land Cover [CLC], 2018). Tanislav (2014) divided the 345 wetland protected areas that cover 10.5% of Romania into wetlands of international importance (i.e., Ramsar sites), community importance sites and special protection areas (i.e., Natura 2000 sites), and wetlands of national importance. Wetland research in Romania currently focuses either on the extension and taxonomy of wetlands at national (Ciobotaru et al., 2016; Feranec et al., 2000; Gâștescu & Ciupitu, 2014; Tanislav, 2014; Török, 2000; Romanescu et al., 2010) or regional level (Ion et al., 2019; Romanescu, 2008; Romanescu et al., 2011), or on particular wetland areas – including the ones located in the North-East of the country (Cîșlariu et al., 2020; Gache, 2012; Pascal et al., 2014; Romanescu et al., 2017; Stoica 2011). There are only a few studies that analyse different types of pressures that the wetlands in Romania are subject to (Matei et al., 2016; Simon & Andrei, 2021).

This paper aims to map the spatial dynamics of water bodies and wetlands in the Jijia-Iași Ramsar Site and to pinpoint the anthropogenic drivers that have been shaping this evolution since the beginning of the last century. Studying the practical implications of the management strategies applied during 1935–2018, new lessons regarding the interactions between the biophysical and the social factors emerge. These may be used as guidelines for the close to nature management required by the Ramsar status of the study area.

In this paper, human interventions are defined as actions taken by human communities to alter the environment, either by changing the land use, or by performing hydrotechnical or agrotechnical works. Wetland sensitivity refers to the propensity of these ecosystems to be impacted by these human-driven changes. By corroborating the two defined elements, several assertions about what is detrimental and what is beneficial to wetlands and their biodiversity may be formulated.

## 1. Study area

The Jijia-Iași Wetlands are located in the North-East of Romania, at the contact between the Continental and the Steppic Bioregions. The site overlaps both the middle and the lower drainage basins of the Jijia River, also comprising the valleys of its tributaries (the Miletin and Jijioara rivers) and other short temporary rivers (Figure 1). The 194.32 km$^2$ study area is a Ponto-Sarmatic wetland with anthropogenic lake surfaces, natural eutrophic lakes, wet and salty marshes and pastures, forests, and arable land. The area covered by wetlands changes during the year, depending on the rainfall fluctuations: shrinking to ~17 km during dry spells, or evolving into a "massive water landscape" in springtime (RIS, 2020). The landscape of intricate water bodies and marshes resembles a deltaic one, motivating the advertising of the area under the names of "the Larga-Jijia Delta", "the Delta of Moldavia", or the "Iași Echo Delta".

The study area was designated as a RAMSAR Site in February 2020, meeting the requirements that define the five criteria of representative/rare/unique wetlands, rare

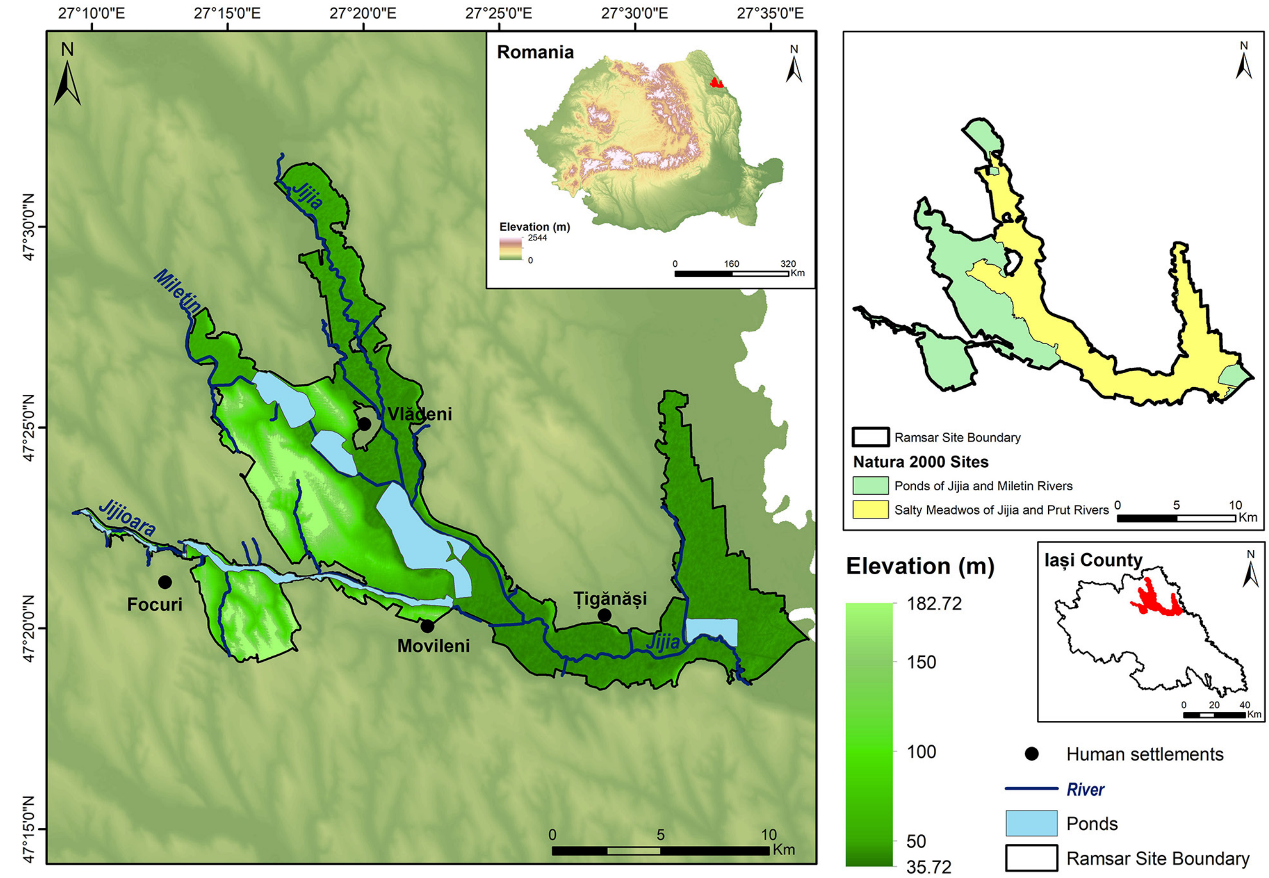


Figure 1. Jijia-Iași Wetlands Ramsar Site location

species and threatened ecological communities, biological diversity, support offered during critical life cycle stages/in adverse conditions, and of hosting more than 20 thousand waterbirds. The ecosystem is a habitat for 256 animal species, of which 225 are bird species. The aquatic vegetation, rich aquatic fauna and compact reedbed attract numerous birds that migrate to steppe regions, making the site the most important waterbird nesting area in the Prut River catchment (RIS, 2020). Therefore, during the high discharges of spring, when the waterlogging process is at its peak, up to 20 thousand birds may be observed in the Vlădeni Fishponds area (Török, 2000). The ecological value of the site has been acknowledged since 2007, as its boundaries correspond to two Natura 2000 sites: the Ponds of Jijia and Miletin Rivers SPA (ROSPA0042) and the Salty Meadows of Jijia and Prut Rivers SCI (ROSCI0222) (Figure 1). Moreover, the RAMSAR Site includes the Teiva Vișina Reserve, an IUCN Category IV area. For all these protected areas, the Orithological Romanian Society elaborated management plans with the support of the European Regional Development Fund (SOR Site, 2022).

## Climatic and water flow related aspects of the study area

Various geologic, geomorphologic, hydrologic, and climatic factors contributed to the formation of the Jijia-Iași Wetlands: the impermeable clay-based geologic setting, the temperate continental climate characterised by frequent droughts, and a hydrological regime with large discharge variations (Iosub et al., 2020; Minea et al., 2020; RIS, 2020; Romanescu et al., 2011). The wetlands are surrounded by glacis slopes and the first system of fluvial terraces, meaning that the concavity of the relief also favoured the accumulation of water and the development of such ecosystems (RIS, 2020).

However, the two components of the water balance (450–550 mm/year rainfall and a 650–700 mm/year yearly potential evapotranspiration), or more precisely 150–200 mm/year water deficit, influenced the human induced landscape changes in the study area, which translated into the construction of terrigen dams and water collections. The specific water input resides mainly in the discharges of the Jijia River and its tributaries, and only secondarily in slope runoff and underground water input (Minea et al., 2020). The surface water input depends on the rainfall regime, which registers large fluctuations that are partially reflected by the river discharges (Figure 2). The most consistent rainfall corresponds to summer (41.2% of the average annual amount), but this does not correlate with the highest river discharge: the Jijia registers only 24.4% of the average annual water volume in this season, due to the very high evapotranspiration rates (49.6%) (Prăvălie et al., 2019) (Figure 3). Complementarily, the maximum discharge of the Jijia and its tributaries is registered during spring (41.1%), which is explained by the positive water balance of the winter (13.2%) and the convergence of water inputs: high rainfall (25.6% of the average annual amount) (Figure 3), and ice and snow melting.

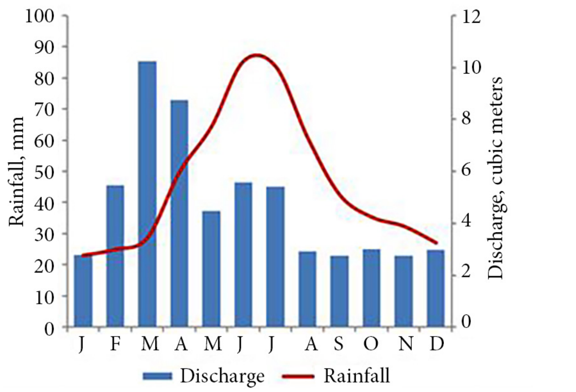


Figure 2. Discharge of the Jijia River and rainfall regime in the Jijia-Iași Wetlands Ramsar Site

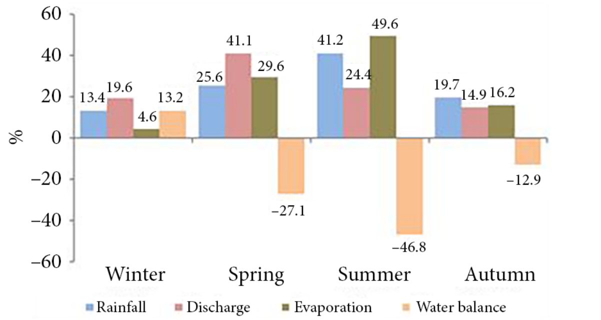


Figure 3. Water balance of the Jijia-Iași Wetlands Ramsar Site

The man-made lakes and the wetlands in the Jijia-Iași Site imply that a part of the water volume of the Jijia River is stored, varying according to the measurement location: 6.7% of the total water volume transported by the aforementioned river at Vlădeni hydrometric station and 8.8% of it at Victoria station (Figure 4). The average discharge of the river also increases towards the confluence with the Prut River (4.8 $m^3$/s at Vlădeni and 6.6 $m^3$/s at Victoria) due to the water input of the two right-side tributaries, the Miletin River (1.23 $m^3$/s average discharge) and the Jijioara River (0.87 $m^3$/s average discharge). The largest water storage corresponds to the highest discharges of the springtime, reaching over 4.7 million $m^3$ in March and 2.8 million $m^3$ in April (Figure 5).

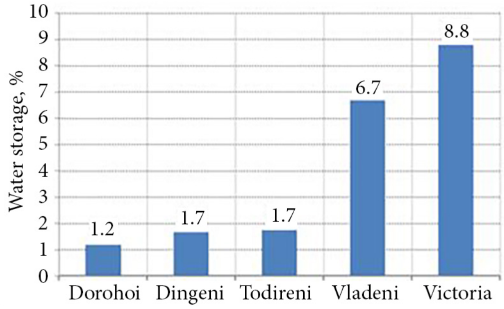


Figure 4. Water storage at different hydrometric stations located in the middle drainage basin of the Jijia River

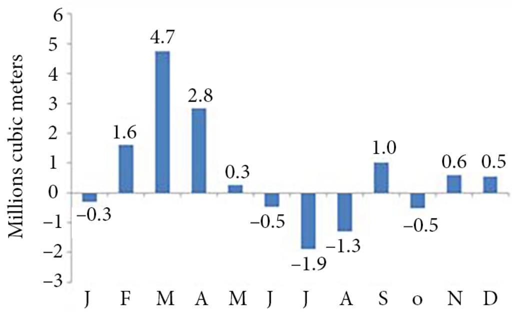


Figure 5. Annual water storage variation in the middle drainage basin of the Jijia River

## 2. Methodology

Wetland mapping is central to understanding the spatial relations between the biophysical and social contexts. The natural and anthropogenic factors as well as their ever-changing interaction coordinate landscape dynamics, which can be documented using maps. The advancement of GIS and Remote Sensing in the last decades has facilitated the monitoring, mapping, and classification of land use (Ghaffar, 2005) and wetlands (Fekri et al., 2021; Thamaga et al., 2022; Wu, 2018; Zhang et al., 2023), also contributing to the processing of older cartographic documents (Chiang et al., 2014; Valent et al., 2016).

Reconstructing historical water bodies or wetlands from old maps is a common practise (Dömötörfy et al., 2003; Pavelková et al., 2016; Šantrůčková et al., 2017), but it is subject to inherent uncertainties arising from conceptualisation, measurement, or analysis processes (Kaim et al., 2014; Valent et al., 2016). Wetlands are sensitive to spatial changes, either due to climatic and hydrological variations, or to human-induced land conversion (Zariņa et al., 2018); which makes their mapping more challenging. Thus, scientists rely on historical maps in order to unlock the cartographic information concerning wetland areas. The extraction techniques differ depending on the characteristics of the maps (e.g., quality, spatial scale, colorimetric scale), ranging from the most basic (manual or semi-automatic vectorisation of the features) to the more complex automatic raster-processing techniques (Baily, 2007; Chiang et al., 2014) that can integrate neural networks (Jiao et al., 2020).

In order to acquire information about the spatial dynamics of the lakes and wetlands of the Jijia-Iași Wetlands Ramsar Site, classical and modern spatial data processing techniques were combined (Figure 6). The evolution during the 20th century was analysed by setting three reference time intervals: 1935–1959 (A), 1960–1983 (B), and 1984 (C), which correspond to the available cartographic materials (Table 1). The maps were georeferenced using the Pulkovo 1942(58) projected coordinated system. The lake and wetland areas were identified using the maps' key, then digitised on the screen (i.e., vectorised) in TNTMips

6.9 by drawing area objects (polygons) over the raster for each lake or wetland feature. This manual vectorisation technique was preferred, although it is more time-consuming, due to the fact that it allows for more reliable and accurate results. The polygons were exported as shapefiles in order to produce two sets of maps for each of the selected periods, using ESRI's ArcMap 10.2.2.

For the mapping of water bodies and wetland features corresponding to the most recent, available time period (2018, D), the CORINE Land Cover (CLC) 2018 data provided by Copernicus were processed using the above said software by extracting the area delimited by the 2422 Ramsar Site boundary and reprojecting it to match the projection used to process the historical maps (Figure 6).

Table 1. Reference periods and the corresponding old cartographic materials

| Period | Reference year(s) | Map type | Scale |
|---|---|---|---|
| A | 1935–1959 | Military map | 1: 20 000 |
| B | 1963–1983 | Topographic map | 1:5000 |
| C | 1984 | Topographic map | 1:25 000 |

The minimum mapping unit of this status layer is 25 hectares, which was considered adequate, especially since the Ramsar Site uses the same data source for the official map of the Jijia-Iași Wetlands (Ramsar Site, 2020). Only the

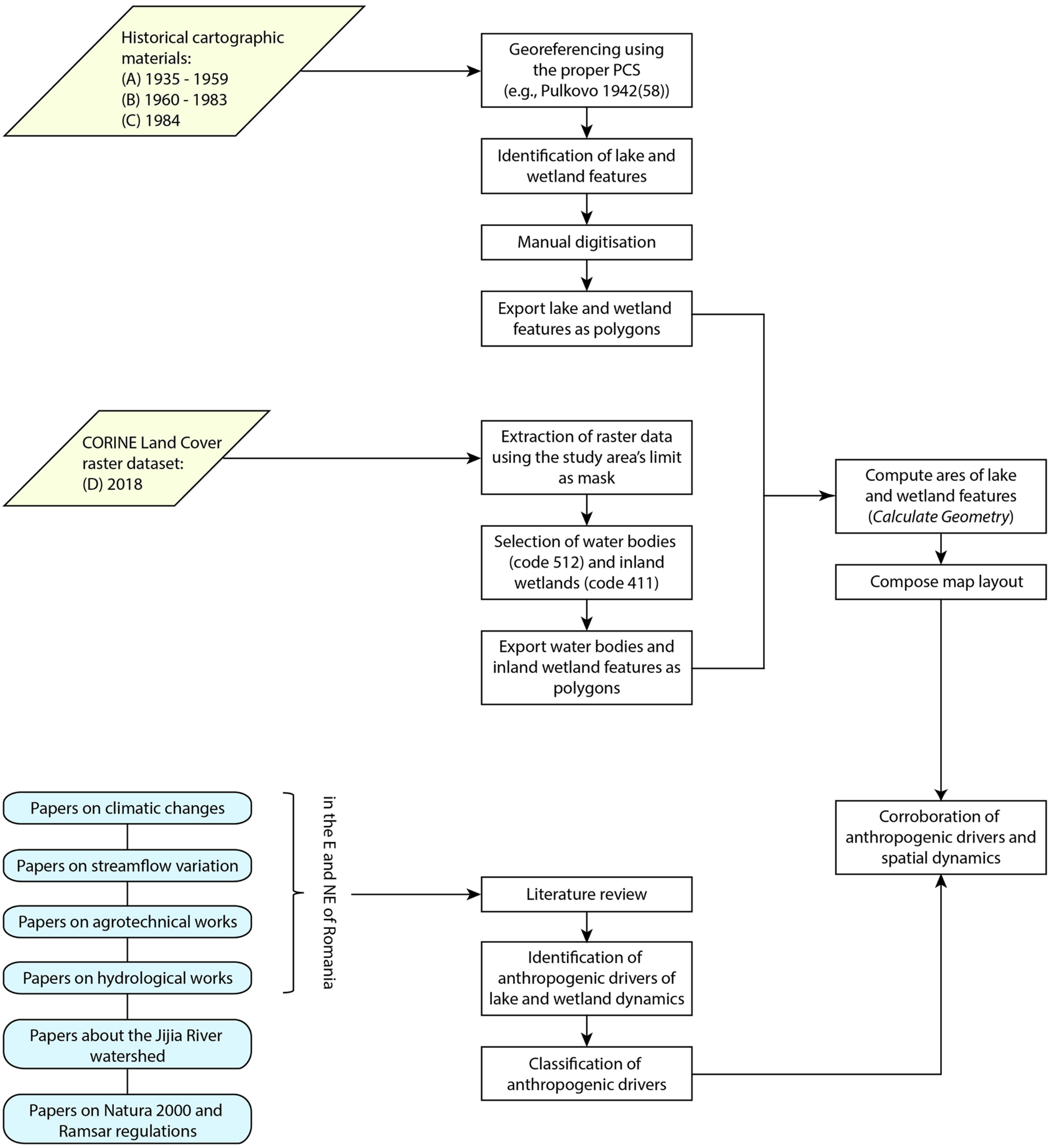


Figure 6. Methodological workflow

inland wetlands (411 code) and water bodies (512 code) were selected from the 44 classes in the CLC nomenclature. The areas of the lakes and wetlands were computed via the Calculate Geometry tool in ArcMap 10.2.2.

The next step was to corroborate the observed spatial dynamics of the lakes and wetlands with the human interventions that acted as drivers of the land use changes (Figure 6). A literature review was performed in order to understand how the study area was modified during the past 80+ years, what motivated those interventions, and how they were expressed on the maps. In order to extract relevant change drivers and chronologically order them, two types of papers were studied: 1) scientific works regarding climatic changes (Croitoru et al., 2013; Minea & Croitoru, 2017b), streamflow variation (Croitoru & Minea, 2015; Gheorghe, 2015; Minea & Chelariu, 2021; Minea & Croitoru, 2017a), agrotechnical (Bucur & Moca, 2012) and hydrological works (Gâștescu & Ciupitu, 2014; Huțanu et al., 2019; Vartolomei, 2004) in the East and North-East or Romania, and 2) papers focusing on the catchment of the Jijia River (Buruiană et al., 2012a, 2012b; Cîșlariu et al., 2020; Gache, 2012; Iosub et al., 2019; Mânzu et al., 2020; Minea & Vasiliniuc, 2007; Romanescu et al., 2017). The rationale for studying scientific works that focus on climatic or hydrological changes is that these elements influence human-induced landscape dynamics. Additionally, the literature review included papers on the regulations specific to Natura 2000 (Blicharska et al., 2016; Louette et al., 2011; Tsiafouli et al., 2013) and Ramsar sites (Bridgewater & Kim, 2021; Hamman et al., 2019; Kingsford et al., 2021), as well as landscape and land use changes that may be traced back to the associated close to nature management (RIS, 2020).

Correlating the shrinkage or expansion of the lake and wetland areas with their anthropogenic drivers, also taking into account the intensity of the human interventions, the management approaches were divided into three categories: detrimental high human pressure, beneficial high human pressure, and beneficial low human pressure (Table 2). The resulting maps and synthesised findings were put into perspective using a timeline, and several inferences regarding the past, present, and future sensitivity of Jijia-Iași Wetlands were formulated.

## 3. Results and discussion

The geomorphologic setting of the Ramsar Site has favoured the construction of man-made ponds; the oldest of which can be traced back to the Middle Ages. These water collections were used as water sources, as well as fisheries, evolving to be attractive for numerous bird species (RIS, 2020). In the last 80+ years, the lakes and surrounding wetlands have registered various volumetric or area related changes, determined by a combination of fluctuations of climatic and hydrological nature, and human interventions.

The first half of the 20$^{th}$ century represented a period of high human pressure on the Jijia-Iași Site, which translated into a low variation of lake areas and significant spatial variation of wetlands. In case A, concerning the reference period 1935–1959 (Table 1), the lakes in the study area covered 1.33 km$^2$, representing 0.68% of the total area of the Ramsar Site, slightly increasing to 1.74 km$^2$ (0.89% of the study area) in case B as shown in Figures 7, 8. In the first two reference periods (A and B), the lakes were located along the Jijioara River, near the settlements of Bulbucani and Mălăești. The low percentage may be explained by the extensive hydrotechnical and agrotechnical works performed during the interwar period on the course of the Jijia River and its tributaries. The engineering works focused on the regularisation of water courses and the construction of levees, aiming to attenuate the negative effects of floods by redimensioning the riverbeds in order to ensure the transportation of a large volume of water, preventing overflows that would exceed the banks of the rivers.

In 1950–1960s, a large area of the floodplains was drained in order to convert it into agricultural land (Minea, 2020). This led to a significant decrease in the wetland areas, which covered 20.62 km$^2$ (10.61%) in period A and only 13.77 km$^2$ (7.08%) in period B. Figure 7 shows a notable shrinkage of the wetland area extending from the confluence of the Miletin and Jijia rivers to the one formed by the Jijioara and Jijia rivers.

The detrimental high human pressure period was followed by a beneficial one, starting in the 1960s. The study area was included in the national programme of territorial planning in the 1970s, leading to a significant expansion of lake areas: 15.20 km$^2$ (7.82% of the Ramsar Site) in case C. The two most notable lakes were the one located between the settlements of Vlădeni and M. Kogălniceanu, and the one located Eastward from Țigănași (Figure 7). This is confirmed by Obreja (1985), who states that several levees were constructed in the Eastern part of the current Ramsar Site; along with several

Table 2. Particularities of management approaches applied in the study area

| Types of management | Effect | Human interventions | Periods |
|---|---|---|---|
| High human pressure | Detrimental | agrotechnical works: land conversion to the benefit of agriculture land<br>hydrotechnical works: wetland drainage, construction of man-made channels used to divert floodwater, construction of levees, dams, regularisation of water courses | 1919-A |
| | Beneficial | construction of retention ponds, ecotourism | B, C-2007 |
| Low human pressure | Beneficial | wetland restoration, the use of ponds for fisheries, pond maintenance, measures that limit pollution | 2008-D |

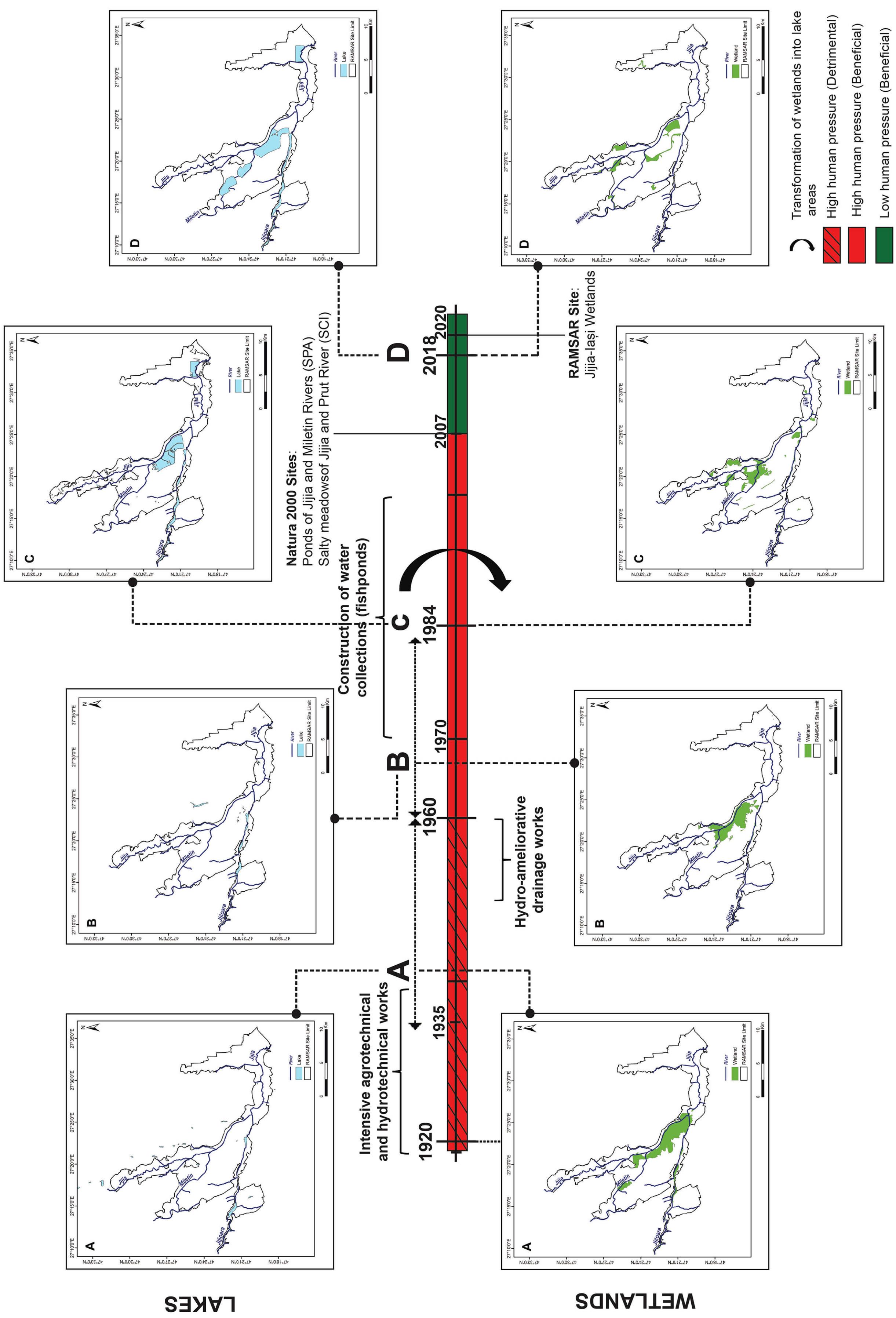


Figure 7. Timeline of lake and wetland area variation in the Jijia-Iași Wetlands Ramsar Site, 1935–2018

anthropic lakes (Vartolomei, 2004). On the other hand, the construction of man-made lakes that were managed as fisheries caused a further decrease in the wetland areas, which covered 12.89 km$^2$ in period C, representing 6.63% of the study area. These ecosystems extended to the North of the Miletin-Jijia confluence, but disappeared almost entirely to the South of this point, where the largest cluster of ponds was constructed in the 1970s.

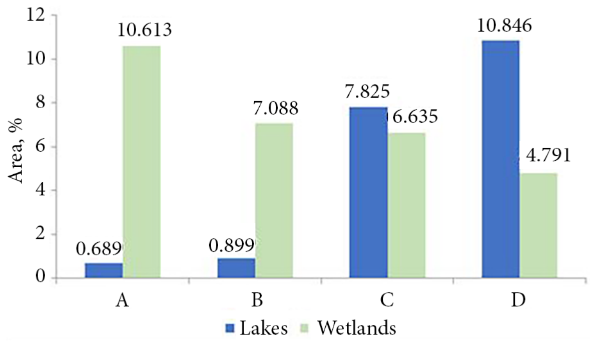


Figure 8. Lake and wetland area variation in the Jijia-Iași Wetlands Ramsar Site, 1935–2018

This uneven evolution continued in the 21st century, with the lake features peaking at 21.07 km$^2$ (10.84% of the Jijia-Iași Site), and the wetland areas plummeting to 9.30 km$^2$ (4.79% of the study area) (Figure 8). Currently, the lakes extend along the Miletin River (Hălceni Lake and the pond located to the Southwest of Vlădeni), between Vlădeni and M. Kogălniceanu settlements, to the East of Țigănași and also along the Jijioara tributary (Figures 6, 8). Wetlands surround the largest lake, located between the confluences of the Jijia River with the Miletin and the Jijioara rivers, also presenting a scattered distribution in the Northeastern part of the Ramsar Site (Figure 7). In 2018, the better part of the study area (80.49%) was represented by lands used for agricultural activities. Lake and wetland features covered 15.63% of the Jijia-Iași Site, while forest and semi-natural areas, artificial surfaces, and water courses represented less than 1.4% each (Figure 9).

The fall of the communist regime triggered economic and social transition processes marked by uncertainty, as well as legislative changes. There is an apparent paradox formed on the basis of wetland shrinkage, despite the fact that the study area was designated as two distinct Natura 2000 sites in 2007 (Figure 7). In this case, it should be highlighted that the decrease of wetland areas took place on account of pond expansions since the 1970s (RIS, 2020). The construction of the water collection system merely continues the hydrological works begun at the turn of the century to reduce flood risk in the Jijia watershed. The floods of 1955, 1969, 1975, 1979, 1980 (Buruiană et al., 2012a; Vartolomei, 2004) and 1985 (Huțanu et al., 2019) may be mentioned as events that contributed to the

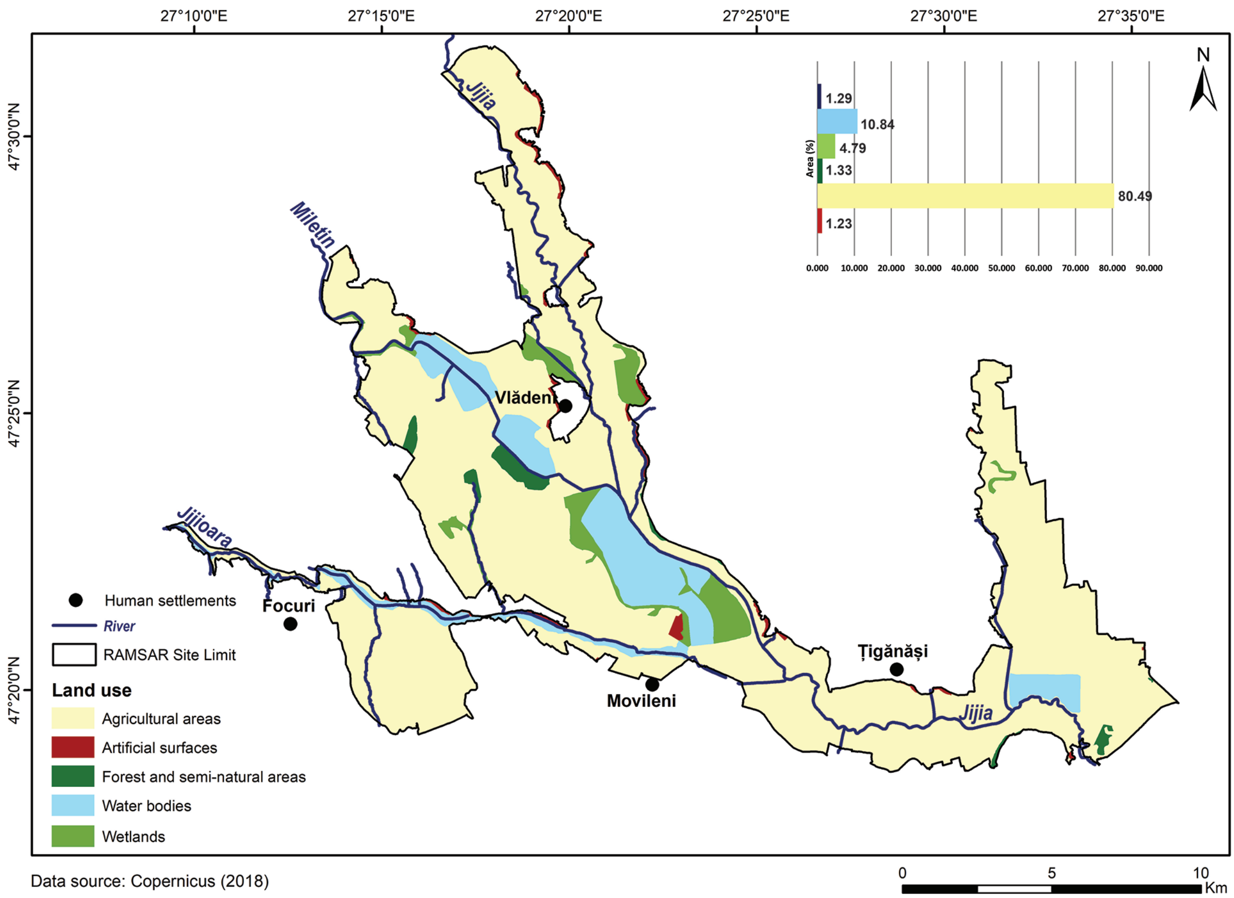


Figure 9. Land use in the Jijia-Iași Wetlands Ramsar Site, 2018

emergence of the high human pressure period (Figure 7).

Overall, the unbalanced dynamics of the wetlands and water bodies did not translate into detrimental effects for the Ramsar Site, but significantly contributed to the boost of the hydrophytes and the aquatic fauna. Thus, since 2007, the human pressure in the study area has been low, taking the form of agriculture activities, fishing, and more recently, ecotourism. In this regard, the Ramsar Information Sheet argues that the maintenance of the ecological character of the study area "depends, on a great extent, on keeping these fisheries viable" (RIS, 2020). The same source identifies a series of factors that adversely affect the Ramsar Site, among which drainage, canalisation and river regulations, annual and perennial non-timber crops, hunting and collecting terrestrial animals, pollution with agricultural and forestry effluents, droughts, fisheries abandonment, water intake and land conversion for agriculture purposes are among the impactful potential threats. Still, all the actual threats maintain a low to medium impact level, meaning that the study area is sustainably managed (RIS, 2020).

Parts of the Ramsar Site have been studied before in the endeavour to monitor landscape changes (Cîșlariu et al., 2020; Gache, 2012; Pascal et al., 2014; Stoica, 2011), integrating a variety of remote sensing and GIS techniques. Gache (2012) studied the Vlădeni wetlands, an important bird breeding area located at the confluence of the Jijia River, the Miletin and the Jijioara tributaries. The wetland is the result of the construction of water collections in the 1970s: the ponds called Vlădeni, Larga Jijia, Movileni-Mălăiești-Forăști-Gropnița, Focuri-Coarnele Caprei, and the dam lakes (Hălceni Lake, Bulbucani Lake). The threats highlighted by Gache (2012) relate to summer droughts, the high cost of water supply in fisheries, fishing poaching activities, illegal reedbed burning, pollution with particles resulting from hill slope or levee erosion, and unregulated clay exploitation.

The 515.34 $km^2$ common floodplain of the Jijia-Prut rivers, which overlaps the South-Eastern part of the Jijia-Iași Wetlands Ramsar Site, was analysed in terms of wetland landscape changes and water bodies (which in this case include rivers, irrigation channels, lakes, and ponds) variation between 2005 and 2012 by Pascal et al. (2014). The authors argue that the common floodplain is composed of riverine (77.96%), lacustrine (16.94%) and palustrine (5.35%) wetlands, and that the wetland area registered an insignificant increase (0.5 $km^2$) between 2005–2012 (Pascal et al., 2014).

The most extended multi-temporal mapping of a part of the study area was performed by Cîșlariu et al. (2020). The spatial dynamics of the Salty Meadows of Jijia and Prut Rivers (ROSCI0222), which overlap the better part of the Eastern Jijia-Iasi Wetlands, were documented with the use of historic maps (Austrian plans, Romanian military maps, Soviet maps, topographic maps) that correspond to 1910, 1944–1954, 1975, 1981 and of satellite imagery from 2009. The data were completed by fieldwork performed to identify current plant communities and via a review of phytocoenological studies. Results show that wetland areas decreased from 88.07% of the total area in 1944–1957 to 26.79% in 1975, and to 17.58% in 1981. On the other hand, grassland area and arable land increased, representing 51.74% of the total area, respectively 24.12% of it in 2009 (Cîșlariu et al., 2020). The paper highlights the primary contribution of historical florists and phytocenological information in the endeavour to accurately interpret landscape changes and to avoid the inherent errors that arise when such analyses are based only on the processing of cartographic materials. Previously, the same study area (Natura 2000 ROSCI0222) was analysed in terms of healthy vegetation by Stoica (2011), using the Normalized Difference Vegetation Index (NDVI) and LANDSAT imagery. The study shows that more than half of the vegetation was well or very well-preserved in 2010.

This paper is the first to map out the spatial dynamics of the water bodies and wetlands located within the limits of the Jijia-Iași Wetlands. We believe that the newly created natural protected area is worth documenting in terms of water bodies and wetland changes through multitemporal mapping, and that expanding the study area beyond the limits of previous studies contributes to scientific progress, particularly when new reference years are set. The limitations of the paper refer to the different scales of the historical maps used to document the variation of lake and wetland features in the study area in the previous century. The scales of the cartographic materials used to map the extent of the aforementioned elements in periods A, B, and C do not match (Table 1), opening the way to accuracy-related issues. Another shortcoming of the mapping methodology is the use of map sheets from different time periods in the endeavour to map out the lake and wetland areas in case A. Map sheets from four time intervals were aggregated in order to compose the study area: 1935–1939 (1 sheet), 1940–1944 (4 sheets), 1945–1949 (1 sheet) and 1955–1959 (1 sheet). Moreover, the identification of wetlands was performed using the maps' key, but the field identification of these ecosystems may have taken place using different criteria, as the term supports many definitions.

The presented findings complement the ones specific to the studies that focus on study areas that are totally or partially included in the Ramsar Site. The threats identified using the Ramsar Information Sheet match the ones described by Gache (2012), which also argue that biodiversity conservation is conditioned by the maintenance of pond fisheries: "the disappearance of one fishery meaning the automatic disappearance of one wetland with the whole associated biodiversity".

The decrease in wetland areas is confirmed by both Pascal et al. (2014) and Cîșlariu et al. (2020), although the related explanations and the reference periods differ. Pascal et al. (2014) consider that wetland landscape changes are "a direct consequence of the water bodies' anthropisation", highlighting that their preservation is compulsory for sustainable management, while Cîșlariu et al. (2020) undertake a Biology-based approach on the issue, arguing that human wetland degradation and the expansion of grasslands represent a natural vegetation response determined by the interaction of natural (temperature increase, rainfall decrease) and anthropic (agriculture development) factors (Triantafyllidis et al., 2020; Zotos et al., 2021). The latter authors consider that it was the wetland shrinkage that favoured the designation of the area as an SCI, on the grounds of habitat diversification. Taking into account the timeline of human interventions and their effects on the spatial dynamics of lakes and wetlands (Figure 7), we argue that anthropic factors represent the main force that shaped this evolution. However, we acknowledge that human interventions were partially motivated by climatic and hydrological conditions, and that the primary driver was the goal of reducing flood risk via various methods with detrimental or beneficial effects on the studied ecosystems.

## Conclusions

In modern times, climate changes emerge as impactful and disruptive factors for wetland conditions, while land use changes fuelled by increased economic pressure threaten the already highly sensitive wetland ecosystems. This calls for improved long-term governance models that prioritise ecosystem conservation and adaptive monitoring programmes. In this context, a correct understanding of past wetland management lessons becomes pivotal for the maintenance of wetland ecosystem services.

Although the Jijia-Iași Wetlands Ramsar Site in the North-East of Romania is one of the most studied wetland areas in the country, little was known about the factors that shape the dynamics of water features in this study area. This paper provides new insights concerning the dynamics of wetlands and lake features in the protected area, also highlighting the anthropogenic driving factors of the presented spatial changes. Furthermore, the proposed framework can be applied to any case study as long as historical data is available.

In summary, over the past 80+ years, the lake features in the study area have grown in size and number, while the wetland areas registered opposite trends, as a result of extensive hydrotechnical works starting in the 1970s. Overall, the wetlands' and water bodies' unbalanced dynamics had no negative effects on the Ramsar Site, but rather aided the growth of aquatic fauna and hydrophytes.

These findings may be used as a basis for decision-making regarding what types of management strategies suit the purpose of biodiversity conservation, which represents the cornerstone of Ramsar sites' functionality. For instance, the increase in biodiversity, the designation of two Natura 2000 sites, and the current Ramsar Site are among the positive effects of the last stages of human management (i.e., beneficial high human pressure in 1960-1984, and beneficial low human pressure since 2007). This suggests that future management strategies should strive to safeguard the desirable current status of the Jijia-Iași Wetlands, but also to advance on the way of mitigating potential local- and regional-scale threats.

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## Author contributions

A-CA: conceptualization, methodology, visualization, original draft preparation, writing-reviewing and editing. IM: conceptualization, data curation, validation, investigation, supervision. DL: writing-reviewing and editing, supervision. MI: data collection and curation, validation, investigation. DB: data collection and curation, validation.

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