

CHANGING TRADITIONAL ECOLOGICAL KNOWLEDGE AND
TRADITIONAL PRACTICES IN THE BIOCULTURAL LANDSCAPE
OF THE BIEBRZA VALLEY



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JOANNA SUCHOLAS

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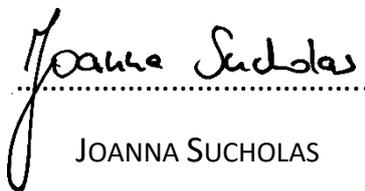
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PROF. DR. PETER POSCHLOD

UNTERSCHRIFT:


.....
JOANNA SUCHOLAS

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SUMMARY

The Biebrza River Valley is a conservation site of one of the largest wetland ecosystems of global significance in Central Europe. The majority of this biocultural landscape consists of semi-natural habitats such as floodplain mires and fen meadows, which were developed through centuries-long traditional hay management and the traditional ecological knowledge (TEK) of local communities. The maintenance of biodiversity of those habitats is largely dependent on both traditional farming practices and the preservation of TEK. However, in the last 60 years, wetland use changes have affected wetland ecosystems and supposedly also TEK. These shifts were related to the transformation of the area's agricultural system, as determined by social, ecological, economic and political drivers. The present study aims to analyse the changes in wetland management practices and assess their implications for TEK and biodiversity conservation in the Biebrza Valley. In addition, to propose recommendations for improvement of conservation and wetland management in this biocultural landscape.

Chapter One places the role of traditional farming and TEK in the preservation of semi-natural wetland habitats in the Biebrza Valley in a broader context. It provides an outline of how wetland habitats and biodiversity have been shaped by agricultural activities since their beginning. The relevance of traditional agricultural practices and TEK for development and maintenance of European high nature value wetlands and the negative implications of land-use changes and agricultural transformation on their biodiversity are discussed. Currently, the management of semi-natural wetlands in EU is often shaped by the agri-environmental schemes (AES) of the Common Agricultural Policy (CAP), in relation to which different opportunities and dangers for biodiversity, traditional agriculture and TEK have been identified.

Chapter Two studies changes in wetland-use and vegetation cover in the Biebrza Valley, driven by agricultural transformation over the last 60 years. Spatio-temporal GIS analysis confirms that all semi-natural wetlands were used for common traditional farming in the 1960s, whereas management abandonment peaked in the 1990s. AES availability has been revealed to contribute to the reimplementation of wetland use.

Chapter Three presents the results of ethnoecological studies in the Biebrza Valley. The studies have revealed deep and complex TEK on plants, wetland landscape and traditional hay

management practices among the local community's older generations. The abandonment of traditional farming practices in recent decades has eradicated a large proportion of TEK among younger farmers.

The results presented in **Chapter Four** confirm that the current management of semi-natural wetlands in the Biebrza Valley is significantly defined by implemented AES. However, traditional farming practices, which are identified as crucial for biodiversity conservation, are poorly incorporated into current management. It was found that AES might even contribute to farming intensification in the area. Therefore, it has been suggested how the use of wetlands could be improved through the revision of AES and beyond.

Chapter Five reviews the results of the three main chapters. TEK, analysed in **Chapter Three**, is deep, complex, and associated with the details of traditional wetland management practices, therefore its application and inclusion in current management is firmly justified. Further, the results of **Chapter Two** and **Chapter Four** on wetland-use changes in the Biebrza Valley are analysed together. The study confirmed that, as a result of the discontinuation of wetland use, a significant part of the wetlands had undergone vegetation succession, which threatens its biodiversity. AES has proven to be an effective financial tool for supporting the re-implementation of wetland management. However, traditional practices are poorly supported in current management, and the biocultural landscape in the area is disappearing. This implies that wetland management needs revision to increase its effectiveness in wetland conservation and enhance the resilience of the socio-ecological system. The proposals include the active involvement of local wetland users, the identification and implementation of key traditional practices, and the implementation of adaptive wetland management supported by TEK.

In conclusion, the research highlighted the explicit biocultural character of the Biebrza Valley and the dependence of effective protection of the biodiversity of semi-natural wetlands on traditional practices. The AES system has contributed significantly to the reintroduction of wetland management after decades of abandonment, so it has proven an effective financial tool of EU CAP to support the use of semi-natural habitats. However, the research showed that the current use of wetlands, defined by the AES, does not support traditional practices, which in turn could have negative consequences for biodiversity. The current use of wetlands requires revision, for which the thesis proposes specific recommendations. These include the

improvement of the AES system as well as the development of culturally appropriate nature conservation and agricultural initiatives in the Biebrza Valley, supporting extensive farming practices. In addition, there is need for further research among local conservationists and policy makers to identify viable opportunities for integrating TEK, local community and traditional practices into wetland management.

CHAPTER ONE: GENERAL INTRODUCTION



'There were as many haystacks as stars in the sky'
An airplane image of wetlands in the Biebrza Valley, 1963.

WETLANDS AS BIOCULTURAL LANDSCAPES

Wetlands are one of the most precious and complex ecosystems of global significance due to the multiple functions they serve, for instance: water purification, carbon management, alleviation of floods and biodiversity preservation (Zedler and Kercher 2005). In addition, they offer people a range of resources, such as energy, fish, berries, peat, game (EEA 2000), medicinal plants (Sucholas et al. 2021), livestock fodder (Biró et al. 2019) and many others. The biocultural landscapes of the floodplains were co-created by humans bound to river floodplains that determined their migration, settlement, trade, forestry, fishery and agriculture (Schindler et al. 2016).

In particular, agricultural activities have greatly affected and altered wetland habitats and their biodiversity throughout history. European wetlands have been traditionally used, notably for grazing, haymaking, hunting, burning, fishing, reed cutting, etc. (Cook and Moorby 1993, Middleton et al. 2006, Poschlod 2015a, Biró et al. 2019). In Central Europe, domestic cattle was introduced to wetlands in the postglacial Neolithic period, around 6800 BP (Ellenberg 1996). Before livestock farming, European wetlands were grazed by wild large ungulates such as Elk and Red deer (Cromsigt 2000). However, it was not grazing but scythe hay mowing that led to the widespread occurrence of fen meadows in Europe (Bignal and McCracken 1996). In Europe, the scythe has been used since the Iron Age, with East Slavs mowing meadows since the 11th century at the earliest (Poschlod 2015b).

Semi-natural fen meadows have emerged from natural sedge-dominated fens and carr forests, the first habitats to be mown (Ellenberg 1996). Peat-forming fen meadows such as tall sedges and sedge moss communities belong to habitats of special conservation importance due to their unique biodiversity and presence of rare specialist species (Wheeler and Shaw 1995). The biodiversity of fen meadows is not as high as that of other grassland types, for instance the calcareous (Poschlod et al. 1998), but would be much lower if not for extensive human disturbances (Werpachowski 2005).

RELEVANCE OF TRADITIONAL FARMING FOR HIGH VALUE HABITATS

Today, areas of high nature value in Europe are characterised by the presence, and often dominance, of semi-natural habitats developed through extensive farming practices (Niedrist et al. 2009, Poschlod and Wallis De Vries 2002). Examples include wetland sites of,

for instance, the coastal floodplain in Estonia (Burnside et al. 2007), the floodplain of the Sava River in Croatia (Gugić 2009), and many others (Godwin 1978, Tucakov 2011, Biró et al. 2020). It is estimated that more than 50% of highly valued biotopes of conservation relevance in Europe appear in rural biocultural landscapes, directly linked with low-intensity farming. Therefore, a considerable number of European species and habitats are dependent on such extensive farming practices (Bignal et al. 1996). This comes as no surprise: the peak in species and habitat biodiversity in the 19th century was associated with the highest diversity of land-use types and the maintenance of semi-natural habitats (Green and Vos 2003, Poschlod et al. 2005). Starting from the 19th century, ‘the traditional agricultural landscape’, featuring traditional farming, was replaced by industrial landscape in many places in Europe (Vos and Meeke 1999).

The traditional practices of extensive farming are ‘not generally a part of modern agriculture’ (Bignal et al. 1996). Besides contribution to high participation of semi-natural habitats (Clark et al. 1994), traditional farming in Europe is characterised among others by low agrochemical input, management techniques that increase diversity of vegetation structure (Kun et al. 2019), long-established management practices (haymaking, pasturing), and a low degree of mechanisation (Poschlod 2015a). Traditional farming practices vary significantly in detail across Europe as adapted to local conditions. Traditional ecological knowledge (TEK) developed among human communities is at the very core of the traditional methods applied (Molnár et al. 2008).

TRADITIONAL ECOLOGICAL KNOWLEDGE AT THE CORE OF TRADITIONAL FARMING

TEK incorporates communities’ knowledge about elements of the environment (flora, fauna, abiotic components, landscape, etc.), beliefs, ethical values and human practices. It accumulates long-term observations and is transmitted orally from generation to generation (Hunn 1993, Berkes 2017, Berkes and Turner 2006). TEK is the subject of ethnoecological studies that seek to understand interactions of human communities with the environment (Toledo 1992, Nazarea 1999). TEK was initially widely recognised by scientists mainly among indigenous tribal communities outside Europe (Posey 1983, Hunn 1990, Turner et al. 2000). However, in the last decades, many studies have also revealed the presence of TEK on natural habitats and their management among rural communities in Europe (Meilleur 1986, Pettersson et al. 2001, Mustonen 2013, Babai and Molnár 2014, Varga et al. 2016). It should

be highlighted that the TEK of living European rural communities differs from indigenous knowledge, since these groups draw from the same Judeo-Christian tradition. Their culture has been impacted by Roman and Greek heritage and may now be influenced by globalisation, agribusiness (Fischer et al. 2012) and education. Therefore, the TEK of European rural communities is defined as 'based upon decades of personal experience with the surrounding landscape, acquired through hands-on management of the landscape, containing centuries-old, communally stored experiences which is mostly independent of western science and connected to rituals of social life' (Molnár et al. 2008).

It is widely acknowledged that ethnoecological studies among tribal communities can be beneficial for nature conservation. Decision makers and conservationists might cooperate with TEK holders and integrate the revealed knowledge, practices and resource use strategies into local biodiversity management (Posey and Balée 1989, Gadgil et al. 1993, Charnley et al. 2007, Pyke et al. 2018). Given the contribution of TEK and traditional practices to the development of high value habitats in biocultural landscapes in Europe (Vermeer and Joosten 1992, Mustonen 2013, Öllerer 2014, Biró et al. 2020), they should be explored, maintained and incorporated in conservation endeavours and land management (Molnár et al. 2019). Even if local traditional farming practices have already been ceased, it should be feasible to reconstruct them from ecological, archaeological, ethnographic, and historical sources (Birks et al. 1988, Biró et al. 2019, Klerk and Joosten 2019) or by conducting ethnoecological interviews with local communities, especially the oldest generation (Molnár et al. 2019).

THREATS FOR BIODIVERSITY FROM LAND-USE CHANGES IN BIOCULTURAL LANDSCAPES

It is observed that the biocultural landscapes of Europe are vanishing, and traditional knowledge and practices are often abandoned (Lieskovský et al. 2015, Birks et al. 1988, Lenzin 1995, Babai et al. 2015, Biró et al. 2014, Valsiuk et al. 2018). This is due to a wide range of factors, such as land-use changes, farming intensification, globalisation, demographic transition in villages, biophysical inconvenience of management, and low productivity of habitat resulting in economic unattractiveness (McGinlay et al. 2017). Changes in agricultural practices and land-use abandonment have a directly negative effect on TEK and the biodiversity of semi-natural habitats such as heathlands (Dolman and Sutherland 1992, Thompson et al. 1995), lowlands, and mountainous grasslands (Poschlod et al. 1998, MacDonald et al. 2000, Fischer and Wipf 2002, Babai and Molnár 2014, Lasanta et al. 2017) as

well as semi-natural wetlands (Joyce and Wade 1998, Middleton et al. 2006, Valasiuk et al. 2018, Biró et al. 2020).

In the case of European wetlands, land reclamation and river regulation, carried out since the Middle Ages and continued on a massive scale since the 19th century, have had a particularly detrimental impact. The wetlands were drained to increase their productivity (Middleton et al. 2006) and transformed into arable fields (Poschlod et al. 2005). In addition, the common use of artificial fertilisers in intensified agriculture led to the eutrophication of wetlands, altering their vegetation. For instance, an excess of nutrients results in the spread of competitive and invasive species that displace wetland specialists, which become endangered species (Zedler and Kercher 2005). The abandonment of hay mowing and the replacement of low-intensity livestock grazing by livestock housing (Clark et al. 1994) lead to secondary vegetational succession and shrub encroachment in wetlands (Truus and Tõnisson 1998, Valasiuk et al. 2018, Biró et al. 2019, Kotowski et al. 2013). The negative ecological consequences of those processes are the loss of habitats, habitat fragmentation, and decrease in species richness (Niedrist et al. 2009, Poschlod 2015b). It is calculated that about two-thirds of European wetlands have been lost in the 20th century (European Commission 1995).

AGRI-ENVIRONMENTAL SCHEMES INTENDED TO SUPPORT THE USE OF HIGH VALUE HABITATS

Continuation or restoration of the extensive farming practices that maintain semi-natural habitats with low productivity but richness in species requires financial compensation for farmers and land-users. In Europe, the management of these habitats is supported mainly by the regulatory system of subsidised agri-environmental schemes (AES), funded under the Common Agricultural Policy (CAP) of the European Union (EU) (Batáry et al. 2015).

In its first decades, CAP contributed to a decrease in the biodiversity of semi-natural habitats in the old EU Member States (Donald et al. 2001, Henle et al. 2008, Pe'er et al. 2014). The reaction to this alarming trend was the development of AES – a policy tool aiming to mitigate the pressure of modern agriculture on nature (connected with usage of artificial fertilizers, pesticides, ploughing of grasslands, etc.). However, regarding agriculturally marginalised areas in the Central-Eastern Member States of the EU, with different agricultural histories and challenges (Tryjanowski et al. 2011), AES are intended mainly to advert land use abandonment and to prevent farming intensification (Kleijn and Sutherland 2003, Batáry et al.

2015). In any case, AES aim to halt biodiversity loss and offset farmers monetarily for any financial losses coming from the implementation of environmentally-friendly measures (Kleijn and Sutherland 2003).

AES are compulsory for all Member States of the EU as part of the 'second pillar' of CAP supporting rural development. The schemes vary significantly between countries, as they are designed on a national level (Science for Environment Policy 2017). They either foster nature-friendly farming practices, which might be implemented in any farm (organic farming, buffer stripes, etc.) or target specific species or high nature value habitats (Batáry et al. 2015).

Over twenty years of research on the effectiveness of AES, summarised by Batáry et al. (2015), confirms general benefits for farmland biodiversity coming from AES implementation. However, it is conditioned by the structure of the landscape and the level of ecological contrast between the land under the scheme and the surrounding area; therefore, AES are found to be beneficial for e.g. intensive monocultural farmlands by providing high ecological contrast (Batáry et al. 2015). AES has been revealed to support the biodiversity of semi-natural habitats, for instance in the case of the largest calcareous grasslands in Europe (in Alvar region in Sweden, Rosén and Bakker 2005) and species-rich mountain grasslands in the Alps (Kampmann et al. 2012). A study by Weis (2001) on the AES-supported reintroduction of sheep grazing in grasslands after over twenty years of abandonment showed a significant increase in species richness.

Much less research on AES effectiveness has been conducted in farmlands of agriculturally marginal areas, despite their high nature value and the occurrence of threatened species (Tryjanowski et al. 2011, Sutcliffe et al. 2015). However, the authors identified that CAP regulations do not adequately support traditional farming in Central-Eastern European countries, given its importance in biodiversity conservation (Beaufoy and Marsden 2010, Sutcliffe et al. 2015). For instance, it was found that CAP regulations promoted only some traditional practices of traditional small-scale farming in Romania and Hungary, whereas the majority were either not supported in any form or prohibited. The authors indicated this as detrimental to both the integrity of the traditional farming system and farmland biodiversity (Babai et al. 2015).

Researchers emphasise that agricultural regulations should primarily be based on the comprehensive recognition of regional peculiarities of the social, cultural, economic and

ecological determinants and agricultural history that have conditioned this region (Tryjanowski et al. 2011, Dahlström et al. 2013, Elbakidze et al. 2013, Sutcliffe et al. 2015). Above all, regulations aiming to protect biodiversity in biocultural landscapes should incorporate or adapt local traditional practices that contribute to the successful maintenance of valuable biotopes and are culturally appropriate to the area of interest (Gugić 2009, Burton and Paragahawewa 2011, Fischer et al. 2012, Babai et al. 2015).

BIEBRZA RIVER VALLEY – BIOCULTURAL WETLAND LANDSCAPE IN TRANSITION

The present study was conducted in the Biebrza River Valley, one of the largest areas of wetland ecosystems in Central Europe. The landscape features a natural lowland floodplain regularly inundated by waters of the naturally meandering Biebrza River, the dominance of semi-natural alkaline fen meadows, carr woods, and a mosaic of sandy mineral hills (Oświt 1973). Centuries of traditional farming have contributed to the development of the typical biocultural landscape of this area.

Wetlands in the Biebrza Valley are preserved under good hydrological conditions and host unique wetland specialists such as nesting waders, including 75% of the EU population of the globally threatened aquatic warbler (Lachmann et al. 2010); elk; and rare vascular and moss plant species. In 1993, the Biebrza National Park (Biebrza NP) was established in the valley 'to protect all nature and landscape qualities (...) as the site stands out for its special natural, scientific, social, cultural and educational values' (Nature Conservation Act 2004). Due to the global significance of the wetlands of the Biebrza Valley, the entire area was designated a Ramsar Site in 1995 (Wassen et al. 2006). In addition, the area is included in the Natura 2000 network under Habitats and Birds Directives (92/43/EEC, 2009/147/EC) as containing 'breeding and resting sites for rare and threatened species, and some rare natural habitat types' ([http1](#)).

Biebrza NP is located in North-Eastern Poland and occupies an area of approximately 60,000 ha with a buffer zone of ca. 67 000 ha (Bołtromiuk 2010), being the largest national park in Poland. Fluvio-glacial waters formed the valley depression at the time of the Vistulian Glaciation. During the Holocene, peat soils developed on the top of the sand filling the valley. Wetlands dominate the area, whereas post-glacial sandy uplands cover ca. 40% (Oświt 1970, Churski and Szuniewicz 1991). The valley consists of three geomorphologically distinct basins:

Upper, Middle, and Lower. The Lower Basin is remarkable for its most naturally retained character (Wassen et al. 2007).

The vast majority of wetland vegetation is influenced by moving water originating from river floods (in a floodplain) and groundwater running out from a morainic plateau (in percolation fens). The vegetation in the Lower Basin has a regular pattern conditioned on its hydrological regime, geomorphology and traditional hay management. Extensive phytosociological studies and peat analyses carried out in the 1960s revealed the presence of five distinctive vegetation zones extending parallel to the river's course (Oświt 1970). The vegetation by the river is mostly composed by reed, great manna grass (*Glyceria aquatica*), *Oenanthe-Rorippetum* and *Caricetum gracilis* associations, and followed by tall sedges with tussock structure, for instance *Carex elata*. Further from the river, alkaline fen meadows with sedge-moss communities and low-sedge-brown moss communities dominate. Finally, the last zone is constituted by alder carr forest.

Before people had started to settle on the uplands along the Biebrza Valley in the 14th century, the area was used only seasonally by hunters, fishermen, cattle herders, haymakers and beekeepers (Kamiński 1963). At that time, woodland and natural fen meadows dominated in the area (Łowmiański 1932). Oak, lime and hornbeam covered mineral hills, whereas alder, birch and ash trees grew in wetlands (Kondracki 1972). Permanently settled human communities started removing trees in wetlands and using the occurring grassy vegetation of semi-natural habitats as a source of hay. For centuries, up to the 1960s, wetlands were managed substantially by traditional haymaking and grazing (Wiśniewski 1964). As they were the only source of subsistence, meadows and pastures in wetlands were of great economic value for the local community.

However, due to agricultural transformation in the area, farming intensification and melioration processes, undrained wetlands have become unattractive to farmers. When the grasslands were drained outside the valley, farmers suddenly gained access to more productive, fertilised meadows. In addition, people have gradually ceased hand mowing in favour of the tractor, for which wetlands were much less accessible (Banaszuk 1991). For those and other reasons, a process of progressive abandonment of semi-natural wetlands started at the end of 1960s inside the Biebrza Valley (Bartoszuk and Kotowski 2009). Secondary

succession with reed and *Salix* spp. has started in the unmanaged wetlands, greatly threatening their biodiversity (Kotowski et al. 2013).

Biebrza NP has striven to remove invading shrubby vegetation, albeit on a very limited scale (Matuszkiewicz et al. 2000). Moreover, reimplementation of management in such a large area of a complicated ownership structure (approximately 50% of the 166,000 plots are privately owned (Kardel et al. 2009)) and dominance of semi-natural wetlands that require biomass removal, revealed greatly challenging for Biebrza NP. The institution faced labour, technical and financial limitations to successful management (Bołtromiuk 2010).

Nonetheless, CAP, encompassing the AES system, was introduced in Poland along with its accession to the EU in 2004. Part of the AES developed were designated to financially support management of breeding bird and grassland (including wetland) habitats under the Natura 2000 network. Therefore, local conservationists from the Biebrza NP hoped and expected that the subsidised AES would become a relevant financial incentive for farmers, and support the national park in continuing or reintroducing management in wetlands (Bartoszuk et al. 2004, Nawrocki 2004). Moreover, they underlined the role of local traditional practices that have contributed greatly to the development of unique wetland habitats and the necessity to foster those practices through AES (Bartoszuk et al. 2004). On the other hand, concerns that other CAP tools may even accelerate agricultural intensification have also been addressed (Nawrocki 2004).

THESIS OUTLINE AND RESEARCH QUESTIONS

Biebrza NP is a wetland conservation area with many habitats of a semi-natural character, developed through centuries-long human traditional agricultural practices embedded in the TEK of local communities. Therefore, the maintenance of unique biodiversity of those habitats in a proper and desirable condition is dependent and conditioned on both extensive farming activities and the preservation of TEK. However, in the last 60 years, dynamic changes to wetland use have affected wetland biodiversity and supposedly also TEK (Fig. 1.). Those shifts were related to transformation of the agricultural system in the area determined by social, ecological, economic, and political drivers. Against this background, the research questions of the present study were formed to assess the implications of those processes on TEK and biodiversity conservation and propose recommendations for improvement of wetland management and conservation in the biocultural landscape of the Biebrza Valley.

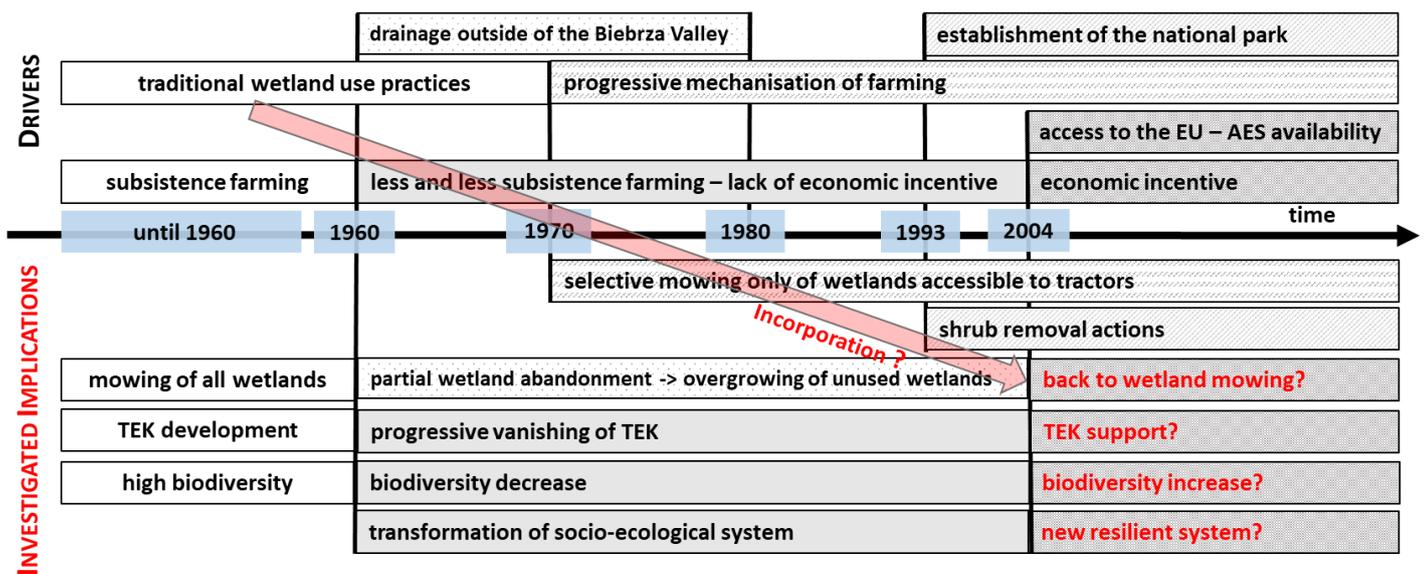


Fig. 1. A timeline of the main drivers of wetland-use changes in the biocultural landscape of Biebrza Valley and the investigated implications on TEK and conservation.

In **Chapter One**, the relevance of traditional farming and TEK in the maintenance of semi-natural wetland habitats in the Biebrza Valley is embedded in its broader context. The tight relationship between man and the wetlands is outlined. At the dawn of human farming activity in Europe, wetlands were already being altered by humans, who co-created their biocultural landscape. The chapter emphasises the dependence of effective conservation of European high nature value wetlands on traditional farming and TEK. Ethnoecological research among

rural communities revealed that TEK, together with traditional practices, should be incorporated into the local management of semi-natural wetlands. Currently the management of semi-natural habitats in EU is shaped predominantly by the AES system, which carries both much potential and great threats for biodiversity, traditional agriculture and TEK.

Chapter Two studies changes in wetland use and vegetation cover in the last 60 years as conditioned by agricultural transformation in the Biebrza Valley. The spatio-temporal GIS analysis aimed to answer the following research questions: How did traditional hay management shape wetland vegetation cover? What consequences has the abandonment of management had for wetland vegetation? Has the availability of AES indeed contributed to the reimplementation of wetland management in the Biebrza Valley? What are the prospects that reintroduction will have a beneficial effect on biodiversity?

Chapter Three presents the results of ethnoecological studies in the Biebrza Valley. Although traditional hay management practices have contributed to the development of high nature value wetlands in the Biebrza Valley, they have never been extensively documented. Moreover, TEK, in which traditional farming practices are embedded, has never been comprehensively studied. Therefore, the urgent need for ethnoecological studies in the area was recognised. The research questions were formulated to reflect whether the local community still has local TEK about wetland plants and vegetation. Has this knowledge changed in the last decades? How does this knowledge relate to the perception of the wetland landscape? What value do wetlands present to local communities? The questions aimed at understanding TEK on plants and vegetation of the local community, wetland landscape perception and values behind the developed and implemented traditional management, which was also documented.

Chapter Four analyses the current management of semi-natural wetlands. Given that traditional hay management practices have contributed to the development and dominance of high nature value wetlands in the Biebrza Valley, it was assumed that the presence of those practices determines the effective conservation of wetlands as well as supporting the local biocultural landscape. Therefore, the main research question was whether traditional hay management practices (provided in **Chapter Three**) are incorporated in the presently implemented use of wetlands. Focus was placed on AES, which are hypothetically the main current regulatory tool shaping wetland management. It was studied how similarity to

traditional practices depends on the type of AES, which AES local farmers prefer, and how the implementation of AES has changed in recent years. The key hay management practices (variables) identified to have a significant impact on the biodiversity of semi-natural habitats were analysed. The relevance of those practices for biodiversity conservation and the conservation implications of current management were broadly discussed. Possible recommendations for addressing challenges in wetlands management in the Biebrza Valley and beyond were outlined.

Chapter Five reviews the results of the three main chapters. The TEK that is still present among local community in the Biebrza Valley, as revealed and extensively analysed in **Chapter Three**, is discussed in short. As the TEK investigated is deep, complex and strongly associated with the details of traditional wetland management practices, its application and inclusion in current management is firmly justified. Further, the results of **Chapter Two** and **Chapter Four** are reviewed together. The implications of wetland-use changes (management abandonment, reimplementation of use by AES system) in the Biebrza Valley for the wetland biodiversity conservation and TEK are analysed. In addition, the importance of traditional practices for biodiversity conservation has been supported by scientific evidence. The final section formulates proposals on how the current system defining wetland management can be improved to more effectively protect biodiversity and be a more resilient system. In particular, attention was drawn to the need for a good recognition of the current socio-ecological system, the active involvement of local wetland users, the recognition and implementation of key traditional practices, and the implementation of adaptive wetland management supported by TEK.

CHAPTER TWO:

WETLAND USE CHANGES AND THEIR EFFECTS ON VEGETATION IN THE
BIOCULTURAL LANDSCAPE OF BIEBRZA NATIONAL PARK, POLAND



The pathways made by cattle and tractors in wetlands, 2015.

ABSTRACT

The Biebrza River Valley is one of the largest wetland ecosystems of global significance in Central Europe. This biocultural landscape consists mainly of semi-natural habitats, such as floodplain mires and fen meadows. For centuries, open wetlands have been used by local communities for subsistence by extensive haymaking and pasturing. In the last decades, due to reclamation and agricultural intensification, wetlands were abandoned and underwent succession. As counteracting shrub encroachment threatening biodiverse habitats was beyond capability of established Biebrza National Park, it was believed that the agri-environmental schemes (AES) of EU Common Agricultural Policy (CAP) would become the main tool to restore wetland use. The objective of our study was to verify the hypothesis that AES reintroduced wetlands management in the area, which has been gradually ceased since 1960s.

For the purpose of our study, we undertook a spatio-temporal analysis of wetland-use cover and vegetation structural changes. We have selected three key time periods: time of traditional agriculture in 1960s, peak of wetland use abandonment in 1990s, and year 2015 – a few years after AES became available in Poland. We have mapped the digitalised aerial and satellite images of the four studied wetland areas in the Biebrza Valley in GIS.

Our analysis revealed that in the 1960s, during time of traditional management, on average 72% of the studied sites were managed. However, 30 years later, approximately 80% of coverage of those areas underwent secondary succession. Mostly large helophytes such as reed and tall sedges spread in the area where mowing and grazing have been abandoned. After 11 years of AES availability, we observed a restoration of management, which involved ca. 31% of study areas. Throughout the study periods, vegetation succession of shrubs and open forest towards dense forest was evident.

It was found that AES contributed to a significant reintroduction of wetland management in the Biebrza Valley. This implies that AES are an effective financial tool of EU CAP to support the use of semi-natural habitats. As a regulation with a high impact, further research is needed on the success of supporting both the biodiversity of those habitats and the biocultural landscape itself.

Key words: floodplain and fen meadow landscape, land use abandonment, spatio-temporal GIS analysis, agri-environmental schemes, management reimplementation

INTRODUCTION

Wetlands are one of the most precious and complex natural ecosystems of global significance. This is down to the range of functions they have, the most important of which are: water purification, carbon management, alleviation of floods and biodiversity preservation (Zedler and Kercher 2005). Besides that, they provide people with a variety of resources such as energy, fish, berries, peat, game (EEA 2000), basketry material (Fajardo et al. 2021), medicinal plants (Sucholas et al. 2021), livestock fodder (Biró et al. 2019) and many others. For instance, river floodplains served humans and determined their migration, settlement, trade, forestry, fishery and agriculture (Schindler et al. 2016).

Throughout the history, agricultural activities have been altering wetland habitats. It is estimated, that in Central Europe people introduced domestic cattle in wetlands around 6800 BP (Ellenberg 1996), since then considerably changing their biodiversity. However, it is believed that hand hay mowing was the main management type, which historically led to the widespread occurrence of fen meadows in Europe (Bignal and McCracken 1996). Generally, fen meadows developed from natural sedge-dominated fens and carr forests (fen forests), which were the first habitats mown with scythe (Ellenberg 1996). Even though scythe has been reportedly used for hay cutting since Iron Age in Europe, East Slavs have been mowing meadows since the 11th century (Poschlod 2015b). More on the development of wetland habitats in Central Europe owing to changing climate and extensive human influences elaborated Poschlod (2015b).

As water is a main factor conditioning the proper functioning of wetlands, its deficiency or contamination contribute to degradation of those ecosystems (Joosten and Clarke 2002). Therefore, European wetland habitats have been very negatively affected by land reclamation and river regulation carried out since the Middle Ages and on a large scale since the 19th century. The main reason for wetland reclamation was conversion of wetlands into arable fields (Poschlod et al. 2005). Massive application of fertilisers in intensive agriculture, as a side effect, led to eutrophication of wetlands, altering their vegetation. An excess of nutrients supports the expansion of competitive and invasive species that replace wetland specialists, which then become endangered species (Zedler and Kercher 2005). Additionally, the excavation of peat for fuel is highly damaging to peat-accumulating wetlands such as bogs and

fen mires (Joosten and Clarke 2002). It is assessed that about two-thirds of the European wetlands have been lost in the 20th century (European Commission 1995).

Abandonment is a factor negatively affecting biodiversity of semi-natural open wetlands (Truus and Tõnisson 1998, Valasiuk et al. 2018, Biró et al. 2019). The maintenance of such habitats is directly dependent, among others, on extensive traditional management (Joyce and Wade 1998, Middleton and van Diggelen et al. 2006). In Europe, high value semi-natural habitats occur in rural biocultural landscapes (Bignal et al. 1996, Fischer et al. 2012, Babai and Molnár 2014). The process of ceasing traditional management among rural communities is driven by many factors, for instance, shifts in rural demography, globalisation, technology development and low biomass productivity of grasslands making management economically less profitable (McGinlay et al. 2017). Therefore, conservation of high value semi-natural habitats requires economic incentives for farmers to engage in management.

In Europe, such financial compensations are mainly secured by the system of agri-environmental schemes (AES) under the Common Agricultural Policy (CAP) of European Union (Kleijn and Sutherland 2003, Sutcliffe et al. 2015, Batáry et al. 2015). Since 1992, AES are compulsory for all Member States of EU as the one of the measures of ‘second pillar’ of CAP supporting rural development (Science for Environment Policy 2017). While retaining the central premise of enhancing biodiversity-friendly agriculture, Member States design their own AES adapted to state farming challenges. Generally, in the case of the old EU members, the AES are intended to mitigate the negative impact of intensive farming on nature, while in the case of the new EU members, where extensive farming has lasted longer, they aim at preventing agricultural intensification and counteracting land use abandonment (Batáry et al. 2015).

In this paper, we analyse the situation in the Biebrza National Park (BNP) in Poland, where many hopes were placed on financial support from AES subsidies to maintain open wetland habitats. Management of semi-natural habitats belongs to one of the major conservation challenges in this protection site (Bartoszuk et al. 2004, Nawrocki 2004). The Biebrza River Valley has one of the most extensive areas of wetland ecosystems (floodplain mires, alkaline fen meadows and carr forest – wetland typology after van Diggelen et al. (2006)) of global significance in Central Europe (Wassen et al. 2006). As wetlands are preserved in good natural conditions and host unique wetland specialists (waders, elk, plant

species), the entire area is in Natura 2000 network under Habitats and Birds Directives (92/43/EEC, 2009/147/EC) and a Ramsar Site since 1995.

The open landscape partly results from human impact, as the local community has been using wetlands as a source of subsistence for centuries. Traditional haymaking and grazing on wetlands were still widely present in 1960s (Sucholas et al. 2022). In recent decades, the economic value of wetlands has decreased considerably due to drainage of grasslands outside the Biebrza Valley and the intensification of agriculture (Banaszuk 1991). Ceasing in management led to willow shrubs encroachment, which the national park was unable to counteract due to lack of logistic and financial resources (Matuszkiewicz et al. 2000, Kotowski and Piórkowski 2003). After accession of Poland to the EU in 2004, CAP funds became available. As part of the AES developed in Poland is dedicated to the protection of birds or habitats (also occurring in the Biebrza Valley), they constituted a potentially key financial incentive to restore the use of open wetlands (Bartoszuk et al. 2004).

In our study, we hypothesise that AES had re-established the management of open wetlands in the Biebrza Valley, the use of which had been gradually discontinued since the 1960s. To achieve this goal, we analysed changes in the land use cover and structure of wetlands in the Biebrza Valley over the last 50 years, at three key time points: traditional use, peak of abandonment, and the emergence of opportunities to implement subsidised AES.

MATERIAL AND METHODS

Study area

Our research was conducted in the Lower Basin of the Biebrza River Valley, where drivers of traditional use abandonment are well understood (Sucholas et al. 2022) and flora and distribution of plant communities was fully studied at the time of traditional agriculture (Oświt 1970, Oświt 1973). The Biebrza Valley extending approximate area of 100,000 ha (the Biebrza National Park covers about 60,000 ha) is located in the NE Poland (53°30'13", 22°45'27'). It is featured by continental temperate climate, 6.6°C of average annual air temperature, 583mm of average annual precipitation and around 200 days of vegetation season (Górniak 2004). This lowland floodplain depression of the naturally meandering Biebrza River consists of three morphologically distinct basins. Fluvio-glacial waters of the Vistulian Glaciation formed the valley, which in the Holocene was filled with peat soils developed on sandy underground. The area comprises 60% wetlands surrounded by post-glacial sandy up-hills, moraines and outwash plain covering 40% of the area (Oświt 1970).

The large part of wetland vegetation grows under conditions of moving water (flooding and percolating regimes). Bog peatlands constitute 0.6% of the Biebrza Valley (Liwski et al. 1986). The geomorphological structure, annual river flooding, influence of groundwater flowing from the moraine plateau and traditional management regime conditioned regular pattern of plant communities in the 12-15 km wide Lower Basin. In the floodplain, reed beds with *Glycerietum maximae*, *Oenanthro-Rorippetum*, *Caricetum gracilis* and *Phalaridetum arundinaceae* developed by the Biebrza River and highly productive but relatively species-poor tall sedges communities of for instance *Caricetum rostrata* and *Caricetum elatae* in the next zone. The first two zones are about 2 km-wide. Further away from the river there is ca. 12 km-wide, less productive vegetation but rich in rare species, which is supported mainly by groundwater. These are alkaline fen meadows dominating in the Lower Basin, comprising sedge-moss communities dominated by species such as *Carex appropinquata*, *Carex nigra* and low-sedge-brown moss communities with *Carex diandra*, *Carex lasiocarpa*. The last wetland zone consists of swamps with birch and alder carr forests (Oświt 1968, Oświt 1970, Pałczyński 1975). Peat under sedge and sedge-moss communities is no more than 2 m deep (Liwski et al.

1984). Sandy uplands and 'mineral islands' covered by arable fields, oak deciduous and coniferous forest features in the landscape (Churski and Szuniewicz 1991).

Natural fens, forest and swamps occurred in the valley before human settlement. At that time, the area was only seasonally used by haymakers, beekeepers, hunters and cattle herders (Łowmiański 1932, Kamiński 1963). From the 14th century onwards, people inhabiting villages, established on the uplands along the river, began to successively remove trees and shrubs in the valley (Wiśniewski 1964). The emerging grassy wetland vegetation was used for subsistence of local communities and was therefore of an immense economic value. Traditional farming, comprising annual hand mowing in the open wetlands and grazing during the growing season in both open landscape and forests, was substantially present until 1960s (Sucholas et al. 2022).

Since the 1960s, regular mowing of the wetlands in the Lower Basin has been successively ceased. First, this was due to land reclamation works carried out in the years 1960-1980 in grasslands outside the Biebrza Valley (Fig. 1). As the farmers who owned those grasslands also owned wetlands inside the valley, they abandoned undrained open wetlands in favour of more closely located, drained grasslands (Banaszuk 1991). Second, the introduction of mineral fertilisers in the following years (to improve the productivity of drained grasslands) also contributed to the decline in use of undrained wetlands, impossible to fertilize due to hydrological regimes. Third, the gradual mechanisation of agriculture from the 1970s onwards was an additional factor in making flooded wetlands inaccessible to the increasingly widely used tractors with mowers (Okruszko 1986). Okruszko (1986) reported that only 10% of previously mown grasslands in the Lower Basin was removed from the biomass. Fourth, along with the establishment of the national park in 1993, there are restrictions on the use of wetlands, such as a prohibition on digging and cleaning drainage ditches previously practised by local people. Fifth, since the 1990s, people have also been emigrating abroad for economic reasons (Bołtromiuk 2010). Wetland abandonment led to secondary succession threatening biodiversity of open wetlands (Kotowski and Piórkowski 2003).

As 50% of the area is privately owned (Kardel et al. 2009) and the national park lacks the financial and labour capacity, the clearing of encroaching shrubs was done on a small scale and only in the state owned wetlands (Matuszkiewicz et al. 2000). In the early 2000s, only

5,000 ha were mown or grazed in the entire park (Bartoszuk and Kotowski 2009). After implementation of EU CAP in Poland, it has been possible to realise AES in wetlands, on both local farmers' and park-owned land. The application for AES is voluntary and obliges the landowner to deploy the required mowing and/or grazing regime. From the outset of the prospect of AES implementation, it is believed that this subsidised system will become the main driver of wetlands management reintroduction (Bartoszuk et al. 2004, Nawrocki 2004).

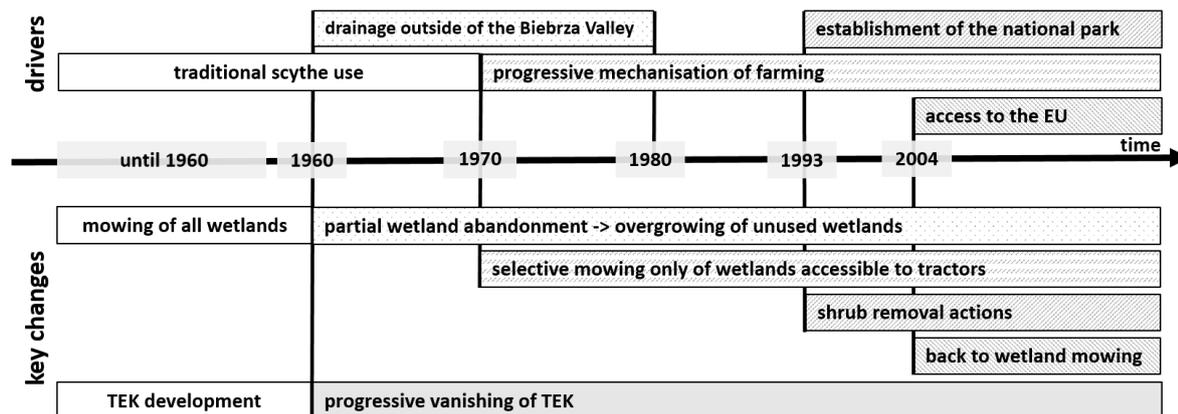


Fig. 1. The timeline and the most important drivers of wetland use changes in the Lower Biebrza Basin, Poland.

Data collection and analysis

For our analysis we have selected three milestone periods in wetland use changes based on literature (Bartoszuk and Kotowski 2009, Sucholas et al. 2022). The first key period was the 1960s, which represented the peak of traditional agriculture and traditional wetland use. The second key moment, constituting the peak of wetland use abandonment, was the 1990s (precisely, the second half of the 1990s, due to the availability of aerial images from that time). This is about 30 years after the gradual cessation of wetland use conditioned by the agricultural and socio-economic factors outlined above, and before the implementation of the EU CAP in Poland. As a third key period, we selected 2015 (11 years after accession of Poland to the EU), in which the possible effects of AES implementation in wetlands should be visible.

In our analysis, we have relied on various types of digitised land cover images (Tab. 1). The data provided by Biebrza NP was already digitised, while the photos shared by the Head Office of Geodesy and Cartography in Warsaw were georeferenced (by using ETRS 1989 Poland

CS92 coordinate system) and digitised using the ArcGis 10.7(.0.10450) system from the software developer ESRI with the components ArcMap and ArcCatalog (Esri Inc, 1999-2018).

Table 1. Types of images used in mapping of land use structure in the Biebrza Valley.

Type of images	Month and years of image taking	Shared by	Relevance to research
Aerial photographs	July 1966/67	Biebrza National Park (in 2018)	Time of traditional wetland use
Aerial photographs	August 1996/97	Head Office of Geodesy and Cartography, Warsaw (in 2018)	After ca. 30 years of wetland use abandonment
Satellite images (ortophotomap)	July 2015	Biebrza National Park (in 2018)	After 11 years of AES availability

The digitised images served as a basemap and were mapped manually. The mapping was carried out with either ArcGIS or open source QGIS 3.4 'Madeira' software. Four wetland areas adjacent to the villages of Pluty, Brzostowo, Rutkowskie and Olszowa Droga located in the Lower Basin of the Biebrza Valley were mapped (Fig. 2).

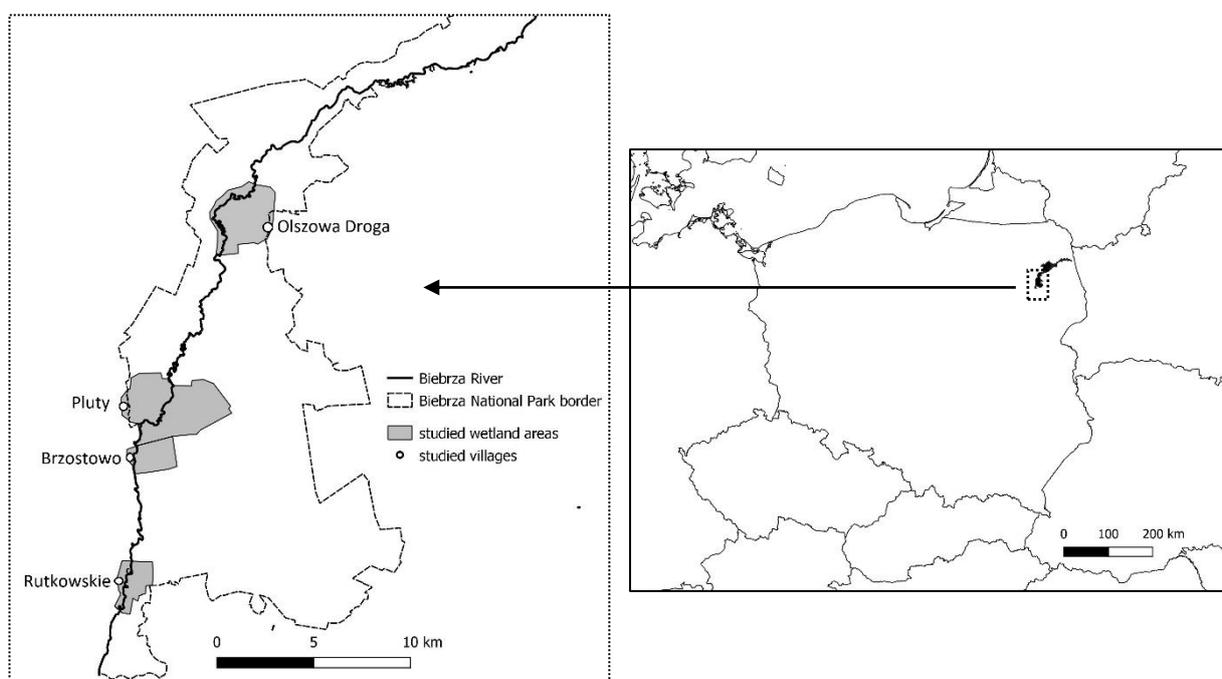


Fig. 2. Studied wetland areas adjacent to four villages: Olszowa Droga, Pluty, Brzostowo, Rutkowskie in the Lower Biebrza Basin, Poland.

In this article, analysed areas are named after the name of the village to which they belong. The areas were of the various sizes, - larger: 1415 ha - Pluty, 921 ha - Olszowa Droga and smaller: 358 ha - Brzostowo, 362 ha - Rutkowskie. The wetland areas were the same as those studied in the related research on traditional wetland management (Sucholas et al. 2022). The results of the mentioned studies, based largely on interviews with the local community (mainly farmers), served as an additional source of information that helped to interpret the mapped land use changes. In our research, we mapped and analysed 14 identified land-use categories summed up in Tab. 2. Fig. 3 shows the examples of the satellite and aerial images of the identified wetland-use categories, analysed in this study.

Table 2. Land-use categories analysed in the study.

Land-use category	Category details
Managed wetland (predominantly meadows)	Wetlands used for haymaking; in 1960s they were additionally extensively grazed (by sparse cattle and horses)
Managed wetland (pastures)	Wetlands used primarily for grazing (mainly by cattle)
Unmanaged wetland (reed vegetation and tall sedges)	Wetlands which have been abandoned
Unmanaged wetland (overgrowing with shrubs)	Wetlands which have been abandoned; succession with shrubs e.g. <i>Salix</i> sp. has started
Open forest	Patchy forest with e.g. <i>Alnus glutinosa</i> or light forest with e.g. <i>Quercus robur</i> , <i>Betula pendula</i> on 'mineral islands'
Closed forest	Dense alder carr or birch-alder forest in wetlands or coniferous forest with <i>Picea abies</i> , <i>Pinus sylvestris</i> , etc. on sandy uphills
Arable land	Crop fields with potato, cereal cultivation and cultivated permanent grasslands
Ditch	Drainage ditches in wetlands
Hedge, tree line	-
Peat cutting	Area in wetlands where peat used to be excavated
Road paved/unpaved	Unpaved roads in wetlands and paved roads in the villages
Built-up area	Area of settlements, farms, yards and home gardens
Oxbow	Old river beds
River	Biebrza River

Based on the four mapped wetland areas in three time periods, we performed statistical analyses of the share of each land-use category in Microsoft Excel. Additionally, the land-use transformation for each area in the study periods was visualised with alluvial diagrams. These diagrams were generated using RStudio (RStudio Inc., 2009-2021; R Core Team, 2019), the package “alluvial” and its function “alluvial()” (Bojanowski and Edwards 2016).

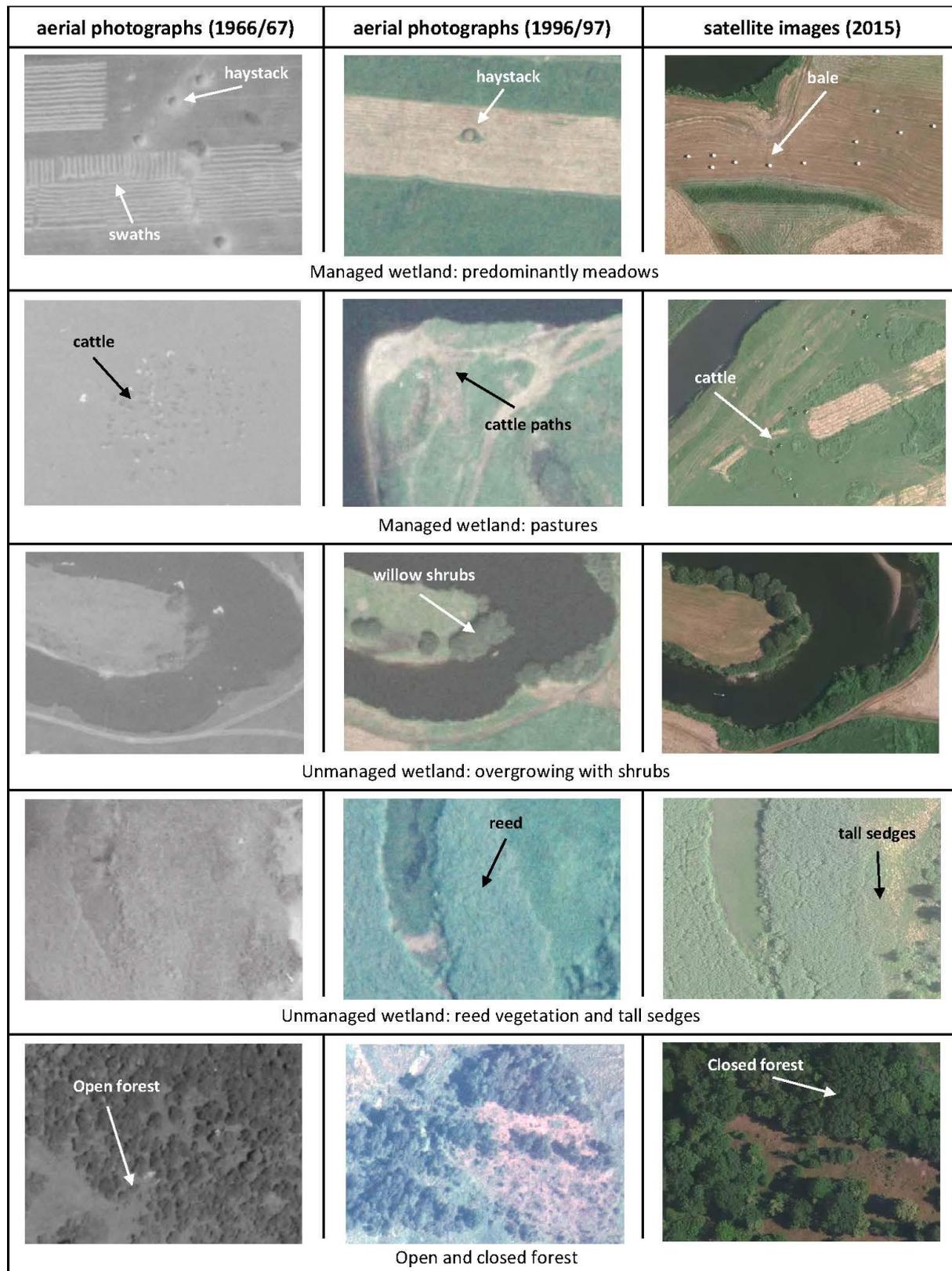


Fig. 3. Examples of the analysed satellite and aerial images of the identified wetland-use categories and indicated land features, which assisted in identification of categories. Analyses concerned three time intervals: 1966/67, 1996/97 and 2015 in the Biebrza Valley, Poland. Images presented in scale 1:2000.

RESULTS

Mapped land-use types

Analysis of satellite and aerial images for four study areas revealed the land cover of these areas in three selected milestone periods (Fig. 4). Visual analysis of the mapped areas has shown an almost complete absence of the category 'managed wetland - predominantly meadows' in 1996 (especially for 'Brzostowo' and 'Olszowa Droga') compared to 1966 when this land-use type was dominant. In 1990s, managed wetlands were located closest to the village, while the cessation of use mainly concerned wetlands that are more distant from the settlement. The 2015 maps showed a presence of this land-use, but on a smaller scale than in 1966. Exceptionally in relation to the other surveyed areas, in 1996 and continuing in 2015, in 'Brzostowo', a part of the wetlands was kept in use as a pasture. Peat extraction was observed only in 1966 in Pluty.

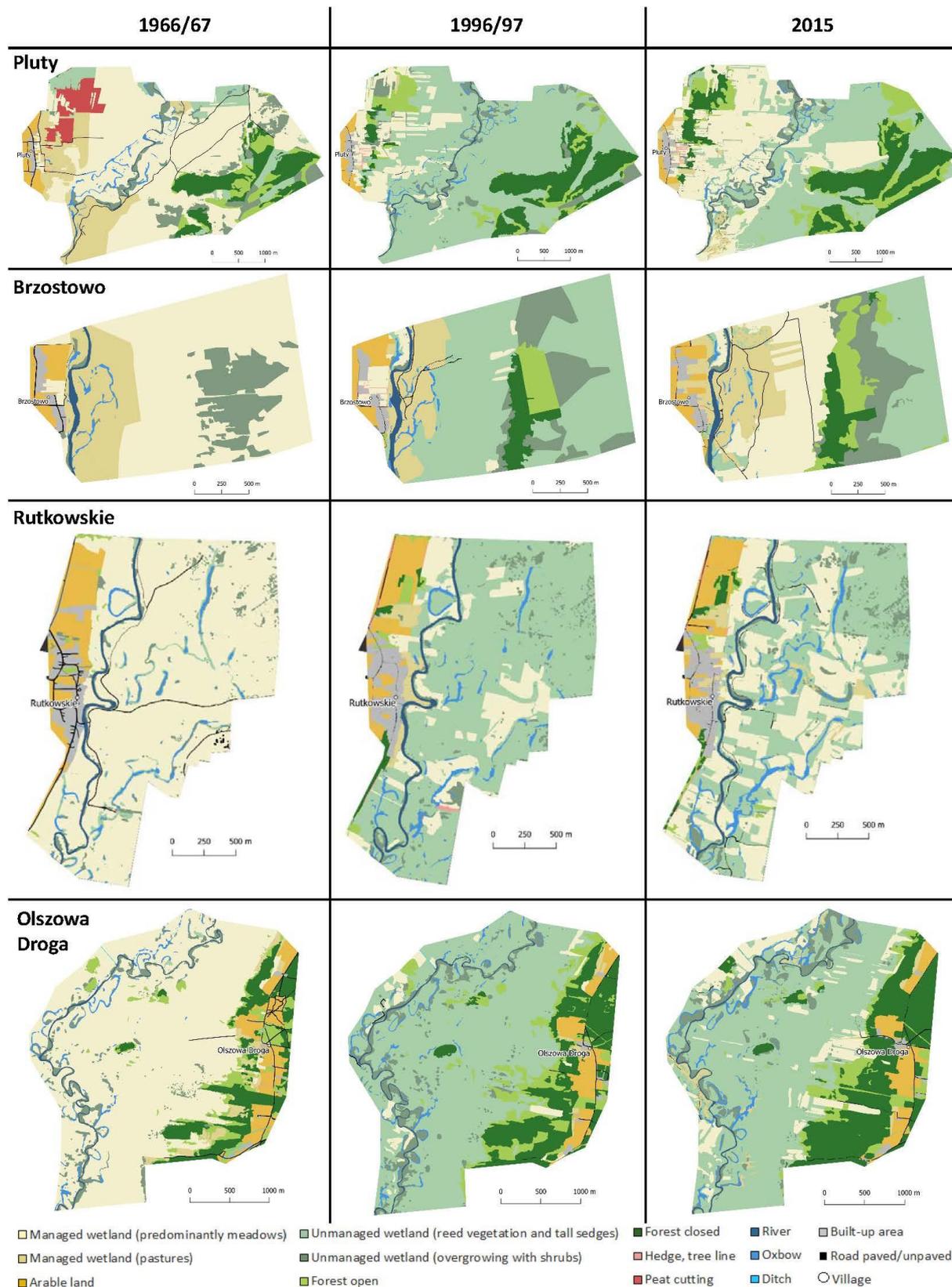


Fig. 4. Changes of the land-use coverage in the four study villages of the Biebrza Valley (Pluty, Brzostowo, Rutkowskie, Olszowa Droga) in three time intervals: 1966/67, 1996/97 and 2015. Mapping done in ArcGIS 10.7 (Esri Inc., 1999-2018) and QGIS 3.4 ‘Madeira’.

Changes of land-use types proportions

Bar charts showing (Fig. 5) changes in the proportion of land cover (Tab. 3) over time by each land-use category in the study villages confirms the map observations. The area occupied by managed wetlands (in total) decreased from an average of 72% in the 1960s to an average of 12% in the 1990s. In 2015, we observed an increase of 'managed wetland' in the study areas to an average of 31% cover (ranging from 12% to 42% depending on the village). In addition, bar chart analysis revealed for almost all investigated areas an increase in coverage by 'open and dense forest' categories over time.

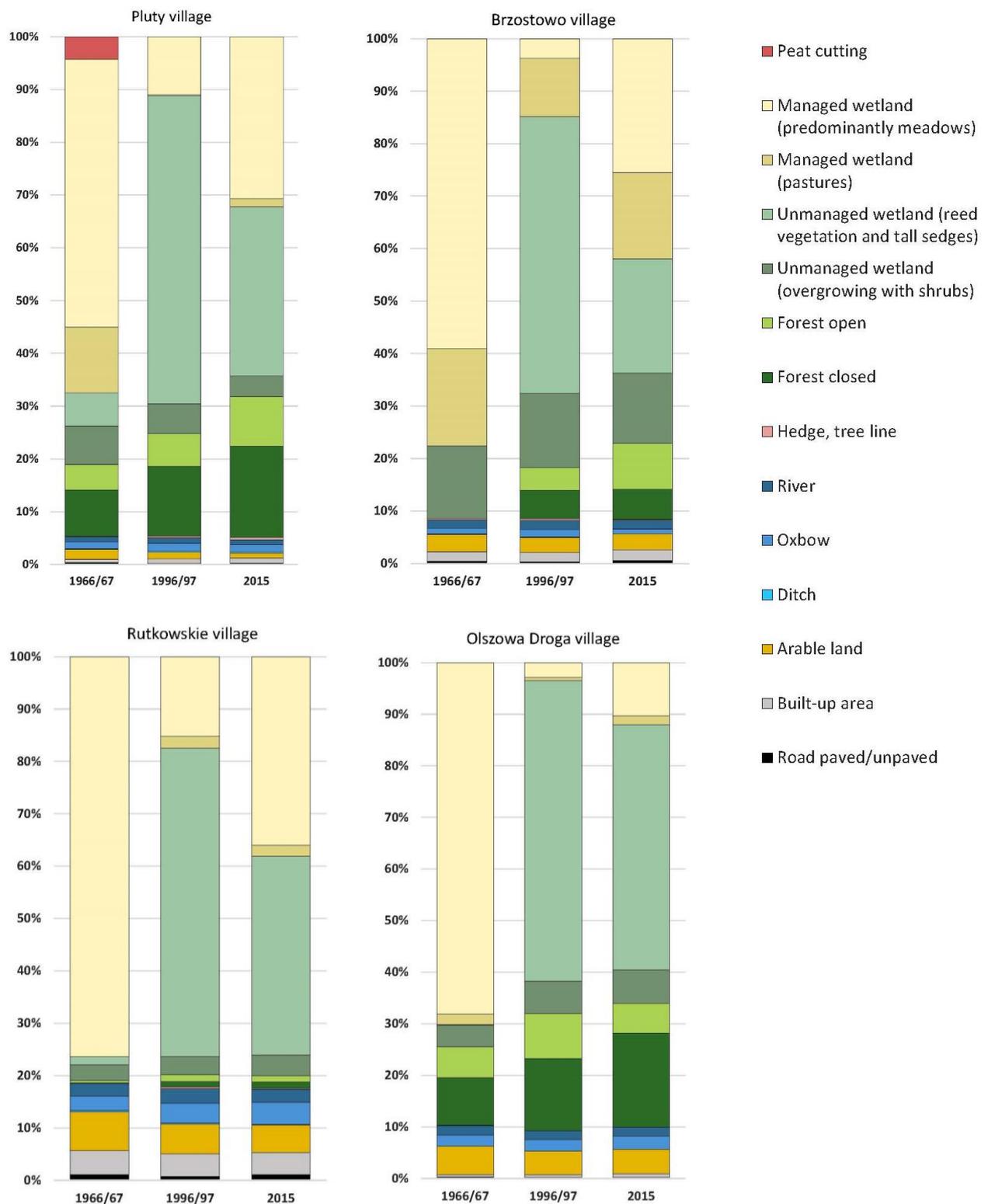


Fig. 5. Changes in the proportion of the land-use categories in four study villages in the Biebrza Valley, Poland (Pluty, Brzostowo, Rutkowskie, Olszowa Droga) in three time intervals: 1966/67, 1996/97, and 2015. Bar charts based on the mapped land-use coverage.

Tabale 3. Land-use categories in four villages in the Biebrza Valley, Poland (Pluty, Brzostowo, Rutkowskie, Olszowa Droga) in three time intervals: 1966/67, 1996/97, and 2015.

Village	Olszowa Droga [in ha]			Brzostowo [in ha]		
	1966/67	1996	2015	1966/67	1996	2015
Time point						
Road paved/unpaved	3,14	2,08	2,32	1,42	1,25	2,08
Built-up area	3,92	4,75	6,32	6,54	6,46	7,27
Arable land	50,25	42,05	43,41	12,00	10,15	10,74
Ditch	0,34	0,10	0,15	0,34	0,17	0,10
Oxbow	20,03	20,73	24,09	3,76	5,13	3,35
River	16,72	15,35	15,18	5,71	6,24	5,72
Hedge, tree line	0,29	0,00	0,04	0,70	1,08	0,64
Forest closed	85,35	129,38	168,17	0,00	19,36	20,78
Forest open	54,61	79,91	52,81	0,00	15,49	31,17
Unmanaged wetland (overgrowing with shrubs)	38,76	58,34	59,62	49,74	50,35	47,70
Unmanaged wetland (reed vegetation and tall sedges)	1,06	536,37	437,96	0,04	188,86	78,09
Managed wetland (pastures)	19,41	5,17	15,93	66,08	39,59	58,83
Managed wetland (predominantly meadows)	627,03	26,69	94,94	211,24	13,45	91,10
Peat cutting	0,00	0,00	0,00	0,00	0,00	0,00
In total	921	921	921	358	358	358
Village	Rutkowskie [in ha]			Pluty [in ha]		
	1966/67	1996	2015	1966/67	1996	2015
Time point						
Road paved/unpaved	3,93	2,78	3,78	5,16	2,52	3,43
Built-up area	16,57	15,42	15,60	8,01	11,94	13,91
Arable land	26,98	20,60	18,96	27,29	18,94	13,78
Ditch	0,75	0,81	0,19	2,22	2,96	1,59
Oxbow	10,15	13,68	15,50	18,85	20,36	20,46
River	8,75	9,84	8,77	13,34	14,96	13,61
Hedge, tree line	0,16	1,43	0,75	1,46	4,06	6,28
Forest closed	0,01	3,71	4,27	123,69	187,56	243,50
Forest open	1,53	4,73	4,37	68,47	87,03	133,73
Unmanaged wetland (overgrowing with shrubs)	10,96	12,43	14,40	102,88	80,07	55,32
Unmanaged wetland (reed vegetation and tall sedges)	5,55	213,42	137,61	88,96	826,49	453,07
Managed wetland (pastures)	0,00	8,25	7,62	176,40	2,92	21,03
Managed wetland (predominantly meadows)	276,84	55,08	130,37	717,34	155,00	435,11
Peat cutting	0,00	0,00	0,00	60,75	0,00	0,00
In total	362	362	362	1 415	1 415	1 415

Development of managed wetlands

A bar chart analysis of the development in consecutive years of area covered by managed wetland in total ('managed wetland [predominantly meadows]' and 'managed wetland [pastures]') in 1966, revealed that at least 80% of managed wetland was abandoned in 1996 in all investigated areas (Fig. 6). In 1996, reed and tall sedges mostly covered previously managed wetlands. In 2015, 'managed wetland' were restored in about 16% of the 'Olszowa Droga' area and up to 45-51% in other study areas.

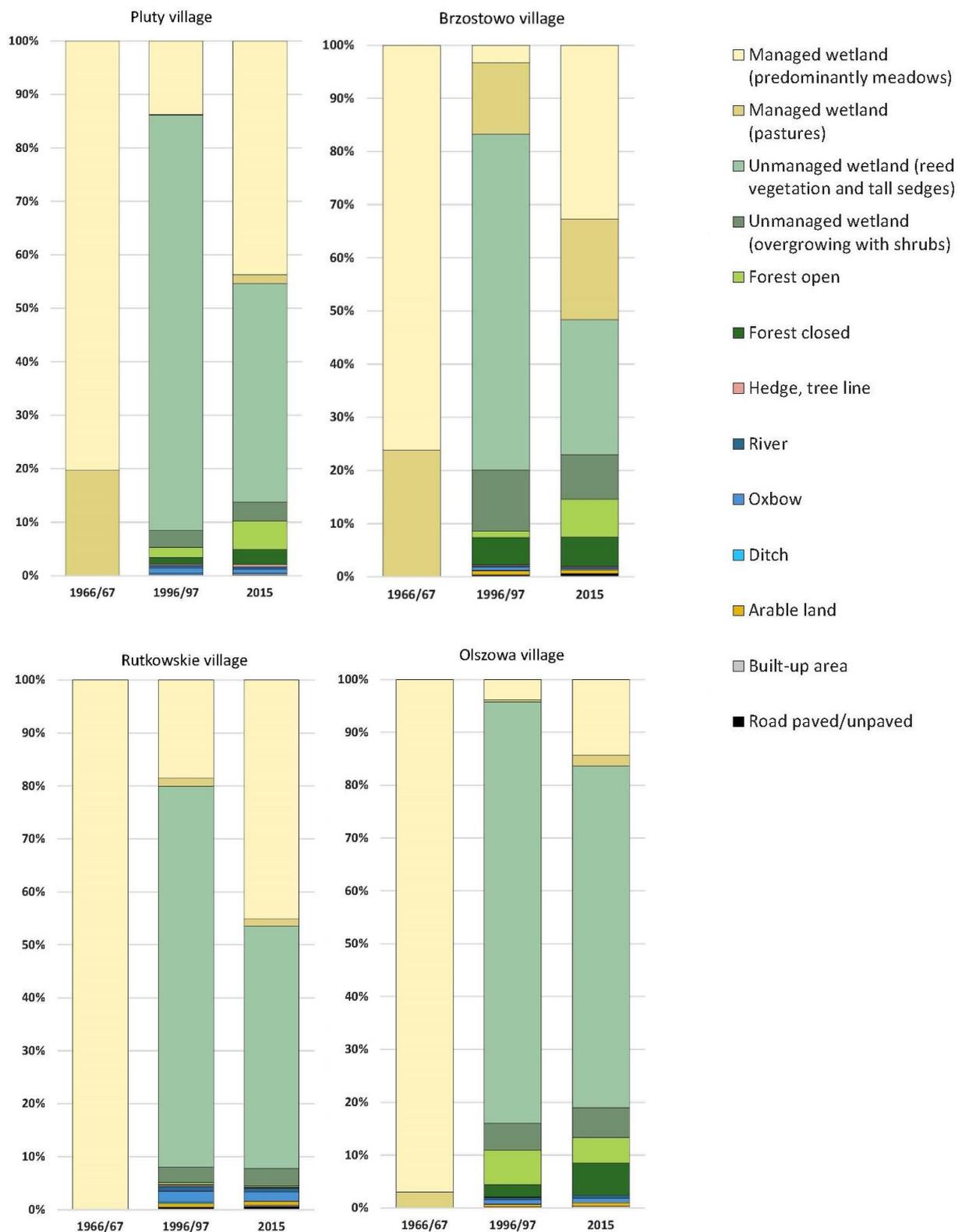


Fig. 6. Land-use development trend of managed wetland in total ('managed wetland [predominantly meadows]' and 'managed wetland [pastures]') from 1966/67 in the time intervals 1996/97 and 2015 in four study villages (Pluty, Brzostowo, Rutkowskie, Olszowa Droga) of the Biebrza Valley, Poland.

Transformation of land-use types

Analysis by alluvial diagrams revealed details of the transformation of all land-use categories in subsequent years (Fig. 7). For instance, an area that was used as 'arable land' in 1966 in the surveyed villages is still arable land 50 years later. The area where peat used to be excavated in the past has been overgrown predominantly by forest in subsequent decades. In 2015, wetland management was restored mainly in areas, which in 1996 had been abandoned and overgrown largely by reed and tall sedges. In the case of 'Pluty' and 'Olszowa Droga', vegetation succession of shrubs and open forest towards dense forest was evident over the period of 50 years.

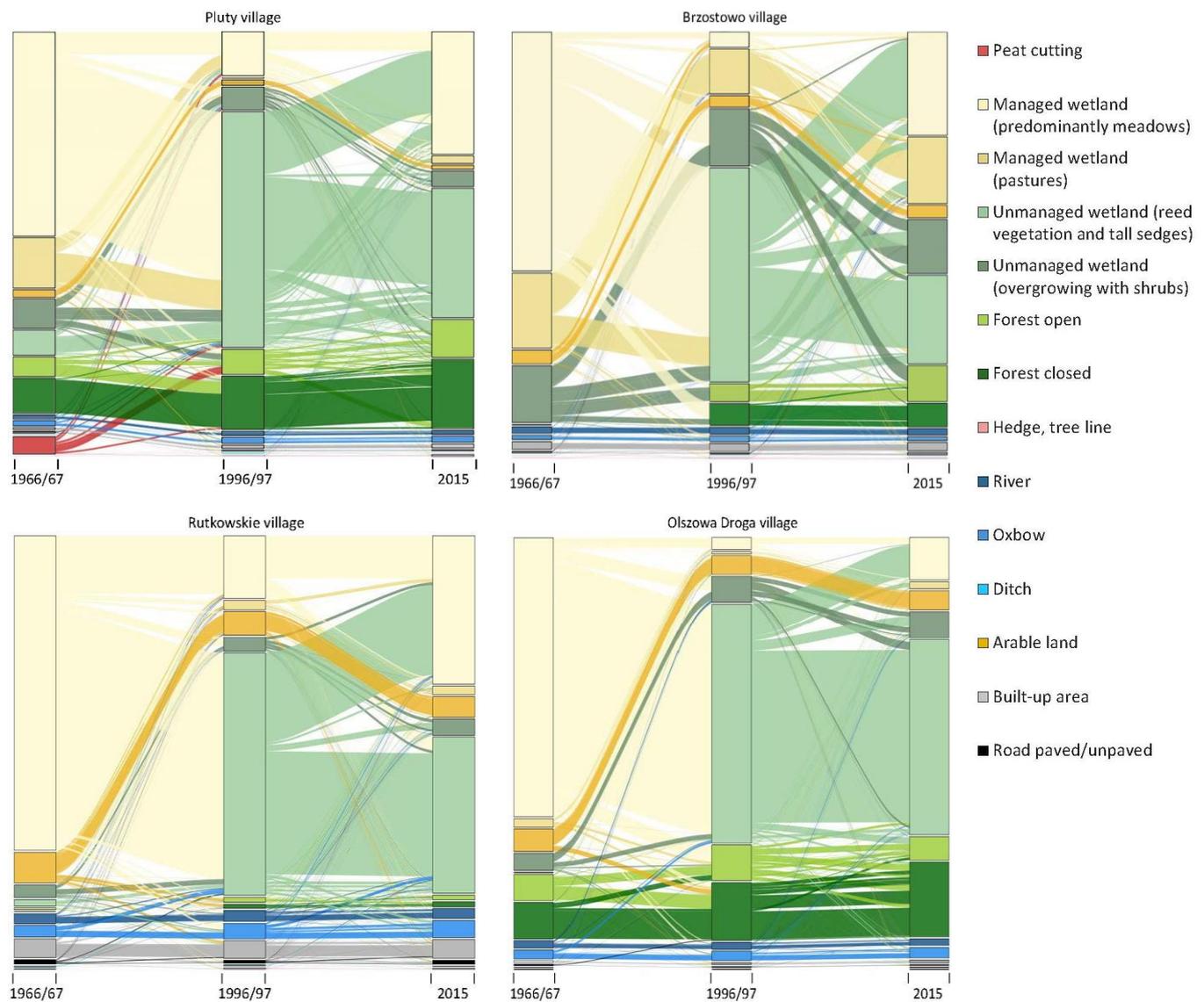


Fig. 7. Transformation of land-use types in four study villages in the Biebrza Valley, Poland (Pluty, Brzostowo, Rutkowskie, Olszowa Droga) in the three time steps: 1966/67, 1996/97, and 2015.

DISCUSSION

Our spatio-temporal analysis confirmed the assumed cessation of wetland use in the 1990s. It applies to a substantial part of the open wetlands as approximately 80% of the area managed in 1960s had been abandoned in 1990s. Above all, abandonment affected wetlands located further away from the villages and owned by farmers inhabiting villages outside the Biebrza Valley, for whom mowing had become financially unviable (Sucholas et al. 2022). Areas of previously managed wetlands (through mowing or grazing during the period of widespread traditional farming) were replaced 30 years later, - mainly by reed and tall sedges as well as increasing shrub and woodland expansion. These results are in line with the findings of Kotowski and Piórkowski (2003), which concerned a much smaller area in the Biebrza Valley. These authors also observed that succession of shrubs and single trees towards the forest usually occurred at the forest boundary. This direction of forest expansion was evident over the three time points studied by us. In the Biebrza Valley, it mainly concerned willow species (*Salix* sp.) as well as moor birch (*Betula pubescens*). Due to the location of carr forest on valley margins, its expansion takes place at the expense of neighbouring sedge-moss and low-sedge-brown moss plant communities (Kotowski and Piórkowski 2003), threatening its biodiversity comprising rare fauna and flora species. The open lowland fen communities host endangered, low-competitive herbaceous plants and mosses (Wheeler and Shaw 1991). An area of more than 60ha, where the local community traditionally extracted peat for heating homes, has also mainly undergone secondary succession following the cessation of mining.

In unmanaged areas adjacent to the riverbed and around oxbow lakes, there is an expansion of reed and *Glyceria aquatica*. Reed often spreads out of its zone to replace tall sedge communities that are more species-rich and are more important as nesting habitats for birds (Szewczyk and Oswiecimska-Piasko 2001). According to the knowledge of the local community, this process is due to mechanical mowing destroying the tussock structure of sedge in favour of reed expansion, as well as the disappearance of trampling by grazing cattle, which has had a reducing effect on reed populations (Sucholas et al. 2022). Linkages between the discontinuation of trampling and uncontrolled spread of reed have also been observed in wetlands in Estonia (Burnside et al. 2007), in the Carpathian Basin (Biró et al. 2019) as well as in experimental studies in the Biebrza Valley (Mirski 2022). Kloskowski and Krogulec (1999) reported that overgrowth of open wetlands by reed and shrubs is the main reason for the

disappearance of breeding habitats of the rare wader species such as aquatic warbler *Acrocephalus paludicola* in Poland.

Such changes in vegetation can be influenced by either cessation of use or reduced water levels, as high water levels reduce nutrient availability. However, the impact of the water regime requires separate analyses. On the other hand, overgrown shrubs and unmown large helophytes have a significant impact on site conditions: they reduce wetness through increased evapotranspiration, reduce nutrient availability (by using nutrients for biomass growth) and directly limit light availability (Kotowski and Piórkowski 2003). In this way, the occurrence of light demanding plants, such as orchids, small sedges and specialised herbs, has significantly decreased (Kotowski 2002).

The temporal dynamics of ditches participation in the landscape revealed inconsistent pattern between study villages. Most likely, it can be referred to the small size of the study object and the limitations of subjective interpretation of the blurred image obtained from aerial and satellite photographs. However, the reduction of the ditches' area of by half between 1996 and 2015 in the village of Pluty (having the largest area of ditches in the landscape of all the villages surveyed) is likely the effect of the law prohibiting the digging of drainage ditches within the national park (Nature Conservation Act 2004).

A significant increase in the proportion of managed wetlands between 1996 and 2015, confirms the hypothesis that AES are a relevant factor contributing to reimplementation of use. The reintroduction of wetland use in the village of Olszowa Droga on a smaller scale compared to the other villages is related to the fact that local farmers living in this low-inhabited village own a small part of the study landscape while farmers settled outside the valley own the vast majority of the area (Sucholas et al. 2022). This observation suggests that subsidised AES primarily motivate local farmers to implement measures, being probably much less financially attractive to farmers living further away (in villages at least 15 km distant [Banaszuk 1991]) from the wetlands they own.

In the 1960s, almost all open wetlands were under a mixed management regime (mown and freely grazed) with the exception of areas that were exclusively grazed (like in Brzostowo and Pluty villages). Free range grazing has virtually disappeared in the Lower Basin in recent decades (Sucholas et al. 2022) even though the area was still characterised as a vast pasture in the 1980s (Kiryło 1988). In both 1990s and 2015, only part of wetlands in the one

of the study villages was used solely as pasture. Therefore, we hypothesise that the AES contribute to the re-establishment of hay mowing management but not grazing.

This is a concerning observation from a conservation point of view, given the type of disturbance provided by and ecological function of grazing, which is distinct from mowing. Cattle, alongside succession prevention, by trampling and feeding preferences increase habitat heterogeneity (Molnár 2014) and have a positive effect on vegetation structure and plant composition (Finlayson and Oertzen 1993, Mirski 2022). They improve seed dispersal (Poschlod et al. 2009, Kotowski and Piórkowski 2003). In addition, they support maintenance of amphibians (Howell et al. 2019), invertebrates (Kucharska and Znaniecka 2005) and nesting birds (Báldi et al. 2005, Manton et al. 2016) as demonstrated by studies carried out also in the Biebrza Valley (Świętochowski 2009, Chętnicki et al. 2013). Possible detrimental effects of grazing are observed when the stocking density is too high (Nolte et al. 2014). On the other hand, disturbance provided by wild herbivores is too limited due to their low densities in the area. For those reasons, the presence of low-intensity grazing domestic livestock seems essential for protection of biodiversity of the open wetlands.

Although the necessity of reintroduction of management to prevent natural succession is hardly questionable, the details of it raise concerns. For instance, the authors wonder whether the reinstatement of mowing in wetlands alone will restore the former plant diversity after so many years of abandonment (Kotowski and Piórkowski 2003). The major debate revolves around AES as the main financial tool of the EU agricultural policy for restoring the use of semi-natural habitats (Kleijn and Sutherland 2003, Batáry et al. 2015). Another research carried out in the Biebrza Valley showed that AES are effective in supporting the occurrence of some bird species but have a negative impact on others (Budka et al. 2019). Mowing in hard-to-reach areas involves the use of equipment that damages vegetation structure (Kotowski and Piórkowski 2003). Researchers argue that AES might fail in biodiversity support due to the way they are designed and implemented, as AES are planned on a principle of generality and are not locally diversified (Żmihorski et al. 2016, Czajkowski et al. 2021). Furthermore, AES impose rigid mowing dates (Babai et al. 2021b), they are a financial incentive that may prove unsuccessful in the long term (Fischer et al. 2012), and they do not involve local community and specialists in design of the land management measures (Plieninger et al. 2006).

The authors indicate the crucial issue: AES do not support traditional practices that underpin the development and maintenance of semi-natural habitats (Beaufoy and Marsden 2010, Fischer et al. 2012, Babai et al. 2015). Maintaining or adopting practices that mimic traditional management is considered essential for the conservation of human impact-dependent habitats and vegetation of floodplains and fen meadows (van Diggelen et al. 2006). Therefore, in the case of a biocultural landscape such as the Biebrza Valley, the key question seems to be whether the management restored with the help of AES incorporate traditional practices, the answer to which requires further research.

CHAPTER THREE:

LOCAL TRADITIONAL ECOLOGICAL KNOWLEDGE ABOUT HAY MANAGEMENT
PRACTICES IN WETLANDS OF THE BIEBRZA VALLEY, POLAND



Data collection in the Biebrza Valley (Poland). a, plant species identification: above - walking with the informant in the wetlands, below - using fresh voucher specimens (Photos by J. Sucholas, 2020). b, mapping – informants from different generations cooperate while creating the local wetland map (Photos by J. Sucholas, 2019).

ABSTRACT

The Biebrza Valley is one of the largest complexes of wetlands (floodplain and percolation mire) and conservation sites in Central Europe. Local communities have managed the area extensively for subsistence and farming purposes for centuries; nonetheless, since the 1960s, hand mowing and livestock grazing have been gradually ceasing due to the intensification of farming, and wetlands have undergone natural succession. Currently, the protection of this vast ecosystem is challenging. Despite its remarkable cultural origin, the complexity of the traditional practices and knowledge of local people have never been studied comprehensively. Therefore, we found it urgent to explore if traditional ecological knowledge that could be used in conservation management of the area still exists among the local community.

We interviewed 42 inhabitants of seven villages located in the Lower Basin of the Biebrza Valley (NE-Poland) in the consecutive years 2018-2020. We applied semi-structured, repeated interviews with farmers (aged 29-89), each lasting several hours. By using different ethnoecological methods (visual stimuli, walks in wetlands, co-mapping of the area), we explored traditional knowledge on the plants, landscape and traditional management of wetlands.

Farmers from the oldest generation, who used to manage wetlands with scythes, shared the deepest ecological knowledge. Local people divided wetlands into zones differentiated by vegetation type and hay quality. Depending on plant composition, people managed wetlands under a mixed regime: mowing once or twice a year during periods that ensured good hay quality and pasturing various livestock: cattle, horses, sheep, pigs and fowl. We identified at least 50 plant ethnospecies, which were described exhaustively by their habitat, morphological features, and mowing and grazing value.

The local community in the Biebrza Valley shared a deep traditional ecological knowledge and had a good memory of traditional farming practices. Research confirmed the unquestionable cultural origin of the local ecosystem, therefore in conservation endeavours the area should be treated first and foremost as a cultural landscape. The documented exceptional local perception of the wetland landscape, elements of traditional knowledge and complex farming practices should be considered for inclusion into conservation management, and cooperation with the local community should also be taken into account.

Key words: ethnoecology, traditional management, knowledge preservation, cultural landscape, conservation area, lowland river meadows

INTRODUCTION

In the last decades, many studies have revealed the presence of deep knowledge of natural habitats and their management among rural communities in Europe (Meilleur 1986, Pettersson et al. 2001, Mustonen 2013, Babai and Molnár 2014, Pawera et al. 2017, Varga et al. 2016). Traditional ecological knowledge (TEK) was previously widely recognised by scientists mainly among indigenous tribal communities outside Europe (Posey 1983, Hunn 1990, Turner et al. 2000, Menzies 2006 and others). Studies on TEK provide insights into the relationship of local human communities with surrounding nature and into people's understanding of the interactions between elements of nature. TEK evolves throughout the centuries-long life experience of a community within a certain environment and is orally transmitted from generation to generation. TEK incorporates knowledge about elements of the environment, beliefs, ethical values and human practices (Hunn 1993, Berkes 2017, Berkes and Turner 2006) which are the objects of ethnoecological and allied studies (Toledo 1992, Nazarea 1999, Hunn 2007). However, this knowledge differs in the context of living European rural communities, which were not colonised, derive from the same Judeo-Christian tradition and whose culture was impacted by Roman and Greek heritage. Additionally, it can be influenced by globalisation, agribusiness (Fischer et al. 2012) and education. Molnar (2008) defines such traditional ecological knowledge as locally embedded, empirical, *'based upon decades of personal experience with the surrounding landscape, acquired through hands-on management of the landscape, containing centuries-old, communally stored experiences which is mostly independent of western science and connected to rituals of social life'*. Such knowledge is locally relevant and applicable, therefore we will name it local traditional ecological knowledge (LTEK).

Research shows that European local communities – either farmers, herders, foresters or fishermen by their traditional practices – have co-created biodiverse habitats, such as high-value grasslands (Poschlod et al. 1998, Poschlod and Wallis De Vries 2002, Niedrist et al. 2009), and often continue to maintain them (Fernández-Giménez and Estaque 2012, Fischer et al. 2012, Babai and Molnár 2014). Similarly, the application of traditional practices has led to the development of some wetland types in Europe (Godwin 1978, Poschlod 1996, Burnside et al. 2007, Gugić 2009, Tucakov 2011, Gómez-Baggethun et al. 2012, Demeter 2017, Biró et al. 2020). European wetlands have been traditionally used for grazing, haymaking, hunting,

burning, fishing, reed cutting, etc. (Cook and Moorby 1993, Middleton and Holsten et al. 2006, Poschlod 2015a, Biró et al. 2019). Owing to that, researchers call for studies in Europe to explore local TEK about landscape, natural resources, land-use practices and their changes, which, when integrated, could help in local conservation and land management endeavours (Molnár et al. 2019). Moreover, the benefits of such studies for nature conservation are already widely discussed and acknowledged on a global (Posey and Balée 1989, Gadgil et al. 1993, Berkes et al. 2000, Huntington 2000, Moller et al. 2004, Charnley et al. 2007, Ballard et al. 2008, Pyke et al. 2018) and European scale (Vermeer and Joosten 1992, Bignal and McCracken 1996, Poschlod et al. 2005, Mustonen 2013, Molnár et al. 2016, Öllerer 2014, Varga et al. 2016, Biró et al. 2020).

Despite the significant share of human-made and human-managed habitats in Europe (Bignal and McCracken 1996, Sutherland 2002, Poschlod 2015b), cultural landscapes are vanishing, and traditional knowledge and practices are often abandoned (Birks et al. 1988, Lenzi 1995, Rotherham 2007, Babai et al. 2015, Biró et al. 2014, Valasiuk et al. 2018) due to socio-economical and technical changes of land use, farming intensification, the lack of a traditional management-inclusive policy or the establishment of protected areas that restrict the application of traditional practices. The discontinuation of traditional practices endangers high value habitats and their biodiversity (Middleton 2013, Poschlod et al. 2005). In the case of wetlands, the common drainage practice for agricultural intensification is the major threat (Poschlod 1996, Joyce and Wade 1998, Joosten and Clarke 2002, Poschlod et al. 2009) along with natural succession caused by land use abandonment (van Diggelen et al. 2006, Middleton et al. 2006). First, these processes degrade wetland vegetation and their biodiversity (Joyce and Wade 1998, Kotowski and Piórkowski 2003, Rosenthal 2010). Second, drainage is the main reason for the eradication of related traditional knowledge, which is no longer implemented (Fawzi et al. 2016, Middleton 2016).

However, even if the traditional farming in Europe is not sustained, it should be feasible to reconstruct it (and the associated knowledge) through the analysis of ecological, archaeological, ethnographic and historical materials (Birks et al. 1988, Poschlod 2015a, Biró et al. 2019, Klerk and Joosten 2019) or by interviewing local communities, especially the oldest generation, who could still store such knowledge in their memory (Molnár et al. 2019). The studies show that knowledge might differ according to generation, gender and other variables

(Reyes-García et al. 2009). In Europe, there are cases of successful nature conservation or restoration by the implementation of traditional practices, for example, the traditional management of subalpine meadows 'Mähder' in Switzerland, supported by a subsidy system (Fischer and Wipf 2002); the conservation of meadow orchards 'Strauobstwiesen' in Germany, regulated by local policy (Bißdorf 2021); restoration projects of German wetlands (Poschlod 1996, Poschlod 1997); traditionally used floodplains of the Sava River in Lonjsko Polje Nature Park in Croatia (Gugić 2009).

The Biebrza Valley in NE Poland (RAMSAR and Natura 2000 Site) is one of the largest high value wetlands of cultural origin in Central Europe. The valley is the biggest conservation area of alkaline fens in the EU that needs to be managed to prevent overgrowing (Kotowski et al. 2013). Over centuries, swamps, fens and flooded marshes in the Biebrza Valley were used by peasants for haymaking and grazing. Starting from the 1960s, a part of the wetlands around the Biebrza Valley was drained to facilitate the intensification of agriculture, which caused the retreat of some farmers in the undrained areas (Okruszko 1990, BartoszuK and Kotowski 2009). The abandonment of wetland use led to shrub and reed encroachment, endangering the biodiverse open wetland habitats (Oświt 1973, Kotowski and Piórkowski 2003). Since the Biebrza National Park was established in 1993, conservationists have been undertaking activities to prevent the succession of vegetation (e.g. shrub removal, mowing with tracked mowers (Matuszkiewicz et al. 2000, Kotowski et al. 2013). However, restrictions have been introduced and farming, financially supported by Common Agriculture Policy, has been intensified after the accession of Poland to the EU in 2004. The general frame of wetland management is often defined by EU agri-environmental schemes (Gotkiewicz and Mickiewicz 2015). All this could eradicate traditional knowledge of local people. Surprisingly, ethnographic studies from the area are scarce (Gloger 1903, Kiryło 1988) and only Kiryło (1988) described, to some extent, the traditional practices on the wetlands and the locals' knowledge in her ethnobiological Masters thesis. Thus, we recognise an urgent necessity for ethnoecological studies in this area. The study aims to identify what traditional knowledge about wetlands is possessed by the local community living in the Biebrza Valley and to discuss if this knowledge should be used in the management of the nature protection area. For these purposes, the following research questions have been formed:

- (1) Is LTEK still present among the local community and how is it distributed?

- (2) How do people perceive and value the wetland landscape?
- (3) How did they traditionally manage wetlands?
- (4) What knowledge do people have about plants occurring in the wetlands?

MATERIAL AND METHODS

Research area

The Biebrza National Park located in Podlaskie Province, in NE Poland (53°28'00"N, 22°39'41"E), with a coverage of ca. 600 km², protects wetland ecosystems in the Biebrza Valley (Kotowski et al. 2013). The climate in the area is temperate continental, the average annual air temperature is 6.8°C and the mean annual precipitation is 583mm. The area has ca. 200 days of vegetation season (Górniak 2000). The Biebrza Valley is a large floodplain depression with three distinguishable basins, covered mainly by wetlands (60%) with sandy 'islands' (40%). The valley is supplied by water from regular annual floods of the Biebrza River (extending up to even a few kilometres in width within the Lower Biebrza Basin [LBB]) and by groundwater running out from a morainic plateau on the other side of the valley in the direction of the Biebrza River. These hydrogeological conditions caused the development of organic-mineral and muddy soils along the river and peatlands in permanently watered areas (Churski and Szuniewicz 1991). Peatland types are typical floodplain and percolation mires (Wheeler and Proctor 2000).

In historical times the area was covered by forests (Łowmiański 1932) with oak, lime and hornbeam on mineral islands and alder, birch and ash trees in swamps. Floodplain mires and marshes by the rivers were areas without trees (Kondracki 1972). Until the 14th century, the Biebrza Valley was used extensively and seasonally by hunters, fishermen, cattle herders, haymakers and beekeepers (Kamiński 1963). Permanent settlement started at the end of the 14th century, and villages developed on the elevated outskirts of the Biebrza Valley. For centuries, serf peasants used wetlands for haymaking and pasture farming, the river for fishing and the woodlands as a source of timber (Wiśniewski 1964); however, details concerning land management remain vague due to scarce ethnographic studies in the Biebrza Valley. The serf system was abolished progressively in the 19th century (Szumski 2002). After the abolition of feudalism, the local community managed wetlands under various proprietary conditions, depending on the village and political system.

Since the times of the first settlement, Poles, *Rusini* (Orthodox Eastern Slavic dialect speakers) and Lithuanians inhabited this area (Kamiński 1963, Wiśniewski 1964). Over centuries, the Biebrza River in the LBB was a frontier between changeably governed countries

(like e.g. the Polish Crown and Lithuania in 1385-1568 or the Congress of Poland and the Russian Empire in 1815-1917) or Polish Provinces (like Masovia and Podlasie in 1569-1795) (Wiśniewski 1975). Even though the whole Biebrza Valley has belonged to the Republic of Poland since 1918 and exclusively Catholic Poles live on both sides of the river in the LBB (Bilska-Wodecka and Matykowski 2008), remnants of the historical borders are still present in the self-perception of the local community. All informants living on the right side of the Biebrza River state: *behind the river, there are Ruscy/Rusini, here, we are Mazury* (related to ethnic group of Poles – Masurians, the former name of Masovians). Informants also often called people living on the left side of the river *Podlachy* (related to the province *Podlasie*) or *Litwasy* (related to times of Lithuanian influence). All informants from the left side of Biebrza confirm such naming. The same type of self-perception was one of the findings of Kiryło (1988).

Owing to the fact that Biebrza wetlands functioned as a natural border, drainage was forbidden over the centuries. Large networks of channels (such as the Augustowski Canal) were built up in the second half of 19th century (Wiśniewski 1975). However, the floodplain of the LBB with its natural hydrological conditions remains well preserved to this day (Wassen et al. 2007) and became the ultimate research area of this study. The wetlands of the LBB were collectively used not only by the local community but also by people living in distant villages (20-30 km away). However, people from distant villages have been progressively abandoning undrained wetlands of the LBB since the 1960s (Fig. 1). This was firstly due to the common drainage of land for agricultural purposes in the outskirts of the Biebrza Valley (between ca. 1960'-1980'), which resulted in the retreat of farmers from the undrained wetlands (Banaszuk 1991). Later, along with process of farming mechanisation starting at the end of the 1960s, the use of the scythe was gradually discontinued (Bartoszuk and Kotowski 2009). The undrained wetlands suitable for scythe mowing were inaccessible for tractors (Okruszko 1986). Even though local inhabitants continued to use wetlands to some extent, a massive process of overgrowing with reed and willows has started in the LBB (Kotowski et al. 2013) and traditional practices have gradually ceased. Currently, the economy in the Biebrza Valley and the whole Podlaskie Province relies on agriculture and tourism; however, it is an economically marginalised region compared to other parts of Poland (Wojciechowska-Solis 2018), and it is marked by mass emigration (Hirszfeld and Kaczmarczyk 2000).

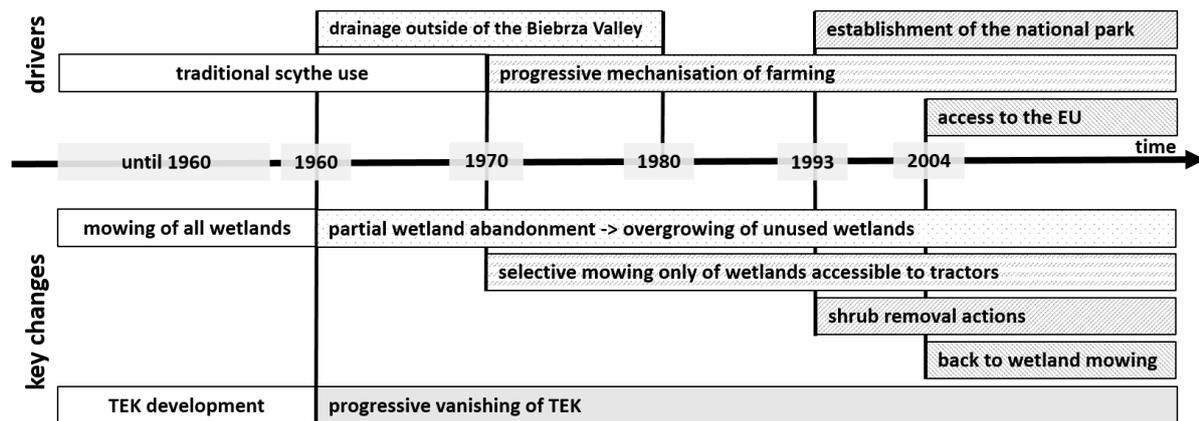


Fig. 1. A timeline showing the key changes in the management and vegetation of wetlands and the main drivers behind these changes (Lower Biebrza Basin, Poland).

The vegetation in the LBB (an area with a length of 30 km and a width of 12-15 km [Okruszko 1986]) has a zonal pattern that is formed parallel to the course of the river. The five vegetation zones are distinguished according to plant composition, source of water and duration of floods. Reedbeds and marshes have developed in the first zone, which is adjacent to the river and periodically intensively flooded. They are dominated by *Oenanthe-Rorippetum*, *Glycerietum maximae* and *Caricetum gracilis* associations. The second zone consists of tall sedges, which form tussocks dominated by such communities as *Caricetum elatae*, *Caricetum rostratae* and *Caricetum appropinquatae*. The first and second zones are ca. 2 km-wide together. In the third zone, which is constantly supplied by groundwater, we find sedge-moss communities with species like *Carex appropinquata*, *C. nigra*, *C. panicea* (for vascular plant species author names see Tab. 5) and *Acrocladium cuspidatum* (Hedw.) Lindb. moss species. The fourth zone is never flooded, but it is watered by groundwater. Low-sedge-brown moss communities grow in this zone, with species like *Carex diandra*, *C. lasiocarpa*, *C. flava* and *Drepanocladus revolvens* (Sw.) Warnst., *Hamatocaulis vernicosus* (Mitt.) Hedenäs mosses, etc. The sedge-moss zones are altogether around 12 km-wide. The final, narrow fifth zone on the valley edge consists of woodland dominated by birch and alder carr forest (Oświt 1968, Oświt 1970, Oświt 1973, Pałczyński 1975).

Pilot study

To define the research area, we started pilot research in summer 2017, during which villages located along the whole Biebrza River were visited. This included some randomly selected settlements and those recommended by people interviewed along the way. Eighteen

villages were visited during the pilot study (Gugny, Zubole, Zucielec, Bajki Stare, Stójka, Olszowa Droga, Kołodzieje, Giełczyn, Brzostowo, Mocarze, Klimaszewnica, Goniądz, Dawidowizna, Budne, Dolistowo Stare, Wolne, Nowy Lipsk, Lipsk) and an average of three members of the local community were interviewed per village. Open, unstructured interviews were applied (Albuquerque et al. 2014). Middle aged or elderly people seated on benches in front of their houses were approached or traditional-looking houses were visited. If these two methods failed, the head of the village was visited. After a short introduction of the researcher, a general explanation of the research and usually some small talk, people were asked a few introductory questions, such as: *Do you live in this village? For how long have you been living here? Do/did you own meadows in the wetlands? Do you remember times when these meadows were mown with a scythe? Do you or your children still use the meadows? Do you know any other person in your village who could help answer these questions?* The first conversations with new persons were not recorded, which facilitated spontaneous and open conversations. Notes were taken during every conversation. The pilot research aimed to identify the key villages for further research – those inhabited by a sufficient number of knowledgeable informants as well as people with less extensive knowledge willing to participate in the research.

Final study sites

During the actual study, continued in the years 2018-2020, seven villages in LBB (Fig. 2) were selected and intensively studied using the same methods. The villages will henceforth be symbolised by Roman numerals. The villages were usually visited during summer, as the full vegetation season allowed for the application of most of the field methods. It was also noticed that people were more open and talkative in the summertime than in late autumn and winter. Each of the studied villages was inhabited by at least two local people with extensive wetland ecological knowledge. The villages are located on different sides of the Biebrza River. Four of them stand on the right side of the river, and inhabitants of these villages own meadows in the wetlands directly connected to the river. The remaining three villages stand on the left river side. One village has meadows connected to the river, and in the other two, the meadows are not adjacent to the river.

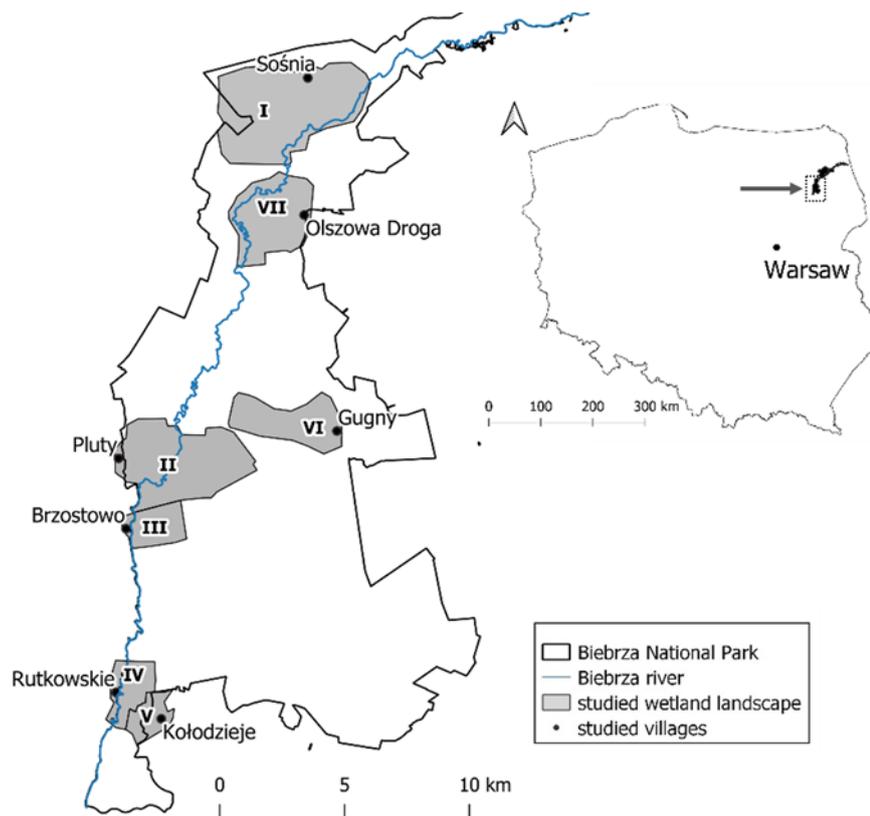


Fig. 2. The research area of the seven studied villages in the Lower Biebrza Basin of the Biebrza National Park (Polnad).

The exact wetland area of study was limited to the landscape recognised by and familiar to inhabitants of the village; the area local people would tell stories about and describe with the use of toponyms; the area owned by the inhabitants of the village in times of traditional management (even if it is not owned by them right now). The studied landscape ranged from 2.5 to 18.6 km² in size. People could usually recognise a wider area, which used to be explored only in wintertime. In summertime, most of the paths connecting the two sides of the wetlands were not accessible because of high water level. Only the frozen water surface made it accessible to the villages on the other side of the river, and people from different sides of the river could meet during e.g. winter dance parties. However, the wider landscape is perceived in a more general way, and people struggled localising some of the toponyms. Therefore, it is not included in the study.

The villages also vary according to their demography and economy (Tab. 1). Three villages – Pluty, Brzostowo, and Rutkowskie – are the largest studied villages, with active young farmers. Two other villages (Kołodzieje, Olszowa Droga) are much smaller but also inhabited by young and active farmers. The two remaining villages, Gugny and Sośnia, are

currently abandoned by farmers, but until the 1970s these villages were active and populated by several dozen families, as stated by informants.

Table 1. Demography of the studied villages and the interviewed local people.

Village	No. of inhabitants (2011)	No. of informants (No. acc. to gender)	Age range of informants (in 2018)	No. of interviewed active farmers	No. of interviewed retired farmers
Sośnia	12	2 (0♀ + 2♂)	65-70	0	2
Pluty	136	7 (0♀ + 7♂)	40-89	4	3
Brzostowo	104	8 (2♀ + 6♂)	29-85	2	6
Rutkowskie	150	3 (1♀ + 2♂)	57-84	0	3
Kołodzieje	ca. 30	5 (3♀ + 2♂)	58-81	1	4
Gugny	5	7 ¹ (1♀ + 6♂)	58-84	1	6
Olszowa Droga	30	10 (0♀ + 10♂)	30-88	4	6
In total		42 (7♀ + 35♂)		12	30

Data collection and analysis

The interviews were carried out with people whose families lived in the same area (the same or the neighbouring village), at least two generations back (their grandparents' generation). Often the most knowledgeable informants had a surname similar to the name of the local village or to names from the local community mentioned by Gloger (1903), which additionally affirms the local origin of the informants. Each informant was interviewed at least once. People with the greatest ethnoecological knowledge were interviewed 2-4 times, with the conversations lasting from two to three hours. The next informant in the village was usually found using the snowball method (Albuquerque et al. 2014). People asked to point the villager with the deepest knowledge would, as a rule, indicate the same persons – probably the most reputable individuals in the village. The conversations had the character of semi-structured interviews, launched with a few questions mentioned in the description of the 'pilot study', and continued with more precise questions (Tab. 2). For the purposes of interview dynamics, the type and the order of the questions were adjusted to the course taken by the informant, as moderated by interviewer.

¹ The number of informants in the village of Gugny is higher than the number of inhabitants due to interviewing people who used to live in the village but had already moved out.

Table 2. The sort of the questions used in the semi-structured interviews exploring people's TEK.

1. To get a general overview of life in the village and understand the informant's perception of farm life and the changes in local agriculture:
Has life in the village changed in the last few decades? What were the main reasons for such changes? Have farming practices in the villages changed? How do you evaluate these changes? What changes influenced farming practices the most?
2. To understand the relation of people to the wetlands and their value for people:
Was it profitable to have meadows in the wetlands? Did their value change? When did you last go to the wetlands? Have you ever mown with a scythe? How much time did you used to spend in meadows in the past? What would you do there?
3. To learn about traditional farming practices in wetlands:
On what terms did people manage wetlands historically? How did the time of haymaking look in this village? How did people use wetlands, meadows and forests? What did mowing practices look like in the times of hand mowing? How did you build a haystack? When and where did people mow? Why in this particular time and place? When did people stop using the scythe in this village? For what reason? Did you continue to use your meadow after the discontinuation of hand mowing? How has the practice of mowing changed?
4. To learn about grazing practices in the wetland:
Did you have livestock? What animals did you have? Did animals graze in wetlands? Where and when did certain livestock graze? When did the grazing season start and finish? Why? Did animals graze in the wetland forests?
5. To learn what people know about plants and account for observed changes in vegetation:
Which plants grow in wetlands? How do you recognize this plant? Where does this plant grow? Is it a common plant? Did the occurrence of this plant change? What do you think, why? Is this plant good for hay? Did animals graze this plant? Which other plant species were grazed?
6. To recognise the perception of the landscape and toponyms used by people:
Where do the most valuable/the worst plants grow? Where were certain farming practices performed (like mowing, grazing, peat excavation, and fishing)? Where is your own plot located in the wetlands? Where did the mowing start, where did it finish? Where were the haystacks built? Where did you find material for building haystacks?

After the first visit in the village and a few initial conversations, during the next interview, questions were sometimes stated in a modified way, by the usage of local expressions describing elements of landscape or vegetation. If the new expression was identified, during the next interview the same person and other people in the villages were asked again for the definition of the term to ensure its meaning. All interviews were literally transcribed and 77% were digitally recorded. The collected traditional knowledge and narratives used by people (besides plant knowledge and toponyms, which were analysed separately) were grouped in a

database according to topic (e.g. grazing livestock, time of grazing, mowing technique, time of mowing, haystack structure, wetland value).

To detect if people had knowledge about the plants, the questions related to plants from Tab. 2 (point 5), were asked. In the next step, to correctly identify ethnospecies to botanical species, one or two of the following methods were applied (Albuquerque et al. 2014) in the case of the most knowledgeable informants (Fig. 3). First, just before the interview, fresh voucher specimens were collected in the wetlands belonging to the village; later these visual stimuli were presented to the informant. This method was applied the most often, and it was the most successful in terms of plant verification by informants. People often immediately recognised plants they could touch, smell, and see in their real size. Second, if the interview was held in the winter season, another kind of visual stimulus in the form of pictures of the wetland plant species was used. For this method, A4 size sheets with photographs of 125 vascular plants occurring in the LBB were shown to the informant. This method turned out to be the most ineffective, as it was challenging for informants to recall plants on the basis of their pictures. After a few applications, the method was no longer implemented. Finally, in every village, one guided tour in the wetlands with the most knowledgeable informant in the village was made to identify plants in the field and note for changes in vegetation observed by the informant. This method was effective in terms of informants identifying ethnospecies and sharing remarks about changes in vegetation. All the ethnospecies mentioned by informants at least twice and ecological knowledge about these taxa were set into spreadsheet. The ethnospecies were classified into lower and higher systematic domains after folk biological taxonomy and nomenclature proposed by Berlin (1992) and Brown (1984). The scientific plant nomenclature and author abbreviations follow The Plant List (<http2>).

To understand the perception of the landscape by the local community, locate the land-use practices and learn the toponyms used in the village, people were asked questions from Tab. 2 (point 6) related to landscape perception. Often, the toponym interviews were group interviews with older and younger generations. The younger man (son or neighbour) assisted the older man to arrange toponyms on the map. Sometimes, together with the informant, the wetland landscape and its partitioning were drawn by hand on a sheet of paper. Printed maps were used for precise localisation of certain management practices and

toponyms in the landscape. For each wetland landscape of the seven studied villages, A0-size maps were printed at 1:25 000 scale. Three maps shared by the Biebrza NP were used: the topographic map from 1960, aerial pictures from the area (from times of traditional management, July 1966-67) and the most recent ortophoto map (July 2015). For mapping toponyms, the informants could use the map they found most familiar and understandable. All information related to the map was plotted on transparent overlays. If the area was covered with too many names, number coding was used for toponyms. The landscape partitioning presented in the results, the simplified traditional land-use map (showing practices from the 1960s) and a cross-section of the elevation pattern were created with Inkscape Software. We set toponyms and the information noted during interviews (e.g. explanation of the toponym's meaning, traditional practices that took place in this location or related oral stories) in the spreadsheet. Afterwards, we clustered toponyms into the landscape element sets named by these toponyms.

RESULTS

Who knows what?

The research revealed the presence of LTEK possessed by members of the local community in the Biebrza Valley, varying in type and complexity according to age, gender and personal qualities (like good memory or talkativeness). Women constituted 15% of all informants. Only elderly women were recommended as 'good informants' in the village. All of the women informants were above 70 years old. Their descriptions of traditional practices were very simplified and general; they were able to list a few wetland species (mean of $7 \pm \text{SD} = 2.5$, max. of 11). As a rule, they had a good knowledge about medicinal plants species, because they used to collect them for trade besides dealing with farming duties. The majority of the informants were men who had usually farmed their whole life. Among them were two local foresters and two beekeepers who also worked on farms of their own for at least part of their lives. We distinguish three groups of male informants according to age: 1st – older than 70 years (15 persons), 2nd – between 46-70 (14 persons) and 3rd – between 29-45 years (six persons). The informants from the oldest group had experienced wetland mowing by hand as adults. They were the major source of information about studied traditional practices, the annual cycle of hay management, agricultural transitions and the drivers behind them, and long-term changes in the landscape and vegetation (as eyewitnesses to all of these processes). In this group, two men were the most insightful informants from all the interviewed people. The younger men from the 2nd group experienced times of mowing by hand in childhood, remembered traditional farm life more from observation and oral stories transmitted by the elderly than participation. Nevertheless, all of these informants had used a scythe at some point in their lives. Frequently they were not sure about the chronological order of the historical changes in farming or the details connected to certain wetland use practices. Men from the 3rd group did not experience mowing with a scythe at all and could not remember any traditional practices. Nevertheless, all of these young farmers were taught farming by their fathers to some extent and continued to use meadows in wetlands.

Informants from the 1st group could name a mean of $14 \pm \text{SD} = 9.3$ plant species (max. of 36); the 2nd group could name a mean of $16 \pm \text{SD} = 9.2$ species (max. of 40); the 3rd group, a mean of $8 \pm \text{SD} = 3.3$ species (max. 13). However, the group of the oldest informants provided

the most comprehensive, almost 'palpable' descriptions of the plants' features, habitats and farming value, in contrast to the younger informants who, even if they listed more species, could rarely name more than two qualities of the plant. The group of youngest informants could list species, though they struggled to identify them properly.

The knowledge of toponyms was shared usually during group interviews by 2-3 persons per village. The informants were from all age groups and cooperated while mapping work. The representatives of the youngest generation were full-time farmers. Informants from the 1st and 2nd group provided all toponyms used in the village. Farmers from the youngest generation who facilitated the mapping work were usually familiar with the majority of the toponyms, but some were new to them. Informants as a rule named toponyms while describing the location of their plot or farming activity in the wetlands.

'Formerly, Biebrza meadows were the only livelihood'

People repeated that wetland meadows used to be of great farming value: *these meadows were a treasure (...) generally it was good hay and the cow could eat everything* (VII). Informant also added that the wetland meadows were the only type of meadows available to local people in some villages: *Who would suppose that one could have a meadow in a crop field (not in the wetland)? No one knew that!* (III). It was the reason behind the high economic value of wetland meadows, expressed by many other narratives: *formerly, a man had to pay big money to buy a meadow (...) a man would sell a crop field to buy a wetland meadow* (III); *at that time, 1 ha of a meadow had a value of 350 pigs (...) people had to collectively buy meadows* (VII); *the one who had meadows along the Biebrza was rich* (VII). People connected the moment of the rapid drop in the value of wetland meadows with the moment of discontinuation of scythe use: *when the scythe 'collapsed' then the value of the meadow dropped prospectively (...) we abandoned these meadows* (III). Informants also confirmed that drainage of some of the land was the main reason for the abandonment of undrained wetlands: *after melioration we didn't use them much anymore. It drove us out of the Biebrza meadows; we stopped using them en masse* (VII). Additionally, people indicated the role of artificial fertilisers, which greatly improved the productivity of drained meadows. Indeed, in this region, in the late 1970s, the 'Association of Agricultural Cooperatives' (*Spółdzielnia Kółek Rolniczych, SKR*) started operating actively and influenced farming practices by e.g. convincing farmers to use mineral fertilisers: *they asked us to buy it so we used a lot of it* (V). This

dramatically diminished the value of undrained wetland meadows, which were impossible to fertilise and less productive: *there is no sense in using fertilisers on the Biebrza meadows, because water will wash out everything* (II). Until the process of agricultural intensification in the Biebrza Valley, haymaking and grazing predominantly took place in wetlands.

Three types of wetland landscape partitioning

People perceive the Biebrza River as the main natural border dividing the landscape and vegetation into two major areas: before the river and on the other side of the river (the latter was generally called *zarzeczce*). We identified three general types of wetland landscape partitioning present in the narratives and perception of the inhabitants of studied villages (Fig. 3). This perceptual division of wetlands into management units depends on the location of the village and roots in traditional practices; it is directly associated with the vegetation type, quality of hay, and division of land ownership.

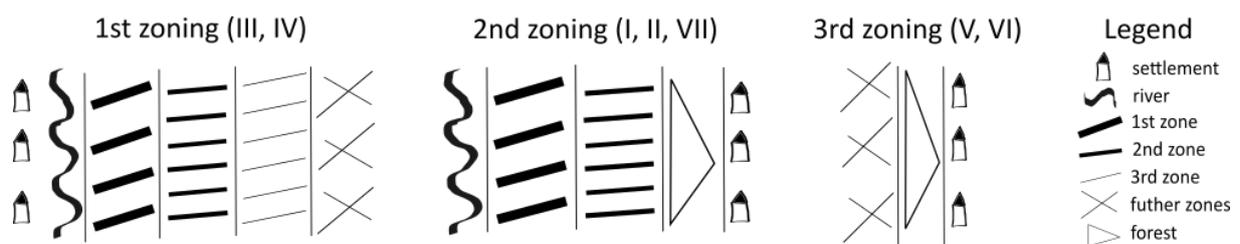


Fig. 3. The three types of partitioning (zoning) of wetland landscape in the studied villages (Biebrza Valley, Poland) differentiated by local people. The Roman numerals in parentheses indicate the village: I – Sośnia, II – Pluty, III – Brzostowo, IV – Rutkowskie, V – Kołodzieje, VI – Gugny, VII – Olszowa Droga.

For villages situated directly in front of the river (1st zoning) the whole managed wetlands lie on the other side of the river. Inhabitants of these villages use the term *branie*, ‘taking’, for the zones they distinguish in the wetlands. This expression is connected with a mowing practice – ‘taking hay’. The first zone is called *pierwsze branie* ‘first taking’; the next zone is called *drugie branie* ‘second taking’. This pattern continues in the further zones. In the case of these villages, *rzeczna trawa*, ‘river grass’, which produces the best quality hay, occurs in the first two zones. The ‘river grass’ was either mown twice a year and used as pasture in autumn (IV) or the ‘first taking’ was used for the whole season only as pasture, *smugi*, and the ‘second taking’ was mown once a year and mixed with grazing (III). In the 1st wetland zoning, all of the following zones, which have worse-quality hay, are called *biele* or *bielne łąki* – ‘white meadows’ (III, IV): *every next taking provides a lower hay quality* (III). These meadows were

mown only once a year (IV) sometimes mixed with less intensive grazing (III, IV). They are also called *pracowite łąki* 'hard working meadows' (IV), because they are arduous to mow due to the presence of sedge tussocks. The term 'white meadows' is alternatively used in a wider context to name all the wetland meadows and distinguish them from any other meadows outside of the valley. The name derives from the phenomenon of fog overlaying the meadows in the mornings and evenings, which, from the perspective of the village, gives an impression of 'white meadows'. However, in further descriptions regarding the 'white meadows', we mean, as abovementioned, wet meadows of worse hay quality.

For the inhabitants of villages situated further from the river (2nd zoning) the wetland landscape on the two sides of the river has two major zones. The first zone of *trawa rzeczna*, 'river grass', directly by the river, produces best hay quality and was mown twice a year (I) and mixed with grazing (II, VII) or mown once and mixed with grazing (II). The second zone is called 'white meadows' and was mown once a year for hay mixed with grazing (I, II, VII). In this case, the forest separates settlements from meadows.

The informants from the village who own wetland without connection to the river (3rd zoning) call all wetlands belonging to them *łąki torfowe* 'peat meadows' (VI) or use the general term for worse meadows 'white meadows' (V, VI), as discussed before. These meadows, situated the farthest from the river, produce the worst hay quality and had different use (see Tab. 3).

Landscape of traditional practices

The landscapes of the studied villages consist of repeating elements, structures or habitats, however, seen from different 'village' perspectives, their traditional function and use varied (Tab. 3). Fig. 4 presents a simplified map illustrating the traditional landscape of the village Pluty (II), which is the most diversified among the studied villages.



Fig. 4. A simplified map presenting the traditional land-use of one of the villages, Pluty (II), in the Biebrza Valley, Poland, in the 1960s. Drawn by J. Sucholas. For detailed explanation of landscape elements see Table 3.

The situation of this village in relation to the river is exceptional, as there is a large accessible area of usable wetlands before the river. The village stands out with the highest number of toponyms saved in the memory of the people (mainly the older informants) – 87 in total (on 14.1 km²). Less than 18% of all toponyms referred to the area of use on the other side of the river, *zarzecze*. The vast majority of the toponyms name elements of a landscape of an area less than 5km² in size, in front of the river. A similarly high number of 69 toponyms is used in the village Sośnia (18.6 km²), now abandoned by its native inhabitants. The village is also situated on the right side of the river and separated from the river by an extensive area of accessible wetlands. Both wetland landscapes (I, II) have been the most anthropogenically modified by piled up roads, digging ditches and peat excavations in former times. Fifty-five toponyms were collected in Rutkowskie and Kołodzieje, the wetland landscapes of which overlap (6.1 km²); then 46 in Olszowa Droga (9.2 km²); 30 in Gugny (5.5km²); and 27 in Brzostowo (3.6 km²). We can see that the more diversified the landscape is by the presence of many oxbow lakes, ditches, paths, mineral islands and the like, the more toponyms were invented by inhabitants. However, people underlined that: *in the past more names were in use that are forgotten now* (II). The local wetland map, rich in many toponyms, was necessary for the local community to orientate itself on the, even if modified, still broad, monotonous and flat landscape. It helped to find his or her own plot, which was not separated by any fence.

Sometimes borders were marked with stones (II), small poles (III) or willow branches (IV, V)². However, such a map exists only in the memory of people who never preserved their oral transmission in written form. The toponyms of meadows were derived from the surname of the owner, the name of the owner's village, a neighbouring landscape element such as e.g. an oxbow, a distinctive landscape feature or certain farming practices. The information about times of traditional farming is encoded in toponyms. For example, toponyms indicate places of former peat excavation, owners of meadows (even if 40 or more years have passed since the land was under their management), grazing animals, growing plant species etc. Generally, even the oldest farmers admitted that they do not know the origin of a name and said that it is very old.

Table 3. Elements of the wetland landscape of the studied villages (Biebrza Valley, Poland) and their traditional use. The Roman numerals in parentheses indicate the village: I - Sośnia, II - Pluty, III - Brzostowo, IV - Rutkowskie, V - Kołodzieje, VI - Gugny, VII - Olszowa Droga. The landscapes of vil. IV and V overlap, hence the no. of toponyms are summed up.

Element of landscape	Meaning	Traditional use	No. of toponyms/village					
			I	II	III	IV/V	VI	VII
<i>biele</i>	all wet meadows in general	various uses	1	1	1	1	1	1
<i>biele, biele wyrzebowe</i> (VII)	white meadows	mown 1/y and grazed by cattle (I, II, VII); mown 1/y + grazed by cattle and horses (III, IV); mown 1/y or seldom 2/y + grazed by cattle and horses (V)	11	20	5	14	9	13
<i>dołek</i> (VII)	small depression near mineral islands; generally hollow in wetlands (VII)	cattle waded there (I); cows were milked here (III); mown 2/y + grazed by cattle (VII)	3	0	1	0	0	1
<i>droga, grobel, drożyna</i> (VI)	road, causeway; generally unpaved, piled up roads in wetlands	used for transporting logs to the river (I); used to get to distant meadows (I, II, IV, VI, VII); river crossing for livestock (III); used to get to the distant village (IV/V);	6	4	1	3	2	1
<i>grądziki</i>	mineral islands; woody patches in wetlands with deciduous trees like <i>Quercus robur</i> , <i>Carpinus betulus</i> , <i>Pyrus</i> spp. etc.	for drying of <i>żaki</i> (fyke nets) (I); grazed by cattle (I, II, V, VII) and horses (I); grazed in spring by cattle (II, VII); grazed <i>smugi</i> (III); mown 1/y (I, II, III); source of wooden material for farming tools and structures (all); source of wood for burning (II, VII)	13	7	2	4	1	8

² Plots in the Biebrza Valley are long and narrow due to the still present legacy of traditional land fragmentation along the length of plots, so that the plot became narrower and narrower but remained constant in length. In former times the long and narrow plots perpendicular to the river were assigned equally to people, so that everyone got better quality meadows by the river and the worse ones further from the river.

jeziora, bajora	lakes (oxbow lakes), swampy ponds	fishing with <i>niewód</i> (seine) (VII), <i>brodnia</i> (type of drag net) (I, VI, VII), <i>żaki</i> (fyke nets), <i>kozak</i> (a type of a fyke net with 'hearts' on two sides [7]), <i>kłomla</i> (wooden landing net) (I, IV); soaking freshly cropped hemp (II); cleared with a scythe (I, II, III, IV, V, VII)	11	7	3	9	3	11
krzewina	shrubs on wet meadows; usually applied to shrubby <i>Salix</i> spp. (e.g. <i>Salix cinerea</i>)	source of material for farming tools and haystack structures (all); used for basket weaving (IV)	0	2	1	1	1	0
kultury	cultivated forest fragments; freshly planted fragments of <i>Alnus</i> or <i>Pinus sylvestris</i> or <i>Picea abies</i> forest	a state property; they used to be fenced for some periods to prevent grazing	0	0	0	0	1	1
las, grąd	forest, deciduous forest on hills and hollows (II,III,V)	source of wood for burning (II, III, V); source of material for farming tools and structures (all); mown for hay (II); grazed by cattle (II, V)	0	2	3	2	3	0
las iglasty	<i>Pinus sylvestris</i> or <i>Picea abies</i> forest (I,V)	source of material for farming tools and haystack structures (all); source of wood for burning (I, V, VI, VII);	2	0	0	4	1	1
łąki uprawne	cultivated meadows	generally not present during the time of traditional management but now present in the areas and in the narration of people	0	1	1	1	0	0
łąki torfowe (VI)	peat meadows	mown 1/y + grazed by cattle and horses	0	0	0	0	1	0
ogrody	gardens	growing of vegetables (I, III, IV, V, VI); grazed by sheep (I, VI); growing of vegetables and hemp (II); growing of flax (III)	1	1	1	1	1	0
olsyna; las olszynowy	<i>Alnus glutinosa</i> forest	source of material for farming tools and haystack structures (all); grazed by cattle (II) + horses (III) + pigs (VI) + sheep (VII); source of wood for burning (VI, VII)	1	2	1	2	1	1
parowy, błota	muddy meadow, muds	used as a pasture for cattle (I); mown 1/y + freely grazed (II)	1	1	0	1	1	0
pola	crop fields	arable land used to grow cereals and potatoes (all); mixed in landscape with <i>smugi</i> (I)	9	1	1	1	1	1
rów, rowek	ditch, small ditch	local melioration (I, II); cattle would drink water here (II); general melioration in the 19 th c. (IV/V, VI); fishing with <i>brodnia</i> (type of drag net [VI]); cleared with a scythe (I, II, IV, V, VI)	2	5	0	2	1	0
rzeka	main river course	for fishing (II, III, IV, VII)	1	1	1	2	0	1
siedlisko	settlements	farm buildings	1	3	1	3	1	1
smugi	typical pastures on wet meadows or between crop fields	used for hay making + grazed by sheep and pigs (I); grazed by horses and cattle (II, V), grazed by geese, ducks, cattle, horses, sheep, pigs (III); grazed by cattle (IV)	1	19	3	1	0	0
torfy	place with peat excavation	peat was excavated for burning (I, II)	2	2	0	0	0	0

<i>trawy rzeczne, łąki rzeczne, równe łąki</i> (IV)	river grasses, river meadows, flat meadows; generally wet meadows directly by the river	mown twice a year (I) + grazed by cattle (VII) + horses, sheep (IV); mown 1/y or 2/y + grazed by cattle (II); used as pasture or mown 1/y + grazed by cattle, horses (III)	3	8	1	3	1	5
		in total	69	87	27	55	30	46

As a rule, the landscape element closest to settlements is *ogród*, the ‘garden’, where people used to grow vegetables and cultivate plants for fibre, such as flax or hemp. *Pola*, ‘fields’ – the ground on the elevated banks of the valley – were used as arable land to grow potatoes and cereals like oats, rye or millet and located around houses (I, V, VI, VII) or behind them (II, III, IV). The old riverbeds – oxbows – are a frequent element of the landscape of villages with access to the river. Notably, the landscape of wetlands near the villages from the upper LBB is dominated by oxbows marking old courses of the Biebrza River (I, VII). In times of traditional management, biomass in the oxbows and in the ditches was regularly removed with a scythe. Stories about using oxbows for fishing with traditional equipment are still vivid in the memory of the people. The term *łąki uprawne* ‘cultivated meadows’ is now applied to the meadows outside the valley as distinguished from *biele* (all wetland meadows in general). Fertilizers and seed sowing improve the productivity of cultivated meadows.

Mineral islands occur as elevated deciduous woody patches in wetlands and served many functions for people (Tab. 3). Grazing livestock could find shelter, shadow and fodder there. Mineral islands were the first accessible pastures in the wetlands in springtime (III, VII). The islands served as the safest place to build haystacks, secure from high water levels. The natural depression, *dotek*, adjacent to the mineral island produced the thickest and best hay quality, dedicated especially to sheep: *hay from the hollows was deliberately separated in a haystack for sheep that ate it directly ‘in the air’* (very quickly, before hay reached the ground in the barn), *it was of such a wonderful aroma* (VII).

Predominantly, the term *smugi* refers to the area that is used solely as a pasture. In one village (I), *smugi* relates to the small meadow stripes formed in the wet depressions between stripes of elevated crop fields, not only grazed but also mown.³ This characteristic stripe mosaic of meadows and crop fields was situated only near the settlement (I). Pastures,

³ Information obtained from the last two elderly inhabitants of the village; they might have an incorrect memory of how *smugi* were used.

smugi, were either found in wetlands (II, III, V), or around settlements (all villages), or exceptionally in the area of the crop fields (I, IV). The majority of the *smugi* in wetlands as well as some forests were used by the whole village. Such areas were named *ogólne* – ‘communal’ (common land).

The inhabitants noticed even slight vertical drop between the river’s course and the surrounding floodplain (Fig. 5). They understand that water flooded from the river and its content work like fertilisers, thus the ‘river grasses’, which were flooded most intensively, have the utmost hay quality and are the most productive, in contrast to the most distant ‘peat meadows’ that are not flooded by the river and are the most unproductive. Additionally, people differentiated plant habitats by a vertical drop – some of the plants grow in higher, others in lower wetlands e.g. in relation to the elevation to the river. The direction of the flooding water and its practical meaning in wintertime were also observed: *when the first frost came, the haystacks built on lower wetlands had to be transported to stables in the first place, otherwise there was a danger of the stacks being undermined and destroyed by the water coming quickly up-down the ice* (VII).

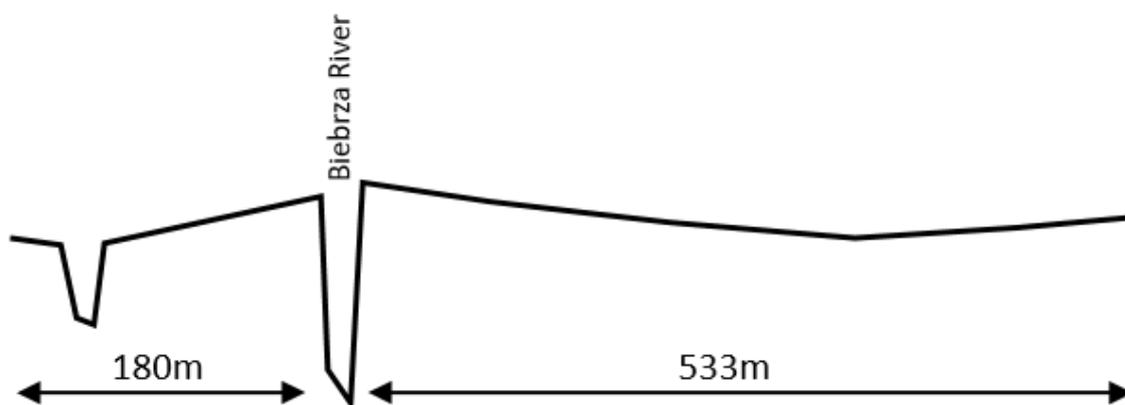


Fig. 5. Fragment of a cross-section of the elevation pattern in wetlands by the Biebrza River (based on stratigraphic cross-section no. 22, Olszowa Droga village area, made in 1960s, from *Wyniki badań glebowo-florystycznych w dolinie Biebrzy dolnej* by J. Oświt, 1965 (Oświt 1965)).

Local traditional wetland management practices

The annual cycle of hay management practices in the wetlands was conditioned by natural factors, of which water level was the most important: *Everything depended on water* (all villages). Open areas and forest in wetlands were the major habitats used to feed the livestock, especially cattle and horses, but also pigs, sheep, geese and ducks. *In the early*

spring, when water moved back from the wetlands and the first grass was visible, cattle was released for grazing on mineral islands (II) or since the beginning of May milk cows grazed there (on mineral islands) the whole month, day and night (...) twice a day we went there by boats for milking (VII) (Tab. 4). Since the pastures in the open wetlands had no fences, livestock either grazed freely in large areas or all cattle belonging to a village was herded by one person, sometimes even a child, in turn: *kolejka; wypas kolejka*, 'queue'. According to this method, the owners of the cattle tended them one by one, for a number of days equal to the number of owned cattle or half of this number (all villages). The fowl (geese, ducks) was usually kept in small pastures around the settlements, besides one village with easy access to mineral islands on the other side of the river (III). This area was used as pasture, *smugi*, for various livestock species grazing altogether (Tab. 4). The situation was similar when it came to pigs, which foraged near the houses, with the exception of the abovementioned village, where they were fed in 'river grasses' (III) and villages (VI, VII) where pigs would graze freely in the *Alnus* forest nearby the settlements. A few informants said that cattle used to eat saplings in spring (VI, VII), which occasionally had ill effects: *everyone had to have vinegar at home to cure a cow which used to have blood in urine after eating saplings of the lime tree* (VI). Sheep were fond of grazing wetland meadows, however, they required drier ground and had to be in sight of people to protect them from wolves. Because of this, they grazed close to the settlements: in drier *smugi* (I), 'river grasses' (III, IV) or *Alnus* forest and *biele* in autumn time (VII). Interestingly, in the past, one of the villages (IV) already had pastures in the zone of crop fields, which were grazed by cattle, horses and sheep until the last mowing date in the wetlands. After the second mowing in the wetlands, the livestock could freely graze 'river grasses' belonging to this village. Horses ordinarily grazed freely in the wetland meadows and forests at night, since during the day they were needed at the farm: *horses made groups while walking in wetlands in the night to protect themselves from the wolves* (VI). Sometimes catching the scattered horses in the morning was challenging, so *the horses were herded to the heaviest mud to hogtie them* (VI). In one of the villages (II) they grazed in wetland pastures situated very close to settlements during the day. The following four types of cattle grazing regimes in wetlands are noted: (1) if the wetlands were intended for hay making and had to produce grass, the cattle grazed in forests during this period, usually tended by the owners in turn using the already described *kolejka* system (V, VI, VII); (2) they grazed pastures close to settlements until the last mowing in wetlands (IV); (3) in the case of large wetland areas, heifers were

herded to the **biele** in early spring and grazed freely day and night until autumn (I, II, III); (4) the lactating cows could graze **biele** destined for mowing under the herder's supervision (I, II, III). The lactating cows were either visited twice a day and milked in wetlands or milked every evening once back home. Many informants believe that cows had less milk in their udders after grazing wetlands, because it was 'sucked out' by the snakes. Traditionally, livestock grazed in wetlands until first snow – **do zapadlych** – as confirmed by all informants.

Table 4. Time and place of traditional farming practices such as mowing and grazing in the Biebrza Valley. The Roman numerals in parentheses indicate the village: I - Sośnia, II - Pluty, III - Brzostowo, IV - Rutkowskie, V - Kołodzieje, VI - Gugny, VII - Olszowa Droga.

Traditional practice		When	Where
mowing	first	around St. Peter's Day 29 th of June (II, III, V, VI, VII), around St. John's Day 24 th of June (I, IV)	biele (V) + river grasses (I, II, III, IV, VII); peat meadows (VI); smugi (I); mineral islands (all); grqd (II); depressions (VII)
	second; called Otawa or Potraw	end of August/beginning of September (I, II, IV, V), around The Nativity of the Blessed Virgin Mary 8 th of September (VII)	river grasses (I, IV, VII); river grasses in front of the river (II); depressions (VII)
grazing	cattle	April/May - 15.10/01.11	smugi + biele + mineral islands (II) + <i>Alnus</i> forest (III); grqd (V); <i>Alnus</i> forest (VI)
		15.05 - 01.11	parowy + biele (I)
		in May, before 1st mowing	mineral islands (VII)
		during mowing time	<i>Alnus</i> forest (VII)
		after 1st mowing	biele (V, VII); peat meadows (VI)
		after 2nd mowing	river grasses in front of the river (II); river grasses (IV, VII)
	horses	1.05-15.10	smugi + <i>Alnus</i> forest (II) + biele + mineral islands (III); grqd (V); peat meadows + <i>Alnus</i> forest (VI); river grasses + biele + mineral islands (VII)
		15.05-01.11	mineral islands + biele (I)
		after 1st mowing	biele (V)
		after 2nd mowing	river grasses (IV)
		1.05-15.10	smugi (III)
	sheep	15.05-01.11	mineral islands + smugi (I)

		after 2nd mowing	river grasses (IV)
		autumn	<i>Alnus</i> forest + <i>biele</i> (VII)
pigs		1.05-15.10	<i>smugi</i> (III); <i>Alnus</i> forest (VI, VII)
		15.05-01.11	<i>smugi</i> (I)
geese and ducks		1.05-15.10	<i>smugi</i> (III)

All informants admitted that the time of the first mowing depended on the water level: *grass started to grow at the end of May (...) usually, first mowing was at the end of June (...) but it depended on the water level* (VII) (Tab. 4). However, as a rule, the Catholic feast days, e.g. St. Peter's Day 29th of June and the Nativity of the Blessed Virgin Mary 8th of September, fixed the start of the mowing, which would begin one day after them. However, if the water level was still high, the first mowing could be delayed until July. At the time of traditional management, all open wetlands and grass in deciduous woody patches were mown: *formerly, with a scythe, everything was mown as low as possible (...) with a scythe one could enter everyplace, even if the water was still there* (VII). The time and place of the second mowing was conditioned by the water level and type of vegetation. Nevertheless, grass needed to be cut at the beginning of September at the latest: *if hay was cut later, cattle did not want to eat such hay* (VII). Sporadically, intensive rainfall in summer prevented the second mowing. All the 'river grasses' which were not used as pastures were mown a second time. A few informants stated that the second cut provided even better hay quality than the first cut: *first hay was a very good fodder – out of thicker grass, however, the second was better – out of very soft grass* (IV). If 'river grasses' were not available to a community, but only the worse quality 'white meadows', then these were also mown once or occasionally twice (V). Mowing in wetlands usually started from the side of the river and was performed by the whole village simultaneously. It engaged people for intensive two-week-long work.

Natural conditions shaped the development of haymaking methods and defined the used materials. All informants said that depending on grass quality, it was mown either *na pokos* – 'in swath' (in case of thicker grasses, the haymaker would mow a swath only from one side – mowing always in one direction) or *na zbijaka* – 'to conglomerate' (a technique applied to thin grasses; the haymaker would mow grass from two sides to achieve a thicker swath – mowing in two directions, back and forth). The first technique was the predominant, while the

second was used on very poor-quality 'white meadows' (V, VII); grasses in the most distant 'taking', like fifth and further zones (III); or on 'peat meadows' (VI). *It was good to start mowing at dawn with the dew when grasses were fresh and not dried by sun* (VII). During dry and sunny weather, hay did not require turning. When hay dried out, women raked it and formed **kopy** (small haystacks). Usually, a couple of people would bring these small haystacks to the final large haystack on **nosidla** (two special wooden rods around three metres long used like a stretcher). Sporadically, hay was not carried by a couple of people but situated with a rope on one wooden pole that was attached to a horse which then carried it to the stack.

A haystack was preferably built on a mineral island if it occurred in the owned plot of meadow, or, as was usually the case, in the middle of the plot (as the most easily reachable and optimal location). As only the haystacks from the meadows close to the settlement were transported on a boat to stable but in most cases stayed in wetlands for the next few months until the winter, a special platform was built under the stack to prevent hay from being flooded and decaying. A few expressions were used for these platforms, such as **art** (VI, VII), **hart** (VI), **podzisko** (II, III, IV, V), **łożysko** (I, V). The structure had a circular shape. It was constructed from any available material – either stones (II, IV) or embedded wooden small poles, ca. 50 cm in height. These poles were additionally covered with branches. In wintertime, when frost made the meadows accessible, people would bring available material needed for platform structures, such as sand (IV), stones (II, IV) or branches (VII): *in summer, it was challenging for us to bring all these branches when the water was everywhere* (VII). The platform structures were so high that *when a man had to come to a stack with a boat (because water was so high) the hay was still not touching the water surface* (IV). The final stack was about 4 m high and 4 m in diameter. It was built by two people who, by giving to a stack a proper shape and arrangement of external hay, provided it with the necessary stability and waterproofing. In the LBB, all haystacks were ballasted by four heavy poles interposed on top of the whole structure. These poles had various names such as **grzędła** (II, III), **koźliny** (IV), **chlusty** (V, VI, VII), **zimówki** (I). Various tree and shrubs species were used as material, depending on what was available (Tab. 5). If wood was not available, they were replaced by ropes made out of hay. As a rule, hay was transported from stacks to the stable on a horse-drawn sleigh in winter, when the wetlands were frozen.

Local plant knowledge

The local community distinguished more than 50 folk generic taxa (ethnospecies) among the plants growing in wetlands (Tab. 5 in Supplementary Material). Some of the plants are named by and aggregated into groups that apply to a higher systematic domain such as a life form. As a rule, people differentiated groups of ‘grasses’, ‘shrubs’ and ‘trees’. Part of wetland species, which, according to people, do not have any farming value, were categorised as *ziota* ‘herbs’, *rodzina zioł* ‘herb family’ by a few knowledgeable informants. These plants, usually with colourfully blossoming flowers, frequently did not have generic names besides those used for medicinal purposes. This group of plants seems analogous to ‘grerb’ – small herbaceous species, a life form distinct from grasses. Species with broad leaves growing on the water were sometimes classified into a group of *kacaki*: *formerly, people named them kacaki* (III). Knowledge about these species was usually related to fishing, with the exception of *Menyanthes trifoliata*, which was a salient ingredient of hay. People also identified other generic taxa, which are not affiliated into any higher category. ‘Grasses’ (which also comprise some other grassland monocots such as sedges and rushes) are the utmost salient species in farming, therefore, there was the most extensive knowledge related to them. They are the prevalent ingredient of hay, dominate the landscape, and form the majority of the biomass collected from wetlands, so even if some of these ethnospecies did not have high fodder value, knowledge about them developed nevertheless. Similarly, ‘shrubs’ and ‘trees’ occurring in the area were salient species used as a source of timber and material for various necessary tools and constructions in traditional farming practices.

Folk plant classification

A single folk generic taxon may refer to multiple botanical species of a similar habitat (*sitorz* *Juncus* spp., *Eleocharis palustris*), similar morphological features (*hoszczka* *Equisetum fluviatile* and *Equisetum palustre*) and/or similar hay value (*rzeżucha* *Carex elata*, *Carex acutiformis* etc.). Sometimes one ethnospecies may comprise a few scientific species; however, it was not the whole plant individual that was identified as a folk taxon, but only the parts without flowering stems in the case of *mózga* *Alopecurus geniculatus*, *Agrostis stolonifera* etc., or only the blossoming parts of the plant in the case of *miotła* *Poa palustris* etc. The taxa of the ‘grasses’ category were predominantly distinguished by comparing their different morphological features (width of the leaves, height, or shape of the stem). In this

way, the subgroup of **trawy mieczowate** ‘sword-like grasses’ (**bluszcz** *Glyceria maxima*, **tatarak** *Acorus calamus*, **kosak** *Iris pseudacorus*) was distinguished by a feature of the relatively broad leaves, which are much broader than those of other wetland ‘grasses’. People stated that some of the wetland taxa have comparable, twin plants occurring in a habitat other than wetlands, usually arable fields. These species were phrased by secondary lexemes (e.g. **hoszczka polna** *Equisetum arvense*, **miotła polna** *Apera spica-venti*), therefore, they might be classified as belonging to a lower domain – specific taxa – of the ethnospecies. Sometimes a single botanical species had clear regional semantic variations. *Phalaris arundinacea* was called **jęczmianka** by inhabitants from villages on the left bank of the Biebrza River, whereas inhabitants of the majority of the villages on the right riverbank and southern part of the LBB claimed that they have never heard this name and call this plant **jemiola/niemiola**. Generally, characterisations of the species derives from traditional haymaking experience with the plants, e.g. what it was like to mow the plant with a scythe, to dry it, to rake it, to make a haystack out of it; how much hay the plant provides; how the plant was used during haymaking, etc. (Tab. 5).

Distribution of species knowledge

When asked to freely list plant species growing in wetlands, people the most often cited **rzeżucha** (*Carex* spp.) – 88.6% of informants, then **mózga** *Agrostis stolonifera*, *Glyceria fluitans* etc. – 77.1%, *Glyceria maxima* – 74.3%, *Phalaris arundinacea* – 68.6%, **trzcina** *Phragmites australis* – 65.7%, **hoszczka** wetland *Equisetum* spp. – 65.7%, *Acorus calamus* – 57.1%, **bobrek** *Menyanthes trifoliata* – 54.3%. A quarter of the informants mentioned **okraglica** *Carex appropinquata* etc. and **kobylak** *Rumex hydrolapathum*. Slightly fewer informants listed **mietlica** blossoming *Poa palustris* etc. and **kaczeniec** *Caltha palustris*, and one fifth of the informants listed: **lepka** *Galium uliginosum*, *G. palustre*, **osty** *Stratiotes aloides*, **mięta** *Mentha aquatica*, **powójka** *Calystegia sepium* and **drabinka** *Potentilla anserina*. Other ethnospecies were mentioned less often. People did not usually mention shrubs and tree species in this part of the interview, as these plants were not included in hay.

Species in habitats

Even if the landscape of the wetlands in the LBB seems to be continuously flat, local people in the first place described the habitat of the species by differentiating lower and higher places. For some plants, like *Glyceria maxima*, **dołek** ‘lowered place’ is applied to, the

habitat that is lowered in relation to the level of the river. However, more often **dołek** related to hollows in wetlands – places where water used to stay longer, which are often differentiated from higher mineral islands and high structures formed by the plants, like tussocks. According to informants, in the hollows in wetlands there grow: *Phragmites australis*, **mózga** *A. stolonifera*, etc., **hoszczka** wetland *Equisetum* spp., *Glyceria maxima*, *Acorus calamus*, *Menyanthes trifoliata*, **lepka** wetland *Galium* spp., *Rumex hydrolapathum*, **olszyna** *Alnus glutinosa*. **Rzeżucha** *Carex* spp. generally grows in higher places (forms tussocks), but also in lowered placed in front of mineral islands. Only in elevated places *Phalaris arundinacea*, **okraglica** *Carex appropinquata*, *C. diandra*, **mietlica** blossoming stems of *Poa palustris*, *Deschampsia flexuosa*, **tabuła** *Filipendula ulmaria*, **sitorz** *Eleocharis palustris*, *Juncus* spp., **wilczy gnat** *Sium latifolium*, **dębina** *Quercus robur*, and **grabina** *Carpinus betulus* occur. Some of the habitats were defined by the occurrence of accompanying species. For instance, a few informants said that: *Calystegia sepium* grows between ‘tall grasses’ like *Phragmites australis*, *Glyceria maxima*, **rzeżucha** *Carex* spp.; *Menyanthes trifoliata* can grow in hollows formed in front of mineral islands together with **lepka** *Galium* spp. and *Rumex hydrolapathum*, providing a specific sort of very high quality hay good for sheep; *Glyceria maxima* can grow together with **mózga** or with *Phalaris arundinacea*. Species like **mózga** and *Phalaris arundinacea* dominate in hay from the second mowing. Conversely, **koluch** *Sparganium erectum* prevails in hay from the first mowing.

Species in the landscape

The location of certain plants within the wetland landscape is embedded in the local partitioning of the landscape (Fig. 3). As informants said, nearby the river and along waterbodies there grow *Acorus calamus*, *Iris pseudacorus*, *Phragmites australis* and *Typha* spp. The ‘river grasses’ of the 1st and 2nd zoning are generally dominated by **mózga** *Agrostis stolonifera* etc., **wilczy gnat** *Sium latifolium*, **marchlaki** *Oenanthe aquatica*, *Potentilla anserina* and **hoszczka** wetland *Equisetum* spp. A bit further away from the river, the second zone of the 1st zoning and the first zone in 2nd zoning are mainly constituted by *Glyceria maxima* and *Phalaris arundinacea*. In zones further from the river (1st zoning) or in between the 1st and 2nd zone (2nd zoning), where the ‘white meadows’ are, **rzeżucha** *Carex* spp. prevails, accompanied by *Menyanthes*, **lepka** wetland *Galium* spp., *Calystegia sepium*, **gęsie łapki** *Comarum palustre*, *Sparganium erectum*. The second zone (in 2nd zoning, VII) is dominated by **siwucha** *Carex*

nigra, *C. flava* etc. and **tymotka** flowering *Carex nigra*, occurring directly in front of the *Alnus* forest. Similarly, in the furthest zone from the river, by *Alnus* forests in the 3rd zoning (VI), **okraglica** *Carex appropinquata*, *C. diandra* prevails on the 'peat meadows'. Many species can occur in *Alnus* forests, and include **kruszewina** *Frangula alnus*, **czarna porzeczka** *Ribes nigrum*, **truskawka** *Fragaria vesca*, *Caltha palustris* and others.

Species in management

Some species indicate a type and quality of vegetation that determines an area's management. Vegetation constituted mainly by **rzeżucha** *Carex* spp. was traditionally mown early, once a year, whereas 'river meadows' dominated by *Phalaris arundinacea* were traditionally mown twice a year. According to the informants, all species called **sitnik**, **sitarz** *Juncus* spp., *Eleocharis palustris* etc. indicate acidic soil; when mown, they provide very bad quality hay. **Okraglica** *Carex appropinquata* etc. and **siwucha** *Carex nigra* etc. indicate vegetation that is not dense enough to be mown using the common method **na pokos** – from one side – and therefore should be mown **na zbijaka** – from two sides – to provide a satisfyingly thick swath.

Value of species used for hay

People expressed the high fodder value of a plant through its positive association with good quality and tasty food. The most valuable plants were most often described as **śladkie trawy** 'sweet grasses', less often **tluste trawy** 'fatty grasses', or **majęce dużo białka** 'being rich in protein'. Conversely, plants that give low quality fodder were defined by all informants as **kwaśne trawy** 'sour grasses'. A few informants named them **końskie trawy** 'horse-like grasses', indicating that horses, believed to have the highest tolerance for different types of fodder, are more happy to eat those plants. Assumptions about the fodder value of the plants were based on observing if livestock eats the plant or not, how quickly it eats the plant, and what preferences the livestock has (for which species it reaches in the first place). Based on those observations, people also assessed the quality of the plants by comparing them to each other. When analysed qualitatively, the order of folk taxa ranked according to the value attributed to the given fodder by local people (based on observed cattle preferences) would be as follows. **Mózga** *Agrostis stolonifera* etc., *Menyanthes trifoliata*, **lepka** wetland *Galium* spp. and *Calystegia sepium* were included in the best fodder unanimously by all informants. *Caltha palustris* in the spring and *Fragaria vesca* in the autumn provide very good seasonal

fodder. The next best in terms of value would be *Glyceria maxima*, **mietlica** blossoming *Poa palustre* etc. and *Potentilla anserina*, which are eaten by cattle in any form. Meanwhile, *Phragmites australis* is a highly valuable plant only when it is young, and cattle does not eat it in the old stage. Similarly, *Phalaris arundinacea* could be ranked as a fodder plant of moderate value, since cattle eat only the very young plant or its leaves, avoiding the hard stem. However, it is good fodder for horses. Some but not all informants evaluated **siwucha** *Carex nigra* etc., **tymotka** blossoming *Carex nigra*, **hoszczka** wetland *Equisetum* spp., *Rumex hydrolapathum* and *Sium latifolium* as good fodder. Next in rank could be **rzeżucha**, a voluminous ethnosppecies covering many *Carex* species. It was usually classified as low-quality fodder which, when young, can be alternatively eaten by cattle. The next could be **rdest** wetland *Persicaria* spp. and **okraglica** *C. appropinquata* etc. – plants eaten by cattle only when the animals have no choice of other fodder. Finally, there would be the group of plants which, according to people, are seldom eaten, like *Acorus calamus*, *Iris pseudacorus*, *Oenanthe aquatica*, **sitorz** *Juncus* spp. etc., **bociany** *Lysimachia vulgaris* etc., *Comarum palustre*, and **tabuła** *Filipendula ulmaria*. The favourite plants for other livestock were as follows: **mózga** *A. stolonifera* etc. is a delicacy for many animals, including cattle (especially calves), horses, pigs, sheep, and rabbits; *Menyanthes trifoliata*, **lepka** wetland *Galium* spp., *Rumex hydrolapathum* and *Fragaria vesca* are the favourite fodder of sheep, whereas *Fragaria vesca* and the leaves of *Caltha palustris* are a delicacy for pigs.

Increaser and decreaser species

The older informants shared the changes they observed in plant occurrence during their lifetimes. People noticed that in recent years a drought led to a decrease in the abundance of **mózga** *A. stolonifera* etc., **hoszczka** wetland *Equisetum* spp. and *Menyanthes trifoliata*. People also observed that the occurrence of *Caltha palustris*, *Oenanthe aquatica* and *Rumex hydrolapathum* is depending on the temperature and snow cover in winter (directly related to amount of water in spring) – the colder and snowier the winter, the more abundant they are. According to many informants, in recent years, *Phragmites australis* started to prevail in vegetation. Firstly, they argued that, it used to be less common in the times when more cattle grazed in wetlands and trampled it. Secondly, it replaced **rzeżucha** *Carex* spp., which does not tolerate mowing with machines, because they destroy its tussock structure. Discontinuation of mowing led to the increase of **krzewina** shrubby *Salix* spp. and

Calystegia sepium. The increased abundance of *Phalaris arundinacea* was noticed in two villages; in one of these, the plant was observed to have replaced *Glyceria maxima*. In the two other villages where regular mowing by the river had been abandoned, more abundant *Glyceria maxima* was observed, together with an increase in the abundance of *Sparganium erectum* in one of the villages. Two informants spotted a local decrease of the **okraglica** *Carex appropinquata* etc. population, which seems to have been replaced by *Deschampsia flexuosa*.

Shrubs and trees

Shrubs and trees used to serve as a source of timber for wintertime. They were also used to make e.g. platforms under haystacks, ballasting poles to cover haystacks, rakes, scythes, rods to carry hay, etc. As a rule, the type of the shrub or tree used, especially when it came to building a platform under a haystack, depended simply on its availability in the landscape. However, 77% informants indicated thin trunks of *Picea abies* as the best source of wood for rods used to carry **kopy** 'small haystacks' to a haystack. Spruce wood was described as lightweight and resistant, therefore perfect to carry heavy 'small haystacks'. Alternatively, birch or alder wood could be used. As many as 71% of all informants indicated a freshly cut small birch tree as suitable to be used as a ballasting pole on a haystack due to its heaviness and elasticity, which made it possible to tie small branches together on the top of a stack. As many as 50% of informants also indicated alder as suitable for this purpose, however two people mentioned that it was a bit fragile. As many as 36% of informants listed **krzewina** shrubby forms of *Salix* spp., *Frangula alnus* etc.; however, they reasoned it was used only due to its common availability. Mostly hard species of **krzewina** shrubs, mainly *Salix* spp., then alder, birch, oak and pine were recommended for the small pales in haystack platforms. Branches of **krzewina** shrubs, mainly *Salix* spp., were commonly used as padding material.

DISCUSSION

Local traditional knowledge of wetlands

Even though traditional land use of wetlands in the Biebrza River Valley has been gradually ceasing since 1960s, the interviewed members of local community, particularly male representatives of the older generation, shared ecological knowledge on plants, landscape, and traditional management that was complex in dimensions and rich in detail. Women, being only partly engaged in traditional haymaking (hay raking and transporting), had much less wetland plant knowledge. As studies of Fawzi (2016) and Mustonen (2013) indicate, women can also be relevant knowledge holders, as long as they are fully engaged in land and resource management. A comparison of our results on traditional farming practices with the findings of Kiryło (1988) from the same area revealed already forgotten elements of knowledge (like herding with a dog, recognition of more habitats). This fact as well as the limited knowledge on plants and livestock grazing preferences amid currently studied younger farmers confirm that since extensive traditional practices are being discontinued, knowledge on nature and its management is no longer generated, which leads to its degradation and loss (Fawzi et al. 2016, Middleton 2016).

We assume, based on plant knowledge shared by older farmers, containing mainly qualities of plants in the context of personal farming experience, that direct contact with plants during haymaking (hand mowing with a scythe, hand raking of hay, building haystacks) and pasturing various livestock in wetlands are crucial factors in knowledge development. The more distanced the farmers are (literally – by machines), the poorer their knowledge, as we can see from the example of young farmers. Similarly to cattle herders (Molnár 2014, Fernandez-Gimenez 2000), farmers in the Biebrza Valley characterised plant ethnospecies by habitat, palatability and the preferences of different type of livestock, however they also added haymaking observations. Interesting remarks on assessing the fodder value of plants by traditional pig keepers (*svinjars*) ‘through the mouths of pigs’ (Molnár et al. 2021) have been affirmed in the Biebrza Valley, where farmers do the same but ‘through the mouths of cattle’, which were the predominant type of livestock grazing in this area. Such knowledge evolves when farmers extensively observe livestock grazing in wetlands or consuming hay.

The basic division of plants into two opposable categories, the 'sweet' (palatable, preferred) and the 'sour' (unpalatable), is an old distinction among Polish peasants (Prawdźic 1899, Kluk 1805). It seems that the quality of hay assigned to the plant depends on the available vegetation type. For instance, cattle with access only to wetland vegetation highly prefer species like *Glyceria fluitans*, *Agrostis stolonifera*, *Glyceria maxima* (our study, Biró et al. 2020, Biró et al. 2019), whereas those grazing in the saline steppe with various drier habitats that include palatable *Festuca* grass would graze such species as alternative fodder in drought time (Molnár 2014).

Knowledge on landscape and vegetation

The local, zonal perception of the wetland landscape is comparable to the scientific division into five vegetation zones in the LBB. However, the local community's perception is strongly associated with management practices and hay quality, whereas the scientific division is based on vegetation type that is collateral to the river and connected with the dynamics of the Biebrza River flooding and groundwater flow (Oświt 1970). In addition, wetland landscape is seen in its vertical dimension, having elevated and lowered places, which are the main criteria of defining folk plant habitats. Although the landscape of the Lower Biebrza Basin is extremely flat when seen from a distance, in fact it includes slightly higher sandy mineral islands (Oświt 1973) and elevated areas on the river edges (Oświt 1970). Both a horizontal zoning pattern as well as a mosaic of elevated and lowered places have practical meaning for farmers and differentiate management units (of various grazing and mowing regime). Similarly the traditionally managed lowland floodplain of the Sava River in Lonjsko Polje Nature Park in Croatia consists of micro-depressions and micro-mountains formed by water flow, creating different habitats and vegetation (Gugić 2009). We identified a modest number of wetland landscape elements in the inhabitants' narratives compared to numerous folk habitats recognised in mountainous areas (Babai and Molnár 2013). This is most likely a result of the uniform landform (Johnson 2000), the relatively species-poor vegetation of floodplain and fen meadows in the Biebrza Valley (Berezowski et al. 2018) and the fact that part of the knowledge might be already eroded when comparing our results with the findings of Kiryło (1988).

Wetland management practices

The traditional management regime in the Biebrza Valley was first of all flexible and conditioned on water level, similarly to management of the floodplain of the Sava River [Gugić 2009]. The first day of mowing was more or less fixed by church holidays – a marker of important activities associated with plants all over Poland. For example, Assumption Day and Corpus Christi Octave are days when herbs are blessed. They remind people to collect particular species of medicinal plants (Łuczaj 2011, Łuczaj 2012). The traditional farming calendar additionally depended on the location of the village, available habitats, vegetation, and type of livestock. The spatio-temporal management had a mixed character (grazing and mowing), as in floodplains of the Sava River (Gugić 2009). In times of traditional farming all wetlands (besides forest) in the Biebrza Valley were mown for hay, which enabled scythe mowing. Generally, scythe mowing, introduced in Eastern Europe in the 11th century (Poschlod 2015b, Truus and Tönisson 1998), is considered a major type of land use, which led to the widespread development of open wetlands and highly biodiverse fen meadows in Europe (Bignal and McCracken 1996, Ellenberg 1996, Middleton et al. 2006). Open wetlands and forests in the Biebrza Valley were also grazed, mainly by cattle and horses, locally by sheep in the dry autumn season and by fowl on soft meadows by the river. In the 1980s the area was still described as a vast pasture (Kiryło 1988). In contrast to Pannonian wetlands in Central Europe, which were grazed extensively all year round (Biró et al. 2019), these wetlands were not grazed in winter (because of snow cover) or in summer, when they were intended to produce hay (at that time *Alnus* forest became alternative pasture). It is worth mentioning that in terms of creating open wetlands, in Europe, grazing by cattle is a 5-7 thousand-year older land-use type than mowing (Middleton et al. 2006). Pig grazing in wetland forests, which was locally practiced in the Biebrza Valley, was ceased in ca. 1970s. This practice was not only historically frequent in Europe (Poschlod 2015a, Biró et al. 2019, Pokropek 2019) but present to this day in wet oak forests in floodplains of the Sava River (Gugić 2009, Poschlod et al. 2002, Molnár et al. 2021).

Haymaking was strictly performed on the owned wetland plots, in opposition to grazing, for which wetlands were used communally, as was traditional also in the wetlands of the neighbouring Narew River (Matus 2000) and the Balkan Sava River (Gugić 2009). Interestingly, some of the farming techniques common in Biebrza, like mowing *na pokos*, the

second mowing called *otawa*, and *klepanie kosy na babce*, sharpening a scythe with hammer on special iron tool, were common in old traditional practices in other Slavic countries and beyond (Pokropek 2019); likewise *wypas kolejka* 'pasturing in queue' (Matus 2000, Gugić 2009). However, these techniques were usually given different names.

Our study shows that even the poor-quality hay from fen meadows dominated by e.g. *Carex appropinquata* were used as fodder if no other type of hay was available, in opposition to the statement that historically low quality hay from fen meadows was used only for bedding (Stammel et al. 2003, Middleton et al. 2006, Poschlod 2015a). However, the farming use of worse quality vegetation in the Biebrza Valley was less complex (usually one mowing, grazing by cattle and horses) than the diversified management regime of highly valued floodplain river meadows (as a rule mown twice, grazed by all possible types of livestock).

Land use changes and conservation challenges

The intensification of farming in the Biebrza Valley, i.e. the gradual ceasing of scythe use and grazing livestock, led predominantly to the abandonment and overgrowing of wetlands in the LBB. Such land use transitions are considered to be the main threats to the biodiversity of wetlands in Europe (Poschlod 1996, Truus and Tõnison 1998, Middleton et al. 2006). For instance, as in wetlands of the Carpathian Basin (Biró et al. 2019) and coastal wetlands in Estonia (Burnside et al. 2007), the lack of trampling cattle in the Biebrza Valley resulted in an uncontrolled spread of reed. Since the Biebrza National Park was established, many scientific research and conservation plans have been proposed and undertaken to protect the unique biodiversity and hydrology of the area (Budka et al. 2003, Bartoszuć et al. 2004, Kotowski et al. 2013, Mirosław-Świątek et al. 2020). However, its protection status limited or banned some of the local community's activities. For example, the burning of wetlands is strictly forbidden due to the risk of peat catching fire (Klimkowska 2004), even though the burning of tussock structured wetlands was traditionally practiced in early spring (Kiryło 1988) and controlled burning is recommended as favouring the population of the Aquatic Warbler (a bird species under conservation; [Kloskowski and Krogulec 1999]). The local community used to extensively hunt for ducks, hares and otters (Kiryło 1988), which is currently forbidden and recognised as poaching. Some traditional practices such as removing vegetation in the oxbows are also not continued. However, further research is needed to explore the current management of wetlands in the Biebrza Valley – which is defined not only by the conservation plans of the

national park but also by EU agri-environmental regulations – and to propose recommendations on how traditional management and knowledge could be integrated into it.

CONCLUSIONS

The research revealed and documented local traditional ecological knowledge on wetlands' plants, vegetation, landscape and the mixed management regime that is still present among the local community of the Biebrza Valley. It confirms essentially and unquestionably the dominantly cultural origin and character of highly valued ecosystems in the studied area, hence the Biebrza Valley needs to be treated as a cultural landscape in any management endeavours. For this reason, the components and complexity of traditional farming and ecological knowledge of local people should necessarily be taken into consideration as inspiration for conservation management plans in the area, and collaboration with the local community should be undertaken in such activities. The research might give an incentive for further studies in other villages of the Biebrza Valley and in other areas of high environmental value and cultural origin.

CHAPTER FOUR:

DOES THE AES-DEFINED MANAGEMENT OF HIGH VALUE WETLANDS
EFFECTIVELY SUPPORT CONSERVATION OF THE BIOCULTURAL LANDSCAPE IN
BIEBRZA NATIONAL PARK, POLAND?



Traditional and modern wetland management in the Biebrza River Valley (Poland). a, traditional hand hay management: above - carrying small haystack on wooden spruce rods (Photo by M. Pokropek, 1968), below - preparing to mow with a scythe (Photo by J. Rybiński, 1960s). b, transport across the river: above - with horses (Photo by J. Rybiński, 1960s), below - haybales transported with a tractor (Photo by J. Sucholas, 2019). c, livestock grazing wetlands on the other side of the river: above - horses (Photo by W. Wołkow , 1960s), below - cattle (Photo by J. Sucholas, 2018), d, hay storing: above - traditional haystacks in the wetlands (Photo by J. Rybiński, 1960s), below - modern bales (Photo by J. Sucholas, 2019).

ABSTRACT

The Biebrza Valley is one of the largest wetland ecosystems in Central Europe. The semi-natural habitats that dominate its landscape have been developed as a result of centuries-long traditional grazing and haymaking. Since the 1960s, partly due to farming intensification, farmers have gradually ceased to farm wetlands. Abandonment has led to secondary succession, thus endangering high nature value wetlands. Biebrza National Park could not effectively counteract this process due to financial problems, among others, so it was hoped that their use could be resumed through subsidised agri-environmental schemes (AES). Given local conservationists' recognition of the importance of traditional practices for nature conservation, our aim was to determine whether they are integrated into current wetland management and to discuss implications of management on biodiversity.

Based on structured interviews with 28 farmers, we collected information on current management of 158 wetland plots and assessed the integration of traditional methods by analysing seven detected key management practices (variables). We examined the level of similarity between each implemented AES and traditional use. We traced changes in the implementation of AES in the Biebrza Valley over the years using data obtained from the Agency for Restructuring and Modernisation of Agriculture (*ARiMR*) to identify the impact of AES on management and conservation.

AES are currently the main conservation and regulatory tool defining management of semi-natural wetlands in the Biebrza Valley due to their significant and increasing level of implementation. The AES with management closest to traditional use was the most frequently implemented scheme, as this AES appeared to simultaneously address agricultural demands most adequately. Despite the discussed positive impact of traditional practices on wetland biodiversity, they are poorly integrated into current management and have almost declined (such as grazing).

Traditional practices that define the biocultural landscape in Biebrza NP and provide effective conservation of high-value habitats are not supported in the current AES system. We suggest that the system needs to be revised and adapted to the current socio-ecological conditions of farming, or else other conservation and agricultural initiatives should be developed in the area.

Key words: semi-natural habitats, traditional farming practices, wetland management, EU CAP policy, Eastern European country, protection area

INTRODUCTION

In Europe, many habitats of high nature value occur in rural biocultural landscapes developed by extensive traditional farming practices, for instance in Romania (Babai and Molnár 2014), Poland (Sucholas et al. 2022), Germany (Poschlod and Wallis De Vries 2002), England (Bignal et al. 1996) and many others. Bignal et al. (1996) estimated that more than 50% of highly valued biotopes in Europe appear on low-intensity farmlands. Biocultural, man-made landscape in Central Europe originated in the postglacial Neolithic period (ca. 5500 BC, Birks et al. 2003). However, 'traditional agricultural landscape', preserved to this day in some rural areas, has existed in Europe since the Renaissance (15th century)(Vos and Meekes 1999). Traditional agriculture consists of traditional farming practices which are 'not generally a part of modern agriculture' (Bignal et al. 1996). Traditional farming in Europe is characterised by features such as low agrochemical input; management techniques that increase diversity of vegetation structure (Kun et al. 2019); relatively high participation of semi-natural habitats (Clark et al. 1994); long-established management practices (such as hay-making); low degree of mechanisation; low external fodder input (Poschlod 2015a); and space-based traditional knowledge of the landscape, its dynamics and functioning (Molnár et al. 2008). However, traditional practices vary significantly in detail across Europe as adapted to local conditions.

Interestingly, the highest diversity of land-use types in the 19th century was associated with a peak in species and habitat biodiversity in Europe (Green and Vos 2003, Poschlod et al. 2005). In other words, traditional farming in Europe contributed to an increase in biodiversity through the maintenance of semi-natural habitats (Poschlod 2015b). Farming intensification and the abandonment of extensive traditional practices are the major threats to the semi-natural habitats of e.g. open wetlands (Biró et al. 2020) or lowland and mountainous grasslands (MacDonald et al. 2000). For instance, abandonment of hay mowing and the replacement of low-intensity livestock grazing by livestock housing (Clark et al. 1994) leads to vegetation succession (Bignal and McCracken 1996). Drainage of wetlands for agricultural purposes (Joyce and Wade 1998), technology development, and use of mineral fertilizers contribute to e.g. loss of habitats, habitat fragmentation, and a decrease in species richness (Niedrist et al. 2009, Poschlod 2015b).

Management of extensive semi-natural habitats has been discontinued due to a wide range of factors, e.g. globalisation, changes in rural demography, and low productivity directly

connected with economic unattractiveness (McGinlay et al. 2017). Therefore, the continuation or restoration of the management of such habitats requires financial compensation for farmers, which in Europe is provided mainly through agri-environmental payments, funded under the Common Agricultural Policy (CAP) of the European Union (EU) (Batáry et al. 2015).

Agri-environmental schemes (AES) are compulsory for all Member States of EU as a part of the ‘second pillar’ of CAP supporting rural development. On the one hand, AES were developed as policy tools aiming to mitigate the pressure of modern agriculture on nature (Kleijn and Sutherland 2003). On the other hand, especially in the case of agriculturally marginalised areas, AES are mainly intended to avert land use abandonment and to prevent farming intensification (Batáry et al. 2015).

The positive effects of AES on the biodiversity of semi-natural habitats have been acknowledged, e.g. in the case of the largest calcareous grasslands in Europe (in the Alvar region in Sweden, Rosén and Bakker 2005) and species-rich mountain grasslands in the Alps (Kampmann et al. 2012). Far fewer studies have been carried out on AES effectiveness in the extensive farmlands of agriculturally marginal areas in the EU’s Eastern Member States, though they are recognised as biodiversity hot spots with numerous threatened species (Tryjanowski et al. 2011). Many authors identify the fundamental problem in the fact that CAP regulations do not support the maintenance of traditional low-intensive farming in East-Central Europe adequately, given its importance for biodiversity conservation (Beaufoy and Marsden 2010, Sutcliffe et al. 2015). For instance, the study of Babai et al. (2015) on traditional small-scale farming in Romania and Hungary found that regulations promoted only a few traditional practices, while others were either not supported in any way or were even prohibited, thus threatening the integrity of the traditional farming system. Above all, agricultural regulations to protect biodiversity developed through traditional farming practices should comprehensively address the local socio-ecological-economical system (Fischer et al. 2012).

In this paper, we analysed the management of high nature value wetlands in Biebrza National Park (Biebrza NP) in Poland – a conservation site of one of the most extensive wetland systems of partly human origin in Central Europe. As a wetland spot of global significance, it was designated as a Ramsar site in 1995 and is currently entirely covered by the Natura 2000

Network. Many waders and ca. 75% of the EU population of aquatic warblers, which are under global threat (Lachmann et al. 2010), nest here.

This biocultural landscape was developed by natural processes and a centuries-long traditional hay management regime. Starting in the 1960s, farming intensification has led to the abandonment of open wetlands, threatening the biodiversity of unique ecosystems by secondary succession. While the established Biebrza NP has faced challenges in the management of semi-natural habitats that contribute significantly to the landscape (Botromiuk 2010), accession to the EU introduced the possibility of financial support for this type of habitats through AES (Bartoszuk et al. 2004). Traditional practices such as horse and cattle grazing, were still present in the 2000s in parts of the wetlands, though on a substantially reduced scale, and this biocultural landscape became popular among tourists because of such practices as cattle swimming across the Biebrza River every day to reach pastures (Nawrocki 2004). Moreover, conservation relevance of traditional management was identified, and the planned AES were positively evaluated as supporting traditional practices (Bartoszuk et al. 2004). In view of the above, we aimed to find out if traditional farming elements, given their value, have been incorporated in wetland management after over 12 years of AES implementation.

The first objective was to detect if elements of traditional hay management practices are integrated in current management and to identify how the level of incorporation varies in respect to management type. Our second objective was to estimate the prevalence of different types of management and to chart the trend of change in AES implementation over the years. We aimed to understand the drivers that led farmers to implement some AES and not others. We sought to reflect on the importance of integrating crucial traditional practices into the ongoing management for effective conservation of wetland biodiversity and to discuss potential solutions for conservation challenges.

MATERIAL AND METHODS

Study area

Our study focused on wetland plots located in the Lower Biebrza Basin of Biebrza NP. Biebrza NP is situated in NE Poland (53°30'13", 22°45'27"). It covers an area of 59,223 ha with an additional buffer zone area of 66 824 ha (Bołtromiuk 2010). Biebrza NP was established in 1993 to protect the ecosystems of the Biebrza Valley. The area has a temperate continental climate; an average annual air temperature of 6.8°C; 583 mm mean annual precipitation; and a ca. 200-day growing season (Górniak 2000). The Biebrza Valley is a floodplain depression with three geomorphologically distinct basins: Upper, Middle, and Lower. Wetlands cover 60% of the area (floodplain and percolation mire); the remaining 40% is constituted by sandy uplands and 'islands' (i.e. small hillocks) covered by forest and arable fields (Churski and Szuniewicz 1991).

Wetlands in the Biebrza Valley are characterised by a regular pattern of vegetation. Five vegetation zones parallel to the course of the river can be distinguished in the Lower Biebrza Basin. Vegetation starts with ca. 2 km-wide regularly flooded zones of reeds (with *Oenanthro-Rorippetum*, *Glycerietum maximae* and *Caricetum gracilis* associations) and tall sedges forming tussocks (with *Caricetum elatae*, *Caricetum rostrata* associations), followed by an approximately 12 km-wide alkaline fen meadows supplied by groundwater, comprising zones of sedge-moss communities (with *Carex appropinquata*, *Carex nigra*) and low-sedge-brown moss communities (with e.g. *Carex diandra*). It ends with a narrow zone of woodlands with birch and alder carr woodland (Oświt 1968, Pałczyński 1975).

In historical times, natural forests, swamps and fens in the Biebrza Valley were used seasonally, e.g. by hunters, cattle herders, or beekeepers (Łowmiański 1932). Over the centuries, since permanent settlement began at the end of the 14th century, local communities used wetlands extensively for haying and pasture farming (Wiśniewski 1964). Until the 1960s, pre-industrial traditional methods of wetland management were in place in the whole Biebrza Valley (Sucholas et al. 2022). Since the end of the 1960s, traditional management has gradually ceased and wetlands have been partly abandoned as a result of farming intensification (Bartoszek and Kotowski 2009). Farmers have gained access to drained, fertilised meadows outside of the Biebrza Valley, which has proven more productive; the previously scythe-

mowed wetlands with tussock vegetation are less accessible to tractors (Banaszuk 1991). A process of overgrowing with reed and willows has started in open wetlands, threatening this unique ecosystem (Kotowski et al. 2013). Biebrza NP has undertaken many actions of removing trees and shrubs, though only on a small scale, given financial and technical limitations (Matuszkiewicz et al. 2000). Biebrza National Park is the largest national park in Poland, consisting of more than 166,000 plots, of which approximately 50% are privately owned, which impedes the effective management of the area (Kardel et al. 2009).

Since accession to the EU in 2004, farmers in Biebrza NP can voluntarily implement AES dedicated for Natura 2000 habitats in their wetland plots. Similarly, AES are being implemented on the remaining state-owned plots leased from Biebrza NP by various entities. When deciding to enrol for the five-year scheme, the owner/tenant of the plot is obligated to implement top-down management practices that are predefined on the national level. Each AES designated for Natura 2000 habitats has a specific environmental objective, such as bird species or grassland habitat protection. The required management practices vary from one scheme to another due to their different conservation objectives. Some requirements are rigid and strictly defined (e.g. absolute prohibition of fertilisation), while others can be locally adapted from a specific pool of possibilities (e.g. one or two swaths, either mowing or grazing-mowing regime). In our research, when determining the management of the study plots, we referred to information collected from farmers on how the AES are actually realised in their plots. Until now, AES for Natura 2000 areas have been available in two rounds, as agri-environmental schemes in the years 2007-2013 and agri-environment-climate measures in 2014-2020 (for better readability, throughout the article we will use one abbreviation, 'AES', to refer to both types of schemes).

Agriculture is the dominant economic sector in the Biebrza Valley. However, the area is an agriculturally marginalised region. The majority (ca. 72%) of farms in Biebrza Valley are smaller than 15 ha. A farm usually encompasses arable land, forest and wetland meadows in the valley (Magrel et al. 2002). The share of farms in the area has been declining in recent decades due to difficulties in farming related e.g. to poor quality of arable land; poor infrastructure; considerable distance of farms from wet meadows; limitations related to the form of protection, with land being part of the national park; or the lack of successors willing to take over the farm. Since CAP funds (mainly direct payments) have become accessible,

agriculture has intensified, leading to increasing pressure on the environment. As farms specialise primarily in milk production, the intensification manifests itself e.g. by an increase in the number of cattle and the introduction of maize monocultures to satisfy higher fodder demands (Bołtromiuk 2010). Nevertheless, the presence of the Natura 2000 network across the entire area is an important regulatory factor, making it necessary to evaluate the environmental impact of planned investments (Gotkiewicz and Mickiewicz 2015).

Data collection and analysis

The study sites were located in villages of the Lower Biebrza Basin, the past traditional wetland management of which was comprehensively reconstructed and described by Sucholas et al. (2022). In the research, two data sets were used (Table 1): (1) detailed information on the current management regime (year 2020) of 168 plots in wetlands adjacent to the seven villages (Fig. 1); (2) information on the realised AES in 405 randomly selected plots (not marked on the map of Fig. 1) in wetlands adjacent to four of the above-mentioned seven villages, in the years 2008-2019.

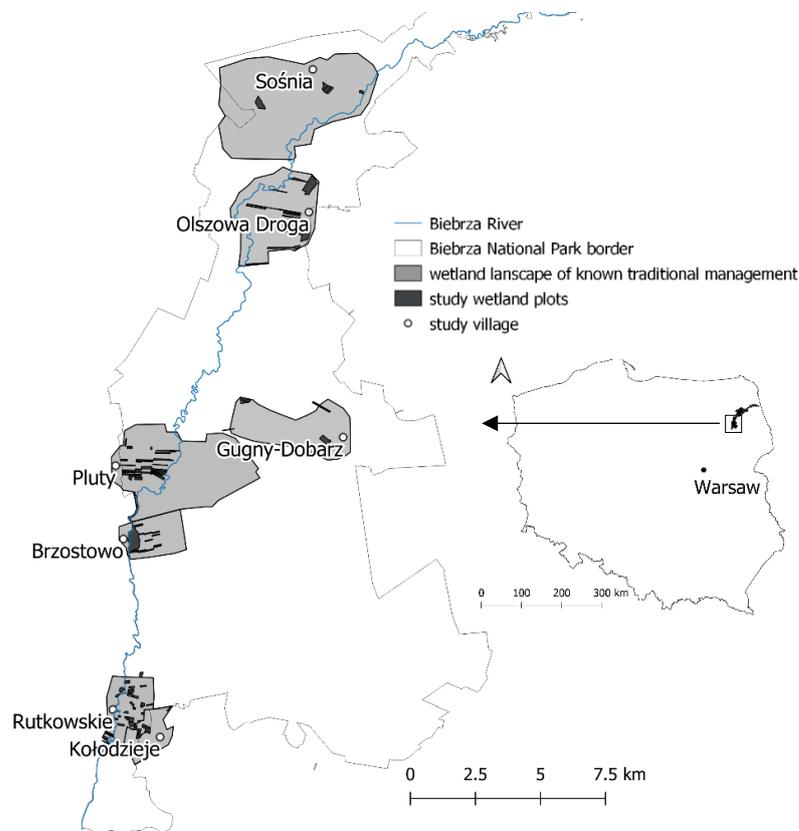


Fig. 1. Study area in the Lower Biebrza Basin of the Biebrza National Park, Poland.

Table 1. Two types of datasets collected for analysis of wetland management in the Lower Biebrza Basin (Poland).

	Wetland management	
	Detailed management of plots	Implementation of AES over time
No. of studied plots	168 (eventually 158) ⁴	405
Ownership of plots	Privately owned plots	Randomly selected privately owned and state plots
Location by villages	Sośnia, Pluty, Brzostowo, Rutkowskie, Kołodzieje, Gugny-Dobarz, Olszowa Droga	Pluty, Rutkowskie, Gugny-Dobarz, Olszowa Droga
Method of data collection	Structured interviews with 28 active farmers	Data obtained from agricultural paying agency (<i>ARiMR</i>)
Timeslot considered	2020	2008-2019
Access to data	2020	12 August 2020
Content of data	Data defining current wetland management regime, e.g. no. of mowings	Realised agri-environmental scheme or agri-environment-climate measure
General method of analysis	Assessing the similarity of current management to traditional	Analysis of shifts in proportion on realisation of AES by year
Aim of analysis	<ol style="list-style-type: none"> 1. Identifying which current management type is the most mimicking or deviating from traditional 2. Identifying which management practices (variables) determine the level of similarity 	<ol style="list-style-type: none"> 1. Identifying what is the direction of changes in schemes implementation 2. Estimation which schemes currently dominate in the area

Detailed management of plots

The local farmers (28 in total), users and usually owners of the 168 plots, provided detailed information on their current management of the plots. 14 farmers belonged to the younger generation of farmers of the same families as those who helped in the reconstruction of past traditional wetland use (Sucholas et al. 2022); the others were found with the snowball method. Each farmer was asked ca. 35 questions on particular management practices in wetland plots, currently realised AES, and previously realised AES (if known). Additionally, general information on the farm (production profile, size of the farm, crop fields, permanent grasslands, wetlands), opinion on AES, plans for the farm, etc., were asked. The interviews aimed at gathering the most relevant data defining wetland management regime, which could be compared with data on traditional management from the same location taken from

⁴ Ten plots were eventually excluded from the study as currently abandoned or representing an insufficient sample under certain AES.

Sucholas et al. (2022). In addition, we strived to understand farmers' motivation and attitudes towards AES.

In our study, we considered, based on Babai et al. (2021a) and Sucholas et al. (2022), the following seven crucial practices/variables defining management and influencing the biological conditions of open wetlands: number of mowings (N), time of the first mowing (M), tool used for mowing (T), grazing time (G), use of fertilizers (F), form of biomass (B), and use of biomass (U). We created a spreadsheet for all 168 analysed plots with information on whether there is an AES in place and which, and how each of the seven variables was realised in two time categories: past (traditional) and present. For instance, for the variable 'number of mowings' – how many mowings were performed in the past and how many are now. To determine exactly how the variable has been realised at a given site in the past, we looked up the location of each plot in QGIS and assigned a traditional use for that site from Sucholas et al. (2022). In order to quantify and synthesize the results of the interviews, we subjectively ranked the current realisation of the variable against the traditional realisation by using a three-degree scale (0-0.5-1). Each of the seven variables of each plot was assigned a value of either 0 or 0.5 or 1, where 1 – reflects a current use identical to the traditional one; 0 – indicates that the current realisation of the variable is extremely different from the traditional one; 0.5 – reflects management which is between extremely different and identical (Tab. 2). Finally, the overall degree of similarity of the current use of each plot to the traditional one was expressed by a simple 'management similarity index' (MS). The MS for each plot is expressed by the calculated mean of the assigned values of each of the seven variables (values varying between 0 and 1 as explained above). The MS reflects how current management is similar to traditional management ('1' reflects maximum similarity of use).

$$MS = \frac{N+M+T+G+F+B+U}{n},$$

n = number of analysed variables; N, M, T, G, F, B, U – the seven analysed variables.

Table 2. Values subjectively ranking the current realisation of the management practice/variable against the traditional realisation (1 – reflects a use identical to the traditional one; 0 – indicates realisation extremely different from the traditional one; 0.5 – reflects management between extremely different and identical).

Variables	Assigned values to current management		
	1 – identical to the traditional	0.5 – different from traditional	0 – extremely different from traditional
Number of mowings (N)	one or two or grazed*	one instead of two; two instead of one; grazed instead of one or two mowings; one or two or three mowings instead of grazed	one in two years
Time of the first mowing (M)	early (second half of June) or grazed*	a little earlier or a little later (beginning of June or in July); mown instead of grazed; grazed instead of mowing	very late – in August or later
Tool used for mowing (T)	scythe or only grazed	tractor with rotary or disc mower	tracked mower
Grazing time (G)	grazing at the same time	grazing ,but in different time slots	no grazing
Fertilizers use (F)	no	a little (sometimes or once a year)	regularly, twice or three times a year
Biomass form (B)	haystack or only grazed	usually bales with dry hay	usually foliated bales with silage
Biomass used for (U)	as fodder or only grazed	both: fodder and bedding	only for bedding

*if the plot had been used exclusively as pasture, a value of '1' is also assigned for the given variable

Then, the plots were analysed according to the deployed AES or lack thereof. We excluded ten plots from the analysis due to the small number of plots (samples) under certain AES (two plots) and due to being covered by forest or abandonment (eight plots). In total, 158 plots were analysed. Boxplot analysis was carried out on MS of study plots grouped according to the deployed AES. Classical hierarchical clustering was applied, which grouped the study plots according to the sameness of the values of variables. The Principal Component Analysis (PCA) was carried out to see how plots cluster and which management variables determine this. PAST4.03, RStudio and Microsoft Excel software was used to carry out statistical analyses. For the plots where the interviewed farmers knew the previously implemented AES, an analysis was made on how the AES in those plots had shifted.

Implementation of AES over time

Further, we analysed implementation of AES since the beginning of their availability in the study area in 2008. For this analysis, data was collected in two steps. (1) We haphazardly selected plots from wetlands adjacent to four villages (103 in Rutkowskie, 100 in Gugny-Dobarz, 100 in Olszowa Droga, 102 in Pluty) from cadastral data in QGIS. (2) We contacted the local Agency for Restructuring and Modernisation of Agriculture (*AriMR*), which was responsible for the disbursement of CAP subsidies and possessed data on AES implemented in the studied region. We requested the agency to provide us with information on an anonymous basis on the AES implemented between 2008 and 2019 on the 405 study wetland plots. Statistical analyses were run in Microsoft Excel to determine the proportions of AES realisation in the study region, trace how the proportions of AES deployed have shifted since the year 2008, and determine the direction of those changes.

AES analysed in the paper

The paper concerned only AES deployed in study wetland plots from all the available AES (11 in total in 2007-2013 and 11 in 2014-2020) designated for the high nature value areas of the Natura 2000 network in Poland (Tab. 3). Throughout the article, the abbreviations of the AES analysed are used. The AES available in the first CAP round in 2007-2013 might be still implemented in wetlands in subsequent years (maximally until 2017 for farmers who joined in 2013).

Table 3. Agri-environmental schemes and agri-environment-climate measures analysed throughout the paper and their abbreviations.

Abbreviation in a paper	Protection objective	Subsidy [€]⁵	National code	CAP period
aquatic warbler	protection of breeding habitats of the aquatic warbler (<i>Acrocephalus paludicola</i>)	ca. 279	4.9.	2014-2020
great snipe	protection of birds' breeding habitats: great snipe (<i>Gallinago media</i>) or common curlew (<i>Numenius arquata</i>)	ca. 249	4.10.	2014-2020
lapwing	protection of birds' breeding habitats: black-tailed godwit (<i>Limosa limosa</i>), common snipe (<i>Gallinago gallinago</i>), redshank (<i>Tringa totanus</i>), lapwing (<i>Vanellus vanellus</i>)	ca. 207	4.8.	2014-2020

⁵ Converted from PLN to EUR according to the value in 2019 before inflation related to the Covid pandemic

peatland II	Peatlands	ca. 280	4.6.	2014-2020
SPA II	Special Protection Area of birds	ca. 140	4.7.	2014-2020
wet meadows	<i>Calthion palustris</i>	ca. 212	4.4., 5.6.	2014-2020 2007-2013
peatland I	peatlands (<i>Caricion dvallianae</i>) focused on Aquatic warbler protection (<i>Acrocephalus paludicola</i>)	ca. 323	5.2.	2007-2013
permanent grasslands	extensively used permanent grasslands	ca. 116	3.1.2.	2007-2013
tall sedge	<i>Magnocaricion elatae</i>	ca. 212	5.3.	2007-2013
SPA I	Special Protection Area of birds	ca. 319	5.1.	2007-2013
SPA I (pastures)	Special Protection Area of birds – exclusively grazed	ca. 319	5.1.	2007-2013

Analysed farms

Based on interviews with 28 farmers, we analysed 28 farms according to their varying production profile. We divided farms into three main production profiles: those producing milk (n=6), those producing meat (n=8) and those producing both milk and meat (n=10). There were also farms that have ceased production in recent years (n=3) and one which has never engaged in such production (referred to as ‘no livestock’). We analysed the proportion of wetlands and other forage production areas (sown permanent grasslands and crop fields) to the total farm size. Then we analysed implemented AES in wetlands belonging to farms of various production profiles to understand the correlation between AES and production profiles.

RESULTS

Detailed analysis of plot management

Current management of the 158 plots was either regulated by one of four types of AES (named as follows: 'aquatic warbler', 'great snipe', 'lapwing' and 'wet meadows') or was not framed by any AES ('no scheme') – this means that it was managed according to the wishes and needs of the farmer. AES were implemented in 81% of the 158 study plots. The boxplot (Fig. 2) analysis of *MS* revealed that management of plots framed by 'aquatic warbler' was generally the least similar to traditional practices. Only the group 'no scheme' included plot used in the same way as traditionally. The use of the plots realising 'lapwing', followed by 'wet meadows', were the closest to traditional out of all the plots with AES.

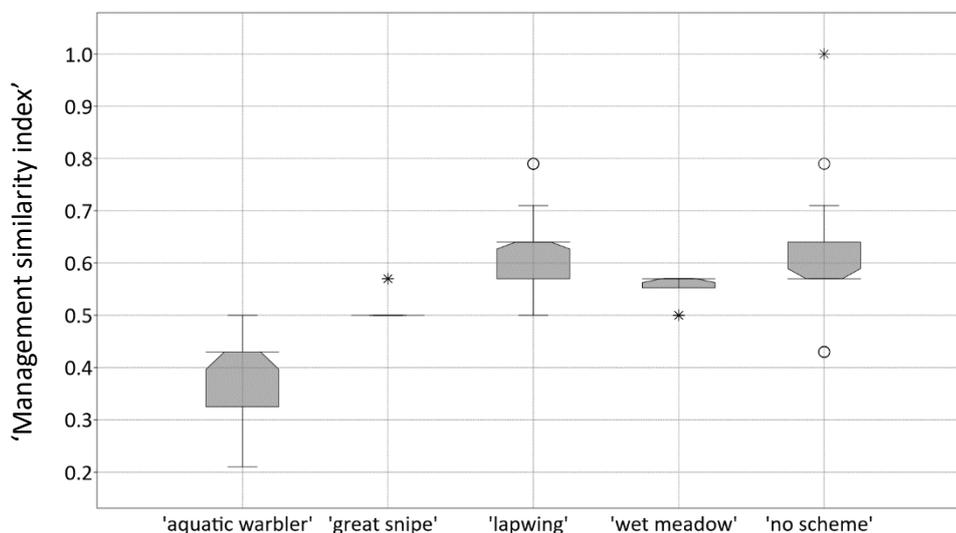


Fig. 2. Boxplot with outliers shows the *MS* – 'management similarity index' of study plots grouped according to management type. The graph presents how similar current management of the study plots is to traditional management. The value 0 – reflects the same management as traditional, the value 1 – extremely different.

Hierarchical clustering (Fig. 3) revealed that plots with ‘great snipe’ were close to part of the plots with ‘aquatic warbler’. Another group of plots with ‘aquatic warbler’, in terms of the nearness of some variables’ values, was closer to all other plots than to a group of plots with ‘aquatic warbler’ and the ‘great snipe’. Plots with ‘lapwing’ were close to ‘no scheme’ plots or to plots with ‘wet meadows’.

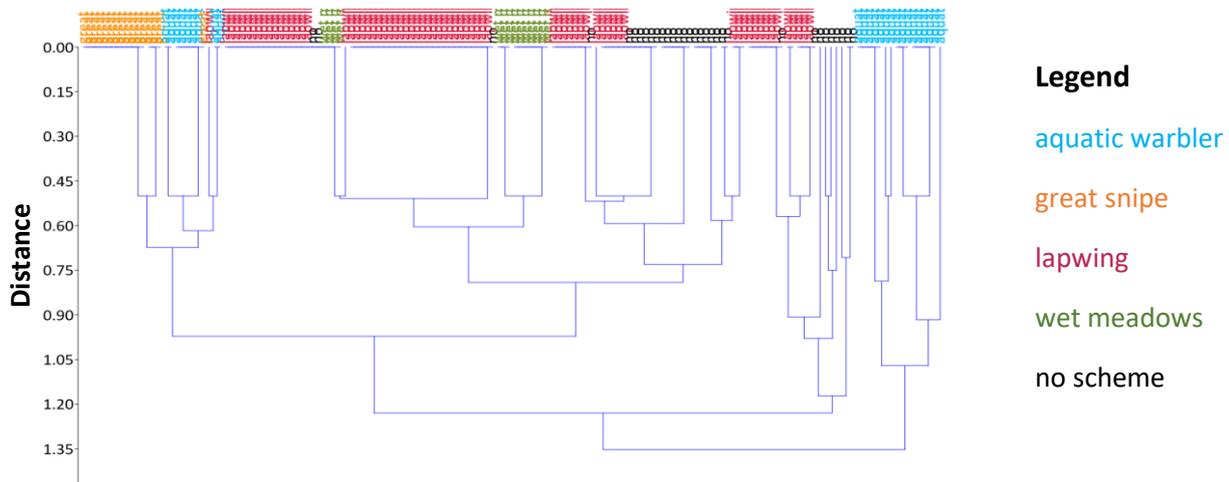


Fig. 3. Hierarchical clustering dendrogram (using Euclidean similarity index) groups plots by the similarity of current management. Coloured names correspond to the five studied management types.

In the PCA diagram both PC1 and PC2 axes were mainly determined by the variable ‘time of first mowing’ (Fig. 4). Most of the study plots with ‘lapwing’ or ‘no scheme’, and all plots with ‘wet meadows’, were positively correlated with this variable. Therefore, the date of the first mowing in those plots was the closest to traditional timing. All plots with ‘aquatic warbler’ and ‘great snipe’ were negatively correlated with this variable, suggesting that the time of the first mowing in those plots deviated the most from traditional. Some plots with ‘lapwing’, ‘no scheme’ and a few with ‘aquatic warbler’ were the only plots positively correlated with ‘grazing’ variables – only those plots were currently grazed. All the plots with ‘aquatic warbler’ and ‘great snipe’ were negatively correlated with the majority of the variables – meaning that management under these schemes deviates most from traditional. Some of the plots under these AES were negatively correlated with ‘biomass used for’ – hay harvested from these plots was used exclusively for bedding.

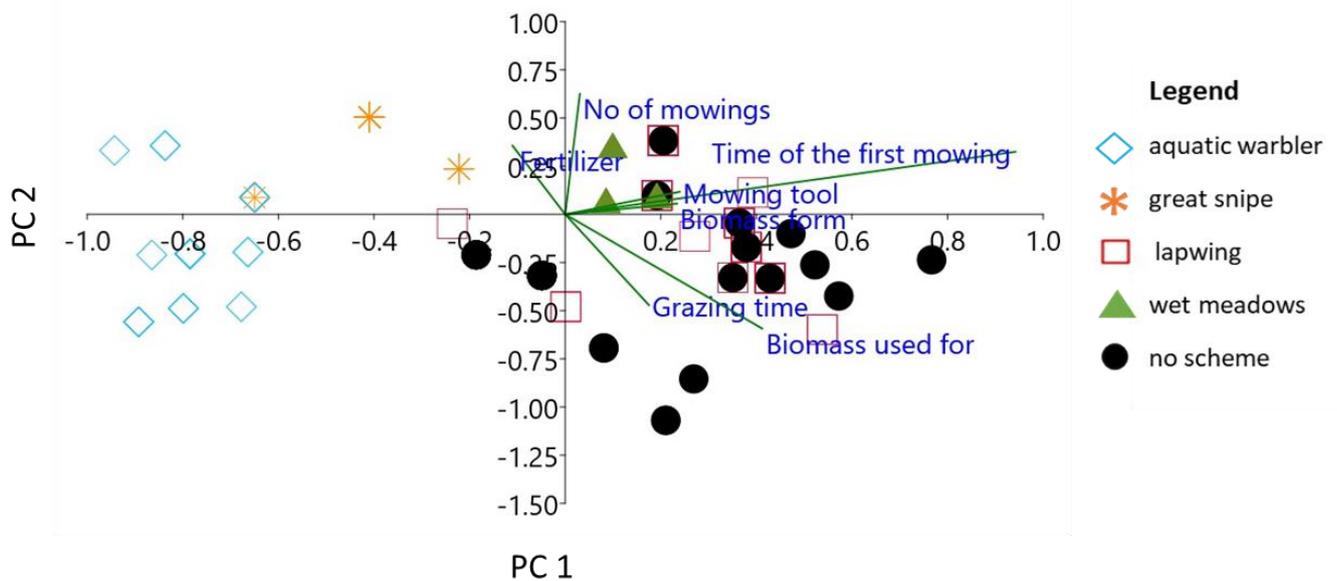


Fig. 4. PCA biplot shows the multivariate variation among 158 studied plots based on seven variables (management practices) from Table 2. Coloured symbols correspond to the five studied management types. The first two principal axes explained 57 % of the variance.

Implementation of AES over time

In 2019, out of 405 plots of wetlands adjacent to the four analysed villages: Rutkowskie, Gugny-Dobarz, Olszowa Droga and Pluty, 40 % had ‘no scheme’ implemented (Fig. 5). In that year, the ‘lapwing’ scheme dominated among the plots with deployed AES (implemented in 50 % of all 246 plots with AES). This was followed by ‘aquatic warbler’ deployed in 32 % of plots with AES.

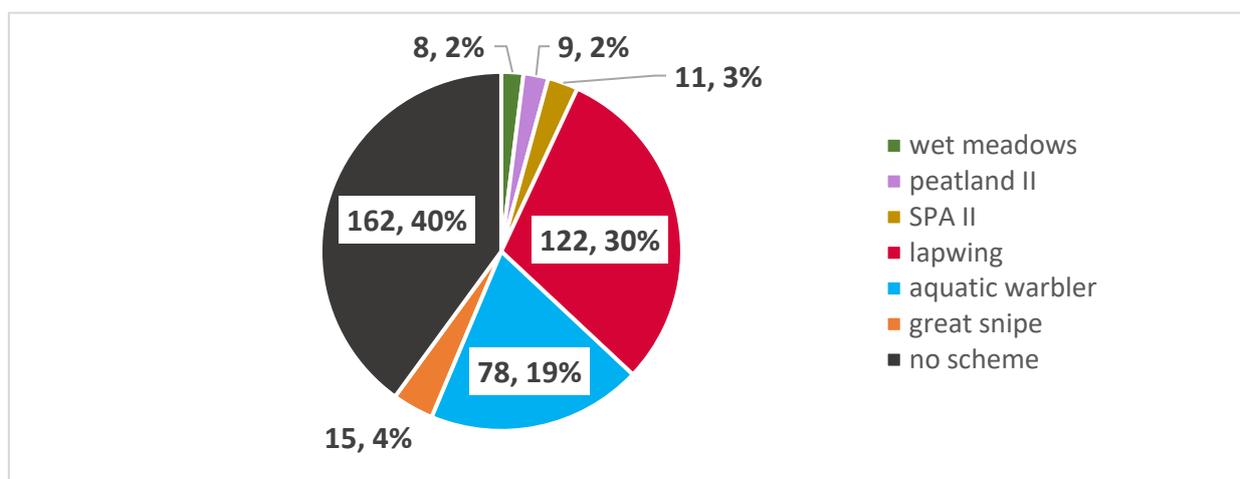


Fig. 5. The realisation of agri-environment-climate measures in 405 study plots in 2019 in Biebrza Valley, Poland.

Analysis of the AES' realisation in the study plots between 2008 and 2019 (Fig. 6) showed that for the first five years, deployment of AES had been significantly increasing, while in subsequent years the proportions remained at about the same level of implementation. As the data on AES realisation in the study years in haphazardly selected 405 plots was anonymously obtained and not assigned to specific plots, it was not possible to trace the implementation of the AES in individual plots in subsequent years. However, since the emergence of new AES (CAP 2014-2020) for farmers to choose from in 2014, 'lapwing' and 'aquatic warbler' have been implemented in an increasing number of plots.

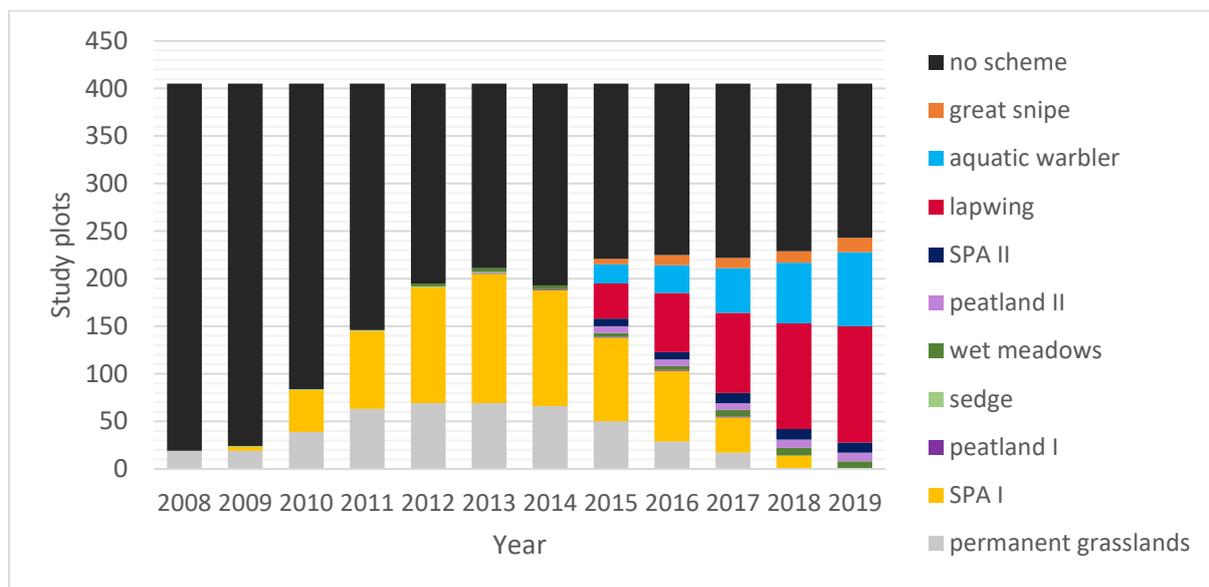


Fig. 6. Realisation of agri-environmental schemes (permanent grassland, SPA I, peatland I, sedge, wet meadows) and agri-environment-climate measures (wet meadows, SPA II, peatland II, lapwing, aquatic warbler, and great snipe) in the years 2008-2019 in 405 study plots in the Biebrza Valley.

Changes in AES implementation based on interviews with farmers

Information about previously realised AES in plots belonging to the interviewed farmers was acquired for 115 plots. Since farmers joined the five-year long AES in different years, information about previous AES comprised AES from both CAP 2007-2013 and the most recent CAP 2014-2020 (Fig. 7). Among the current AES, 'lapwing' (56.5%) and 'aquatic warbler' (ca. 15%) dominated the sample of 115 plots. In 65 plots with the currently deployed 'lapwing', six other AES had been implemented previously (mainly 'SPA I' and 'aquatic warbler').

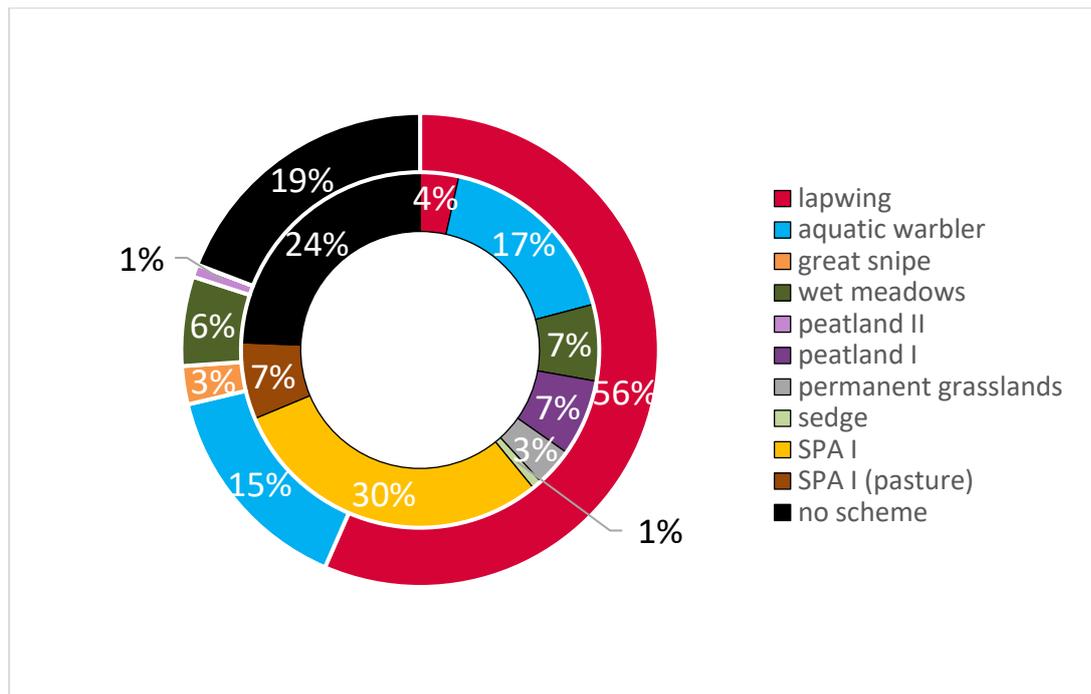


Fig. 7. Changes in implementation of AES in 115 study plots managed by the interviewed farmers in the Biebrza Valley. Previous AES implemented in those plots – internal circle; current AES (in 2020) – external circle.

Farm profiles and implemented AES

Wheat, oat, triticale, corn, and potatoes were cultivated in the crop fields. Cereal yields dominated in the crop fields and were intended for own use as livestock fodder. The relatively smallest holdings were those specialising in milk production ($M = 23.33$, $\pm SD = 10.23$) and 'no livestock' farms ($M = 17.25$, $\pm SD = 3.23$), while the largest were those producing milk and meat ($M = 36.3$, $\pm SD = 15.7$) (Fig. 8). One 'no livestock' farm had only wetlands and no crop fields.

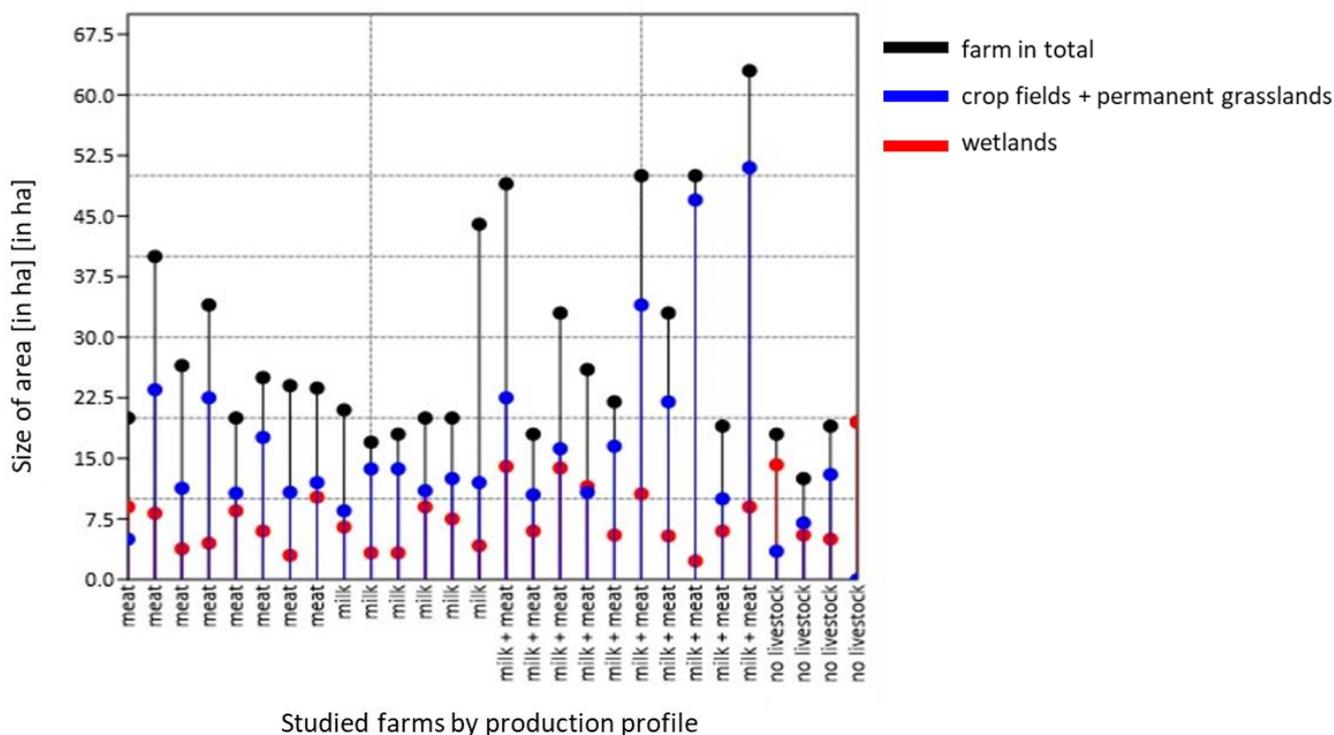


Fig. 8. Total size of the studied farm (including own and leased land), size of the crop fields and sown permanent grasslands (counted together), and size of wetlands of study farms with different production profiles (meat, milk, milk and meat, no livestock) in the Biebrza Valley.

'No livestock' farms most often implemented the 'great snipe' in wetlands (Fig. 9). 'Lapwing' was by far the most common AES in wetlands belonging to farms that produced both milk and meat, or were specialised in either milk or meat production.

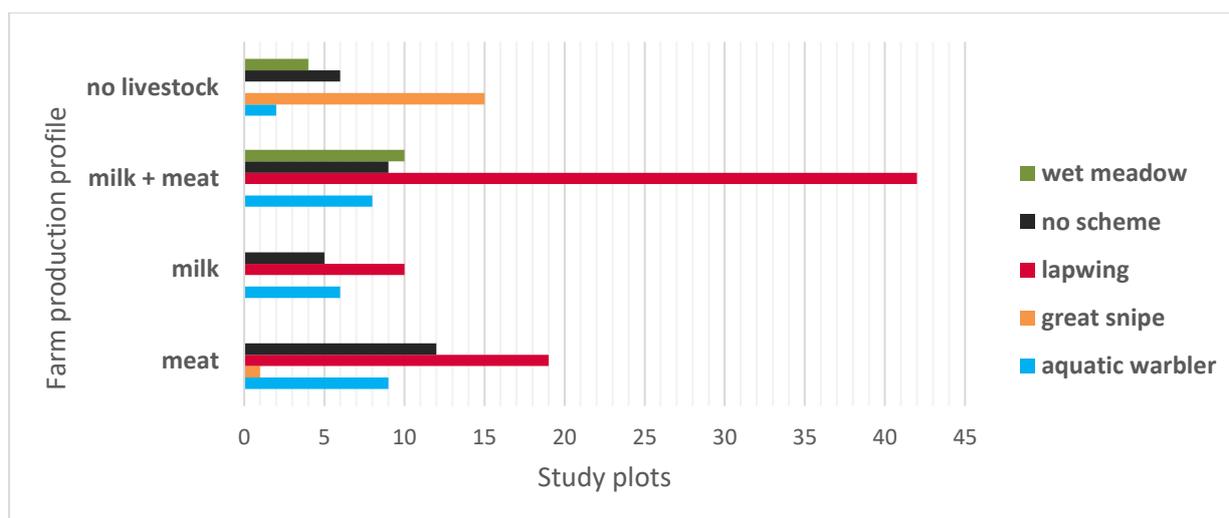


Fig. 9. Agri-environment-climate measures implemented in 158 plots of interviewed farmers (2020) in the Biebrza Valley according to farm production profile.

DISCUSSION

Analysed agri-environmental schemes

Many hopes were placed on the possibility of resuming wetland use and maintaining traditional practices in the Biebrza Valley through the deployment of AES (Bartoszuk et al. 2004). Our study showed that, after 12 years of availability, AES became relatively widely implemented among the surveyed wetland plots, and are therefore a regulatory tool with great influence on how wetlands are managed and conserved. However, our research has shown that currently only limited practices of some AES relate to traditional management.

For instance, some of the practices under 'lapwing' are the same as traditional, including early mowing in June, which allows to obtain good quality hay. In the majority of cases, this hay is used as fodder and grass is mowed a second time. Similarly, farmers harvest good quality hay from the early-cut plots under 'wet meadows'. This AES was much less prevalent, given its restriction to *Calthion palustris* vegetation. 'Lapwing' is the most commonly deployed AES in the study area. First, it seems to be a versatile AES, implementable in many wetland sites, as the target bird species occupies a wide range of habitats. Second, it has been proven most advantageous for farmers, due to the satisfactory quantity and quality of hay obtained and the relatively high subsidy. The largest farms surveyed, which were geared towards milk and meat production and had a high demand for feed, mostly implemented this AES.

Management of 'no scheme' plots was not regulated by any strict set of guidelines. For this reason, farmers cut the grass once it had grown back sufficiently and the water level was low enough. The use of these plots was, on average, more akin to, rather than deviating from, traditional. Nonetheless, practices that may have had a negative impact on biodiversity were in place. These plots tended to have a very early first cut (early June) and were the most frequently fertilised of the plots studied.

Management under 'aquatic warbler' was found to deviate most from traditional practices due to e.g. late mowing, which in some cases takes place once every two years. Consequently, the harvested biomass is not used as fodder in any of the study cases. Late mowing often entails challenging conditions, such as high water level, so special tracked mowers are utilised. In our analysis, this mowing vehicle was considered the most divergent

from traditional tools, due to its invasiveness and the level of devastation of soil surface and vegetation it brings about (Banaszuk et al. 2016). The use of plots with 'great snipe' is similarly deviant from the traditional one. This scheme was adopted mainly by farmers without livestock, for whom wetlands are not of farming relevance but only an additional source of income from subsidies.

Despite the low farming attractiveness of 'aquatic warbler', it was the most frequently applied AES right after 'lapwing', and can be linked to one of the highest payments. However, our analysis has revealed a trend of shifting away from this AES in favour of 'lapwing'. Similarly, 'SPA I', which entails late mowing, was replaced by 'lapwing' in many plots, which farmers justified by their preference for better quality hay.

Our study revealed that a farmer who had implemented AES in his plots and then discontinued it found AES limiting and unprofitable for his meat production farm. He was obliged to leave a part of the meadow uncut, which lowered the quantity of biomass harvested. In the past, open wetlands (besides exclusively grazed riparian sites) were completely mown (Sucholas et al. 2022). Currently AES require a proportion of plots larger than 1ha to be left unmown (Szońska and Barbara 2015). These unmown fragments are valued particularly as refugia for invertebrates, for instance snails (Lipińska and Bielański 2022) or butterflies (Lebeau et al. 2015). Humbert et al. (2009) concluded that leaving strips of uncut grass is the simplest compromising method that combines the necessity of meadow cutting with leaving unmown grass in which meadow fauna could find a shelter. However, our studies revealed that some farmers have a low degree of understanding for this practice. Other reasons farmers gave for not applying AES were: rigid mowing dates, financial penalties for not respecting the mowing deadlines, complicated regulations, and inspections.

Most of the farmers justified the implementation of the AES by the possibility of obtaining additional income. Farmers who decided on AES were usually those who declared a desire to develop and modernize their farm, in contrast to farmers not implementing AES, who had no plans to invest. Farmers deploying AES rated livestock grazing as unsuitable for modern agriculture, time-consuming and inefficient.

Conservation relevance of the key wetland management practices

Grazing

Conservation of open wetlands by grazing cattle is a highly desirable management method. Many wetland species have adapted to grazing (Biró et al. 2019) since cattle grazing was introduced in wetlands in Central Europe ca. 5-7 thousand years ago (Middleton and Holsten et al. 2006). Cattle, among other activities, increase habitat heterogeneity through trampling and fodder preferences (Molnár 2014) and have a positive influence on grassland bird abundance (Báldi et al. 2005); nevertheless, eventual overgrazing is detrimental (Bignal et al. 1996).

Traditionally, from May until the first snows in November, cattle and horses grazed both in open wetlands as well as in carr forests and oak woodlands on mineral islands. Sheep, ducks, geese and pigs were also frequently grazed in wetland pastures closer to human settlements (Sucholas et al. 2022). As late as the 1980s, the Lower Biebrza Basin was still described as extensive pasture (Kiryło 1988, Banaszuk 1994).

At the time of joining the EU in 2004, the grazing system was still present, but its implementation was very limited. Research has shown pasturing to be the preferred method of floodplain management in Brzostowo village seeking to maintain populations of waders such as the lapwing, black-tailed godwit and red shrank. At that time, grazing 150 dairy cows on a 300 ha wetland area was considered the optimum number to support nesting birds. It was predicted that this system would become unprofitable for farmers, so AES subsidies appeared to provide an opportunity for its maintenance (Nawrocki 2004).

In the first years of CAP, farmers pasturing cows in this village deployed the highly paid, 'SPA I', in their plots; this scheme obligated them to graze. In the next CAP round, this scheme paid much less, and all the farmers surveyed decided on 'lapwing'. As 'lapwing' is much lower paid than the previous 'SPA I', and permits two mowings to provide good quality hay but does not require pasturing, eventually all studied farmers converted management to haying only.

Our research revealed that cattle grazed only on part of the surveyed plots. In one of the studied villages, the last two farmers practising free grazing, specialised in milk production, planned to discontinue pasturing entirely the following year, deeming it unprofitable. The majority of farmers who continued to pasture did not have any AES implemented in their

plots. In a village popularised as a village of ‘happy, swimming cows’, in 2019, there were only two farmers pasturing around 30 cows, and by 2021, grazing had disappeared completely. Our research cases have demonstrated that the AES system does not encourage grazing, which used to occur throughout the Lower Biebrza Basin and has now almost completely declined.

Timing and number of mowings

In the haymaking process, applied equipment, timing and frequency of cutting are the key factors affecting diversity of flora and fauna (Humbert et al. 2009, Kołos and Banaszuk 2018). Meta-analysis of studies on grassland mowing regimes in Europe has shown that it is difficult to formulate a general conclusion on what time and frequency of mowing is best for a given grassland type, as this will depend on the considered target species and grassland site conditions, which vary substantially (Tälle et al. 2018). Nevertheless, the recurring recommendation for semi-natural wetlands is the local traditional hay management regime developed under unique site conditions (Middleton et al. 2006, Kołos and Banaszuk 2021).

In our study area, traditional timing and frequency of mowing was flexible and conditioned by natural circumstances as well as a given farm’s demand for good quality hay. The first cut was usually made at the end of June, after the water had receded following spring flooding and vegetation had reached its regeneration optimum. The second cut applied only to the ungrazed floodplain located near the river. The more distant tall sedge and fen meadows were never cut twice, as they would have been unable to regenerate and provide nutritious hay, according to the farmers.

Mowing tool: scythe

Mowing with a scythe, introduced in Eastern Europe by Slavs in 11th century (Poschlod 2015b), was a main type of land use, which led to the widespread development of open wetlands in Europe (Middleton et al. 2006). In the Biebrza Valley, fen meadows were traditionally mown with a scythe, whereas none of the plots surveyed were currently mown by hand (with a scythe). None of the currently available AES propose or require manual mowing. Surveyed farmers usually mowed meadows with a rotary mower or, less frequently, tracked mowers.

Research has confirmed that of all the various mowing techniques, the scythe is the least detrimental for wildlife, and therefore the most appropriate tool (Humbert et al. 2009),

especially in protected areas (Kołos and Banaszuk 2018). As the height of the swath is important, mowing too low has been found to be the scythe's only disadvantage. In the case of the scythe or other tools, a swath height of at least 10cm is considered optimal for fauna survival (Humbert et al. 2009).

Up to twice the mortality of grassland fauna was observed with the rotary mower than with the bar mower (Humbert et al. 2009). An illustrative example is the situation in Germany, where the widespread use of rotary mowers has contributed to a reduction in the amphibian population and thus in the number of white storks (Oppermann et al. 2000).

Mowing with the tracked mower is of particular concern. While the effectiveness for bird population is encouraging, it has a negative impact on vegetation. The tracked mower favours proliferation of effective clonal spread species and diminishes the number of rare species. Additionally, peatland microtopography is reduced (Kotowski et al. 2013) and sedge tussock structure is destroyed by caterpillars. All of the above factors lead to a homogenisation of the vegetation structure.

The scythe is acknowledged to be the most suited for mowing sedge wetlands due to the low degree of alternation of tussock structure (Kołos and Banaszuk 2018). Cutting with a scythe above sedge clumps allows vegetation to regenerate and continue to serve its functions. Tussocks are considered to increase the biodiversity of fens, providing them with a larger surface area, many heterogeneous micro-habitats, and periodical changes in species composition. The maintenance of a proper tussock structure is recognised as crucial for the conservation of fen diversity (Peach and Zedler 2006).

Biomass form: haystacks

Another traditional practice not applied in any of the studied plots is the process of stacking haystacks. Traditionally, people raked the cut hay by hand and left it in swaths for about two weeks until it dried out. In the meantime, they turned hay manually to speed up the drying process. Then they stacked hay on platforms. Haystacks usually remained in wetlands for up to six months, until the first frost made it possible to take hay to the barns (Sucholas et al. 2022).

Haystacks are suggested as an option in the requirements of AES, with the possibility of leaving the hay for up to six months in wetlands. In practice, however, all of the surveyed

farmers baled dry hay or haylage. They cut, turned and baled hay with the help of tractors equipped with tools such as the rotary (disc) mower, tedder and baler. Baled biomass needs to be removed from wetlands within two weeks.

Research indicates that the subsequent stages of biomass processing after cutting have a significant impact on fauna biodiversity. For example, grasshoppers are accumulated in one place by windrowing and physically removed from the meadow by bailing (up to 70%, Oppermann et al. 2000). A similarly negative impact has been argued in the case of snails – the majority of their population is removed from fen meadows along with the biomass. The authors pointed out that, among other things, tedding the swath by hand could potentially save the snails that would have been shaken out of the grass (Lipińska and Bielański 2022). A study by Blodgett et al. (1995) revealed that wheel traffic over mown grass after cutting was the major factor increasing beetle mortality.

These and other examples indicate the detrimental effects of mechanised biomass harvesting on small mammals, amphibians and invertebrates (Humbert et al. 2009). In this regard, traditional, extensive methods of hay processing seem to be the most beneficial for the survival of wetland fauna.

Conservation challenges, limitations and recommendations

Based on our research and the above discussion, we have identified several conservation issues that require revision. We provided recommendations (R) for conservationists, regulatory designers, and decision makers that might increase the effectiveness of biodiversity conservation in the Biebrza Valley or any other protection site experiencing comparable challenges.

Integration of crucial traditional practices

Our findings, such as the vanishing of grazing, late mowing dates, and absence of hand mowing or haystacking, indicate that traditional practices are not the main point of reference for the AES regulatory system. Even if some traditional practices (like haystacking) are mentioned in the AES documents, their implementation is not emphasized (Szońska and Barbara 2015). Our results suggest that the final implemented management is the simplest and most time-efficient one for a farmer, considering the chosen regime (e.g. require only mowing) or harvesting method (baling). This situation raises concerns in the case of an area

like the Biebrza Valley, which, like other biocultural landscapes in Europe, is a 'largely historical product' (Agnoletti 2014) for which the relevance of conserving traditional practices is acknowledged. R: 1. Detection, prioritisation, and subsidisation of crucial traditional practices (such as grazing, timing of mowing, frequency, equipment, process of biomass removal) and their details (Babai et al. 2015). 2. Interdisciplinary cooperation between ecologists (especially local) and landscape historians for an accurate recognition of crucial practices (Plieninger et al. 2006).

Financial and labour resources for scythe mowing

Our interviews revealed that AES obligating farmers to scythe mow were available only in the first round of CAP. Besides this, for several years, Biebrza NP has been organising an international mowing competition during which a few hundred hectares are mown with a scythe (http3). Apart from this event, however, manual mowing has not been implemented on a wider scale, given that it is a time- and labour-consuming, and therefore financially demanding, method that Biebrza NP is not equipped to deploy over such a vast area (Kotowski et al. 2013, Kołos and Banaszuk 2018). We suggest other ways to seek funding for conservation and above all draw attention to the fact that high nature value sites, especially wetlands with the numerous ecosystem services they provide, are common goods that should be of concern not only to local conservationists. R: 1. Search for other sources of funding, such as citizens' participation (Valasiuk et al. 2018). 2. Organisation of campaigns involving volunteers.

Grazing abandonment

Our analyses revealed that livestock grazing is no longer viable for farmers, especially those focused on farm development. Moreover, we identified situations when such farmers implement and profit from AES subsidies, which allow them to obtain high quantities of good quality hay but do not require pasturing (and thus livestock is moved into cowshed). The situation is bizarre and worrying, because AES, initially intended to support extensive management, now constitutes additional income that accelerates farming intensification. R: Development of e.g. small profitable businesses with organic dairy products based on extensive grazing.

Regulations on the rule of generality

Currently, AES are developed on the national level, following the rule of generality. Top-down management makes it challenging, if not impossible, to address the socio-ecological system and locally specific demands adequately and effectively. R: Regulations developed and planned at the regional level, in a locally specific context.

AES - limited to one plot and one target species

Concentrating on one target species raises concerns that the regulatory framework might not be adequate to farmers' needs, and could contribute to ecological, social, cultural or economical losses (Babai et al. 2015). For instance, management under AES specified to a requirement of the one species might not comply with the needs of other species of protection concern that share the same habitat (Lipińska and Bielański 2022). Budka et al. (2019) found that AES supported one bird species but were limiting the occurrence of other birds. Studies from Natura 200 sites in Slovenia (Šumrada et al. 2021) demonstrated the negligible positive impact of targeted AES on grassland biodiversity. R: AES extended to the landscape level (Tschardt et al. 2005).

AES – fixed and late mowing dates

Rigid and late mowing dates (determined by the end of the breeding period of the target species) require the use of equipment, e.g. the tracked mower, which destroys the tussock structure of vegetation favoured by the target species, the aquatic warbler (Valasiuk et al. 2018); this indicates the lack of a comprehensive approach. Additionally, fixed mowing dates and their control by authorities that do not respect changing weather conditions and flooding periods proves particularly inappropriate for the management of habitats located in a river valley (Czajkowski et al. 2021). Farmers producing milk or meat resign from AES with late mowing, not meeting farm demands. This provides a basis for questioning the validity of AES that have no practical application, are not implemented, and do not enforce the execution of the intended conservation plan for their target species. R: 1. More flexible and adaptive strategy of AES (Babai et al. 2021), respecting changing weather conditions and flooding periods. 2. Identification of farming demands.

Farmers as passive participants of the system

The current way of functioning of the AES system in Poland leaves farmers as passive participants, realizers of top-down defined management. The authors indicate that

involvement of farmers is crucial for the environmental success of AES implementation, enabling them to develop more professional attitudes (Batáry et al. 2015), strengthen their relationship with nature, and increase commitment in the schemes' realisation through improved understanding (Babai et al. 2015). Additionally, land users' lack of recognition and awareness of their important role in protecting valuable and unique habitats, and the multiple benefits that flow from this, lead people to focus only on the economic aspects. R: 1. Recognition of attitudes towards environment and wetland management (Batáry et al. 2015). 2. Training of farmers on AES to increase understanding of the purpose of AES requirements (Lobley et al. 2013). 3. Education campaigns on the benefits of nature protection (environmental, social, psychological, and cultural). 4. Participatory methods engaging farmers in AES design (Science for Environment Policy 2017). 5. Integration of local traditional ecological knowledge (Sucholas et al. 2022).

Only financial incentive

According to a survey by Gotkiewicz and Mickiewicz (2015), among 70 farmers in the Biebrza Valley, only 3% decided to join AES because of their willingness to protect nature; the vast majority were motivated by financial incentive. These results were confirmed both in our study and in the study of Czajkowski et al. (2021). After the drastic decrease in the value of wetlands, with their use no longer at the core of subsistence farming (Sucholas et al. 2022), a subsidy for their continued use seems reasonable and indeed necessary. Management based only on financial incentive incorporates a risk of discontinuation once subsidies cease (Kovacs et al. 2021). Fischer et al. (2012) has suggested that only the inherent demand to maintain the surrounding ecosystem in desired ecological conditions, coming from the users (farmers) themselves, ensures the survival of the system. R: 1. Identification and enhancement of the links between the local community and nature. 2 Development of new connections, non-governmental programs and initiatives (Fischer et al. 2012), such as local businesses based on ecosystem services, e.g. sustainable collection of wetland medicinal plants (Sucholas et al. 2021).

CONCLUSIONS

At present, the AES have become the main system regulating and defining management of semi-natural habitats in Biebrza NP and therefore have a profound impact on the biocultural landscape of the area. We conclude that with this regulatory system, the traditional practices that form the biocultural landscape and provide effective habitat conservation are not efficiently supported. We have even observed that AES may contribute to the disappearance of those practices. Therefore, we suggest that the AES system requires revision and adaptation to current farming socio-ecological conditions, or else other conservation and agricultural initiatives need to be urgently developed in the area.

CHAPTER FIVE:
GENERAL DISCUSSION, CONCLUSIONS AND FUTURE PERSPECTIVES



FUTURE?

(PHOTO BY J.SUCHOLAS, 2018)

TRADITIONAL ECOLOGICAL KNOWLEDGE AND TRADITIONAL FARMING IN THE BIEBRZA VALLEY

Ethnoecological studies in the Biebrza Valley revealed TEK among the local community. Even though traditional farming, which fosters TEK preservation and development, has been abandoned decades ago, people could still share extensive, locally specific TEK.

For instance, it was found that people have developed their own zonal perception of the wetland landscape that is close to the scientific division of wetlands, in which similar vegetation zones, collateral to the river, are distinguished (Oświt 1968). However, in the scientific approach, wetland zonation is based on vegetation type and hydrological regime, whereas for local people it has a practical meaning. They distinguish more zones and associate them with hay quality, the applied management regime of grazing and mowing over the growing season, and ownership. Zonation is constantly present in people's narratives, for example, the location of certain plants in wetlands is embedded in the local partitioning of the landscape. In addition, wetland landscape is seen in its vertical dimension, having higher and lowered places, which has practical application for people. Although the landscape of the Lower Biebrza Basin seems to be extremely flat, in fact it includes slightly higher sandy uphill (Oświt 1973) and elevated areas on the river edges (Oświt 1970). Additionally, informants notice the elevated sedge clumps and the lowered wetlands around them. The vertical dimension serves as one of the main criteria for defining folk plant habitats, which are used to determine the quality of hay harvested from a given habitat.

Furthermore, wetland place names were investigated and documented for the first time. Until present, these only existed in the oral narratives of local communities. The toponyms refer to characteristic features in the landscape, such as oxbow lakes, ditches, mineral islands and the like. Some toponyms also indicate the past owner or management, thus preserving elements of local history, like in Johnson's study (2000). Such a local map is necessary and still valid for the local community to orientate itself on the broad, monotonous (even if modified) and flat landscape.

Moreover, TEK embraces more than 50 folk generic taxa (ethnospecies) of plants growing in wetlands. The majority of the taxa are aggregated into groups of a higher systematic domain of life form, for instance 'grasses' and 'trees'. The revealed plant classification of the local community in the Biebrza Valley corresponds to the plant taxonomy of other traditional societies analysed by Berlin (1992). The most voluminous group of

'grasses' comprises more taxa from a botanical point of view than just *Poaceae* species, among others, sedges and rushes. As 'grasses' dominate the landscape and some of them have high fodder value (like *Glyceria fluitans*, *Agrostis stolonifera*, *Glyceria maxima*), they have been subject to very precise characterisation. Similarly to cattle herders (Molnar 2014, Fernandez-Gimenez 2000), farmers in the Biebrza Valley described plant ethnospecies by habitat, palatability, and the preferences of different type of livestock; however, they also added haymaking observations. The study showed that even low-quality hay from fen meadows dominated by e.g. *Carex appropinquata* was used as fodder if no other type of hay was available; this is in opposition to the statement that historically such hay was used only for bedding (Stammel et al. 2003, Middleton et al. 2006). Comparing these results with the findings of other studies (Biro et al. 2019, Molnar 2014), it might be assumed that the quality of hay assigned to the plant and the purpose depend, to some extent, on the vegetation type available to the community. Extensive plant knowledge also included the use of wetland shrubs and tree species for constructing haystacks, making hay tools, and many others. People also shared their long-term observations of changes in occurrence of plants such as *Menyanthes trifoliata*, *Phragmites australis*, *Rumex hydrolapatum*, linking them explicitly to land use changes and climate change.

On the one hand, natural conditions shaped the development of haymaking methods and defined the resources used. For instance, the annual cycle of hay management in the wetlands was primarily conditioned on water levels (as in the Sava River floodplain [Gugic 2009]). On the other hand, given that wetlands were the only source of subsistence before the process of agricultural intensification in the area, the subsistence demands of the local community were the second major factor shaping the applied management regime. The finally established rhythm of management was a result of these two factors and an adaptation to local environmental conditions. Nevertheless, as natural conditions are dynamic and slightly different each year, the traditional management regime was first of all flexible.

Traditional spatio-temporal wetland use had a mixed character of grazing and mowing. As the GIS analyses confirmed and informants reported, in the 1960s, almost all open semi-natural wetlands (besides forest) in the Biebrza Valley were mown for hay, which enabled scythe mowing. On such a large area, it was possible to graze scattered horses and cattle throughout the whole growing season. The animals grazed freely both in the open wetlands

and in the woods. Only larger herds of dairy cows were herded by people and prevented from entering the areas to be mown shortly before the haying season, which fell at the end of June. The riparian vegetation, which consisted of the most palatable plants, was often exclusively grazed, also by sheep in the dry autumn season, and by fowl, or was mown even twice a year. Interestingly, pig grazing was also locally practiced in carr forests. This practice was not only historically frequent in Europe (Poschlod 2015 bo, Biro et al. 2019, Pokropek 2019), but is present to this day in wet oak forests in the floodplains of the Sava River (Poschlod et al. 2002, Molnar et al. 2021).

In summary, ethnoecological research in the Lower Biebrza Valley has uncovered knowledge that has never been explored before, apart from a study from Kiryło (Kiryło 1988), which documented grazing, fishing and hunting practices. It has emerged that the local community's TEK is deep, very locally situated and complex, with interconnected elements. Besides being of value in itself as local cultural heritage, it also represents practical added value, providing a kind of extension to scientific knowledge of this wetland ecosystem as well as a new perspective. The fact that this knowledge is derived from experience, long-term observation, and thus a well-founded understanding of wetlands, is an irrefutable argument that it should be considered and included in the management of this area together with the farming practices that have co-created wetland habitats.

WETLAND USE CHANGES IN THE BIEBRZA VALLEY AND THEIR MULTIDIMENSIONAL IMPLICATIONS

As wetlands were still the only source of the community's livelihood in the 1960s, they represented an enormous economic value for their local owners, as repeated by informants. The 1960s was the last moment of commonly deployed traditional use in semi-natural wetlands in the Biebrza Valley. In the following decades, wetland management was gradually abandoned due to the modernisation of agriculture and in favour of recently reclaimed grasslands, which were fertilised and therefore more productive. The economic value of the non-drained, less productive wetlands in the valley, which could not be fertilised due to constant waterlogging, dropped dramatically. Only the farmers who lived nearest to the wetlands continued to pasture and mow, increasingly with tractors (Banaszuk 1991).

The present study confirmed that the cessation of use peaked in the 1990s, as approximately 80% of coverage of semi-natural habitats managed in the 1960s underwent

secondary succession. In unused areas, reed and tall sedges have started to dominate, and willow shrubs and trees to expand at carr forest edges. Forest cover extension occurs at the cost of neighbouring sedge-moss and low-sedge-brown moss plant communities. The biodiversity of fen communities, which host endangered, low-competitive herbaceous plants and mosses (Wheeler and Shaw 1991), is thus threatened (Kotowski and Piórkowski 2003). The expansion of *Phragmites australis* has also been observed by informants who link this, as scientists do (Burnside et al. 2007, Biró et al. 2019, Mirski 2022), to the significant decline in cattle grazing. In addition, reed often spreads out of its zone to replace tall sedge communities that are more species-rich and more important as nesting habitats for birds (Szewczyk and Oswiecimska-Piaso 2001). Overgrowth of semi-natural wetlands by reed and shrubs was considered the main threat for the rare wader species such as the aquatic warbler *Acrocephalus paludicola*, the nesting habitats of which are declining (Kloskowski and Krogulec 1999). Moreover, unmown large helophytes, such as reed and sedges, alter habitat conditions and, by limiting the availability of light, lead to a decrease of light-demanding plants such as small sedges, orchids, etc. (Kotowski 2002).

Authors indicate that the cessation of traditional practices results in TEK degradation (Fawzi et al. 2016, Middleton 2016). The present study found that the oldest generation had the broadest knowledge. TEK was much more eroded among the younger generation. The older farmers have experienced traditional mowing and grazing in the wetlands in their daily lives. Hand swathing, raking hay, building haystacks, herding cows since early childhood meant that they interacted with wetlands in a direct way. Younger farmers, on the other hand, encounter nature through the machinery they use, spend much less time in wetlands, and do not have the opportunity to learn well about them. These observations confirm that TEK develops primarily through direct interactions with nature, fostered by traditional farming methods. In addition, a part of the body of knowledge that was still being investigated by Kirylo (1988) has now been eradicated among the community. It was also observed that the creation of the national park increased the local inhabitants' distance from the wetlands, both by introducing bans on certain practices and by creating a spatial barrier. However, this phenomenon requires a separate study.

As expected (Bartoszuk et al. 2004), the subsidised system of AES has provided financial incentive fostering reimplementation of wetland management in the Biebrza Valley.

An analysis of satellite and aerial images demonstrated that the cover of managed wetlands in the study sites has increased from an average of 12% in 1990s to an average of 31% in 2015 (after 11 years of AES overall availability). In addition, an analysis of haphazardly selected wetland plots showed that in 2019 AES were implemented in 60% of the 405 plots considered. This implies that AES are an effective financial tool for supporting the use of semi-natural habitats in the Biebrza Valley, which has a great regulatory influence on wetland management and thereby on conservation of biodiversity and preservation of biocultural landscape.

The environmental effects of AES are poorly recognised both in the Biebrza Valley and the country as a whole (Gotkiewicz and Mickiewicz 2015). However, a study conducted in the valley has shown that AES might support the occurrence of some bird species while negatively influencing others (Budka et al. 2019). Authors also indicate that the regeneration of biodiversity after reimplementation of abandoned management is a slow process (Aavik et al. 2008). Others wonder whether it is possible to recover previous plant diversity through the reimplementation of management when succession is at an advanced stage and some species might already be displaced from the plant community (Kotowski and Piórkowski 2003). The experiments, in which mowing was reintroduced without grazing, had limited success in restoring floristic diversity in wetlands (Bartoszek 2003, Kotowski and Piórkowski 2003).

The implementation of any single type of biomass removal management in a semi-natural habitat, whether it be grazing, mowing or burning, has been recurrently indicated as insufficient. Authors emphasise the necessity of adapting culturally appropriate practices (Burton and Paragahawewa 2011) that mimic traditional management methods, which are determinants of local uniqueness and variations within the ecosystem (Poschlod et al. 2005, van Diggelen et al. 2006, Babai et al. 2015). Moreover, details of the management regime are also relevant, for instance in case of mowing, not only the used equipment, but also timing and frequency, which are always locally specific (Humbert et al. 2009, Kołos and Banaszuk 2018).

It has already been indicated that AES often do not support traditional management (Beaufoy and Marsden 2010, Fischer et al. 2012, Babai et al. 2015). Therefore, the results of the analysis of the current wetland management in the Biebrza Valley, determined to a considerable extent by the implemented AES, are a bad premise, as traditional practices are poorly supported by those schemes. For instance, it was found that scythe mowing was not

required by any of the AES implemented (Sazońska and Barbara 2015), whereas hay stacking, although proposed in the AES management guidelines, was not implemented in any of the study plots because farmers preferred to bale hay. Similarly, if farmers had a choice between a mixed management regime involving grazing and mowing or mowing alone, they opted for mowing only. Farmers choose the simplest and most time-efficient management method if a more extensive method is not strictly required of them or they do not fully understand the point of implementing it. Furthermore, under the current agricultural system, livestock grazing is no longer viable for farmers, especially those geared towards farm development. Grazing in wetlands continues mainly by farmers who are not implementing any AES. The few farmers who have adopted AES that allow early swathing (thus obtaining good quality hay) but do not strictly require grazing have ceased grazing and moved livestock to cowsheds as a more profitable form of farming. This demonstrates the extremely negative environmental and cultural effect of the AES, which was initially intended to support traditional extensive farming (Bartoszuk et al. 2004) and now provides additional income that accelerates agricultural intensification and contributes to grazing abandonment.

Additionally, the timing and frequency of mowing is not currently determined by the traditional mowing regimen but often by the breeding period of target bird species. Therefore, some AES require a very late first mowing compared to the traditional date. The scheme intended to protect the aquatic warbler (endangered waders of high conservation value) is the second most frequently implemented AES. Late mowing under this AES often concerns plots in remote wetlands and entails difficult high water conditions, where adapted tracked mowers are used for mowing. The vehicle has been shown to have a beneficial impact in supporting the bird population but a negative effect on vegetation and soil by reducing peatland micro-topography and damaging the structure of tussocks by caterpillars (Kotowski et al. 2013 (Banaszuk et al. 2016)). A proper tussock structure is crucial for conserving fen diversity as, among others, it increases surface area, provides heterogeneous microhabitats and changes in species composition over time (Peach and Zedler 2006). Hence, the destruction of fen meadows, which are the breeding habitat of the aquatic warbler, may also indirectly have a negative effect on its population in the long term. Informants have also observed that tall sedge habitats destroyed by tracked mowers are more easily invaded by reed.

RELEVANCE OF TRADITIONAL PRACTICES IN BIODIVERSITY CONSERVATION

Traditional practices are recommended as the most appropriate for the protection of high value semi-natural habitats, being the ones that led to the formation of those ecosystems and their biodiversity in the first place (Middleton et al. 2006, Kołos and Banaszuk 2021). For instance, since cattle have been grazing in wetlands for millennia, wetland plant species have adapted to this type of disturbance (Biró et al. 2019). However, the beneficial effects of traditional practices and methods on the biodiversity and structure of semi-natural habitats have also been scientifically proven and acknowledged.

Cattle grazing in grasslands has a positive effect on vegetation, improving habitat heterogeneity through trampling and forage preference (Molnár 2014), enhancing vegetation structure and plant composition (Finlayson and Oertzen 1993, Mirski 2022), and increasing seed dispersal (Poschlod et al. 2009, Kotowski and Piórkowski 2003). In addition, cattle are beneficial for grassland fauna such as amphibians (Howell et al. 2019), invertebrates (Kucharska and Znaniecka 2005), and nesting birds (Baldi et al. 2005). Research conducted in the Biebrza Valley has also shown the positive impact of cattle on bird populations (Świętochowski 2009, Chętnicki et al. 2013). Moreover, study has demonstrated that grazing is the most preferable and beneficial management for waders breeding in the floodplain area of the Biebrza Valley, which has traditionally been used exclusively as pasture (Nawrocki 2004). Generally, negative effects of grazing occur when an area is overgrazed through too high cattle density (Nolte et al. 2014).

From studies analysing various mowing tools, such as the bar mower, rotary mower and scythe, it was deduced that the scythe is the most appropriate tool in terms of the protection of biodiversity, as it is the least harmful for grassland fauna (Humbert et al. 2009). In addition, the scythe is the best tool for mowing sedge-dominated fen meadows, only altering the tussock structure to a small degree compared to other mechanical mowers (Kołos and Banaszuk 2018).

From the perspective of biodiversity conservation, the process of harvesting the mown biomass is equally important. Here, again, the extensive method of building haystacks and leaving them in grassland for a longer period proves much more advantageous for biodiversity than baling hay and its fast clearing. For example, beetles and snails are physically removed in

quantities that are detrimental to their populations (Oppermann et al. 2000, Lipińska and Bielański 2022). Tractor wheels, on the other hand, are a major contributor to beetle mortality (Blodgett et al. 1995).

RECOMMENDATIONS FOR CONSERVATION AND WETLAND MANAGEMENT

The absence of scythe mowing, hay stacking and the decline of grazing in the Biebrza Valley in the current management, which is mainly defined by the implemented AES, indicate that this system needs to be revised, as it may have negative implications on biodiversity. Moreover, as research has shown, this system might even contribute to farming intensification in the area, for instance by fostering the housing of cattle. Overall, the biocultural landscape is disappearing in the Biebrza Valley.

Even though the relevance of traditional practices was generally recognised even before the implementation of AES, and local conservationists hoped that the AES would support those practices (Bartoszuk et al. 2004, Nawrocki 2004), ultimately less emphasis is placed on them in the management requirements. This may be due to a lack of deeper investigation of those practices and a discernment of which practices are key to maintaining biodiversity. Therefore, crucial traditional practices analysed in the study, such as grazing, timing and frequency of mowing, applied equipment and the biomass removal process, should be recognised, prioritised and subsidised in the first place (Babai et al. 2015). However, this is complicated by the AES being planned in accord with the rule of generality (Czajkowski et al. 2021), which contradicts the addressal of a locally specific context.

Researchers also have concerns about other aspects of the current AES. They point out that their environmental effects would be more beneficial if AES were extended to the landscape level (Tschardt et al. 2005) rather than targeting a single bird species or a plot of land (Lipińska and Bielański 2022, Budka et al. 2019). They also indicate the negative consequences of rigid mowing dates that do not respect changing weather conditions or, for example, changing water levels in wetlands (Czajkowski et al. 2021). This makes AES incompatible with local natural conditions and agricultural needs. For this reason, a more flexible and adaptive approach has been suggested (Babai et al. 2021).

Fischer et al. (2012) discussed the socio-ecological transformation that traditional agricultural systems in Europe have undergone. In the past, rural communities have had an

inherent need to rely on natural resources (such as hay) as their sole source of livelihood, thereby maintaining biodiversity of semi-natural habitats. For this reason, if human impact on habitats is to be maintained, it is necessary to recognise the current socio-ecological system. An increased understanding of this system would strengthen the beneficial relationship of local communities with valuable habitats or create and support new linkages as well as encourage culturally embedded connections and management practices (Burton and Paragahawewa 2011). These factors have been identified as key to increasing the resilience of the system. Currently, farmers in the Biebrza Valley have only an external, economic incentive to use wetlands, as shown by the research (Gotkiewicz and Mickiewicz 2015, Czajkowski et al. 2021). This carries the risk that if subsidies cease, the management will not continue either, so in the long term such a system may fail (Kovacs et al. 2021). A practical example of building stronger human-nature connections is the promotion of viable local businesses. These might include the manufacture of dairy products based on milk from extensively grazed cows or commercial harvesting of medicinal plants from semi-natural habitats, thus adding economic value to them (Sucholas et al. 2021).

Moreover, the recognition of the current socio-ecological system is in line with recommendations that farmers, as users of wetlands, should not just be passive participants in the top-down imposed wetland management. Their active involvement is underlined as key to achieving positive outcomes. It is important to identify the local population's attitudes towards nature and wetland management (Batáry et al. 2015). In addition, campaigns on the multiple environmental, social, cultural and psychological benefits of nature protection can be organised. Other steps include the education about the ecological purpose of the implemented management (Lobley et al. 2013) and involvement of farmers themselves in the design of AES (Science for Environment Policy 2017). A better understanding of the AES system and management requirements would increase the commitment of farmers in their implementation (Babai et al. 2015) and encourage them to develop more professional attitudes (Batáry et al. 2015).

The top recommendation for improving wetland biodiversity conservation, besides active participation of farmers, recognition of their needs, identification and incorporation of crucial traditional management practices, is the investigation of TEK among the local community. TEK research has never been indicated as relevant for the proper conservation of

biodiversity in the Biebrza Valley before. Firstly, since TEK underpins and corresponds to traditional practices, exploring it can increase understanding of those practices. Secondly, as the socio-ecological system in the area has changed and is undergoing constant transformation (for example due to climate change), the most appropriate approach is adaptive management of natural resources (Fischer et al. 2012). TEK itself is indicated as a type of adaptive management of natural resources as it develops by interpreting and adapting to environmental responses in order to various impacts on environment (Berkes et al. 2000). Therefore, learning about and incorporating TEK into the adaptive management of wetlands in the Biebrza Valley may increase its effectiveness in protecting biodiversity and enhance the resilience of the socio-ecological system as proposed by authors concerned with the conservation of various other ecosystems (Berkes et al. 1994, Berkes and Turner 2006, Charnley et al. 2007).

CONCLUSIONS AND FUTURE PERSPECTIVES

The presented research results highlight the clear biocultural character of semi-natural wetlands in Biebrza Valley developed by centuries-old traditional hay management practices co-shaping these ecosystems and enhancing their biodiversity. It was demonstrated that traditional practices are deeply connected to, and embedded in, the investigated TEK of the local community. This indicates the utmost importance of ethnoecological research in biocultural areas for the proper conservation of valuable biotopes. However, due to dynamic land-use changes and the transformation of socio-ecological systems in high value rural areas in other Central-Eastern European countries in recent decades, TEK is being degraded, as further confirmed by the research presented here. Therefore, ethnoecological research in these regions is urgent.

The AES system has contributed significantly to the reintroduction of wetland management after decades of abandonment and has proven to be an effective financial tool of the EU CAP to support the use of semi-natural habitats. However, the AES subsidy system's very poor support for the key traditional farming practices identified in the Biebrza Valley entails threats to both biodiversity and the biocultural landscape, the disappearance of which has been observed. Therefore, the thesis outlines some recommendations for improving wetland management to protect their biodiversity and the biocultural character of the area more effectively by revision of the AES system and beyond. In addition, propositions were

made on how to increase the resilience of the current socio-ecological system by better recognising it and, for example, promoting culturally appropriate wetland management practices, as well as integrating TEK into adaptive wetland management.

The research results imply the need for interdisciplinary cooperation between local ecologists, landscape historians and ethnobiologists in the development of conservation management in high value biocultural areas. It is also hoped that the results of the study will alert decision makers to the need to revise the existing management system.

Further research is needed to identify what practical opportunities of wetland management system improvement are possible through, for example, analyses of the AES policy system. Another valuable direction is research involving local conservationists and decision makers to identify viable opportunities for integrating TEK, local community and traditional practices into wetland management.

Extensive hay management and preservation of TEK is not the only relevant factor conditioning effective conservation of semi-natural wetlands in the Biebrza Valley. There are also other highly important determinants such as water management (Berezowski et al. 2018) and climate changes (Mirośław-Świątek et al. 2020). However, these were not the subject of the present thesis.

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SUPPLEMENTARY MATERIAL

Supplementary Material for Chapter Three

Table 5. Ethnospecies of Biebrza wetlands and related local traditional ecological knowledge (contains mainly direct quotes from informants).

Folk generic taxa (literal translation)	Scientific name	Habitat	Localisation	Features	Mowing value	Grazing and hay value	Plant changes	Other uses
Life form: trawy 'grasses'								
<i>rzeżucha</i> (bittercress, I-VII); <i>rezucha</i> (bittercress-like, I-VII); <i>rzeż</i> (cutting, VII); <i>rodzina rzeżuchowatych</i> (bittercress family, VII)	<i>Carex</i> spp., e.g. <i>Carex elata</i> All., <i>Carex acuta</i> L., <i>Carex acutiformis</i> Ehrh., <i>Carex riparia</i> Curtis	Where <i>rzeżucha</i> grew, there was only one mowing; it does not grow in 'river meadows' (VII); tends to grow in higher places (II); grows in lowered places in front of mineral islands (VII); a fine type grows on mineral islands covered by deciduous trees (II) and rarely closer to the river (IV); forms worse, 'white meadows' <i>biele</i> (III, IV, V); grows where the meadow is not used any more (V)	Grows halfway between forest and river (VII); small <i>rzeżucha</i> grows closer to the river, on the other side of the river there is plenty of the tall <i>rzeżucha</i> (II); it grows in the 2nd zone; in all further zones 'horse-like grass' <i>końska trawa</i> grows, meaning thicker <i>rzeżucha</i> grazed by horses (IV); on two sides of the melioration ditch (V)	It usually forms tussocks or seldom grows flat (II, VII); it is sharp on the edges, one can split one's finger when it is in the hay (II, III, IV, V, VI, VII); one can easily go over it with one's hand in one direction, in the opposite it cuts the hand open, it has little teeth (IV); it can be low, acidic (II) or tall grass, even up to 0.5 m (II, III); it can be broad and even 1 m tall (IV); lightweight (VII); there is a few species of it (VII);	When it forms tussocks it is difficult to mow; when it would fall down between tussocks it was difficult to rake by hand; it is easy to cut with a scythe (VII)	Young grass is eaten by cattle but it is left when old, hard and dry (IV, VII); cattle eat only the tips of the old grass; generally livestock was not keen to eat it (V, VII); it is 'horse-like grass' – horses are willing to eat it (II, IV); the old and dry has no value (VII); it can be used for bedding or as fodder - it cleans the bodies of cattle and acts like a buffer in fodder (II)	Today the only plants that grow are those that can break through the reed bed, like <i>rzeżucha</i> (VII); when we mowed with a scythe it formed tussocks, later tractors and machines destroyed it and the grass is different now (II)	

<p><i>siwucha</i> (greyish one); <i>siwuchowate</i> (greyish ones, VII)</p>	<p><i>Carex panicea</i> L., <i>Carex flava</i> L., <i>Carex nigra</i> (L.) Reichard</p>	<p>It does not grow alone but is mixed with other grasses; grows in the lowermost area; just in front of the forest where water stays all the time (VII)</p>	<p>Grows on the edges of the meadows, just by the forest (VII)</p>	<p>It has grey leaves, a little broad; it is different than <i>rzeżucha</i> – it is a rather low and softer grass (VII)</p>	<p>Sometimes it was so thin that it was mown from both sites to obtain a good, thick swath (the method <i>na zbijaka</i>) (VII)</p>	<p>It is good for cattle; cattle on meadow would eat it immediately; cattle would eat this grass instead of <i>rzeżucha</i>; it does not have too much value and protein (VII)</p>		
<p><i>tymotka</i> (Timothy, VII)</p>	<p><i>Carex nigra</i> with inflorescences/ seeds</p>	<p>The lowest area, where water stays all the time (VII)</p>	<p>Just in front of the forest (VII)</p>	<p>It is from <i>siwuchowate</i> family but has thick seeds halfway up the plant; when one touches it the single seeds fall down (VII)</p>		<p>Cattle like to eat it (VII)</p>		

<p><i>trzcina</i> (reed, II, III, IV ,V ,VII); <i>trzcinka</i> (small reed, VI, VII)</p>	<p><i>Phragmites australis</i> (Cav.) Trin. ex Steud.</p>	<p>Edges of the lakes; in grass where the area is lowered (III); by the river (VI, VII); in old river beds that are overgrown (VII)</p>	<p>By the lakes (III) and the river (VI, VII) and in overgrown oxbows (VII)</p>	<p>It grows tall and has broad leaves (IV)</p>		<p>Cattle like to eat the young shoots, especially young leaves (IV, VII); in spring cattle do not let it grow because it eats everything immediately (VII); it is sweet like corn (VII); cattle eat it happily because it is sweet (IV); when it is older and thick like a finger cattle do not eat it (IV); it is good grass for fodder (VI)</p>	<p>Formerly there was no reed by the river because cattle trampled it out; where was <i>rzeżucha</i> in the past, but now it is not mown, the reed came in; formerly there was just a little of the reed, now it covers hectars (VII); it is moved by the water flow from one place to another (IV)</p>	
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<p><i>jęczmianka</i> (barley-like, I, VI, VII); <i>jemiola</i> (mistletoe, II, III, IV, V); <i>niemiola</i> (mistletoe-like, II, III, IV); <i>trzcinówka</i> (reed-like, III)</p>	<p><i>Phalaris arundinacea</i> L.</p>	<p>Grows in the 'river meadows' (II, III, VI); on higher mineral islands (VI, VII); generally in higher places in wetlands (II, VII); by the river, where is red sand and two mowings in the year (VII); it dominates in the second mowing (VII)</p>	<p>Grows in the 2nd zone, on the other side of the river (III, IV); or in the 1st zone and on small mineral islands (II, VI, VII); grows between mineral islands and river, not by forest (VII)</p>	<p>It is tall (II, III, IV, VII); has broad leaves that come apart on the sides (III, IV); similar to reed; main stem is hard like a straw and thick like cereal; it does not grow densely (VII); softer than reed and a little twisted (II); it grows tall like rye, up to 1 m (IV); is massive and hard (I, IV, V); blossoming it has a raceme, little seeds like groat (I)</p>	<p>Extremely difficult to mow (I, III, VII); man needs a really good scythe to cut it (I); if somebody was too slow then one could not cut it (VII); it gives a really long swath, long like a scythe (VII);</p>	<p>It is not the best but not the worst grass (III, VII); it is not so edible (III); cattle eat leaves very happily, so probably it is sweet but neither calf nor mature cattle eat the hard stems; cattle eats it when there is nothing else to eat; the old people always said that it is a sweet grass and horses eat it happily; when one brought it to horse for a night, in the morning one could find only little remnants (VIII); the old, 1 m tall grass is too old for cattle; it gives better hay when it is mown early (IV); cattle likes it (IV, V); it is good grass for fodder (VI), but worse than <i>bluszcz</i> (VII)</p>	<p>Formerly, this grass was very rare, now it has replaced <i>bluszcz</i> (III); it appeared after melioration (VI)</p>	
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<p><i>mózga</i> (might derive from verb 'to touch fleetingly' or from Polish <i>mozga</i>, botanical name of reed canary grass, I-VIII)</p>	<p>Not blossoming parts/stage of <i>Agrostis stolonifera</i> L., <i>Glyceria fluitans</i> (L.) R.Br., <i>Alopecurus geniculatus</i> L.</p>	<p>Lowered places, in hollows in wetlands (I, II, III, IV, VI, VII); it dominates in a second swath <i>na potraw</i>, it is rare in the hay from the fist mowing (I, III); it likes to grow at waterlogged conditions; in hollows between mineral islands (VII); in 'river grasses' (I, II, IV, VII)</p>	<p>It grows in the 1st zone (III, IV); by the river (I, VII) and by mineral islands (VII)</p>	<p>Has pointed leaves (III); it is soft, dense, fine and small grass (I, III, IV, V, VII); one cannot cut oneself with this grass; when it grows higher it lies down immediately, it cannot stay straight, because it is thin at the bottom and has broader leaves higher up that go sideways; there is no main stem, leaves grow directly out of the ground (IV); it has a nice scent (III, IV); it is a little darker grass (VI); it is not blossoming; leaves are broader than <i>okraqlica</i>; one can walk barefoot on it; when one squeezes it up, it is gone, it is like a foam (II); one walks on it like on an eiderdown (I, IV); one can sleep on it (IV); when it dries out it becomes cyanic (VII)</p>	<p>It is challenging to mow it because it is so soft; the mower just takes and mills it instead of cutting (VII); a scythe must be sharpened, peened, otherwise the grass just lies down (I,IV)</p>	<p>Cattle eat it happily (III, V, VII); formerly, when we pastured pigs, they loved it (III); it is highly good fodder grass (VI, VII); horses like it most (VII); basically, all animals liked it (I, VII), even rabbits, because it is tasty and probably also has some special properties (I); it is something good!; it is a noble grass; cattle loves it because it is fatty and the most valuable (II); when it was in the hay, everyone gave it directly to little calves; it is good fresh and dried (IV); it is the best grass of them all (IV, V)</p>	<p>There is much less of it because it is drier now (I, II)</p>	
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<p><i>okraglica</i> (rounded one, II, III, IV, VII)</p>	<p><i>Carex appropinquata</i> Schumach., <i>Carex diandra</i> Schrank</p>	<p>It grows in worse quality meadows (III, VII); it grows in 'peat meadows'; in the place where there is no body of water, no lake, no river (VII); it is in the higher places (II)</p>	<p>It grows in further zones (III); it grows in meadows belonging to the village VI; it grows far away from the river, by the forest (VII); it does not grow in our meadows (II)</p>	<p>It usually grows in tussocks (III, VII); it is a tall grass; has rounded leaves; more rounded than <i>rzeżucha</i> (III); the stems are extremely hard; they are so hard that they shine; the stem is very thin, similar to reed but thinner; when covered with water it turns red; it is generally red; it has very less glue inside (VII); the stem is rounded (II); the stem is rounded at the bottom; it belongs to the same group of species as <i>miotlica</i>; it is very hard; it is 0.5 m tall or more and on the top has very fine, single ears; its thin stems lie down sideways (IV)</p>	<p>One mows this grass a bit later because it grows slowly; especially when it is grazed it has little growth; difficult species to mow; it is so hard that a scythe just lies it down or it is humming on its stem and cannot go through it; moreover when it is mown, a swath goes between tussocks and it is difficult to take it out with a rake; rakes would lose teeth during this work; usually it is mown on two sites (<i>na zbijaka</i>) to give a thicker swath (VII)</p>	<p>People mowed it for hay because they had no choice; it is low quality, weak grass; now they mow it just for bedding because it is not suitable for fodder; in autumn they gave it to heifers because milky cows did not want to eat it (VII)</p>	<p><i>I cannot find it on our meadows... Maybe it changed so much? The one I see here now, is much softer (VII)</i></p>	
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<p><i>mietlica</i> (broom-like, III); <i>miotlica</i> (broom-like, II, IV); <i>miotła</i> (broom-like, II, III); <i>miotłka</i> (little broom, III, V); <i>jęczmianka</i> (barley-like, III)</p>	<p>Blossoming stage of <i>Poa palustris</i> L., <i>Deschampsia flexuosa</i> (L.) Trin. and other thin <i>Poaceae</i> species in wetlands</p>	<p>One can find it also in the cereal crop field <i>polna mietlica</i> 'crop field mietlica' (<i>Apera spica-venti</i> (L.) P.Beauv.) when it is not artificially fertilised (III); it prefers higher places (V)</p>		<p>It is tall and thin (II); it has dense, fine leaves and a long stem with ears; when it starts fruiting, the seeds will be everywhere (IV); fine grass (V)</p>		<p>Cattle like it (III, IV)</p>	<p>In front of the forest there should <i>okraglica</i> grow but now grass is another, much thinner (<i>Deschampsia flexuosa</i>); has <i>okraglica</i> changed so much? (VII)</p>	
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<p><i>hoszczka</i> (of more onomatopoeic derivation naming something that is crackling, creaking, I-VII); <i>hoscka</i> (III)</p>	<p><i>Equisetum fluviatile</i> L. (syn. <i>Equisetum limosum</i> L.), <i>Equisetum palustre</i> L.</p>	<p>Muddy places, lowered places (I, II, III, VII); in 'river meadows' (VI); it can grow by the river (V) only when water stays longer and there is a good soil (VII); more often it is in hollows between mineral islands (VII); it accompanies <i>Menyanthes trifoliata</i> (II); it is everywhere in the meadows; here more, over there less, but everywhere in our meadows in general (IV); in watery meadows (V); it likes when there is water (I); there is also <i>hoszczka polna</i> 'crop field <i>hoszczka</i>' (<i>Equisetum arvense</i> L.), which is similar but does not grow in wetlands (III, VII)</p>	<p>Grows in <i>parowy</i> (area with muddy meadows) (III); closer to the river (II, VI); in muddy places on <i>smugi</i> (pastures) (II); it grows in the middle between the river and forest zone (VII); everywhere in wet meadows (IV); grows on two sides of the melioration ditch (V)</p>	<p>It is extremely fragile; has no glue inside (VII); it is easy to break, because the stem is divided in pieces (II); it is rounded; grows tall; the stem has 'knees', 'connectors' and when grass is dry it breaks in the knees; it is pipe-like (IV); it makes a 'snapping' sound (I); it can be even up to 1 m tall (II); one can find a similar type in the crop field (I, IV), but the river type of <i>hoszczka</i> is thicker and taller (IV)</p>	<p>It is not suitable for mowing (III); it is easy to mow; we could mow it with a scythe during a day (I, VII); when it dries out, then it is extremely fragile; raking had to be done in the early morning 'with the dew' or in the evening when it is softer and not so fragile; when it is dry one cannot rake it and put it on the haystack (I, II, IV, V, VI, VII); it could be raked and brought to a stack also on a humid day (IV); because of lack of the glue it would 'escape' from the rake; we had to carry small haystacks, <i>kopki</i>, with a <i>hoszczka</i>, to a haystack, supported by four pairs of forks, otherwise it escaped (VII); hay containing only <i>hoszczka</i> would be very difficult for a bale maker to collect (II)</p>	<p>Cattle eat <i>hoszczka</i> from wetlands but the one from the crop fields they do not even touch; but generally it is not the best grass (II); it is a tasty grass; cattle and sheep like it, but horses less (I); it is good fodder grass (VI); cattle ate hay with it, but when it was prepared in good way – sometimes when it was in a haystack in too wet form and was pressed too much, it got mouldy, so cattle did not want to eat it (IV)</p>	<p>Formerly, there used to be more of it (II); now there is much less of it because it is too dry (I)</p>	<p>Medicinal plant, collected and sold (II, III); only <i>hoszczka</i> from the crop field is a medicinal plant, from it wet meadows is not (IV)</p>
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<p><i>bluszcz</i> (ivy, I-VII); <i>blusc</i> (ivy, III); <i>miecz</i> (sword, VII); <i>trawa mieczowata</i> (sword-like grass, VII)</p>	<p><i>Glyceria maxima</i> (Hartm.) Holmb.</p>	<p>Lowered places, hollows (II, IV, VII); it grows in places with waterlogged conditions; it sometimes grows between <i>mózga</i> (II) in river meadows (II, III) but also accompanies <i>jemiota</i> (IV); in muddy places, but not everywhere (V)</p>	<p>It grows in the 2nd zone, on the other side of the river (III, IV); it grows in the 1st zone (II); grows in the middle place, halfway between forest and river, but closer to the river (VII)</p>	<p>It is tall (III, VII); has broad leaves like two fingers; grows dense; it is hard; they called it fern because it has dense flowers on one side (III); the broad leaves are like feathers on two sides (IV, VII); it is from the sword-like grass family <i>mieczowata</i>; it has sweet glue inside stem; it has a nice scent; it is very sharp, rough; one can cut his fingers; it is sharper than <i>rzeżucha</i>; similar to reed but smaller (VII); it is a thick grass (IV, VII); it has broader leaves than <i>jemiota</i> and is shorter; when it is young it stays more straight, the older lies down on the ground; it bends to its side like wheat or rye; it twines, creeps; when one straightens it up, it is long; when <i>jemiota</i> grows on the side <i>bluszcz</i> vines on <i>jemiota</i>(IV)</p>	<p>It is demanding to mow it because it is hard (III); it is generally easy to mow, any scythe could cut it; but it takes time to dry it out because it has so much glue inside (VII); it is not easy to mow, when it lies down and somebody is not a good mower then they just touch it on surface and the whole mass stays unmown (IV)</p>	<p>Because it is sweet, cattle likes it (II, III, VII); it is a very good fodder grass; cattle and horses and other animals eat it happily (II, V, VII); especially young plants are a delicacy for cattle (III, IV); the old form is too hard for cattle (IV); all sword-like grasses <i>mieczowate</i> are good fodder (VII); when it ferments in bales it becomes yellow and is excellent; especially, one can give this grass to a cow when the cow is not giving milk (VII)</p>	<p>Now there is much less of this grass (II); formerly, there was more <i>bluszcz</i>, now it is replaced by <i>jemiota</i> (III); formerly it was rare, because it was mown every year; now there is more of it, because one cuts the grass higher (with machines) (VII); now it is more common than in former times (I)</p>	
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<p><i>tatarak</i> (sweet flag, I-VII); <i>trawa mieczowata</i> (sword-like grass, VII)</p>	<p><i>Acorus calamus</i> L.</p>	<p>On the edges of the river (III, VII); mainly by the lakes (IV, VII); it grows by bodies of water in wetlands and generally everywhere in wetlands (VII); in more wet, muddy places, hollows, in waterlogged conditions, not on mineral islands (IV)</p>	<p>By the river (III, VII) and lakes (VII, IV), in the 1st zone (III)</p>	<p>Has broad leaves (II, III); has smelly roots (II); leaves are flat (II); it has a characteristic, thick rhizome; sword-like family grass (VII)</p>		<p>Cattle prefer not to eat it (IV, VII)</p>		<p>Medicinal plant; rhizomes are collected for sale (II, III, IV); leaves put under bread to keep it fresh (II, VII)</p>
<p><i>kosak</i>; <i>kosac</i> (VII); <i>kosaciec</i> (<i>kosaciec</i> is a Polish name of Iris, <i>kosa</i> means a scythe, IV); <i>trawa mieczowata</i> (sword-like grass, VII)</p>	<p><i>Iris pseudacorus</i> L.</p>	<p>On muddy edges of the lakes and river (IV)</p>	<p>By the lakes and river (IV)</p>	<p>When it is ripe, it has a pod similar to the broad bean (III); it blossoms yellow; sword-like family grass (VII)</p>		<p>It is an exception when cattle eat it (VII)</p>		

<p><i>sitorz</i> (<i>sit</i> in Polish means rush, all the local names are variations of <i>sit</i>, III); <i>sitnik</i> (VI, VII); <i>sitarz</i> (VII)</p>	<p><i>Juncus conglomeratus</i> L. (III, VI, VII), <i>Juncus articulatus</i> L. (III)</p>	<p>Grows in acidic soils, in acidic meadows; where it grows, the grass has no value; grew in front of the forest, where cattle used to graze (VII)</p>	<p>Used to grow ca. 100 m in front of the forest, where cows used to graze, near the <i>grobel</i> (causeway) (VII)</p>	<p>It is thin and has seeds at the top; grows in groups (VII)</p>		<p>This grass has no value; cattle do not like it; a cow will not take it in its mouth (VII) w</p>	<p>When cattle grazed it, there used to be a lot of it, now there is much less of it and generally it is overgrown by reed (VII)</p>	
<p><i>sitorz</i> (<i>sit</i> in Polish means rush, all the local names are variations of <i>sit</i>); <i>sitkorz</i> (III); <i>scypiorek</i> (III, IV)</p>	<p><i>Eleocharis palustris</i> (L.) Roem. & Schult.</p>	<p>It grows between other grasses in meadows; on the elevated mineral islands (III)</p>	<p>Mineral islands (III)</p>	<p>It is very small and thin (III)</p>				

<p><i>sitarz</i> (<i>sit</i> in Polish means rush, all the local names are variations of <i>sit</i>, IV)</p>	<p><i>Schoenoplectus lacustris</i> L. (Palla)</p>						<p>It was used for swimming lessons. One collected two handfuls of long stems and tied each of them up with a string at the ends. Then one clenched them so strongly that one got two bolsters. They would not soak with water. Then one connected the two bolsters with a strings. One could lie down on this strings and had bolsters on two sides. Then one could swim easily.</p>
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Life form: <i>ziota 'grerb'</i> (+ <i>Lythrum salicaria</i> L.)								
<i>bociany</i> (storks, III)	<i>Lysimachia vulgaris</i> L., <i>Symphytum officinale</i> L.			Plants from herb family that are visible above the grasses (III)		They have no fodder value (III)		
<i>żywokost</i> (comfrey, III, VII)	<i>Symphytum officinale</i>	Grows on the edges of waterbodies, like river, lakes (III, VII)		Has long, broad leaves; it blossoms pinkish; has brown roots; belongs to the herb family (VII)		It has no fodder value (III, VII)		Medicinal plant (III, IV, VII); it is good for joint pain (VII); I collected it in the winter, dug it out with an axe, cut the roots, dried it out and made an ointment with oil (VII); my mother told me that people harvested it barefoot and directly put it on aching places (III)

<i>tabuła</i> (<i>Spiraea</i> , IV, VII)	<i>Filipendula ulmaria</i> (L.) Maxim.	Grows in little elevated places and on mineral islands (VII); it grows in a muddy <i>olsyna</i> (<i>Alnus</i>) forest (IV)		It blossoms white; it is tall; has quite a hard and thick stem; belongs to the herb family (VII)		It has no fodder value		Medicinal plant; people collect and sell it; only flowers are harvested; it can be cut with a sickle (VII)
<i>drabinka</i> (a little ladder, V, VII); <i>srebrnik</i> (silver-like, III); <i>gęsie łapki</i> (little goose paws, IV)	<i>Potentilla anserina</i> L.	It grows, though not necessarily, in wet meadows; it grows close to the river (IV)	It grows in the 1st zone; it does not really grow in the further zones (III, IV)	It looks like a small ladder; has a nice scent; belongs to the herb family (VII)		Cattle eat it		Medicinal plant, people collect it and sell
<i>gęsie łapki</i> (little goose paws, III, VII)	<i>Comarum palustre</i> L.	It grows in wet meadows, on the other side of the river (III, IV); it grows at waterlogged conditions; on the edges of lakes (VII)	It grows in further zones, closer to the forest (III, VII)	The stem creeps on the ground; one can stumble against it and fall over (IV)		It is more like weed; it is not a good fodder; it is not edible (VII); cattle do not eat it (IV)		
<i>mięta</i> (mint, I-VII)	<i>Mentha aquatica</i> L.	In wet meadows, everywhere (all)		It is from the herb family (VII)				

Life form: kacaki (+ *Alisma plantago-aquatica* L., *Sagittaria sagittifolia* L. [III,IV])

<p><i>bobrek</i> (bogbean, II, III, IV); <i>bobik</i> (a little bean, I, II, III, IV, VI, VII); <i>gęsie tapy</i> (goose paws, III); <i>boberek</i> (bog-bean-like, II); <i>bober</i> (beaver-like, II); <i>bobownik</i> (bog-bean-like, V)</p>	<p><i>Menyanthes trifoliata</i> L.</p>	<p>It grows in waterlogged conditions; it must be in water (II, IV); in lowered places, in hollows (IV, V); between the tussocks (IV); in hollows in front of the mineral islands, together with <i>lepka</i> and <i>topian</i> (VII); where <i>lepka</i> grows there is also <i>bobik</i> (VII); it can grow in the <i>Alnus</i> forest, <i>olsyna</i>, and in front of the forest in <i>biele</i> (white meadows) (III)</p>	<p>It grows in the zones further from the river (III, IV); in <i>smugi</i> (pasture), in places far from the river (II); in the middle place between river and forest; by mineral islands (VII)</p>	<p>Has three rounded leaves that are thick (all) but soft (VII); it used to grow in large aggregations in meadows (VII); it is very bitter (II)</p>	<p>It is really easy to mow, very light; where the <i>bobik</i> grows, the swath is extremely thick (VII)</p>	<p>Cattle and sheep eat it happily; when sheep finds <i>bobik</i> in a hay they are delighted; it is a highly valuable fodder (VII); cattle eat it (I); I did not give it to cattle because it was too bitter (IV); the mixture of <i>bobik</i>, <i>lepka</i> and <i>topian</i>, which grow by the mineral islands, in hay has an amazing scent and sheep eat it directly in the air (very quickly); the hay with this mixture was deliberately rationed to sheep (VII)</p>	<p>Formerly, it used to be abundant (V, VII); back then, there were extensive fragments of <i>bobik</i> in meadows; today there is much less of it (VII); formerly, there was plenty of it, now there is much less because it is drier (I, IV)</p>	<p>Medicinal plant that is collected and sold; it used to be collected and sold fresh and wet (I, II, III, IV, V); it pays off to sell it; people used to harvest it directly from boats (IV); we use it at home to heal stomach pains (II)</p>
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<i>kacak</i> (marsh marigold-like, III); <i>kaczeniec</i> (marsh marigold, II, III, IV, VI, VII); <i>topian</i> (burdock, VII); <i>nikwiat</i> (no-flower, II)	<i>Caltha palustris</i> L.	Grows in spring (II, III, VII); in the whole <i>biele</i> (all wet meadows) (III, VII); it grows when water is still there; after a long winter with snow, in spring there is plenty of them in the water (VII)	All <i>biele</i> (wet meadows) (II, III, VII)	It is quite fragile (III); it blossoms yellow (II, VII)		The leaves used to be harvested for pigs (VI); when cattle used to graze it in spring, they had a fatty, yellowish milk later on, it looked dyed; the milk trader always said that it is dyed with carrot (II, VII)	It needs high water in spring to grow; when the winter is long and snowy then there is a lot of water in the spring and <i>kaczeniec</i> is there (VII)	
<i>osty</i> (thistles, II, III); <i>oset jeziorny</i> (lake thistle, IV)	<i>Stratiotes aloides</i> L.	Usually in the lakes (II, III, IV, VII); plenty of lakes have a name derived from <i>osty</i>		It breaks high through the surface (III); it blossoms white or blue (II); it blossoms white (II); it is so spiny that one can split one's legs during fishing; it is difficult to fish with a net because of it; even with a boat it is difficult to go through it (IV)	People used to mow it with a scythe to clean the lakes (IV)			
<i>grązel</i> (water-lily, II); <i>ryjki</i> (little snouts, IV)	<i>Nuphar lutea</i> (L.) Sm.	On the whole surface of the lakes (IV)	We have a lot of it in lakes (IV)	It has roots like an arm (IV)				
<i>grzebilja</i> (water-lily-like, VII); <i>lilija</i> (lily, VII)	<i>Nymphaea alba</i> L.	Lakes (VII)	We have it in lakes (VII)	It blossoms white (VII)				

Life form: unaffiliated taxa								
<i>lepka</i> (sticky one, II, III, IV, VII)	<i>Galium uliginosum</i> L., <i>Galium palustre</i> L.	It grows between <i>rzeżucha</i> (III); it grows closer to the river, where there are floods from the river; it grows together with <i>bobik</i> in hollows by mineral islands (VII)	In the middle place between the river and forest, but closer to the river; by mineral islands (VII)	It blossoms white (III, VII); it creeps; it grows quite massively (VII); it winds over other plants and sticks to them (II, IV); it is a soft grass; it sticks to the fingers (IV, VII); when there are other plants around, it grows on them, if there are none, it creeps on the ground; it is somewhat heavy; it has little, fine leaves on the whole stem (IV); it is from <i>seradela</i> (bird's-foot) family; it blossoms for the first early mowing (VII)	It trails behind the scythe (VII)	It is a very good fodder grass (VII); cattle and sheep eat it happily (IV, VII)		
<i>powójka</i> (bindweed-like, III, IV, VII); <i>powojka</i> (bindweed-like, IV)	<i>Calystegia sepium</i> (L.) R. Br.	It grows between tall grasses, like <i>bluszcz</i> , <i>rzeżucha</i> , reed (III, IV, VII); by the river it is very rare; a similar species grows in the crops fields and climbs on the cereal (<i>Convolvulus arvensis</i>) (IV)	It does not grow by the river but in the zones further from the river (III, IV, VII)	It blossoms white (VII); it climbs high and winds over other tall plants (III, IV, VII); it is very difficult to break through this plant by hands (VII)		All animals like to graze it (III); cattle eat it like honey; it is a delicacy, a luxury for cattle (VII)	When in the 1980s we ceased mowing <i>biele</i> intensively, it started to grow everywhere (VII)	

<p><i>kobylak</i> (II, III, IV, VI); <i>kobylak bielny</i> (wet meadow <i>kobylak</i>, II);<i>topian</i> (burdock, VII);<i>szczaw koński</i> (giant water dock, VII)</p>	<p><i>Rumex hydrolapat hum</i> Huds.</p>	<p>It grows in lowered places, in hollows (III) massively (VII); in muddy places; on the edges of the lakes (IV); a similar species grows in gardens and is called <i>szczaw</i> (dock) (II)</p>	<p>By the lakes and bodies of water (IV), everywhere in lowered wet meadows (III, VII)</p>	<p>It has very broad leaves, that is why sometimes they call it <i>topian</i> (burdock) (III, VII); the leaves are more rounded; the whole plant is more green (VII); its roots are thick like an arm; its seeds are like groat (IV)</p>		<p>Cattle prefer not to eat it (IV, VII); it was mown for hay because cattle like it, too (III)</p>	<p>Formerly, there used to be plenty of it; when there was ice in winter, <i>kobylak</i> constantly moved with the the pulled out ice to new places and would root there; now the years are dry, there is no ice that moves it to the new places, so it grows rarely</p>	<p>Medicinal plant and people collect and sell it</p>
<p><i>marchlak</i> (carrot-like, III); <i>marchwianka</i> (carrot-like, IV)</p>	<p><i>Oenanthe aquatica</i> (L.) Poir.</p>	<p>It grows when a lot of water stays in spring (III); in 'river meadows' (III, IV); grows in muddy places (IV)</p>	<p>It grows in the 1st zone, on the other side of the river (III, IV)</p>	<p>It has a hollow inside the stem; one could stand on it like on a bridge (IV)</p>		<p>Cattle prefer not to eat it (IV)</p>	<p>In the years when the meadows stay dry it does not grow (III)</p>	
<p><i>truskawka</i> (strawberry, VII)</p>	<p><i>Fragaria vesca</i> L.</p>	<p>It grows in <i>Alnus</i> forest, <i>olsyna</i> (VII)</p>	<p><i>Olsyna Alnus</i> forest (VII)</p>	<p>It blossoms white; grows very low, just over the ground (VII)</p>		<p>Pigs like to eat it; sheep with cattle used to graze it in autumn; sheep could only eat</p>	<p>Back then, there used to be plenty of it in the forest (VII)</p>	

						strawberries, does not need anything else; it is a delicacy for sheep (VII)		
<i>rdest</i> (knotgrass, III, IV); <i>derdys</i> (knotgrass); <i>derdes</i> (knotgrass, III)	<i>Persicaria amphibia</i> (L.) Delarbre, <i>Persicaria hydropiper</i> (L.) Delarbre	It grows in wet meadows, in acidic places; similar species grow in crop fields (III)	Wet meadows and crop fields	It has willow-like leaves; there are a few types of <i>rdest</i> , some of them are smaller, some of them more massive (III); it is rare here (IV)		Cattle eat it only when they have to (IV)		
<i>wilczy gnat</i> (wolf bone, III)	<i>Sium latifolium</i> L.	In slightly elevated places; small mineral islands in wet meadows (III)	In the 1st zone behind the river (III)	It has a very hard stem; it could blunt a freshly sharpened scythe; it blossoms white (III)		Cattle do not want to eat the old form (III)		
<i>koluch</i> (spine-like, IV)	<i>Sparganium erectum</i> L.	It grows where <i>bobik</i> grows; by the ditches (IV); in <i>biele</i> , (wet meadows) (IV, VII); it grows in grass for the first mowing, not for the second (VII)	In the middle places between river and forest (VII); in further zones (IV)	It has flowers on one side (III); it is spiny (III, IV)			We did not have much of it back then, now we have more (VII)	
<i>koczki</i> (III); <i>pałka</i> (cattail, IV)	<i>Typha</i> spp.	In muddy wet meadows; on the edges of the lakes (IV)		It has a fluff that blows with the wind (IV)	People used to mow it with a scythe to clean the lakes (IV)			

<i>skołodźrza</i> (III, IV); <i>babka</i> (plantain, II)	<i>Plantago media</i> L., <i>Plantago lanceolata</i> L.							Medicinal plants, leaves are collected and sold (II, IV); people used it <i>na obryw</i> (kind of folk disease) and put it on abscesses on the skin (IV)
<i>świńska trawa</i> (pig grass, III, IV)	<i>Polygonum aviculare</i> L.							Medicinal plant, collected and sold
<i>jaskrawiec</i> (<i>jaskier</i> – Polish botanical name of buttercup <i>jaskier</i> -like, IV)	<i>Ranunculus repens</i> L., <i>Ranunculus flammula</i> L.	It grows in <i>smugi</i> (pastures)		It is a burning plant – when put on skin on the inner part of the wrist, it makes a wound (IV)		Cattle do not eat it		

Life form: shrubs and trees

<p><i>krzewina</i> (shrub-like, I-VII);<i>krzewa</i> (shrub-like);<i>wici</i> (twine-like);<i>tozina</i> (<i>toza</i> - Polish common name for <i>Salix cinera</i>);<i>rodzi na tozinowatych</i> (<i>toza</i> family, VII)</p>	<p>Shrubby forms of <i>Salix</i> spp., e.g. <i>Salix cinerea</i> L.</p>	<p>Wet meadows (VII); grows by the rivers and stabilizes the edges (II, III)</p>	<p>In all wet meadows (VII); by the river and lakes (II, III)</p>	<p>It is a small <i>wierzba</i> (a tree from of <i>Salix</i>) (VI, VII); has broader leaves and darker bark (compared to <i>wierzba</i>) (III, V, VII); leaves are shiny (VII); there are a few types of <i>krzewina</i>: green, red, hard and soft; it is twisted (II)</p>	<p>It was used to build a structure under the haystack (III, IV, V, VI, VII); it was used for small poles stuck in the ground (platform) under the haystack; the branches were used as material layered on pole platforms (III, IV, V, VI, VII); straight trunks of harder <i>krzewina</i> were used as ballasting poles interposed on the top of the haystack (II, IV, VI, VII); branches used to mark the borders of the plots during haymaking in wetlands (IV, V); if you encounter it in the grass during mowing, then you immediately blunt your scythe, it is so hard (VII)</p>		<p>It started to grow everywhere when we stopped mowing meadows (VI, VII)</p>	
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<i>krzewina</i> (shrub-like, I-VII)	Shrubby forms of <i>Alnus glutinosa</i> (L.) Gaertn., <i>Frangula alnus</i> Mill.				It was used to build a platform under the haystack (III, IV, V, VI, VII); it was used for small poles stuck in the ground under the haystack; used as material layered on the pole platform (III, IV, V, VI, VII); trunks used as ballasting poles on the top of haystack (IV, VI, VII); to mark the borders of the plots during mowing in wetlands (IV, V)			
<i>wiklina</i> (osier); <i>złotooki</i> (golden eyes, IV)	Flexible types of <i>Salix</i> spp.			It is very flexible; there are three specific taxa of flexible <i>wiklina</i> : yellow, red (named <i>różga</i> , rod) and green (IV)				
<i>wierzba</i> (willow, III, VII); <i>wierzbin</i> (willow-like, V, VII)	Tree form of <i>Salix</i> spp. e.g. <i>Salix alba</i> L.	It does not grow on the edges of rivers and lakes as opposed to <i>krzewina</i> (VII)		There are a few species of it; has narrow leaves and fair bark (III); it grows very tall; is usually fragile (VII)				

<p><i>brzoza</i> (birch, III, IV, V, VI, VII); <i>brzezina</i> (birch-like, I, II, VII); <i>brzózna</i> (birch-like, II)</p>	<p><i>Betula pendula</i> Roth., <i>Betula pubescens</i> Ehrh.</p>	<p>It grows in wet meadows and on sandy mineral islands (II)</p>			<p>Used for small poles stuck in the ground (platform) under the haystack (IV, VI, VII); trunks used as ballasting poles interposed on the top of the haystack (I, II, III, V, VI, VII); material used for <i>nosidła</i> – wooden rods used to carry hay to the haystack (III, IV, V); material for the scythe (V)</p>	<p>Cattle can eat the leaves</p>		<p>Medicinal plant; leaves are collected and sold (II, III, IV, V, VII)</p>
<p><i>kruszwina</i> (alder buckthorn-like, III, IV, VII); <i>wilczywe</i> (wolf-like); <i>kruszyna</i> (alder buckthorn, VII)</p>	<p><i>Frangula alnus</i></p>	<p>It grows in <i>olsyna</i> <i>Alnus</i> forest (III, IV); grows in forests (VII)</p>	<p>We have a lot of it in the <i>olsyna</i> <i>Alnus</i> forest (III)</p>					<p>Medicinal plant; we cut the branches, then peeled off the bark, then dried it out and sold it; wood used as firewood (VII)</p>

<i>dębina</i> (oak-like, II, III, VII); <i>dębiak</i> (oak-like, VII)	<i>Quercus</i> spp.	In elevated places in wetlands such as mineral islands (II, III, VII)	On many mineral islands (VII)		Used for small poles under the haystack; branches put on the pole platform structure under the haystack; trunks used as ballasting poles on the tops of the haystacks (VII)		On some mineral islands it used to grow very well, but it wilted (VII)	
<i>jegła</i> (<i>jodła</i> – Polish botanical name of <i>Abies alba</i> , so might be translated as fir-like, III, VI, VII); <i>świerk</i> (spruce, I-VII); <i>jegielka</i> (fir-like, II, III); <i>choja</i> (maybe from <i>choinka</i> - Christmas tree, IV)	<i>Picea abies</i> (L.) H.Karst.	In sandy places (VII)		There are two specific taxa: red and white; red has a reddish wood after cut and darker needles, the white one has light wood and lighter needles (III, V, VII); it turns red when infected by woodworms; wood is more yellowish (VII)	The trunks were used for <i>nosidła</i> (wooden rods used to carry hay to the haystack) due to certain qualities of wood, which is strong, tough and light (all); used for small poles (platform) under the haystack or as ballasting poles interposed on the top of the haystack (IV); material used to make a scythe (V); the white one is better for <i>nosidła</i> because it is lighter when dries out (VII)			The roots were used to make <i>brodnie</i> (type of drag net for fishing) (VI)

<p><i>olsza</i> (alder, III, IV); <i>olcha</i> (alder, II, IV, V, VII); <i>olszyna</i> (alder-like, I-VII); <i>olska</i> (alder-like, II)</p>	<p><i>Alnus glutinosa</i></p>	<p>In lowered places; muddy soils; in wet places it can form a forest (all); it grows everywhere in wet meadows (III)</p>	<p>Forms a forest in further zones (III, VII)</p>		<p>Used for small poles stuck in the ground (platform) under the haystack (I, III, IV, V); the branches were used as material layered on the platform (I, IV, V); trunks used as ballasting poles interposed on the top of the haystack (I, IV, V, VII); used for <i>nosidla</i>, wooden rods used to carry hay to the haystack (III, IV); it was not suitable to be used as ballasting poles put on the haystack because it was too fragile (VI)</p>			
<p><i>sośnina</i> (pine-like, III); <i>sosna</i> (pine, III, VI, VII)</p>	<p><i>Pinus sylvestris</i> L.</p>	<p>In sandy places (VII)</p>			<p>Used for small poles stuck in the ground (platform) under the haystack (VII); used for <i>nosidla</i>, wooden rods used to carry hay to the haystack (III)</p>			<p>The roots were used to make <i>brodnie</i> (type of drag net for fishing) (VI)</p>

<i>lipa</i> (lime, III, V, VI, VII)	<i>Tilia</i> spp.		We do not have a lot of it (III)		Branches put on the pole platform under the haystack in the winter time (VII); best material to use for <i>nosidta</i> ; wooden rods used to carry hay to the haystack because it is strong and light wood (III)			When a cow ate too much of the young sprouts in the springtime, then it had inflamed urine with blood in it; it could be healed with 0,5l of spirit vinegar; because of this, back then everyone had to have vinegar at home (VI)
<i>leszczyna</i> (hazel, III, VII); <i>lescyna</i> (hazel-like, VIII)	<i>Corylus avellana</i> L.				Branches covered the pole platform under the haystack (VII)			
<i>osa</i> (aspen-like, III, VII); <i>osika</i> (aspen, III)	<i>Populus tremula</i> L.	Also grows in wet meadows (III)		The wood is soft (VII)	The trunks used for <i>nosidta</i> , wooden rods used to carry hay to the haystack (III)			

<i>grabina</i> (hornbeam-like, III, VII)	<i>Carpinus betulus</i> L.	On mineral islands (VII)	On many mineral islands (VII)					In <i>grabina</i> forest one can collect <i>Armillaria</i> mushrooms (III)
<i>porzeczka czarna</i> (blackcurrant, I-VII)	<i>Ribes nigrum</i> L.	It grows in olsyna <i>Alnus</i> forest (II, III)						Medicinal plants, leaves are collected and sold

