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Chapter 6

Water Meadows as European Agricultural Heritage

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Abstract From the Middle Ages until the twentieth century, water meadows in Europe were primarily irrigated to improve their productivity and to lengthen the growing season. They were water management systems designed to collect and use water and to discharge it: water had to be kept moving. This chapter presents a general overview and a history of research on European water meadows. It also examines examples from the sandy landscapes of northwestern Europe, from Slovakia, and Norway. Three main types of water meadows are distinguished: simple dam systems, more elaborate catchworks, and highly developed bedworks. Of these, bedworks were technically and organizationally the most complex; they were also the most costly in construction and maintenance. Most water meadows were abandoned in the twentieth century; in many places, however, their traces can still be

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recognized in the landscape. They are both an interesting part of European agrarian and landscape heritage and a carrier of regional identity. In recent years, a number of water meadows have been restored, for ecological, water management, tourism, and heritage purposes.

Keywords Water meadows · Irrigation · Landscape · Europe · Slovakia · Norway

Introduction

Well-functioning meadows were essential to the survival of farm animals; European farmers, therefore, managed them meticulously, partly with systems of irrigation. Irrigated meadows are known in historical and landscape literature by the general term water meadows (Fig. 1). They must have been successful, as they appeared all over Europe for many centuries (Leibundgut and Kohn 2014a, b; Leibundgut and Vonderstrass 2016). They were still an important feature in the European landscape in the early twentieth century, then fell into disuse, and disappeared from the landscape. Water meadows are now a rare sight, little known to modern farmers and water managers. Even most handbooks on irrigated agriculture do not mention them (see, e.g., Achtnich 1980).

Fig. 1 In 1820 or 1829 John Constable (1776–1837) painted water meadows near Salisbury. This painting is one of the oldest pictures of water meadows. Wiltshire is one of the regions in which extensive traces still exist nowadays. In fact, this particular complex, dating from the seventeenth century, is well preserved and is still managed by the Harnham Water Meadows Trust (Cook 2008; Cook and Cutting 2008). Original: Victoria and Albert Museum, London; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Today, ecologists, landscape historians, and, to a lesser degree, water managers are paying more attention to water meadows. Traces of former water meadows have been rediscovered, mapped, restored, or reconstructed. They are valued as heritage and in some regions serve as a resource in small-scale tourism. They also have ecological potential and offer possibilities to local water management.

Water meadows were created by flooding meadows. There seem to have been two main reasons for irrigation of meadows. The first was to have an earlier harvest in the spring. At the end of the winter period, animal fodder became scarce (hence, the hunger gap); with flooding, which kept temperature at a constant and relatively high level, spring grass could start to grow and animals could begin to graze weeks earlier. The second reason for water meadows was its role in gaining higher productivity. When hay was harvested, meadows normally continuously lost organic material and minerals; however, irrigation kept conditions wet during summer and meadows—to which silt and lime were sometimes added—were kept productive (Williamson and Cook 2007, pp. 1–2; Cook et al. 2003). Dutch research from the end of the nineteenth century shows that the harvest from water meadows was more constant than that from regular meadows, particularly in dry years (Thissen and Meijer 1991).

The chemical effect of flooding is more complicated. The Swedish authors Emanuelsson and Möller (1990) have stressed that it can act as a sink to phosphorus and nitrogen, thereby reducing the need for artificial fertilizers. English research has confirmed the effect on phosphorus but has found no evidence for that on nitrate (Cook et al. 2003). Flooding may also have had the effect of diminishing the numbers of mice and grubs (Ewald and Klaus 2010, p. 118).

Some authors note additional reasons for the use of water meadows and make clear that regional differences were present. Whereas in temperate parts of Europe, flooding was used to avoid frost, in the North of Sweden winter irrigation was used to create an ice crust on a wet meadow, which prevented bushes and trees from springing up (Emanuelsson and Möller 1990, p. 136). In parts of the Alps, the amount of rainfall affected the use of water meadows. Drainage channels, *waale*, in South Tirol were concentrated in the driest places (Hallmann and Peters 1995); in the Mediterranean, a long tradition of irrigation made productive agriculture possible in dry regions (Emanuelsson 2009, p. 283). Most Mediterranean irrigation systems are primarily applied to the production of food crops and are not considered here—in this chapter, we focus on the use of irrigation in meadows.

In recent years, the growing interest in water meadows has led to much local research as well as to a number of survey studies. Notably, the Swiss geographer Leibundgut (Leibundgut and Kohn 2014a, b; Leibundgut and Vonderstrass 2016) describes meadow irrigation as an element of a larger group of activities under the banner of traditional irrigation, focusing on Central Europe. In this chapter, we offer additional information, particularly on Atlantic Europe, and look more closely at the heritage of this form of water management. After a section on the history of research on water meadows, we present a typology and history, followed by three regional case studies. In the final section of this study, we address heritage explicitly.

History of Research

Until the early twentieth century, most research and writing on water meadows came from agronomists, who were interested in how they functioned and were maintained.

Fig. 2 Troll's map of water meadows ('Rieselwerke') in Central Europe in 1937. From: Böhm 1990; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

More than one hundred sixty references can be found in German libraries, ranging from 1743 to the present. In the second half of the twentieth century, when only a few water meadows were still functioning and the system was largely a relic, new groups became interested in the subject, among them historians, ecologists, and water managers. At that time, agricultural historians in the UK began studying water meadows (e.g., Kerridge 1954). Later, landscape historians and landscape archaeologists discovered the subject; their research, more highly developed in the UK than elsewhere, combines detailed and well-documented fieldwork with old maps and other archival sources along with the personal experiences of farmers who developed their knowledge of the workings of water meadows from direct experience (Cook and Williamson 1999, 2007; Brown 2005). In recent years, many publications in Germany and elsewhere in Central Europe have come from ecologists, who have often developed their studies as components of restoration projects.

There are few detailed maps of the historic distribution of water meadows. A map of water meadows in a large region of Germany was published by Böhm (1990) and was based on data collected by the famous German ecologist Carl Troll between 1939 and 1946, the last period in which a substantial number were still functioning (shown in Fig. 2). Troll was aware of the human influence on landscapes and advocated a geographical science that combined physical geography with human geography and ecology. Other distribution maps have also been constructed. Among others, the ecologist Baaijens and collaborators recently mapped five hundred systems identified in Dutch nature reserves (Baaijens et al. 2011, p. 21), and Emanuelsson and Möller (1990) mapped the nineteenth-century systems of Scania, in the South of Sweden. These maps use different criteria, classifications, and sources which makes them difficult to compare. A further map of European water meadows was produced by Leibundgut (Leibundgut and Vonderstrass 2016, pp. 1–53). Although it is rather simplified, this map does show the widespread occurrence of these systems in mountains and lowlands.

Types of Water Meadows

To understand the landscapes of water meadows, it is essential to keep in mind that the water had to be kept moving. Therefore, installations had to be deployed to flood meadows and to drain them. The diagrams exhibited in Fig. 3 show the complex annual program of some English water meadows. More such time schedules are available; together, they show a huge variety in approaches to management. Flooding could occur in different seasons, although emphasis was on winter. In one Swiss case, meadows were flooded between November 11 and the beginning of May (Ewald and Klaus 2010, p. 120).

Fig. 3 Two yearly cycles from English sources. Above: Wye Valley, Surrey, reconstructed from James Simmons's diary; below: late nineteenth century as described in *Encyclopedia Britannica*, 1880. *Source* Cook and Williamson 2007, p. 114 (originals: Dr Kathy Stearne); released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

In the functioning and layout of water meadows, we can discern three main types. Our typology is based on technical workings, which seems most relevant for a landscape approach. Leibundgut presented a different approach, based on natural habitat, technology, and social background. On these bases, he discerned four types of irrigation systems: namely, Alpine, Alpine Piedmont, Low Mountain Range, and Lowland, each of which is characterized by specific designs and cooperative arrangements (Leibundgut 2004).

Fig. 4 Catchment work in the Black Forest, after Böhm (1990)

First in our typology are the most primitive installations or dam systems. A small dam with a sluice in a stream was sufficient for inundating adjoining meadows; these installations may be medieval or even earlier. In some cases, temporary structures, for example, wooden fences in a stream, were used—among them, the so-called wild inundations noted by Brinckmann (2015, p. 312). A related type of dam system is the deliberate flooding of land with water from rivers, meant not only to bring water but also silt to the land. Most such small-scale water meadows were developed by individual farmers; they left almost no traces in written records and did not attract much interest from early agronomists.

Catchworks, or catch meadows, are the second type of meadow and are located on slopes (shown in Fig. 4). Water flows through a leat or canal in the upper part of a meadow and then flows in a kind of film over the land. In more elaborate types, a number of embankments cause the water to flow in different steps. In a variation in Romania (Botzan et al. 2004, pp. 598–605), the water is allowed to overflow or to pass through holes dug in the embankment. In the Netherlands, such water meadows have been found in stream valleys, showing that even small differences in height can be used to effect in these systems.

Leats, the often short but sometimes very long canals that branch off streams and run almost horizontally to them, are the main indicators of catchworks. They can be spectacular: In Switzerland, they cross valleys by way of aqueducts (Konold 1994; Leibundgut and Vonderstrass 2016). They can also be much smaller; it can therefore be difficult to distinguish between smaller canals and mill leats, as irrigation and water mills use the same water. Though they seem to be in competition, this distinction is perhaps not too important. Most irrigated water collects at the lower end of a meadow and is then available to mills (Hallmann and Peters 1995). Moreover, irrigation is not a year round activity. Archival sources show that farmers would accord with mill owners on alternating use of the water. In 1663, we find that the owner of a paper mill in the Dutch village of Loenen, in Veluwe, the Netherlands, developed an agreement

Fig. 5 Bedworks in a nineteenth-century agricultural handbook. *Source* Staring 1868, pp. 903–904; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

with the farming community where the miller would clean the stream in the month of May and would after this go on to water the meadows and marshes for two weeks (Kobussen 1997, p. 80). Elsewhere in Europe, many farmers profited from irrigation of their lands by mill leats (Leibundgut and Vonderstrass 2016, p. 2, 265).

The third type of meadow irrigation system, bedworks, is the most developed and most labor-intensive method; hence, it is the most expensive (shown in Fig. 5). However, it is also the type that is most easily recognizable in the landscape. The high operational costs apply to initial layout, which transforms the meadow's surface; this initial work also calls for employing a specialist to manage and maintain the meadow—who, in England, is known as a drowner. It also seems to be the most recently developed type. The oldest examples date from the seventeenth century and they are characteristic of the Early Modern Period (Cook et al. 2003). In the Netherlands, these systems principally date from the second half of the nineteenth century. The use of water meadows has been widespread in Europe. Our hypothesis is that they are most abundant in regions where meadows (hence, animal husbandry) are an important part of the agrarian system and, secondarily, where there is a reasonable population density. The third factor is that physical circumstances must be favorable (where water, e.g., contains calcium).

Historical Development

It is often difficult to date traces of farmers' activities in the landscape. That is certainly true in the case of water meadows and especially so for dam systems and

catchworks. Little knowledge can be gleaned from written sources, as medieval sources are not always easy to interpret and the toponymical sources, which are important here, are particularly tricky. The toponym Brühl, found in written sources in different parts of Germany from the eighth century onwards, is one such case, which has variously been explained as designating a hunting park and, more recently, as an index of irrigated meadows (Konold 2004, p. 20). Nevertheless, many such systems have been dated to the medieval period and possibly even to the Roman period (Konold 2004, p. 19).

Medieval irrigation, primarily of meadows, was known in different parts of Europe, including areas outside the Mediterranean such as Lower Austria and the Allgäu in the twelfth century (Cate et al. 2004, p. 217) and around tributaries of the Danube in southwestern Germany during the fourteenth century. In some cases, these installations consisted of weirs (Konold and Popp 2004, pp. 23–25). Perhaps the most fascinating among them are the catchworks built by Norse colonists on Greenland, the remains of whose agricultural activities could only have been medieval, as the Norse colony on Greenland was founded during the tenth century and perished during the fifteenth century (Krogh 1982; Arneborg 2005; Adderley and Simpson 2006). Recent research has confirmed the existence of these water meadows, although aspects of the watercourses and ridges are of a natural origin (Edwards and Schofield 2013). The earliest irrigation techniques used may be connected to a bishop from Norway and field reorganization occurring around 1126 (Panagiotakopulu and Buckland 2012; Panagiotakopulu et al. 2012). This evidence suggests that catchworks were common practice in Western Norway at this time.

The High Middle Ages were a period of high population pressure and, consequently, intensive agriculture. This fact has been used to argue that a peak in the use of irrigation systems occurred in Europe during the thirteenth and fourteenth centuries (Leibundgut and Vonderstrass 2016, p. 1–26). Insufficient data causes this position to remain hypothetical. In the Netherlands' sandy landscapes, hay meadows were divided and became private property during the Late Middle Ages (Vervloet 2010), a fact which suggests intensification of agriculture during a period that is generally described as a period of crisis.

Many old irrigation systems were abandoned in the course of time (Konold 2004, p. 20) until interest in flooding revived, particularly among eighteenth- and nineteenth-century estate owners. Agronomists became newly interested, and agricultural experiments and improvements were fashionable and brought prestige to the estates. The more elaborate water meadow type appeared in handbooks and was propagated in agronomic journals (Konold and Popp 2004, p. 25). Figure 5 shows bedworks by the Dutch agronomist Staring. Staring was an exceptional case, as he also showed an interest in the simple, small-scale, older works that most scientific writers did not find worth mentioning.

The nineteenth century is often described as the last peak in water meadows. In southwestern Germany, new water meadows were laid out during the middle

Fig. 6 Water meadows in the Hriňová-district, Slovakia: actively used (a) and abandoned (b).
 Source Dr Martina Slámová

decades of the century, although proponents of meadows were often disappointed by the slow pace of the work. Many of these survived into the twentieth century. This new interest led to the introduction of meadow irrigation into regions where it had been unknown, including Norfolk, England (Wade-Martins and Williamson 1994), the Czech Republic (Dvořák et al. 2004, p. 312), Slovakia (Fig. 6), Hungary (Fejér 2004, p. 400), and some of the poor heathland regions of the Low Countries.

Regional differences in the development of agriculture led to regionally distinct developments and chronologies in the use of water meadows. In Scania, Sweden, the growing amount of arable land outpaced the supply of manure in the middle of the nineteenth century and the following decades showed a growth of water meadows until the arrival of artificial fertilizers ended the practice (Emanuelsson and Möller 1990). In mid-nineteenth-century Switzerland, on the other hand, growing imports of grain, facilitated by a growing railway network, diminished home production of grain and triggered a shift to dairy farming. The combination of less grain and more cattle, in its turn, led to a shortage of straw. Many meadows were converted into *streuwiesen* (straw meadows) and investment in their productivity came to include irrigation (Ewald and Klaus 2010, p. 121).

Around 1950, a substantial number of water meadows were still used and maintained; most have since been abandoned. Nature reserves sometimes preserved their traces; however, industrial agriculture, collectivization in Eastern Europe, land consolidation in Western Europe, and ancillary works erased them, along with other field structures, from agricultural land.

Case Study One: The Sandy Landscapes of Northwestern Europe

The zone of sandy regions that runs from Flanders through the Netherlands and northwest Germany to western Denmark is characterized by soils with low natural productivity. The problem that occupied the agricultural sector most during the nineteenth century was how to turn the extensive heathlands in these regions into decent agricultural land.

For centuries, the heathlands had functioned within a system of mixed farming, in which small open fields and individual enclosures were used for crops, particularly for rye. Cattle and sheep were kept for meat and other products, but primarily they were held for their manure, which fertilized the arable land. Heathland occupied more than half of these sandy regions, and large-scale reclamations were impossible because of a lack of manure. Old water meadow systems seem to have existed in this region, even where a substantial part of the surface water came from heathlands and was acid as well as poor in minerals. In northwest Germany, such meadows were often organized as cooperatives (*Genossenschaften*) (Hoppe 2001). In Germany's Lower Saxony, systems of small canals, ditches, and ponds (*Weiher*) collected water from houses, streets, and stables and brought it into the meadows to increase their productivity. These systems were probably most in use during the nineteenth century.

In Belgium, new experiments were started in the 1840s. In 1849, for example, the Belgian Government began one of the largest irrigation projects to date, the reclamation of heathland near Lommel (Jansen 2015) (Fig. 7). These experiments received immediate attention in the Netherlands; experiments were also begun there soon after. From the 1840s to the 1860s, regional farming organizations and the Dutch Government encouraged farmers to build water meadows. They also invested in a new national network of canals, whose side effect was to open up some of the sandy region's more isolated parts. The canals' water level was often higher than the adjoining low-lying heathlands, which made them perfectly suited for irrigation (Fig. 8).

In the final decade of the nineteenth century, the interest in water meadows revived once again. This time, the *Nederlandsche Heidemaatschappij*, the Dutch Heathland Company, had a primary role; it had been founded in 1888 on the model of the Danish Heathland Company and also active in the construction of water meadows (Emanuelsson 2009, p. 285). Behind the society were large landowners from the eastern provinces; particularly prominent was a group of large textile manufacturers that had recently started to establish themselves as a new landed gentry. Members of this class also sat on the State Commission on Irrigation, formed in 1893, which recommended the system four years later. In the next few years, it was mainly the Dutch Heathland Company that realized a number of new water meadows (Thissen and Meijer 1991).

Fig. 7 Bedworks at Lommel (Belgium). Onroerend Erfgoed Vlaanderen (Hilde Verboven), nr DSCN0037; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Fig. 8 Irrigated meadows near Weert (Limburg, NL), laid out by the Maastricht industrialist J. Chainaye during the 1850s, using water from the Zuid-Willemsvaart. With 110 ha, it was the largest complex of water meadows in the Netherlands. The system remained in use for many decades and is still recognizable in the field. Left: topographical map, scale 1:25.000, sheets 725 (1901) and 726 (1896), ©Kadaster, Apeldoorn (NL). Right: photograph J. Renes; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Fig. 9 Water meadows at Lankheet (Overijssel, NL). Left: two fragments of the original plan for the Lankheet. Upper right: the restoration plan by landscape architect Berno Strootman. *Source* Baaijens et al. 2011; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Two Dutch historical geographers who conducted research on nineteenth-century reclamations and found evidence of water meadows started the most recent rediscovery of water meadows in a 1991 article (Thissen and Meijer 1991). They focused on water meadows as a nineteenth-century agricultural innovation. Belgian ecologist Joël Burny (1999) had already begun to interview farmers about old agricultural practices in northern Flanders's sandy landscapes. One of his 1999 book's most spectacular parts was the detailed information on innovations to water meadows made in this region (for a recent update, see Jansen 2015). Shortly after, Dutch ecologist Gert-Jan Baaijens (Baaijens et al. 2001; Baaijens et al. 2011) observed structures in the landscape that he interpreted as traces of former irrigation. Although his findings initially met with skepticism (from the author of this case study among others), his basic idea has been confirmed by archival research and is now generally accepted (Brinckmann 2015). Still more historical research is badly needed.

Some water meadows have been restored in recent years. Among the most impressive is the Lankheet landed estate (shown in Fig. 9). Here, the former water meadows are used for water storage, featuring reed swamps to purify water (by taking out phosphates and nitrates) for irrigation and nature development as well as to supply biomass for energy (Baaijens et al. 2011). The estate's restorations are an excellent example of adaptive reuse of a historic water management system.

Case Study Two: The Hriňová District, Slovakia

The Hriňová region is situated in one of five regions in Slovakia that government has classified as a traditional landscape with scattered settlements (Petrovič 2006), indicating that it continues to show many traces of the agricultural landscape and settlement patterns practiced before the collectivization of the late 1940s. Settlers from Wallachia colonized this area from the sixteenth to eighteenth centuries (Ira et al. 2008). The Riecka catchment of this region has an area of eight hundred twenty-nine hectares; more than ninety percent consists of this “traditional agricultural landscape”; remaining parts are comprised of forests and a handful of residential areas (Slámová et al. 2015). The area is near the Polana Protected Landscape Area, which became a UNESCO Biosphere Reserve (BR) in 1990. Biosphere Reserves are divided into three zones: a core zone, a buffer zone, and a transitional zone; designated “traditional agricultural landscapes,” such as the catchworks, are elements of the transitional zone (Fabriciusova et al. 2015) (Fig. 10).

No literature on historical irrigated meadows in Slovakia exists. However, our recent fieldwork in the Hriňová area of Central Slovakia, which included interviews with local inhabitants, has resulted in new insights on catchworks. Using a Global Navigation Satellite System (GNSS) Leica GS05, 3736.68 m of catchworks was mapped in 2013 in the Riecka catchment (Slámová et al. 2015). It was observed that 42.82% of these catchworks were functional, 2.28% was partially functional, and 53.59% was non-functional.

Today, catchworks are mainly placed on slopes with meadows and pastures and correspond to sites and habitats of European significance (as designated by

Fig. 10 Water meadows in the Hriňová-district, Slovakia. *Source* Dr Martina Slámová; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

NATURA 2000) or national significance (Slámová et al. 2015). To understand the history of land use, we looked at those sites on three series of historical maps: military mapping (1764–1787), the military map (1810–1869), and topographical maps (1957–1971). The topographical maps show the sites of today's catchwork as agricultural, whereas the nineteenth-century maps show one-third of that land as still forested; the eighteenth-century maps show the majority as forested. These facts suggest that most catchworks date from the eighteenth and nineteenth centuries.

Recently, the administrative body of the Protected Landscape Area and the Biosphere Reserve Polana initiated a project on water meadows in the area which focuses on identifying landscape features and disseminating scientific knowledge among stakeholders and the community. The Action Plan for the Polana Biosphere Reserve for 2014–2018 is an innovative management model. It includes a coordination board, or advisory body that operates in the territory, in which the management of the Reserve as well as other stakeholders are represented. The Action Plan also encompasses a strategy for enhancing regional identity and landscape awareness among local inhabitants. It covers all forms of cultural, historical, and natural heritage (Fabriciusova et al. 2015).

Catchworks are a sophisticated historical irrigation system that is part of the landscape's heritage. A catchwork system retains water and supports the diversity of habitats and land covers. It is not yet clear if the spatial distribution of habitats positively correlates with those of catchworks. Although catchworks provide adequate soil conditions (that is, moisture) for the presence of habitats that include hydrophilous tall herb fringe communities found in the plains and montane to alpine

Fig. 11 Part of historical irrigation canal at Måbø farm, inner Hardangerfjord region, W-Norway (Photograph Sebastian Eiter/NIBIO); released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

levels as well as moist or wet eutrophic and mesotrophic grasslands, these habitats were only observed locally around springs or streams. Permanent mesotrophic pastures, aftermath-grazed meadows, and lowland hay meadows are maintained by mowing, fertilizing, and traditional management (Slámová et al. 2015, 2016) (shown in Fig. 11).

Case Study Three: Norway

There is no specific term for water meadows in the Norwegian language. A hay meadow in general is called an *eng* or, when it refers specifically mowing, a *slåt-teeng*. Most parts of Norway have always had enough precipitation for cultivation of farmland, including meadows, without recourse to irrigation. Exceptions are the farming settlements in the northern part of the Gudbrandsdalen Valley and the innermost fjord districts of Western Norway (Aamo 1972; Christensen 1997). Northern Gudbrandsdalen is located in the most extreme rain shadow, east of the main Scandes mountain ridge, and receives as little as about three hundred millimeters of annual precipitation. The inner fjord districts of Sogn and Hardanger have a somewhat higher amount of precipitation, but they feature steep slopes and coarse soil with a low capacity for water retention (Fig. 12).

Fig. 12 Half-open wooden pipe to lead irrigation water at Søre Neset farm, Vågå, E-Norway (*Photograph* Hans Joramo/De Sandvigske Samlinger Maihaugen); released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Historically, in this region, systems of small canals were built, which were sometimes combined with half-open wooden pipes to bring water from the mountains to farmland (Fig. 12). These canals, generally called *vassveiter*, occur with local variations. Local terms for a half-open pipe include *tro* (and its plural *trø*), *dæle*, or *lekja* (Ile 1958). These irrigation systems are up to several hundred years old and several kilometers long (Christensen 1997). They not only irrigated farmland but also sent water to farmsteads for household use (Dokken et al. 1999). Maintenance of these systems consumed substantial efforts and had to be carried out annually; maintenance was possibly also carried out more frequently on demand (Kjøl 1979; Dokken et al. 1999) and was performed with care: Even wind shields were built to prevent snow from blowing away from farmland before it melted (Sømme 1954). However, relatively high precipitation, which could be accompanied by a melting of snow right before the vegetation season, in some years and places could reduce or even eliminate the need for irrigation (Sømme 1954). Since the beginning of the twentieth century, it has become more common to use sprinkler irrigation: Motorized pumps bring river water from the valley bottom through tubes and then spray it on the fields. Farmers who could not afford to make larger investments lost their water supply for some time during the transition from the old to the new system (Kjøl 1979). Some farmers still to some degree use mountain water directly (Sømme 1954; Christensen 1997), or, indirectly, when they generate hydroelectricity to run the pumps.

Politicians quickly recognized the importance of irrigation to the productivity of meadows and other farmland. Subsidy schemes for irrigation were introduced from the early twentieth century and applied regularly around the Second World War (Borgedal 1966). In 1939 about seventy-six hectares of farmland were irrigated nation-wide; thirty-five hectares of this was grassland (Borgedal 1966). By 1959, irrigation capacity in Norway had increased to one hundred eighty hectares, with an expected further increase (Borgedal 1966).

Some irrigation canals were still maintained and functioning as late as the 1990s (Christensen 1997). The once high importance of these historical irrigation systems to the community and farming economy is reflected well in their rather strong local appreciation as cultural landscape heritage. Their descriptions can be found in local historical literature, while maintenance and restoration is performed as part of cultural history hiking trails or outdoor museums. National awareness of historical grassland irrigation, however, is clearly lower.

Cultural heritage in Norway from 1537 or earlier is automatically protected by law. Newer heritage sites must be protected individually. We do not expect many farmland watering systems to be old enough for automatic protection, nor do we know of any instances of individual protection in law or as part of a protected area. There should be ways to fund restoration and maintenance of water meadows, nevertheless, perhaps within a scheme of environmental measures in agriculture under the auspices of local authority districts (*spesial miljøtiltak i jordbruket*), the national cultural heritage fund (*Kulturminnefondet*), or as part of valuable agricultural landscapes (*utvalgte kulturlandskap i jordbruket*).

The Rediscovery of Water Meadows in the Twentieth Century

Following the nineteenth-century success of water meadows, new developments in agriculture led to their gradual disappearance. The main factor in their decline was the introduction of cheap artificial fertilizers that ended the problem of scarcity of manure. Although new water meadows were established during the first half of the twentieth century in some localities (Dvořák et al. 2004, p. 314), they disappeared elsewhere quickly. Most water meadows were abandoned during the twentieth century; in many cases, their very traces disappeared. The most prominent type, bed-works, was most threatened. Many were leveled since they were inflexible in use; less suited for pasture, as cattle could destroy elements of beds and ditches; and both capital and labor-intensive. A national survey of ancient meadows and pasture in Sweden (conducted from 1985–1997) produced only negligible figures for the artificial flooded meadow and artificial watered meadow categories: One hundred seventy-three and fifty-eight hectares, respectively, were found in the entire country (Ihse and Lindahl 2000, p.). In Switzerland, water meadows are still in use solely in the small region of Langenthal. Even here, they had almost disappeared (diminishing over time from seven hundred hectares around 1900, eighty hectares in 1984, to very few fields today) when local initiatives were started to revive the old irrigation systems (Ewald and Klaus 2010, p. 118; Leibundgut and Vonderstrass 2016, p. 2–297).

In recent decades, interest in water meadows has been growing again, primarily among ecologists and landscape historians (Cook et al. 2003; Baaijens et al. 2011). Several regions have restored water meadow as has been noted and listed by Leibundgut and Kohn (2014b). A landmark publication by Leibundgut and Vonderstrass (2016) describes a number of water meadows that have been restored and reused. In the eastern part of the Czech Republic, the Josefovské Grasslands Ornithological Park, a complex of irrigated grasslands in the floodplain of the Metuje River, has been in the process of restoration since 2008. In the Netherlands, recent interest from ecologists has brought the first restorations and reconstructions, notably those at Lankheet. In Germany, several nature restoration projects for safeguarding wetlands or for retaining biodiversity on alp meadows where water meadows are maintained or have been reconstructed are underway. In Western France, the region of Basse-Normandie and the European Agricultural Fund for Rural Development (Feader 2010) subsidizes farmers to preserve water meadows in the Cotentin and Bessin wetland of the Nature 2000 framework (Feader 2010). Other such projects can be found in England and Sweden (Emanuelsson 2009, p. 287).

What interests ecologists about water meadows are the specific flora and fauna that thrive there and arise due in part to the wet environment and in part to specific management practices (Cummins and Cutting 2007). Water meadows also conform

to the European programs and subsidies for maintaining high nature value grasslands (Müller 2017; Keenleyside and Oppermann 2009).

Conclusion

The main reason to preserve and restore water meadows is heritage. They are remnants of past agriculture, showing the value and scarcity of meadows in a period in which the existence of farmers was always threatened by natural and economic fluctuations. Historic landscapes tell the story of past struggles for survival and show how the efforts to improve agriculture led to local solutions and specializations and, hence, to characteristic landscapes.

Western Europe in particular has a long tradition of describing and protecting the landscapes and individual relics of past agrarian practices for their cultural, aesthetic, and ecological values (Niemeier 1961; Antrop 2005; Council of Europe 2000). Officials and citizens alike see these landscapes as a building block for local and regional identity and as a major resource for rural tourism, ecological restoration, and multi-functional agriculture. There are plans to prepare a proposal for inscribing a selection of European water meadows as World Heritage Sites in UNESCO's World Heritage Program (Leibundgut and Vonderstrass 2016, p. 1–234). In recent years, the protection of historic agrarian landscapes has been extended past Europe, again through the World Heritage Program (Von Droste et al. 1995).

Although the traces of historic water meadows are subtle and will not get much attention from the majority of tourists, they add a story to the landscape interesting to small-scale ecotourists, particularly walkers. In parts of the Alps, the irrigation canals are a normal feature in tourist leaflets and footpath descriptions. Examples can be found in Tirol, where the leats are known as Waale, and in Valais (Switzerland; Crook and Jones 1999). A few places present water meadows as ecomuseums (Leibundgut and Vonderstrass 2016, p. 2–110), as, for example, the Harnham complex once painted by Constable (Fig. 13).

A final argument for protecting water meadows is water management. Their specific structures, designed for both irrigation and drainage, makes them useful for temporary storage of water. This possibility has become more visible in recent years, as water management is increasingly combined with ecological aims, stimulated by new legislation such as the EU Water Framework Directive. After centuries of focusing on maximum drainage on behalf of agriculture, water managers now seek the efficient use of local water, which means, for example, upstream water retention. Reactivating water meadows can be part of such measures that may become ever more relevant as climate change brings stronger fluctuations in precipitation.

Fig. 13 Harnham water meadows nowadays. In the background Salisbury cathedral is seen, making this one of the most iconic water meadows landscapes. *Photograph* Lorraine Blakey; released under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Water meadows are probably not very well known to the general public, but they are an interesting part of European water heritage. In the past, they were widespread and in all their variety they are demonstrations of past creativity and innovation by farmers. Most water meadows lost their function over the twentieth century, and many systems have disappeared without a trace. However, some systems have been used until recently or even into the present, and traces of abandoned systems have been rediscovered in recent years. Their future survival depends mainly on new functions: ecology, tourism, or water retention in the face of climate change.

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