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Wetland Reclamation and the Development of Reclamation Landscapes: A Comparative Framework

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ABSTRACT

Wetland reclamation has occurred under diverse geographic and socio-political conditions. A single reclamation event however, forms only one step in the evolution of what we refer to as reclamation landscapes. This paper assesses how interacting physical geographical, cultural and biological processes shape the landscape diachronically. Using a triangular model, we compare two wetland landscapes: the Pontine marshes in central Italy, reclaimed as part of Rome's early Imperial expansion; and the Onlanden area in the northern Netherlands, reclaimed by emergent state societies in the Middle Ages. Reclamation turned out not fully resilient from a cultural perspective in both cases, as physical geographical and biological processes continued to raise challenges in both reclamation landscapes. It is argued that the triangular model offers potential to systematically explore the drivers behind landscape evolution comparatively. A better understanding of such drivers may in turn improve current landscape management policies, including rewilding efforts.

KEYWORDS

Human-environment interaction; longue-durée; resilience; affordances; landscape dynamics; wetland reclamation; Italy; Netherlands

Introduction

People have exploited wetland resources since the beginning of time. This exploitation will always have had some sort of an impact on the landscape it concerned, but the degree to which this resulted in a transformation of that landscape varies profoundly over time and place (Lillie and Ellis 2007; Menotti 2012; Menotti and O'Sullivan 2013). It seems generally accepted that the most profound and sustained changes in wetland landscapes result from reclamations. Such reclamation activities, or reclamation plans, represent a major step in human relations with landscapes, both in terms of scale and impact: reclamation does not take place in order to allow people to benefit from the richness the area provides as it is, but rather to transform the ecosystem and the physical landscape into one fully adapted to human needs.

Interestingly, definitions of wetland reclamation seem to represent rather static notions of wetland landscapes 'before human interference': the United Nations define

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(wet)land reclamation as 'the gain of land from […] wetlands, […] and restoration of productivity or use to lands that have been degraded by human activities or impaired by natural phenomena.' (GES 1997). Similarly, in earth sciences wetland reclamation (there used in the opposite sense – as a synonym for wetland restoration) is defined as 'the rehabilitation of degraded wetlands habitat, reconstructing the impacted habitat as closely as possible to its original condition with respect to hydrological, ecological (vegetation, habitats), and morphological (soil) components' (Koroglu 2015, 742). Both definitions, although referring to different processes, seem to imply that before becoming (or unbecoming) a wetland, such landscapes had witnessed little to no change.

From an archaeological perspective, such static notions of pre-reclamation conditions in wetlands are highly problematic – not just because such areas had often already been subject to human interferences for thousands of years, but also because of various natural processes that, in interaction with such human interferences, could alter landscapes profoundly. This paper therefore aims to develop a more nuanced understanding of the effects of wetland reclamation upon what we dub reclamation landscapes, by looking at both the long-term history of such landscapes, and the role of human and environmental processes.

Human, or societal, objectives with respect to reclamation landscapes, as stated above, can be simplified as aiming to transform a landscape dramatically in order to serve human needs, in most cases agricultural, but sometimes residential in nature as well. While reclamation projects were undertaken under diverse geographic, socio-political, and socio-economic conditions (and hence their outcomes in terms of landscape development are highly variable), a comparative framework seems to hold potential to obtain insight into underlying constants and trends in the development of reclamation landscapes worldwide – and in turn will inform strategies for future management and development of these landscapes.

Thus, we apply a comparative approach that allows identifying underlying patterns in the role of such human and environmental factors and, most importantly, in their interaction. To highlight such patterns we apply a particular model in the comparison of the long-term development of two geographically, culturally, and ecologically distinct wetland reclamation landscapes. These landscapes concern the Pontine marshes in central Italy, reclaimed amongst others as part of Rome's Imperial expansion, and the Onlanden peatland landscape in the northern Netherlands, which first underwent a major reclamation phase in the medieval period. The study of these two particular landscapes serves to evaluate the potential of the model as a tool to realize, in the future, an understanding of the diversity and commonalities in the evolution of reclamation landscapes. This, we hope, may also provide a basis for more informed, sustainable choices in the future management of such landscapes.

Theoretical Considerations Regarding Reclamation Landscapes

In this paper, we focus on the effect of reclamation activities within wetland landscapes. It is, in this respect, vital to introduce the concept of a 'reclamation landscape'. We consider every landscape where at any moment in time a reclamation activity took place, a reclamation landscape. We believe that the development of such landscapes was historically contingent and path dependent: the state of the landscape at any particular moment in

time was essentially shaped by the entire sequence of previous engagements with and natural processes in that landscape. Hence reclamation cannot be seen as an event independent from the longer-term development of the landscape. This implies that this particular landscape is then a reclamation landscape in all its history, including, in hindsight, the centuries or even millennia preceding the first reclamation activities, but in which humans already interfered with the landscape, thereby actively modifying its physical characteristics. Moreover, we argue that peoples' long-term understanding and awareness of a landscape were a prerequisite for selecting this landscape for reclamation in the end. On the other side of the chronological spectrum, we persist to designate a landscape as a reclamation landscape after 'failed' reclamations or present rewilding projects. It cannot unbecome a reclamation landscape anymore.

We take this reclamation landscape as an object of study, rather than the reclamation initiatives and activities associated with a particular period or cultural group. This allows us to frame such reclamation activities within the long-term history of human interactions with and developments within these landscapes and hence also provides a more neutral basis to assess the effects of reclamation projects: even if for past societies failed reclamations could have very negative consequences, reasoning from the landscape itself, reclamation never failed, nor was it a success: reclamation was merely one phase in its development. We thus also divert from an approach which treats reclamation as a single (even if sometimes long) event, in which a simple relative chronological division is proposed in pre-reclamation phase, reclamation phase, and reclaimed phase, or polder.

We emphasize that while reclamation intended to achieve landscape transformation, other processes could lead to equally transformative changes – while by definition, a human actor needs to be involved in reclamation, this is not true for all transformations. After all, natural phenomena resulted in major, and sometimes very sudden, transformations of landscapes since the beginning of times. We thus link on to the growing consensus that non-human entities must be accepted as actors. In this respect, we feel that the concept of affordances is most easily applied to reclamation landscapes. Affordances, a concept made famous by Gibson (1986), imply that an object, or in this context, the landscape, must be accepted as an actor communicating with, or rather asking questions to, people looking upon it. What exactly this question is however, does not only depend on the characteristics of the landscape at that moment in time, but also upon the people involved. When a group of people has reached a certain level of organization and technique, a wetland landscape may be asking them to 'reclaim' it, even when the same landscape under different societal conditions may have asked a different question.

This does not imply however, that only the people play a role in this after all. Affordances provide an excellent framework to explicitly address the feedback loops generated from wetland ecosystems some decades, or even centuries, after reclamation activities took place. For example, as a result of erosion and sedimentation, soil subsidence or climate change a landscape may be changing, thus asking new questions to the societies involved. What happened next heavily depends upon what is technically possible, as well as societally required or desirable. This feedback from the system also links on to resilience in an interesting way. Resilience suggests that a particular system is able to withstand severe shocks without fully breaking down as a system (Walker et al. 2006). This seems to collide with the objectives of reclamation, but it might very well be that, whilst initially severely suppressed, elements of this system may continue to play a role in the background.

While in approaches focused on reclamation phases societal context (rising socio-political complexity, technological developments, ideology) take centre stage, the more holistic approach to reclamation landscapes advocated here considers such cultural processes in dialogue with natural processes, both biotic and abiotic: in reclamation landscapes in particular, continuous and highly unpredictable feedback loops from natural responses to cultural activities result in a web of intended and unintended outcomes that play out over both the short-term and the long-term. We thus consider reclamation landscapes as complex systems that require more flexible, non-linear approaches in order to understand their evolution (McGlade and Van der Leeuw 1997; Crumley et al. 2017).

The Evolution of Reclamation Landscapes: A Comparative Approach

Our approach builds upon a recently proposed triangular model described in more detail by Schepers et al. (2021; see Figure 1). This model considers every landscape as the result of the interplay between three major driving forces: biological processes, physical-geographical processes, and cultural processes. Through a weighing of the relative impact of these three main processes, a landscape can at any given point in time be placed within this triangle. It is vital to emphasize here, that no position of the landscape within the triangle is, as a rule, the preferred position.

While in essence static (it reflects the formative processes in a landscape at a given point in time), the model allows assessing the dynamics of landscape developments through comparative application. Such comparison can be diachronic, (e.g. tracing changes in the position of a landscape within the triangle in different time slices), geographic (e.g. comparing the position of different landscapes within the triangle) or both. In this way, the model allows for a comparative exploration of the different processes that shape landscapes in a long-term perspective.

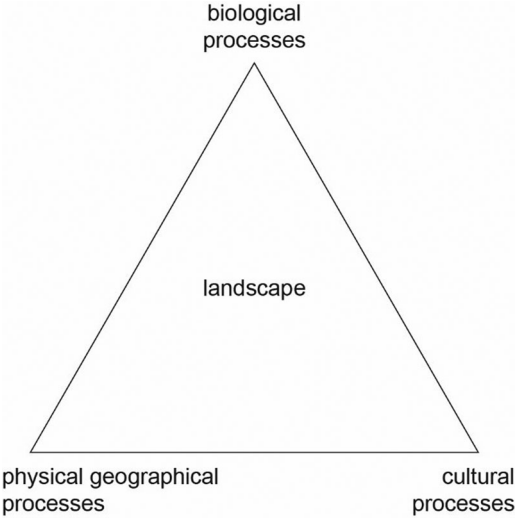

Figure 1. The triangular model (from Schepers et al. 2021).

In this paper we combine diachronic and geographic comparisons of our two study areas (see also discussion). Starting point for the comparison is a period-by-period review of the presently available research findings with respect to both study areas, as compiled by the first and second author for their respective regions of expertise (De Haas: Pontine marshes; Schepers: Onlanden). We defined six simplified time slices: the Bronze and Iron Age (1), the Roman Period (2), the Middle Ages (3), the Early Modern Period (4), the twentieth century (5), and 'now' (6). Based on archaeological, environmental and historical sources, for each area and time slice a qualitative assessment is made of the influence of biological, physical geographical and cultural processes on the landscape. Subsequently, we estimate the position of both study areas within the triangular model relative to one another – which is an interpretive process that takes place in direct mutual discussion between both authors. Whilst not exhaustively, we will make explicit on a number of places how we feel the relationship between people and their environment can be related to the concept of affordances (Gibson 1986, see section 3).

The final step in the comparison then is an evaluation of the evolutionary trends as highlighted by the triangular model for the subsequent time slices. This evaluation allows us to highlight recurring patterns in the development of these landscapes, and also forms the basis for a general evaluation of the role of reclamation projects in the evolution of the landscape into the present and future.

The Reclamation Landscapes of the Onlanden (Northern Netherlands) and Pontine Marshes (Central Italy): A Short Introduction

The two reclamation landscapes that are object of study are the Pontine marshes in central Tyrrhenian Italy, and the Onlanden in the northern Netherlands (Figure 2). Both areas are characterized by an extensive and ongoing research history, which includes

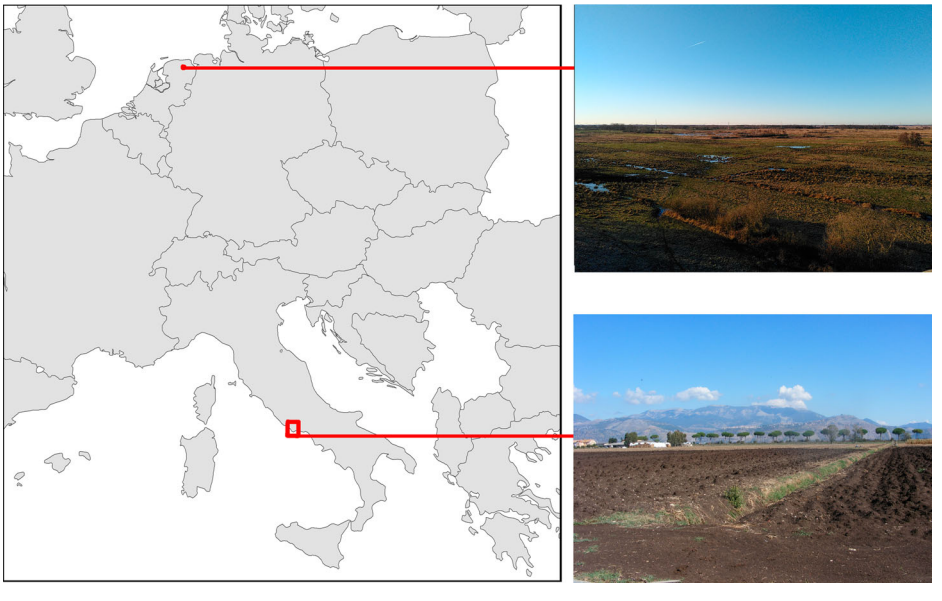

Figure 2. location of the Onlanden (top) and Pontine marshes (bottom).

various types of archaeological, palaeo-environmental, and geological studies. Both these areas specifically serve as examples of well-studied reclamation landscapes and we heavily rely on previously published work by ourselves and others for this paper. For more detailed information, as well as the source data underlying various aspects discussed here, we refer to the original sources.

The Pontine marshes are situated in the Pontine plain, on the Tyrrhenian coast of central Italy south of the city of Rome. Although as a whole referred to as the Pontine marshes, this plain consisted of different physical geographical units: to the northwest they included badly drained tuff hills; along the coast was a system of relatively high marine terraces characterized by geological processes of uplifting (a horst) that formed a relatively dry area within the marsh, but at the same time contained a series of lagoons. These marine terraces close off a depression (a graben), filled with peaty and clayey sediments, in part covered by colluvial and alluvial sediments provenient from the adjacent Lepine mountains and Alban hills. As this inner plain lies at a lower altitude than the marine terraces (around or a few metres above sea level), for several millennia this inner plain formed a badly drained depression with few outlets towards the sea. As we will see, because of their centrality in relation to Rome, seat of power from the Roman period into modern times, communities have tried to reclaim these wetlands in many historical periods. For the Pontine marshes, we may draw on an extensive body of data. Most of these, including high-resolution settlement data from archaeological field surveys as well as extensive palaeo-environmental records have been gathered over the past 15 years as part of the Pontine Region Project (De Haas 2011, 2017; Tol et al. 2021; Feiken 2014; Van Gorp and Sevink 2019). These data are complemented by written sources and historical scholarship on the medieval and early modern history of the area (Walsh, Attema, and de Haas 2014; Tol and de Haas forthcoming)

The Onlanden are located in the Northern Netherlands, on the border between the provinces of Groningen and Drenthe. The area is divided in a number of sub-regions, largely determined by its reclamation history. In this contribution, we will primarily focus on the area known as the Roderwolderpolder. This relatively low-lying area has a diverse ecological history, but has been 'wet' in varying, and relevant, degrees throughout history. The southern part of the area consists primarily of peat soils. These occur in the Northern area as well, but there these have been covered by younger, clay sediments. The hydrological and pedological conditions of the area explain the name Onlanden, which literally translates to 'bad lands'. No actual settlements developed within the reclaimed area, but villages do occur on higher sandy outcrops around it. The most important of these is the city of Groningen, which over time has expanded significantly and now borders the area. The expansion of the Medieval town of Groningen probably triggered the intensification of the exploitation and reclamation of the Onlanden in the Middle Ages. It has long been known that numerous raised homesteads or small dwelling mounds occur in the area that date back to this period. A major field-work project focusing on the aforementioned Roderwolderpolder was carried out from 2008 to 2011, resulting in an extensive edited volume that is the basis for the present analysis (Nicolay 2018a).[1]This is published in Dutch, but English summaries are provided for all chapters. This project followed the intended transformation of the area from an agricultural area, into an area used simultaneously for (wetland) nature development and water retention.

A Diachronic Assessment of the Pontine Marshes and Onlanden

The Pontine Marshes

Timeslice 1: The Bronze and Iron Age

The prehistoric landscape was shaped by geological processes of uplifting of the coastal horst and the lowering of the inland graben. In the Bronze Age under wet climatic conditions, an extensive wetland gradually drowned as a result of the closure of beach ridges, which was in turn caused by increased sedimentation along the coast (Sevink et al. 2020). In the Iron Age dryer climatic conditions and sedimentation processes gradually led to the drying up of the fringes of the lake.

In the Bronze and Iron Age, the wetland was surrounded by sparse settlements occupying favourable locations such as levees, affording a good place to settle. One example is the site of Tratturo Caniò, where people engaged in small scale mixed agriculture as attested to by pollen of *Avena/Triticum* and seeds of emmer wheat, hulled barley and lentil from Bronze Age layers. The bone assemblages include cattle, ovicaprine and pig bones (Feiken et al. 2012). Elsewhere along the edges of the wetland, ditches were excavated to drain plots of land for small-scale arable farming. Such activities may also be attested to by layers of so-called *terra bruciata*, which reflect processes of peat oxidization (Sevink 2020).

Associated plants indicate a wet environment with alder trees and, in higher locations, oak, birch, and pine. Associated animals attested in bone samples from Tratturo Caniò include fish (roach), ostracods and rodents (Feiken et al. 2012). Molluscs however, show little to no indications of open, dry terrain or woodlands, and Bakels et al. (2015, 66–67) suggest that already in the Early Bronze Age there is evidence from pollen that forests in higher terrain were partially replaced by secondary shrub vegetation, and the alder carr along the edges of the lake was also reduced.

So, overall, the prehistoric landscape was shaped predominantly by geological and physical geographical processes. Human interferences in the landscape were of limited scope, but they did already play a significant role in modifying vegetation and hydrology at the local scale. Also, extensive wood cutting in the Lepini uplands led to increasing levels of colluviation and alluviation in the graben in the Iron Age. This caused the development of relatively high and dry areas within the marsh that were relatively well-suited for settlement and agriculture. These locations may have served as a spring-board for more extensive, planned interventions in the landscape in the Roman period.

Timeslice 2: The Roman Period

In this phase, cultural processes had become much more dominant in the development of the landscape, both in terms of physical geography and ecosystems. This is largely due to rapid organizational and technological developments within the Roman Empire in its early stages. This resulted in the laying out of large infrastructural works, such as the famous Appian Way (Via Appia) which cross-cut the Pontine marshes. Archaeological research shows that around the same time in the late fourth century BC, villages were established along the road, and numerous colonist farms were established in their surroundings (Tol and De Haas 2017).

Around this time, the landscape consisted of peatland with on its margins higher areas with colluvial and alluvial sediments. In terms of affordances, this landscape now offered

the potential to play a role in feeding the population of the city of Rome. Roman hydrological interventions were crucial to develop this peatland marsh for agricultural exploitation: a large-scale cadastral/drainage system was laid out over an area of more than 120 km^2. This regular system of north–south and east–west oriented canals and ditches formed the first large-scale human 'rationalising' imprint on the landscape. It was connected to a number of major drainage outlets, both newly excavated canals (ao Rio Martino and Decennovium) and canalized rivers (Figure 3). This drainage system made use of the natural relief within the landscape, thus not using pumping devices.

On-going environmental research by the authors shows that the ecological implications of these changes were probably profound, although not uniform or sustained. The cadastrated area was used for a combination of arable faming (as suggested by macrobotanical remains of emmer wheat and ruderal plants) and different kinds of pastoral activities. However, the relative dryness of the landscape seems to have varied within the area, and we may envisage specific locations with different levels of wetness being used for different kinds of activities. Moreover, radiocarbon dates from deposits filling the ditches of the cadastral system show that parts of this drainage system already

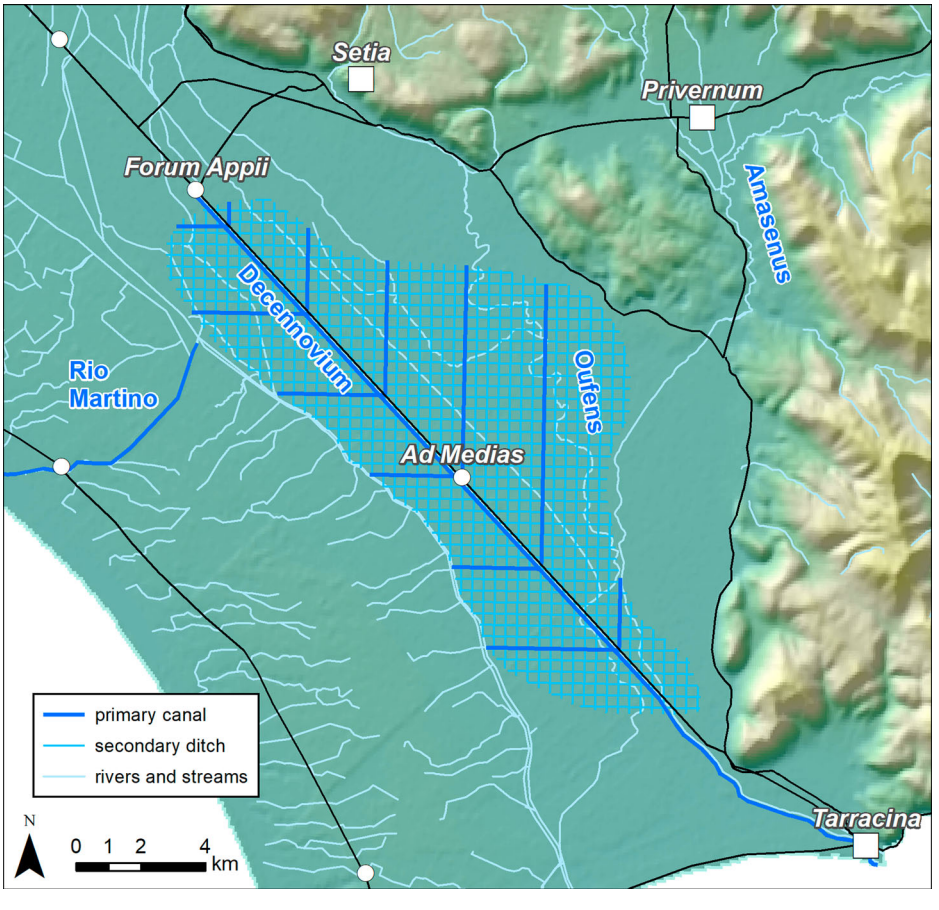

Figure 3. Reconstruction of the Pontine cadastre and associated drainageways (after De Haas forthcoming).

went out of use in the Roman Republican period, with concomitant changes in both the aquatic environments of remaining ditches and canals and in the adjacent ruderal landscape. Such changes are reflected in the distribution of settlements, which in the second and first centuries BC and the first century AD increasingly focused on areas close to the main drainage axes (and the associated road infrastructure of the Via Appia). The problems with drainage of the marsh were further aggravated by subsidence of the peatlands and sedimentation by the Amaseno river near the coast, which blocked the outlets of the main drainage ways. Thus, while cultural factors (Roman state-level interferences) were for a while quite dominant in the development of the landscape, it seems physical geographical factors posed insurmountable obstacle to sustainably manage the reclamation landscape.

Timeslice 3: The Middle Ages

Already in Roman Imperial times, traces of human interferences in the Pontine marshes become more sparse: from archaeological research we know that virtually no settlements existed in the area from the third/fourth century AD onwards (except for a few sites along the Via Appia), and that the drainage system had stopped functioning. This meant that as a result of technological and organizational limitations (a lack of capacity to maintain the drainage system), the landscape reverted into a marsh, with expanding peatlands at its core. Although environmental data for this period are scarce, the landscape changes must have led to an expansion of marsh vegetation and forests along its margins, at the expense of ruderal and arable vegetation types.

While archaeological sources suggest settlement all but stopped, written sources do suggest the marsh continued to be an important economic asset for people from the towns on the edge of the mountains surrounding the marsh: local noblemen leased out rights to hunt, fish and extract wood, and also tried to reclaim areas within the marsh. These attempts were generally short-lived and unsuccessful (Linoli 2005; Walsh, Attema, and de Haas 2014).

Timeslice 4: The Early Modern Period

In early modern times (sixteenth to ninteenth century AD) we see a gradual increase of human interferences in the landscape: not only was the marsh exploited more intensively, it was also exploited in different ways. Besides a more intensive and commercial exploitation of wetland resources (e.g. large-scale production of charcoal and exportation of timber), pastoral and small-scale agricultural exploitation expanded with the foundation of semi-permanent settlements (so-called *lestre*). Moreover, serious attempts to once again reclaim the marsh were undertaken by the papal state; the most notable of such projects, undertaken by popes Sixtus V in the late sixteenth century and by Pius VI in the late eighteenth century, entailed extensive drainage works focused around the re-excavation of Roman drains (Decennovium, renamed Linea Pio; Fiume Sisto) and the construction of agricultural estates in the marshes (cf. Linoli 2005).

Despite the increased organizational and economic capacities of the papal state, these reclamation projects did not result in the permanent reclamation of the marsh. Several factors contributed to this: political and especially financial troubles of the papal state, a dependence on old technologies (e.g. windmills were not used for water pumping), but also fierce opposition from local peoples who saw their economic resources

threatened. Natural processes played their part as well. On-going sedimentation blocking waterways and short-lived events (flash floods) made the drainage system of the area vulnerable and difficult to maintain. The ecosystem itself also played a crucial role: diseases, in particular malaria, spread by *anopheles* mosquitoes, put tremendous stress on the population.

At the same time, these attempts did leave a sustained mark on the landscape, and must have had an effect on ecosystems and biodiversity as well – even if we again dispose of little data to reconstruct these effects. We may imagine that the more varied use of the landscape led to the rise of new landscape niches (e.g. a combination of arable land, marshlands, meadows and forests) and perhaps increasing biodiversity. At the same time, intensive exploitation may have led to the decline of some of these niches, especially forests, and associated animal species such as fish and fowl.

Timeslice 5: The Twentieth Century

After the unification of Italy and WWI, the 1920s and 1930s witnessed a profound anthropogenic transformation of the landscape: the reclamation – or *bonifica integrale* – of the Pontine marshes became one of the most important political, economic and ideological projects of the fascist regime. This reclamation not only drained the marshes for arable cultivation, but also entailed a massive planned migration of colonist farmers and the 'sanitization' of the area through attempted eradication of diseases, most notably again malaria.

The scale and impact of these reclamations was massive, as some summary statistics highlight. In total 1175 km^2 of terrain were drained through a system of main canals (in total 283 km), secondary canals (1289 km), and ditches (2.122 km); 10.000.000 m^3 of soil and 4.000.000 m^3 of stone were used to construct dikes and fill depressions; waterflows were regulated through two large and c. 20 smaller pumping stations. Subsequently, an almost entirely new infrastructure was laid out, which included 1.380 km of roads, 13.515 km of roadside ditches, 1280 km of irrigation canals and 4538 water wells. Besides the few small pre-existing settlements, 4198 farmsteads, numerous hamlets and borghi, four larger villages and one city (Littoria/Latina) were constructed (data after Linoli 2005; 44 and Massaro 2005, no page number). Thus, the Pontine marshes were drained and turned into agricultural land.

It goes without saying that these interventions had a tremendous impact on ecosystems: marshes with their associated flora and fauna largely disappeared, and thousands of hectares of forest were cut down; some stretches of forests near Terracina and west of monte Circeo (now a nature reserve) were preserved, but also thoroughly 'cleaned' of shrub vegetation in order to combat mosquitoes. Ruderal and arable vegetation expanded, new species were introduced; famously, eucalyptus trees were planted to absorp water and break the wind. With the reclamation of the marsh environment, malaria (and the mosquitoes that spread it) was combatted with chemicals such as carburol and later DDT, with highly adverse environmental effects.

Timeslice 6: Now and Further

Since the Fascist reclamations, the Pontine landscape has witnessed a gradual increase in the intensity of agricultural and industrial exploitation as well as in settlement. Farming of cereals and maize takes place on an industrial scale, while on better soils fruits and

vegetables are grown. These types of agriculture are water-intensive, put tremendous strains on water supply systems and have contributed to rapid soil deflation (Serva and Brunamonte 2007; van Gorp and Sevink 2019). In addition, industrial areas, urban sprawl and particularly solar power plants have expanded over former agricultural areas. With these activities, wetland ecosystems have disappeared (a few nature reserves excepted). Thus, while cultural factors have increasingly come to dominate over physical geographical and biological processes, current land use practices will lead to continued subsidence and may prove to be ultimately unsustainable (cf. Sevink et al. forthcoming).

The Onlanden

Timeslice 1: The Bronze and Iron Age

Weichsel ice age coversand landscapes dominated the wider area until about halfway the Holocene, but gradual sea level rise resulted in these being covered by peat and clay sediments. Remnants of Neolithic occupation in particular are occasionally found on top of the now buried coversand landscape (see f.e. Groenendijk 2008; Kamstra, Peeters, and Raemaekers 2016). This is also true for the Onlanden area, where Neolithic remains surfaced in the southernmost part, where the cover sand deposits occur on slightly smaller depth (Hoebe 2018). The gradual drowning of the Onlanden landscape initially resulted in a predominantly oligotrophic peatland landscape.

Eutrophication of the area set in before the Bronze Age. This transformed the area into a eutrophic mire landscape (Aalbersberg 2018). Human impact on the landscape, or at least, signs of human presence in the area are virtually absent. Palynological research shows somewhat higher cereal values for the early Bronze Age, but the chronological resolution does not exclude the possibility that this actually still concerns a Late Neolithic signal (Woldring and Zomer 2009). Moreover, these values probably reflect activities on the adjacent higher sand soils and not the peat area itself. The eutrophic phase lasts relatively short and in the central part of the Onlanden, bog peat starts to grow in the Late Bronze Age. Overall, physical-geographical and biological processes dominate the landscape, cultural processes play a minor role.

Timeslice 2: The Roman Period

The area remains a largely deserted wetland throughout the Roman period (Nicolay 2018c, 790). There are some minor indications for human settlement on the peatlands (Wieringa 2010), but these must have been scarce and their impact on the landscape was probably negligible. It is in this period, that the habitation on dwelling mounds on the salt marshes north of the Wadden Sea grew considerably (Bazelmans et al. 2012). Traditionally, archaeologists have had some attention for relations between the people inhabiting the salt marshes and their contemporaries in the sand districts (Van Zeist 1988), but the peatland areas are considered virtually empty. In the northern part of the Onlanden, near Matsloot, peatland formation comes to a halt in this period, as the area gets covered by clay (Woldring and Zomer 2009). Some natural succession may have occurred in peatland vegetation in the southern part of the Onlanden. The balance between the three driving forces as defined for the landscape triangle has not changed much compared to the preceding period.

Timeslice 3: The Middle Ages

From the tenth century onwards, people carried out major reclamation activities in the peat area, as well as in the clay-on-peat area in the north of the Onlanden. These activities took place in several phases, gradually spreading over the area from the clay areas in the north (Zomer 2018). The now dominant theory is that, in contrast to many other peat reclamation activities in the Netherlands, no large religious or worldly power initiated and coordinated these activities, but that they must be considered local initiatives, possibly lead by a historically poorly visible local elite (Zomer 2018, 84; see also Zomer 2016). Dozens of raised farmsteads were created in the area, whereby different types arose in response to local variations in hydrology and sedimentology, for example by the presence of a clay layer on the peat deposits in the northern part of the area (Nicolay 2018b; see timeslice 2).

Characteristic for the direct human impact on the landscape are the numerous ditches that were dug in the (clay-on) peat area to allow agricultural usage of the grounds surrounding the farmsteads. Botanical analyses show that pasture and meadowland dominated the area from the very beginning, ultimately resulting in an 'agricultural industrial area', with a clear emphasis on animal husbandry. With perhaps the exception of the vegetation in the ditches and a rare bramble thicket, virtually all vegetation was clearly synanthropic in nature. Arable farming, if at all, took place on a very limited scale only (Schepers 2018). In terms of affordances, this implies that, whilst arable farming did play a major role in feeding the population, the Onlanden mainly offered opportunities for animal husbandry.

The botanical analyses also show that the, already quite wet, area, was becoming wetter and wetter over the centuries, and ongoing clay sedimentation occurs in the north (Figure 4). Throughout the Medieval reclamation period, which lasted until the fourteenth century, people were constantly modifying the landscape and some of the farmsteads were abandoned at an earlier stage already. The ongoing problems with water management eventually caused people to abandon the area.

The balance between physical-geographical, biological, and cultural processed shifted dramatically in this stage. Cultural processes significantly impacted the landscape. Within this timeslice however, people were already experiencing the consequences of their actions.

Timeslice 4: The Early Modern Period

Most farmsteads are indeed abandoned in the fourteenth century, but some of these are occasionally visited over the following centuries. The exact nature of human activities in this period is unclear, but permanent habitation must have been reduced to an extremely limited number of somewhat higher elevated platforms. These scattered and few homesteads made use of existing ditch patterns and probably maintained the ditches in the direct vicinity of their houses, but the large-scale systematic ditching and parceling that characterized the medieval landscape are lacking in this stage. The landscape became wetter, as reflected in the wetter grassland types reconstructed through palaeoecological analyses. It cannot be determined whether or not habitation in this phase was year-round or seasonal. In the nineteenth century, the last remaining farmsteads were abandoned. From that time onwards, extensive seasonal exploitation of the area only took place by farmers living at the higher grounds surrounding the Onlanden.

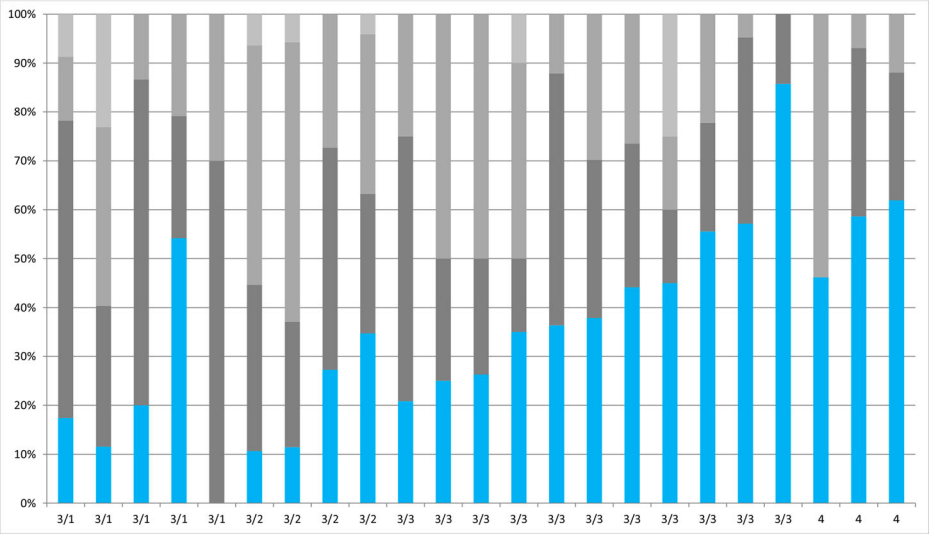

Figure 4. Archaeobotanical samples covering habitation in the Onlanden throughout the High Middle Ages (stages 3/1-3/3) and early modern period (stage 4) show that the area becomes wetter throughout time. Blue: relative proportion of wetland taxa in a sample; Grey: other taxa (After Schepers 2018).

Timeslice 5: The twentieth Century

The area was not repopulated in the twentieth century. Nevertheless, land use intensified, which required new ditching and modern pumping stations to get rid of excess water in the summer months in particular. Moreover, fertilizers allowed for the development of agriculturally valuable, but ecologically poor grasslands in parts of the area. In this phase, maize was grown in addition to the area being used for grazing and especially hay-making. Evidenty, all of these activities, including maize production, testify to animal husbandry once again being the primary form of land use.

Timeslice 6: Now and Further

Relative sea level rise makes it increasingly difficult to discharge water on the Dutch coast by opening up the sluices on the sea side. Thus, there is an increasing necessity to be able to temporarily store water in so-called water retention areas. Again, in terms of affordances, the Onlanden provided excellent opportunities for this particular function, and was indeed transformed into such an area. This involved much more than simply abandoning the present land use. The purpose was to transform the area into a landscape that combined the 'functions' wet nature and water storage. A series of (small) dikes was built around the area. Within these dikes, parts of the landscape were actively lowered by big machinery. The unequivocal agricultural appearance of the area, consisting of numerous straight and evenly distributed ditches, was no longer useful and considered aesthetically undesirable from a 'nature' perspective. While you do not need a trained eye to recognize this agricultural history when visiting it now (cf. Figure 2), the massive transformations are undeniable. The cultural landscape has not been considered a factor in this process. So far, the Onlanden is considered a success, and even a good practice example on the national level in terms of climate adaptation measures. This

includes both the nature development and water storage potential in the area (Veraart et al. 2019).

Comparing The Evolution of the Pontine Marshes and Onlanden

From this diachronic overview it is clear that both study areas undergo massive changes over time, but that these changes follow different paths. In order to compare the development of these two reclamation landscapes, we have used the information presented above (summarized in appendix 1) as a starting point for the infill of the triangles (Figure 5).

In the Bronze and Iron Age, signs of human presence in the Onlanden area are extremely limited, in the Pontine Plain human interferences were slightly less faint (Figure 5(a)). Although the Onlanden landscape changes in Roman times, these changes are almost completely natural. This means that the Onlanden does not change position in the triangle. For the Pontine Plain, however, the Roman period is the first time slice in which major reclamation activities take place, which has a major impact on the balance between the driving landscape forces (Figure 5(b)).

After Roman times, the influence of cultural forces on the Pontine Plain landscape heavily decline. The opposite happens in the Onlanden Area, where major reclamation activities take place. However, a constant struggle with water, both in the form of events (flooding) and gradual wetting of the area over time, made us decide to move the Onlanden area slightly more towards the physical geographical corner than the biological corner (Figure 5(c)). The Onlanden and the Pontine Plain more-or-less switch positions again in early modern times, without the Onlanden becoming as 'natural' as in Prehistory again. The medieval farmsteads are re-used by a small group of farmers, not actively carrying out reclamation activities themselves. The history of the area thus allows for these activities (Figure 5(d)). Interestingly, we see a similar development in the Pontine marshes, yet with a more profound impact on the landscape: here renewed reclamations also build on the infrastructure and drainage laid out in Roman times.

While industrialization and modernization affect both the Onlanden and the Pontine Plain in the twentieth century, the degree of landscape transformation and the role of cultural processes therein still differs. Where the Pontine Plain transforms into a heavily exploited agricultural area with extensive infrastructure and complete villages and towns, the Onlanden are no longer inhabited themselves. Yet, cultural processes heavily affect the area and pull it towards the cultural corner (Figure 5(e)). Interestingly enough, the strongest divergence between the two areas in terms of the balance between the driving landscape forces happened only recently. Agricultural activities have been abandoned in the Onlanden, and the development of wet nature has become an explicit purpose for the area. This simultaneously serves physical-geographical as well as biological processes, and, arguably, societal challenges. Whilst this transformation away from the cultural processes side of the triangle is evidently heavily steered by cultural decisions and evolving perspectives, the resulting landscape is profoundly less culturally dominated in its physical manifestation. Such a shift has as of yet not happened in the Pontine Plain (Figure 5(f)).

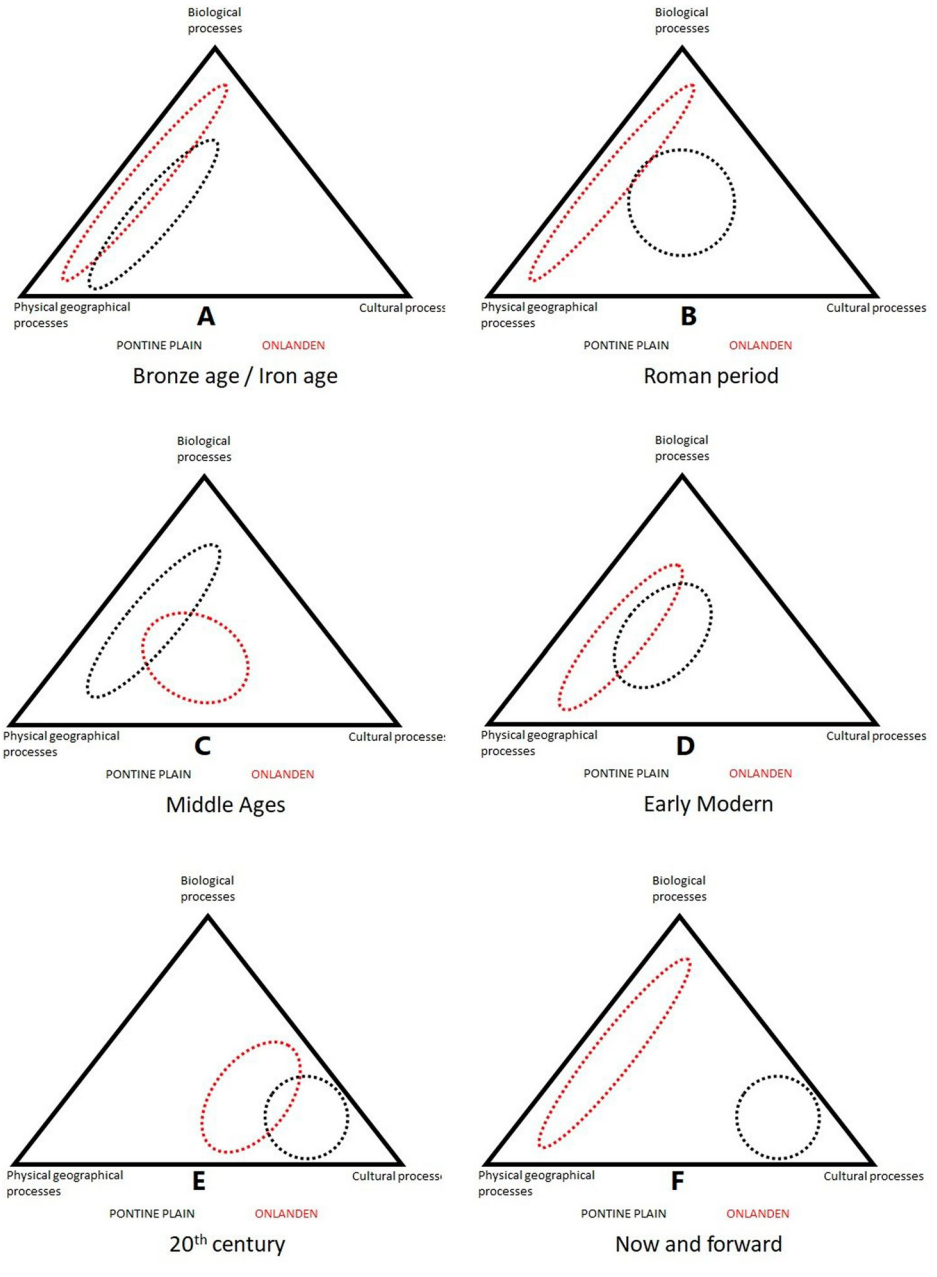

Figure 5. The landscape triangles filled in for the different time slices for both study areas.

Our period-by-period comparison allows for some interesting observations about the evolutionary trajectories of both landscapes and the role of different processes therein. First, it appears that throughout time, cultural processes were more dominant in the Pontine marshes than in the Onlanden; only in the Middle Ages this balance seems to have been reversed. We might explain this difference in terms of the socio-political centrality of both reclamation landscapes: throughout history, the Pontine marshes were

situated close to the core of a major empire and, later, strong states which would have the technological and financial means to interfere directly and on a large scale. This can certainly not be said for the Onlanden, which would have been exploited by smaller-scale rural communities and, at times the relatively modest urban polity of Groningen.

Another point that arises is that, despite (at times massive) technological inputs and investments, in both cases up to the twentieth century physical geographical and biological processes were decisive in the long-term development; past societies were not able to maintain the landscape in a stable shape for more than, perhaps, a few hundred years at most. While we acknowledge that the abandonment of settlements and drainage works may have been a conscious choice, such choices were to a large extent caused by natural processes (e.g. soil deflation, the blocking of drainage). Continued reclamation of these areas was beyond the technological and organizational capacities of societies in both areas.

In that sense, reclamation itself was not as resilient as we might think from our present-day perspective, in which people seem to have the technological means to dominate the landscape in all its aspects. However, the Onlanden case clearly shows that while this may in principle be true (man decides to rewild this area), this is in fact still a consequence of the changing natural context (climate change, drainage issues). In this sense, the Onlanden might well serve as a model for the future of the Pontine plain, where a continued domination of cultural processes to maintain this area as an agricultural landscape seems unsustainable and arguably also undesirable in light of sea level rise, water deficits and soil deflation.

Discussion

Above we presented the comparative application of the triangular model and highlighted some of the most interesting points that emerge from this comparison. While we feel these clearly show the usefulness of this approach, there are aspects of our approach that deserve further discussion. This discussion will also form the starting point for a broader evaluation of the potential uses of the comparative application of the model.

It should be emphasized that our approach is not based on a direct comparison of a fixed set of (quantifiable) proxies. Both areas are characterized by very different histories of field research – the Onlanden have seen systematic excavation and palaeoecological analysis, the Pontine plain mainly systematic field surveying and palaeo-geographic studies. Also, written sources are totally lacking for the Onlanden in the Roman period (which is located outside of the then Roman empire), and these are very scarce for the Middle Ages. Archaeological data, however, are rich and of high quality thanks to extensive recent investigations. Interestingly enough, the balance between written sources and archaeological data for the Middle Ages, is more or less reversed for the Pontine Plain, where written sources are available, but archaeological data are few. All this implies that the data themselves are highly heterogeneous and hence the filling out of the triangular model is an interpretive process rather than a neutral exercise in direct data comparison.

That being said, we argue that the nature of the triangular model actually allows it to be applied much more widely than quantitative approaches. Although quantifiable proxies might be used to analyse the different processes explored here, our more intuitive approach is much better suited to consider the diverse knowledge about physical-

geographical, biological, and cultural processes. It can thus provide a richer and more complete basis for comparison – even if it is difficult to disentangle physical-geographical and biological processes, or to assess which processes dominate as causal relationships within processes of change, can often not easily be determined. This is in no way meant as a disqualification of measurable data in general, but we argue our approach forms a flexible complementary way to compare long-term trends in landscape evolution.

In this, the triangular model also brings a more balanced perspective. In much scholarship, landscape change is mainly considered along the lines of the classic 'nature-culture' dichotomy; in other words, primacy is given exclusively to cultural and biological factors, while the physical geography is primarily viewed as a static background (Schepers et al. 2021 for a discussion; *cf.* Bintliff 1991; Smith 1992). However, in wetland landscapes in particular, physical geographical processes such as peat oxidization, soil compaction, and flooding-induced sedimentation are too big of a factor to not treat separately. The triangular model considers such processes as potentially equally influential as the archaeologically more tangible cultural and environmental processes. As we have tried to show in Section 5, the concept of affordances (Gibson 1986) provides an excellent tool to make this interaction more explicit.

A comparative analysis of reclamation landscapes also proved to be highly enlightening for us as individual researchers working within different research traditions and studying distinct cultural and historical contexts. Sitting together as researchers working in two areas that do not share a direct socio-political, socio-economical, or physical-geographical element, we both acquired a fresh and critical 'outsider' perspective on our study regions, which allowed us to clearly identify strengths of and gaps in our respective datasets. Such new insights can aid in steering future research to fill gaps or exploit further strengths.

While this study only provides an initial comparison, of arguably quite distinct contexts with limited historical similarities, we have thus found this experience rewarding and see ample scope for future work using this approach. We stress that the model is versatile, and can be applied to a variety of landscapes (not only reclamation landscapes) in different historical contexts and with different histories of research. It allows us to systematically develop a broader view on (different types of) landscapes and to identify potential patterns in their development. For example, by expanding the present study, we could better understand long-term human-environment interactions in reclamation landscapes on a European or even global scale. This includes not only the physical attempts to alter the landscapes, but also collects a history of ideas and mentalities.

Of particular interest in such a broader comparative framework would be the identification of recurring developmental patterns – and the parameters that cause such patterns. For instance, we here compared two reclamation landscapes of quite different size (the Pontine marshes is considerably larger than the Onlanden area). Although this is no problem on a conceptual level, it might be the case that spatial scale is an important parameter (e.g. large reclamation landscapes may prove to be less stable and/or more prone to rapid transformations). Similarly, other parameters might prove to cause recurrent patterns in the evolution of reclamation landscapes. Did states and empires, disposing of ample resources and technological knowledge and often reclaiming landscapes in radical ways, perhaps in general introduce less sustainable forms of reclamation than smaller-scale societies – as may be suggested by our two case studies? To what extent

were prior engagements with the landscape crucial for successful management and exploitation of reclamation landscapes?

These considerations also necessitate a renewed consideration of the relation between reclamation, reclamation landscapes, and resilience. As stated in the introduction, the prime objectives of reclamation landscapes seem to collide with resilience: they explicitly aim for a drastic landscape transformation and thus a 'system change'. In various wetland landscapes, however, reclamation activities over time repeatedly faced challenges posed by the wetland landscape itself, be it sometimes with extreme delay. Perhaps, the wetland landscape rather than ancient society did withstand reclamation after all, and has proven itself patiently resilient.

In light of the theme of this special issue, we should also address the relation between landscape evolution and cultural heritage in the present. In this contribution, we not so much emphasize the threat human reclamation works in wetland landscapes pose to existing cultural heritage, but rather acknowledge that the reclamation elements are part of cultural history in itself. This holds true not only for their physical remains (elements such as ditches, canals, and dikes), but also the history of thought and mentality, and the knowledge about the landscape that affected how people delt and deal with wetlands. Whether we like it or not, reclamation activities had a huge impact on the landscape and have thus become part of our environmental heritage (Matthes 2019). So, even when restoring wetland landscapes, their history affects today's possibilities (Norstedt, Hasselquist, and Laudon 2021).

From a long-term perspective it is clear that the notion of a 'pristine' or 'original' landscape to which the current landscape might revert through rewilding or other measures, is misguided: reclamation landscapes have constantly changed, not only as a result of continuous human interferences, but also because of environmental and physical geographical processes. But this does not mean that we advocate against (nor in favour of) major modern transformations of reclamation landscapes away from the cultural side of the triangle. Rather, we hope to have shown that a less linear thought about landscape developments could potentially serve as an inspiration to make current major changes appear less dramatic, but rather consider them as just another step in a dynamic, non-linear process of landscape evolution.

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Appendix 1. Summarized characteristics of the study areas with respect to the main driving processes.

	Pontino			Onlanden		
Time slice	Physical geography	Ecosystems	Cultural factors	Physical geography	Ecosystems	cultural
1. Bronze and Iron Age	shallow lake with surrounding peatland and levees	Freshwater marshes with surrounding oak forest and shrub vegetation	Small-scale settlement on fringes involved in woodland exploitation, pastoralism and arable farming	Coversand landscape	Dry forests	Bronze and Iron age settlements, arable farming
2. Roman period	Relatively dry peatland/floodplain	Species-rich grassland, ruderal and arable vegetation	managed landscape with drainage infrastructure, roads, villages and isolated fams; meadows and arable farming	Peatland landscape	Bogs and mires	Virtually empty/not detected
3. Middle Ages	Peatland/floodplain	Freshwater marshes with forests and shrubland	sparse seasonal settlement; fishing, hunting and woodland exploitation	Oxidizing peatlands	Species rich synanthropic grasslands, eutrophic ditches	Pastures and meadows, modest house platforms, small scale arable farming
4. Early modern	Peatland/floodplain	Freshwater marshes with forests and shrubland	(short-lived) Attempts at reclamation, reviving drainage infrastructure; seasonal agricultural expoitation (lestre) from inland areas and adjacent towns	Wet landscapes, some settlements, but coversand outcrops emerging	Species rich grasslands, eutrophic ditches	Population density declining, partial abandonment, last settlements abandoned nineteenth century, pastures and meadows
5. twentieth century	oxidizing peatland/dry floodplain	grassland, ruderal and arable vegetation	Large-scale landscape transformation: *bonifica integrale*		Species rich grasslands, eutrophic ditches	No settlements, seasonal use for grazing
6. Now	Oxidized, subsiding peatland and floodplain	Grassland, agricultural areas, urbanization. High decrease in biodiversity as a result of nitrogen deposition, industrial pollution and lowering of water table	'industrial' farming, urbanization, expansion of solar power plants	Permanently wet landscape	Mires and marshland, partial open water	Water retention area, as well as 'nature' as function. Agricultural use abandoned