Land and Water, Land to Water, Water to Land: Resources, Extreme Events, and Institutional Development in Medieval and Early Modern Rijnland (The Netherlands)

Sander van der Leeuw

School of Human Evolution and Social Change

Arizona State University

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Abstract

This paper uses a case study on the evolution of a small Rhine river delta area in the Netherlands, to illustrate the land-water co-evolution of the environment, the technology used to exploit it, and the institutions established to govern it. Three strands thus are interwoven in this paper:

(1) Land needs to be protected yet utilized. However, an equilibrium between both is not always easy to achieve. In this part of the Rhine delta, as a result of exploitation, we see shifts from agriculture on fertile peat to stock-raising on infertile peat, to peat extraction, to inundations, and to drainage in order to regain fertile soil.

(2) In the dynamic between collective authority and individual ownership which accompanies these changes, and which, elsewhere, has been called 'the dilemma of the commons', we observe here how individuals beget institutions and institutions beget individuals.

(3) In the process, new technologies are invented, but these always have unintended and unexpected consequences. They enable us to overcome challenges posed by the natural environment, until eventually the consequences of that conquest undermine the conquest itself in a dramatic manner. Then, new technology needs to be brought in and the cycle repeats itself.

Together, these three dynamics jointly drive the region further and further from its point of departure … towards the bottom of the sea.

Introduction: the Pre- and Proto-History of the Area

The area presently called ‘Rijnland’ in the Netherlands is situated just behind the Dutch coastline between two ancient branches of the Rhine near its mouth. The term ‘Rijnland’, however, is also used for the administrative entity that governs water management in the area. In this chapter, I will try to show that such conjunction is not accidental. To do so, I will describe the genesis and evolution of the area through time from around 2000 BC to the present. In that period, the natural dynamics of the region were completely brought under control of humankind, or to use the term of Tim Ingold (1982): ‘*Nature was appropriated’*.

Like every river, the Rhine has for tens of millennia deposited large amounts of gravel and sand in front of its mouth, along the North Sea. As the sea level rose under the impact of climate change, and the deposits built up simultaneously, river flow slowed down, and the level between water and land diminished until in many places it was only a few feet in difference. A true delta emerged, in which the sea and the river continually struggled for dominance. Sometimes above and sometimes underwater, the natural levees became areas on which vegetation took root. But as long as the sea regularly inundated it during winter storms, and deposited large amounts of sand on the levees, the vegetation could not really establish itself.

Around 2000 BC, currents in the North Sea shifted and caused the slow buildup of a row of levees (‘dunes’) that protected the area immediately behind it from the sea (van der Leeuw, 1987, Brandt & van der Leeuw 1988). Although other branches remained ‘open’, the largest mouth of the Rhine shifted towards the North, freshwater accumulated further south, and as the vegetation flourished in the zones that were now protected from the sea the area became a peat-marsh.

Eventually, people settled in that marsh, initially on small tufts of peat that were a little higher than the surrounding landscape, and on the edges of the creeks that drained the area. These early settlements consisted of a very small number of houses (generally 1-4). People exploited the land by planting some cereals and other edible plants and by allowing some domesticated cattle and sheep to graze there (Brandt, van Wijngaarden & van der Leeuw 1984). But the battle against the water dominated their lives. One finds drainage ditches around the individual houses, and with time, individual houses were built on small artificial mounds ('*terpen'* in Dutch) to ensure that they were not inundated in periods of high water when storms or high tides in the North Sea blocked the Rhine's mouth and freshwater accumulated behind the dunes (Figure 1, *cf.* Brandt, Groenman & van der Leeuw, 1987).

FIGURE 1 ABOUT HERE

To cultivate their crops, people also had to drain the peat. But as soon as the water table was lowered, the (drying) peat either oxidized (burnt away) or blew away, lowering the level of the land. This engendered a positive feedback loop that lowered the land, made drainage more and more difficult, and heightened the danger of inundations. The drainage ditches grew longer and longer, eventually creating a complicated system that has been laid bare by archaeologists. These longer ditches are the first sign that people began to collaborate and organize themselves in the battle against the water.

By about AD 900, the inhabitants' strategy in dealing with the water changed – they began to collaborate in enclosing certain small surfaces by means of artificial defense systems (dikes, '*dijken'* in Dutch) that were several meters high. The labor involved could never have been accomplished without a common effort, and we may interpret this as a sign that local collaboration and organization had reached a new level.

The Middle Ages: Keeping the Land Dry Leads to the Formation of Rijnland

Around 1000 AD, another factor entered into effect: the political organization of the area (cf. van Tielhof & van Dam, 2006, the most recent authoritative work on the history of Rijnland, upon which I have heavily relied for this paper, including for the illustrations[1]). Feudal lords began to play a role in the western part of what is now the Netherlands. An endless series of skirmishes between small local potentates ultimately created a political hierarchy. Not surprisingly, this process was somewhat more advanced in the drier parts of the delta than in the wetter areas nearest the coast. In particular, the bishopric of Utrecht, situated on 'higher' ground (the sandy moraines left by the last Ice Age), had a longer history as a political entity than the 'lower' areas immediately behind the dunes, collectively called '*Holtland*' ('the woodland', from which the current '*Holland'* derives). The two areas, Holland and Utrecht, remained politically distinct for most of the Middle Ages, though there was the usual series of political and military conflicts between the Counts of Holland and the Bishop of Utrecht.

During this time, Holland was administratively divided into several parts (so-called '*baljuwschappen'*), of which two are particularly important for this story: *'Rijnland'*, with Leyden at its center, and *'Kennemerland'* with Haarlem as its focus (cf. figure 2 a). Both towns were located at the easternmost edge of the natural levees ('dunes') that protected the landscape from the sea and were therefore themselves relatively safe from inundation.

FIGURE 2 ABOUT HERE

Around AD 1150, the mouth of the ('Old') Rhine to the west of Leyden was definitively closed by the lateral northward transport of large amounts of sand in the current along the coast.

[1] I owe Jan Kolen (Free University, Amsterdam), for drawing my attention to this magnificent overview, and for procuring me a copy of it.

This caused the area behind the dunes to suffer more frequently from inundation, and by AD 1280 collective action had to be taken on a larger scale. Not surprisingly, the first major collective intervention – the damming of the Rhine upstream to protect the inhabitants of *Rijnland* from flooding by the river – occurred at the boundary between Utrecht and Holland (cf. figure 2b). Canals were then dug from Leyden to the North and the South, to ensure that the area's surface water could be evacuated without danger to the population of *Rijnland*. But canals have the unfortunate property that they can, if the water level inverts, also be sources of flooding. Hence, sluices had to be constructed at the mouth of both canals (see fig. 2b).

Nevertheless, *Rijnland* remained very vulnerable to flooding, especially from the North, via the two large lakes (*'Zoetermeer'* and *'Haarlemmermeer'* respectively) to the north of Leyden. It quickly became clear that to protect the *Rijnland* from this danger, cooperation was necessary with *Kennemerland* so that a dam and a sluice could be built at the hydrologically most propitious location; this was along the edge of the open mouth of the Rhine to the north of Haarlem.

This cooperation is the first tangible sign that water management has its own rules and its own geography, which do not necessarily follow those of politics or administration. One cannot safeguard against flooding if there is no unified management. The risk is too great that differences of opinion lead to disaster. Hence, for the purposes of water management, and water management only, the southern part of *Kennemerland* soon became part of *Rijnland*. In doing so, a typically Dutch solution was found: to create a 'water authority' that could impose its power on all the different political and administrative authorities within its territory, including the highest, *in so far as water issues were concerned.* From this point forward, there were two '*Rijnlands*', that of the *baljuw* (the highest civil administrator representing the count), and that of the *'dijkgraaf'* (not accidentally called the 'count of the dijken' (dams). The territory of the latter (marked in a red dotted line of fig. 2a) exceeded that of the former.

The Early Modern Period: Land is Turned into Water

Once drained, peat is incredibly fertile as it consists entirely of decaying or decayed organic matter. Once the medieval water problems at the regional scale had been solved, therefore, the area very quickly became a rich and intensively cultivated agricultural zone. But maintaining the agricultural intensity depended on the ability to continually drain the land. Between plots of cultivated land, narrow ditches (*'sloten'*) were dug to drain them. These drainage ditches ended at larger artificial or natural waterways, evacuating excess water to the main streams or canals crossing the territory of Rijnland.

As a result of the shrinking of the peat inherent in this loss of water, as well as the oxidation of the organic material due to the intensive cultivation, the surface of the peat descended about one meter per century, coming closer and closer to the subsurface water table (fig. 3). Initially, because the land became wetter, its fertility declined, as did the yields of the farmers cultivating it. But ultimately, the surface of the land actually descended below that of the water. Urgent solutions were needed, again requiring major investments.

FIGURE 3 ABOUT HERE

As a consequence, dams (*'dijken'*) were built on both sides of the draining waterways to prevent the land from further flooding. But to remove excess water, it now had to be moved up and away, instead of downward. To solve that problem, horse- or wind-driven watermills were introduced in AD 1408, which pumped the water up from the drainage ditches into the major waterways. A map from around AD 1480 (fig. 4) shows the number of mills dotting the landscape at that time.

FIGURE 4 ABOUT HERE

However, lowering of the land surface with respect to the water table also changed the economy of the area. The local reduction in the cereal yield occurred at a time when, elsewhere, grain was cheap and easy to obtain. Hence, it became more attractive to let the land (now often soggy) revert to pasture for grazing cattle and sheep. Milk and butter, as well as meat, fetched good prices in the growing number of towns of the area but required much less labor than cereal cultivation. In turn, this forced many marginal farmers to find other means of subsistence. Some adopted other rural professions, such as fishing, but many of them moved to the towns, where there was demand for cheap labor in such typical urban activities as trade and industry.

The 14th to 16th centuries saw a very important expansion of urbanization in the area, under the impact of rapidly growing long-distance trade and the industrial production of trade goods. In particular, the Dutch coastal towns of the 13th century became involved in trade between the Baltic countries, Great Britain and the Atlantic coast of France. They brought dried fish, pelts, and other Nordic items to Britain and France, exported British wool to Flanders and Flemish (woolen) cloth to both France and the Baltic, and transported wine from the Garonne area in Aquitaine to both Britain and the Baltic. As that trade intensified, the Dutch coastal towns of Leyden, Haarlem, and especially Amsterdam, grew rapidly and began producing their own trade goods.

These industries that emerged in the 14th century needed fuel, and by this point most of the original *Holtland* had little forest left. Indeed, the only locally plentiful fuel was the (dried) peat that was sold in the form of turves for heating and industrial production to such ends as pottery making. Consequently, the price of turves increased drastically, and more and more farmers reverted to digging away their land and selling it as fuel. Relatively quickly, this created surfaces of open water, which, in turn, became a danger to the remaining land by undermining its stability and subjecting it to flooding in stormy weather (cf. figs. 3, 5a, 5b).

FIGURE 5 ABOUT HERE

In the last phase of the Early Modern Period, major collective activities were made possible by concerned volunteerism, which was subsequently replaced by wage labor paid for by a land tax imposed by the authorities of the (now) *Hoogheemraadschap Rijnland*. As land was progressively dug away, of course, this reduced the revenue necessary for the maintenance of the dams, canals and sluices that kept the water under control. Hence, the water authorities limited peat extraction and forced those who practiced it to buy other tax-liable land to compensate for the loss of income. In the process, the water authorities gained control over aspects of *land* management.

This was made all the more urgent because the increase in open water required a reorganization of the water management. Improved sluices were installed along the northern edge of *Rijnland*, which opened to drain the land during ebb and closed to protect the land at high tide (cf. fig. 6). To realize these improvements, the *Hoogheemraadschap* took control of and responsibility for all the dams and related engineering works in the area, further extending its control.

FIGURE 6 ABOUT HERE

The 'Golden Era': Water is again Transformed into Land

In the Netherlands, the period 1550-1650 is commonly called the 'Golden Century.' It is the era in which the Dutch gained their freedom from Spain after a war that lasted 80 years

(1568-1648), their merchant fleet vied with the British for control of the Oceans, and Dutch merchants, particularly from the western part of the country (*Holland* and *Zeeland*), founded trading posts and colonies around the world (Dutch East Indies, Southern Africa, Brazil, Eastern North America, etc.). The Dutch coastal cities grew exponentially, and Amsterdam became one of the capitals of the world. Many of their inhabitants profited from the rural poverty to buy up tracts of agricultural land, grassland, or peat (cf. fig. 7). From this point onwards, the towns had a direct economic interest in the countryside. In this phase of Dutch history and water management, the towns in the area vied with the *Hoogheemraadschap* for control over the countryside.

FIGURE 7 ABOUT HERE

Continued misery in rural areas maintained the influx of poor peasants into the cities, and kept the price of labor low, thus stimulating shipbuilding and other crafts and industries that, in turn, enabled this rapid urban growth. Fuel was critical to expansion, and the economy of the area became more and more dependent on the provision of what was, in effect, the first fossil fuel of the modern world: peat. Once the land had been burned away, techniques were developed for peat exploitation underwater, clearing away all the peat down to the sands and clays below. As the areas of open water multiplied, and became deeper and deeper, so did the number of floods and other 'accidents'. But while the grain price remained low, little was done to mitigate the risks.

In the meantime, the *Hoogheemraadschap* itself ran into financial problems. The agrarian crisis of the first half of the 17th century coupled with the decline in peat production impoverished the population and pushed agricultural tax revenues to an all-time low. Many influential urbanites bought up large tracts of farmland in Rijnland, which they exploited by selling peat. As peat became the dominant source of income, the next predictable step was to impose a tax on peat rather than on land.

Rising urban wealth and the need to feed a rapidly growing urban population in the 17th century led to a rapid increase in grain prices in the 1660's, again tipping the balance between water and land. For a period of some 30 years, agriculture once again became profitable. Hence, some of the (artificial) lakes in *Rijnland* and other parts of Holland were pumped dry by first digging a canal around them, and then installing at their edges batteries of windmills, each of which lifted the water a little higher until it could eventually be dumped into the canal surrounding the drained area (cf. figs. 8). After such an area had been laid dry, drainage ditches were dug across them in a rectangular pattern to ensure the maintenance of a low water table. The fertile clays thus laid bare were quickly turned into rich cereal fields. The investment needed to do all this, however, was beyond the means of what remained of the impoverished rural population, nor could it be funded by the *Hoogheemraadschap* as long as its principal source of income was the land tax. Private investment by rich urban shareholders, associated for this purpose in *ad hoc* partnerships, took over the financial burden.

FIGURE 8 ABOUT HERE

FIGURE 9 ABOUT HERE

In 1675, just after a major war (1672-1674) between the Netherlands (read: *Holland*) on the one hand, and Britain, France and two German principalities on the other, the main dam protecting the *Rijnland* against flooding broke on two occasions (cf. fig 10). Similar events occurred again in the following century. Delayed maintenance may well have been a factor because the *Hoogheemraadschap* was no longer solvent. The disaster of 1675 was of such proportions that the towns (led by Amsterdam, Haarlem, and Leiden) loaned the *Hoogheemraadschap* the necessary funds for repairs and improvements.

FIGURE 10 ABOUT HERE

Subsequently, the Hoogheemraadschap began raising funds for maintenance and investment by emitting bonds against future revenue from the peat tax. The cities' inhabitants, many of whom already owned land in Rijnland, subscribed to most of these bonds. The loans set in motion a process whereby the cities and their inhabitants ultimately established control over the *Hoogheemraadschap*.

Regaining lost ground

After about 1700, agriculture did not return to profit in a major way until the second half of the 18th Century. At the same time, underwater peat exploitation neared the limits of what was feasible with the technical means available at the time. Income from peat (and the peat tax) declined, while protecting the banks of the lakes became an increasingly urgent and costly affair. Inhabitants and authorities were therefore faced with the question whether it was worthwhile to continue exploitation of the area. Yet, deserting it would have led to major inundations and other problems.

The solution chosen was to once again transform water into land. The few attempts at draining small man-made lakes in the 17th Century had demonstrated that the rich soils at the bottom could be profitably used to produce meat, milk and milk products. Hence, *Rijnland* and other authorities devised schemes to fund the dry land reclamation of many of the lakes, borrowing money against future tax freedom, or investing some of their own funds. The positive results of this venture initiated a phase of major land reclamation focused on lakes of limited depth and size all across *Rijnland* and, in effect, all over Holland.

During the 18th Century, plans to drain the (huge) *Haarlemmermeer* were considered and reconsidered several times. This large surface of open water was an important part of the transportation network, yet its size and shallow depth made it very dangerous to shipping whenever there were high winds or storms, and its edges were regularly inundated. In particular, with strong western winds, its eastern edge became a real cemetery for ships[2]. But the huge costs involved could not be borne by the *Hoogheemraadschap* or other local or regional authorities, in part because the 18th Century was a much less wealthy time for the Netherlands than the preceding one. Time and again, the plans were postponed. However, after the French occupation of 1795-1814, the federation of provinces that constituted the Republic of the Seven United Netherlands (*Republiek der Zeven Verenigde Nederlanden*) was replaced by a Kingdom that included *Holland, Zeeland*, and the five other provinces. The State now had the resources needed for the project, and the invention of steam engines to drive the pumps made it technically feasible.

But it was not until a furious hurricane in November 1836 drove the waters as far as the gates of Amsterdam, and another on Christmas Day the same year that sent waves in the opposite direction to submerge the streets of Leiden, that the mind of the nation was seriously turned to the matter (fig. 11A,B). On August 1, 1837, King William I appointed a royal commission of inquiry, and in the following May the work began. First, a canal was dug around the lake, fittingly called *Ringvaart* (Ring Canal), to carry the water drainage and boat and ship traffic that had previously gone across the lake. This canal was 61 km long, and the dug-out earth was used

2 Hence the name for Amsterdam's airport, *Schiphol*, which literally means 'hell for ships'.

to build a dike between 30 and 50 m wide around the lake. The area enclosed was more than 180 km^2, and the average depth of the lake was 4 m. As the area had no natural drainage, around 800 million tons of water were raised by mechanical means.

FIGURE 11 A,B ABOUT HERE

Unlike the historic practice to drain polders using windmills, steam powered pumping stations were exclusively used, a first at that time. Three steam-engines were built: the *Leeghwater*, the *Cruquius* (the largest Watt-design reciprocal stroke steam engine ever built and now a museum), and the *Lijnden*. Pumping began in 1848, and the lake was dry by July 1, 1852. Rather than being incorporated into any particular existing administrative organization, it was given the status of an independent municipality within the province of *Noord-Holland*. The state thus directly assumed control over the territory newly reclaimed.

With the reclamation of the *Haarlemmermeer*, the history of water and land in *Rijnland* comes to a provisional end, as no major reversals or new reclamations occurred in the area subsequently.

The Aftermath

Elsewhere in the Netherlands, this project was followed by other increasingly ambitious ones, well into the 20th century. Initially, these reclamation projects were concerned with large parts of the so-called '*Zuiderzee'*, the large open water in the center of the country. In 1929, it was closed off from open sea by a dam connecting *Noord-Holland* and *Friesland*. Draining the first of the 'polders' in what was now called the *IJsselmeer (*ex-*'Zuiderzee')*, the *Wieringermeerpolder*, was completed in 1930. During the Second World War, this was followed by completion of the *Noord-Oost Polder* (1942). After the war, two huge new polders were also reclaimed, respectively called *Oost Flevoland* and *Zuid Flevoland*. In total, 1650 km^2 of land were reclaimed in the 1950's-1980's (cf. fig. 12).

FIGURE 12 ABOUT HERE

A last major flood occurred in 1953 when a large part of *Zeeland* and *Brabant* were inundated by a combination of an extremely high tide and a strong westerly storm. This came at a time when the dams protecting these areas had been weakened by lack of maintenance during the Second World War and its aftermath. It led to a major project (the so-called '*Deltawerken'*) that now protects the area, but the idea to reclaim more land was abandoned when the Netherlands opened its trade borders more and more to agricultural products from elsewhere in Europe.

Both in the case of the reclamation projects in the *IJsselmeer* and in that of the *Deltawerken*, only the national government had the means to undertake them, and it therefore exerted its authority over them. In effect, from its first emergence out of the sea until 1986, the whole of *Flevoland* and its inhabitants was subjected to the authority of a single person appointed by the government, the '*Landdrost'*!

Summary and conclusion

The outline of the story recounted here is well-known; the western Netherlands were created, rather than peopled, by its inhabitants. Water was initially a threat to be fled and then to be contained. The point here is that not only the land itself, but its institutions and its culture as well emerged from the interaction between people and water.

The need for drainage and containment first led people to collaborate and to develop new techniques to deal with the dangers of both short-term floods and longer term degradation of terrestrial resources. The dynamics coupling environmental limitation and social will resulted in newly invented management techniques that addressed and frequently solved differences of opinion and created powerful institutions. Thus, the first supra-regional authority, the *Hoogheemraadschap* under its President, the *Dijkgraaf*, was created in response to the water management issue – an issue that could not be left in the hands of much smaller principalities.

In the struggle, water was transformed into land for cultivation and grazing, land was then transformed into lakes by selling it in the form of turves to fuel hearths and industries, and ultimately, these lakes were drained to re-create agricultural land when the need was felt. The process resulted in, the surfaces of large parts of the western Netherlands having been lowered to between 1 and 6 m below sea level, creating a situation of extreme vulnerability to any sea level rise that might be caused by climate change.

But one of the important lessons of this story is that it is also a kind of cyclical *'Tragedy of the Commons'*. It evidences the ongoing battle between individuals, institutions creating opportunities for individuals by containing the water, individuals creating new water-related threats, calling for strengthened institutions, etc.

Individuals first colonized these low-lying parts of the delta. As they drained it for cultivation, or to build small artificial mounds ('*terpen'*) to keep their houses and animals dry during floods, other longer-term threats emerged that could not be dealt with individually. Large-scale drainage systems were dug, and instead of building individual artificial mounds, people began collectively to protect land against floods by building dikes (artificial levees). In the process, they created institutions such as the *Hoogheemraadschap* to guard their collective interests.

Once that was done, and cultivation enabled people to make a good living in the area, land degradation arose and the economy shifted to grazing. Grazing is less demanding of the land and the drainage infrastructure than agriculture. When land became unsuitable for even that form of exploitation the same individual interests transformed land into fuel. Thus it created open water and undermined collective safety as well as the institutions that had been put in place to protect against the water.

From yet another perspective, it is all about spatial and temporal scales. Ultimately, when water became a local and regional threat once more, and there was insufficient land to provide food, the tendency was inverted by non-rural individuals who saw the interest and provided the means to collectively transform water into land. These means were derived from activities elsewhere, first in different urban sectors of the regional economy (successively fishing, regional trade, industry and banking), and later on the high seas (long-distance trade, and piracy), or in the Dutch colonies. In the process, the area became increasingly dependent on other parts of the world, other resources, or other feedback cycles (the spatial scale of the system was stepped up each time a disaster threatened or hit.) Thus, the reclamation of the *Haarlemmermeer* was funded in part by the increasing stream of riches gained in the Dutch East Indies, where a system of intensive agriculture for the European market had been instituted after 1815. In turn, the reclamation of Flevoland was made possible by the economic boom after the Second World War, to which the birth and growth of the European Union was also closely related.

Temporally, as long as the local and regional cyclic 'lows' did not coincide then the highly artificial and very costly system could be maintained. Local profits could be made thanks to investment of funds gained elsewhere. In *Rijnland* this was the case when either urbanites or the cities collectively intervened to fund the protection of land against water. Nevertheless, if there was a temporal overlap between ‘lows’ in both regional and more global cycles, problems hit with redoubled severity, such as in the 18th and the first half of the 19th Century. Then, disaster could only be averted by yet another increase in the spatial and the temporal scale of the system. For example, by invoking the help of the national government to drain the *Haarlemmermeer*, it dramatically reduced the frequency with which problems hit and strengthened both the material *and institutional* infrastructure that maintained the polder in a ‘steady state’. In the process, the scope and scale of threats and institutions bootstrapped themselves to eventually encompass all of the Low Countries, shaping much of Dutch society to this day.

Finally, the story beautifully illustrates the role of risk perception in generating unintended consequences in environmental management by society. In their attempt to deal with frequently occurring events in the interaction between people and their environment [such as the seasonal inundations that led people to ‘invent’ artificial mounds (‘*terpen’*)] human intervention would lead to new perspectives and new actions [such as the enclosing of whole areas by artificial levees (‘*dijken’*)]. However, frequently these changes engendered new risks, of which neither the nature nor the spectrum of periodicities was known. When these risks materialized (in the form of decadal or even centennial floods, for example), other means were sought to deal with them, and the changes wrought in the environment introduced yet other risks – again of unknown nature and temporal spectrum. The investment to maintain these solutions could prove too costly by the local population resulting in the additional risk of an area becoming dependent on another region’s economic cycles.

In each instance, the ‘solution’ to an imminent challenge was based on interventions in the environment that triggered other challenges down the line. The latter were less frequent and involved a larger spatial scale. As a result, over time the 'risk spectrum' shifted from relatively frequent, spatially limited risks to less frequent, but more important risks. In environmental studies this dynamic is referred to that of 'unintended consequences'. Ultimately, the accumulation of risks with unknown, longer, temporalities leads to an accumulation of risks that could burst upon the scene simultaneously: 'a time-bomb' or 'crisis' such as the current environmental crisis.

Although the consequences may be unintended, they are far from unexpected. Similar situations and chains of events have occurred whenever and wherever people tried to impose particular 'solutions' to the challenges posed by the environment. They seem profoundly inherent in human interactions with the environment, as often those interactions are based on making a distinction between 'us' and 'our environment'. Indeed, that environment is not 'ours' on which to possess or impose 'our solutions'. In the current extreme form, the aforementioned position is a particularity of western culture that has become more and more prevalent since the 14th century. Maybe we should take a closer look at the world-view of societies like the Achuar, who do not make such a Manichaean distinction between ourselves and our environment (Descola, 2005).

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FIGURE 1

Figure 1: 'Terps' are artificial mounds build in the very wet and inundation-prone landscapes of the western Low Countries as refuge against rising water

FIGURE 2A

Figure 2a: The territorial organization of western Holland during the 13th century. The colored surfaces indicate the different 'baljuwschappen' (terrestrial subdivisions under a 'baljuw' who is the representative of the count and the person responsible for the management of the area). The red dotted line indicates the limits of the 'Hoogheemraadschap Rijnland' (from: Tielhof & van Dam, 2006)

FIGURE 2B

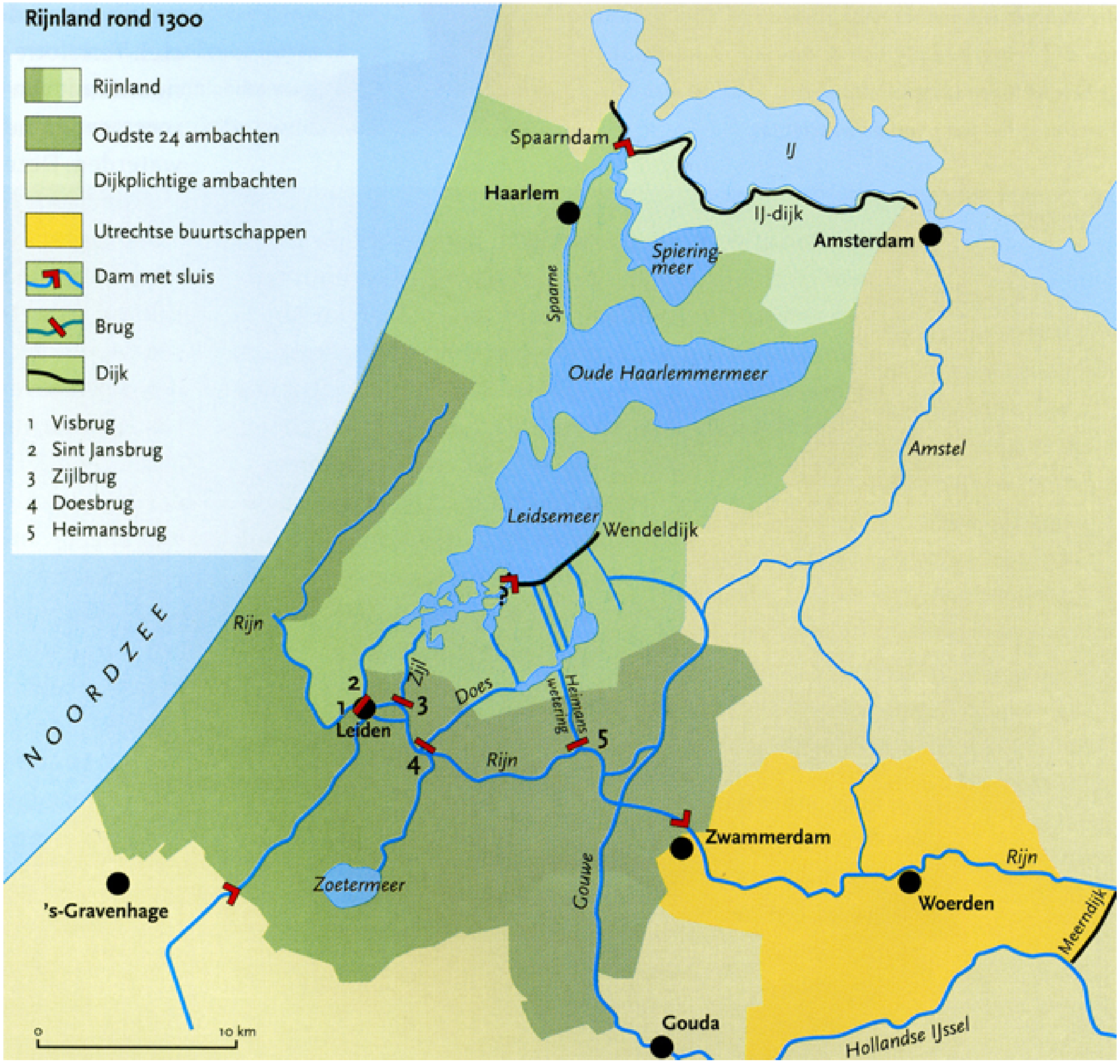

Figure 2b: Location of the first engineering works in Rijnland: The variously colored surfaces represent the main territorial divisions. The red chevrons indicate locks and sluices, the red rectangles bridges, and the thick black lines the levees constructed to defend the land against water. The numbers indicate the names of the bridges (from: Tielhof & van Dam, 2006).

FIGURE 3

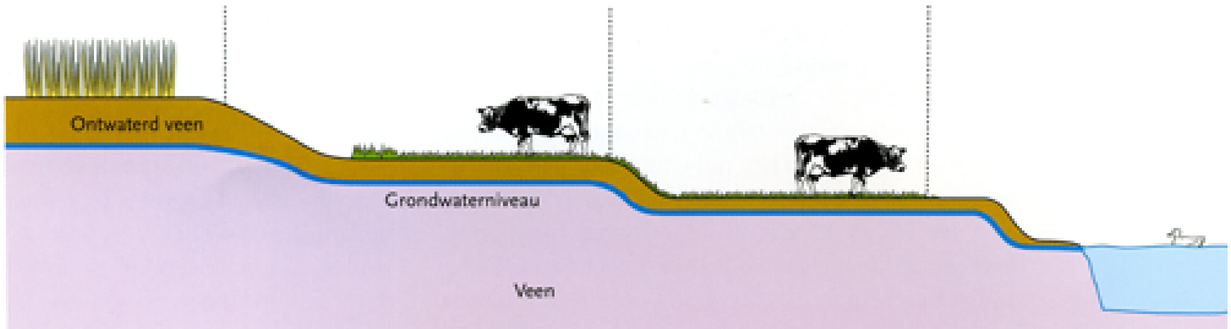

Figure 3: From left to right, schematic representation of the changes in economic activities as the land surface is lowered due to drainage and oxidation of the peat. The purple layer represents waterlogged peat, the brown layer drained peat. Initially, the land is farmed, but relatively quickly only grazing is possible. That continues until all the peat is dug away, and only water remains (from: Tielhof & van Dam, 2006).

FIGURE 4

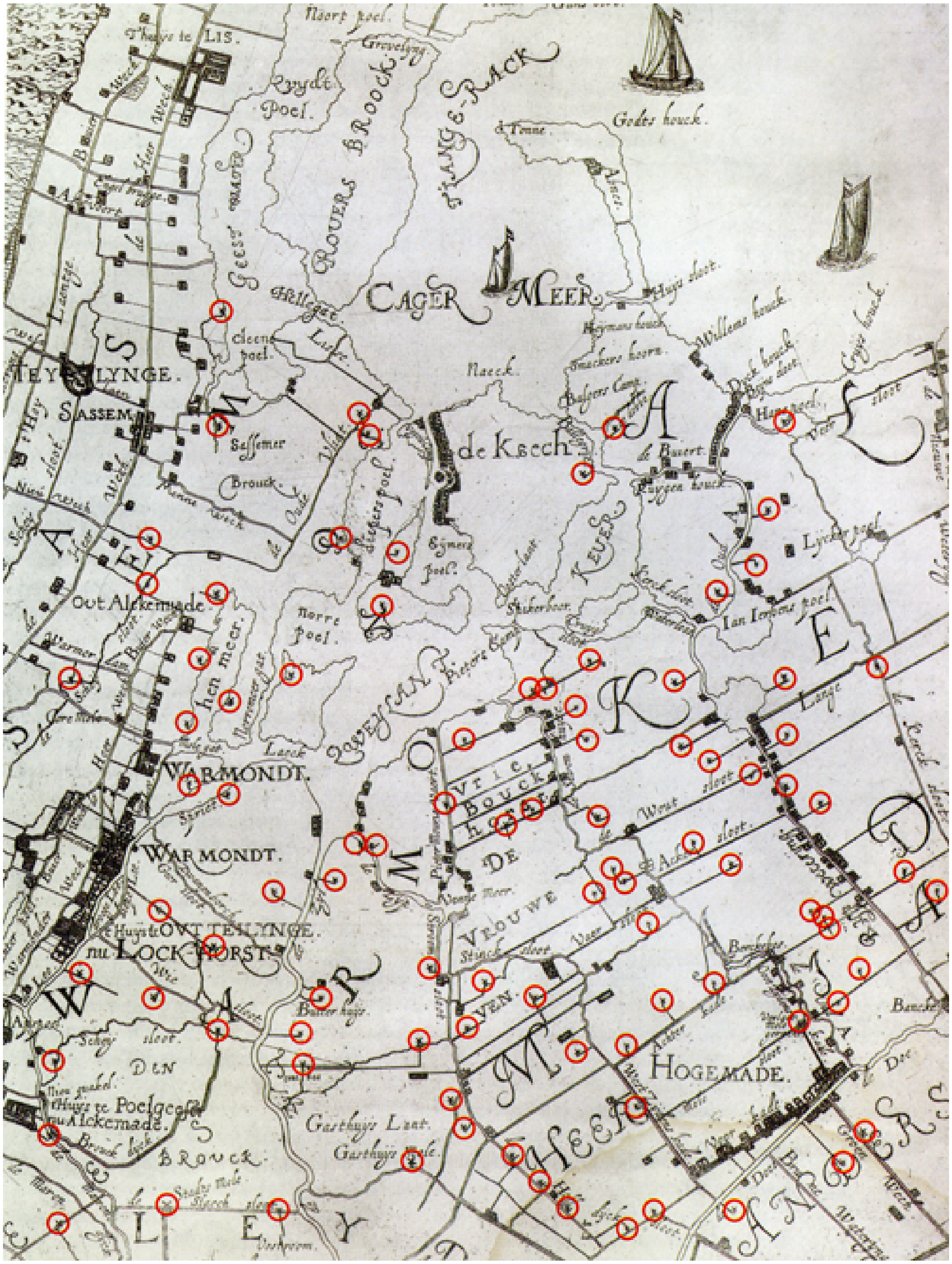

Figure 4: The spread of windmills. Each red circle indicates a windmill on this map of around 1500 (from: Tielhof & van Dam, 2006).

FIGURE 5A

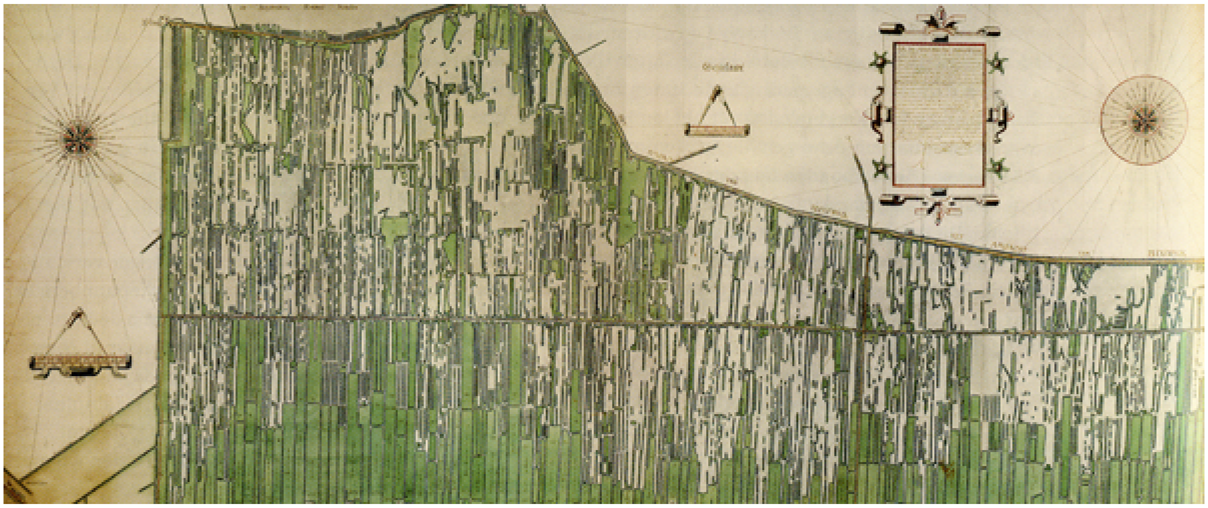

Figure 5A: Digging away the peat – which is sold as fuel – leaves a landscape intertwined with surfaces of open water (from: Tielhof & van Dam, 2006).

FIGURE 5B

Figure 5B: After most of the peat is sold, a lake is all that remains (from: Tielhof & van Dam, 2006).

FIGURE 6

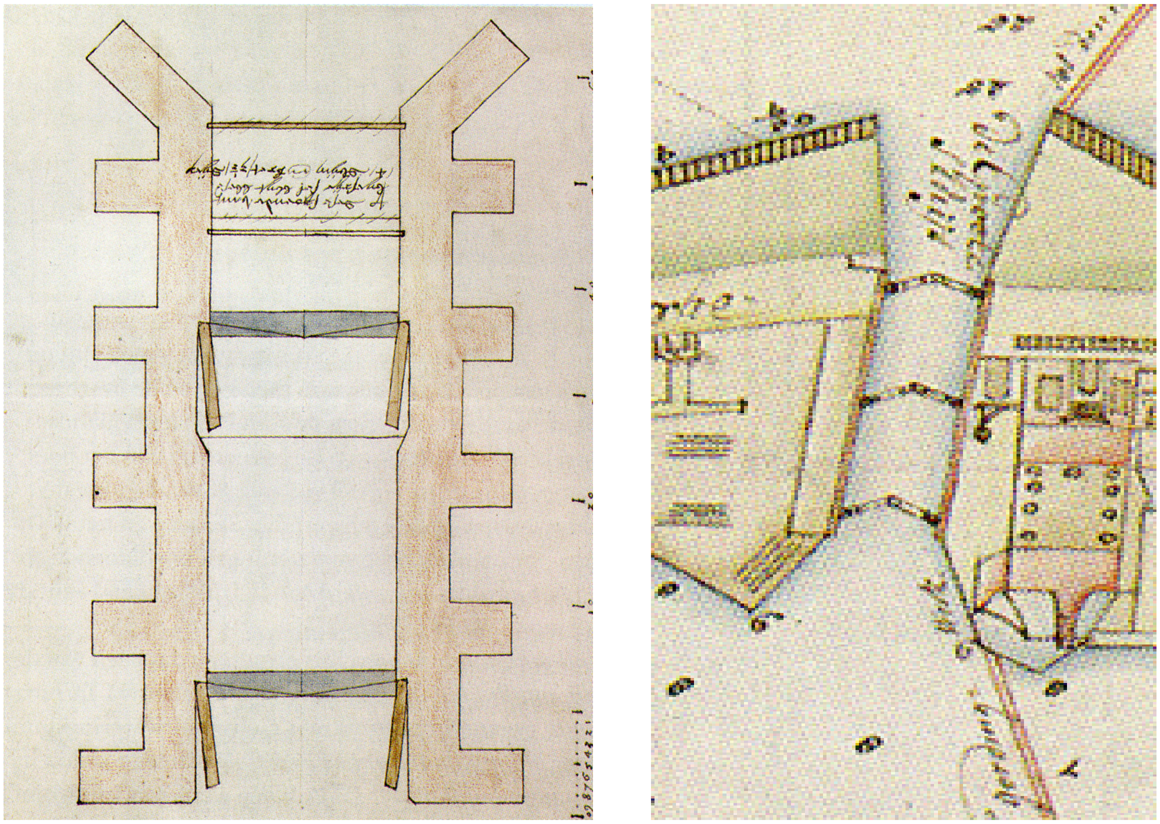

Figure 6: Improved locks close due to high water pressure on the outside, and automatically open when the pressure inside is higher, so that an area can be drained (from: Tielhof & van Dam, 2006).

FIGURE 7

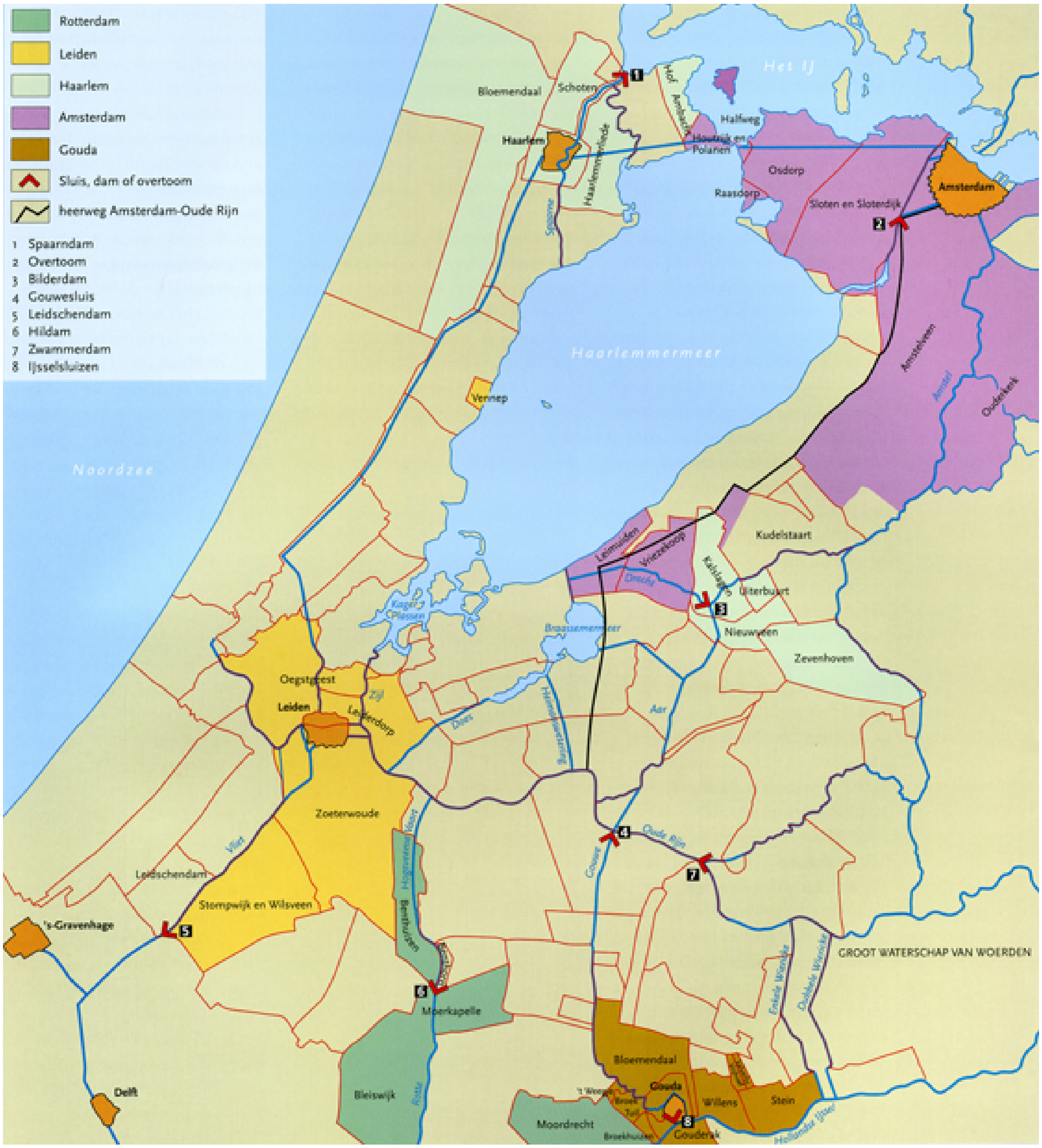

Figure 7: Only the cities have enough money to buy up the impoverished agricultural lands: Rotterdam (dark green), Leiden (yellow), Haarlem (light green) and Amsterdam (purple) quickly come to own large tracts of Rijnland. The numbers refer to smaller settlements in the area (from: Tielhof & van Dam, 2006).

FIGURE 8

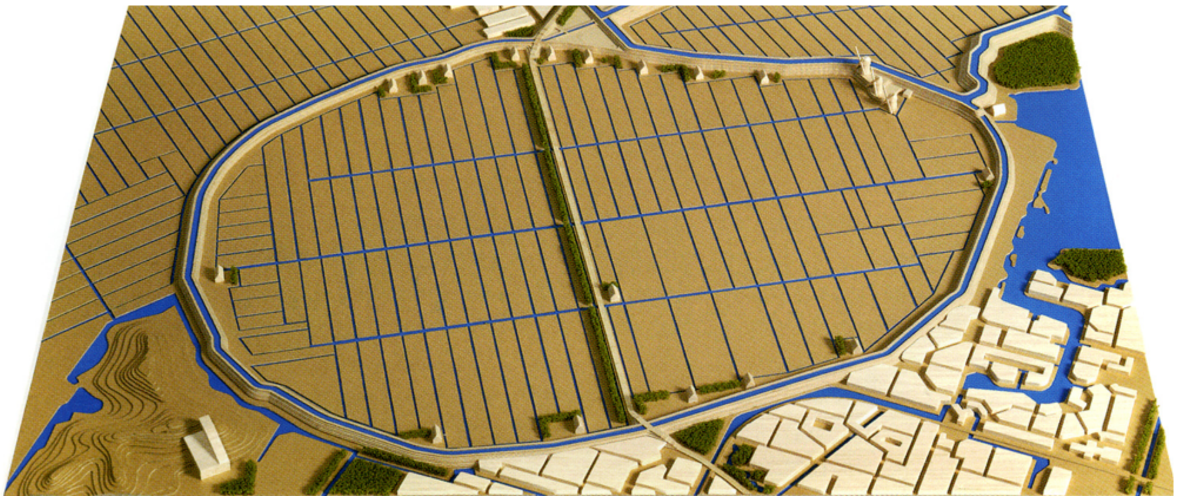

Figure 8: Scale model of a 'polder', surrounded by a circular canal (the 'Ringvaart'), and drained by a network of ditches ('sloten') and small canals ('vaarten') (from: Tielhof & van Dam, 2006).

FIGURE 9

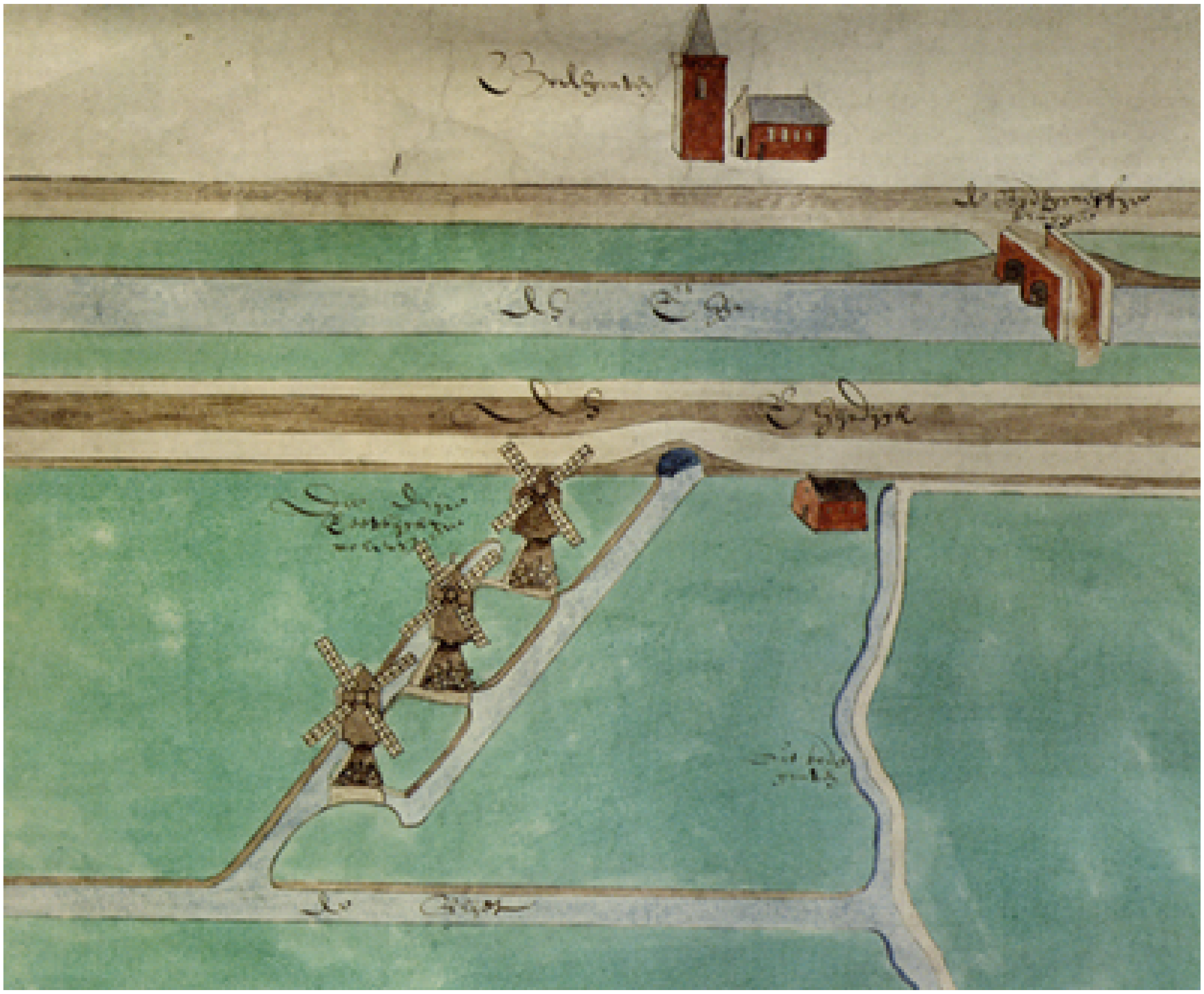

Figure 9: sets of thee windmills lift the water in stages from the level of the drainage network, into the circular canal ('Ringvaart'), from where it drains into the sea (from: Tielhof & van Dam, 2006).

FIGURE 10

Figure 10: The breakthrough of the levee near Spaarndam in 1672 inundated large tracts of land (from: Tielhof & van Dam, 2006).

FIGURE 11A

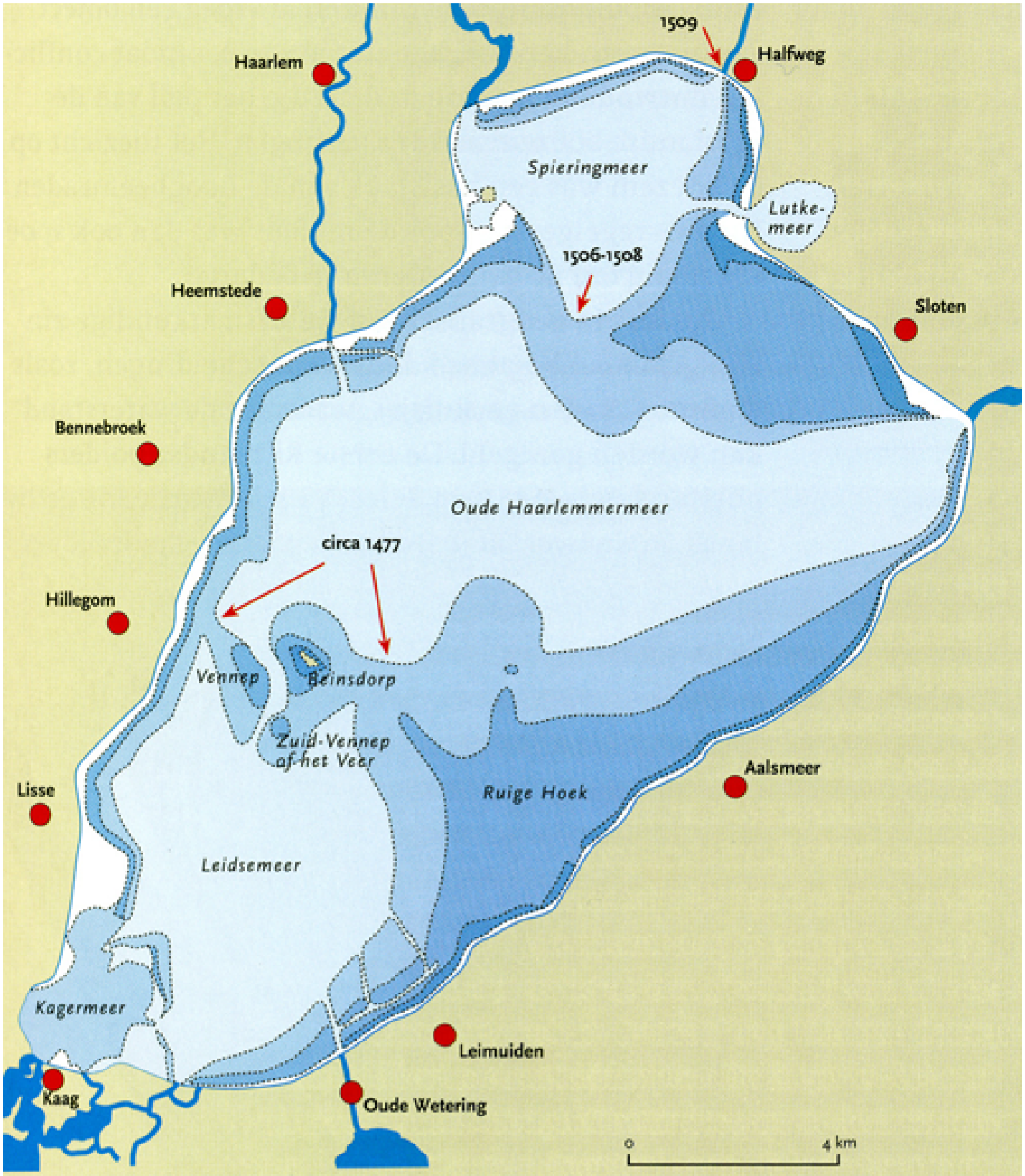

Figure 11A: The Haarlemmermeer around 1850. Due to removal of peat and successive inundations, the lake had become so large that it was a threat to neighboring cities and towns (from: Tielhof & van Dam, 2006).

FIGURE 11B

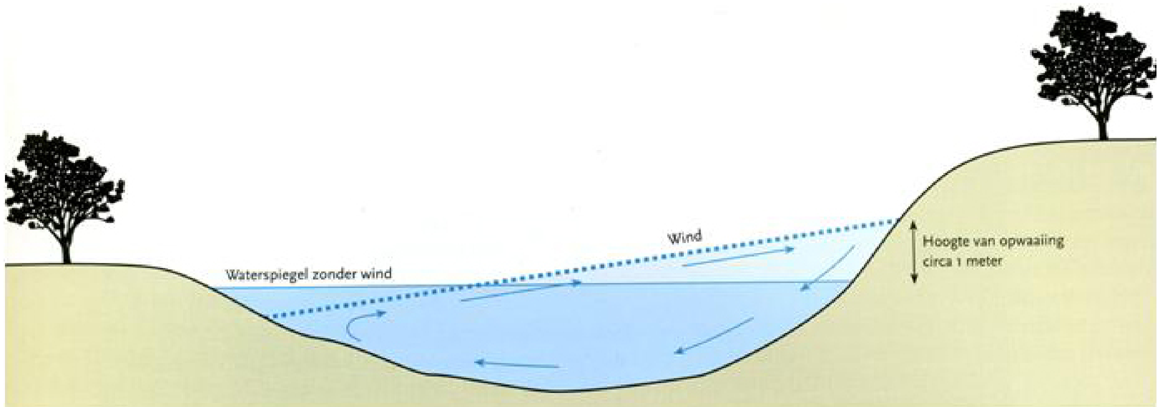

Figure 11B: When there was a strong Southwesterly wind, the waves in the Haarlemmermeer were pushed up towards the northeast to such a level that the levees were in danger of breaking (from: Tielhof & van Dam, 2006).

FIGURE 12

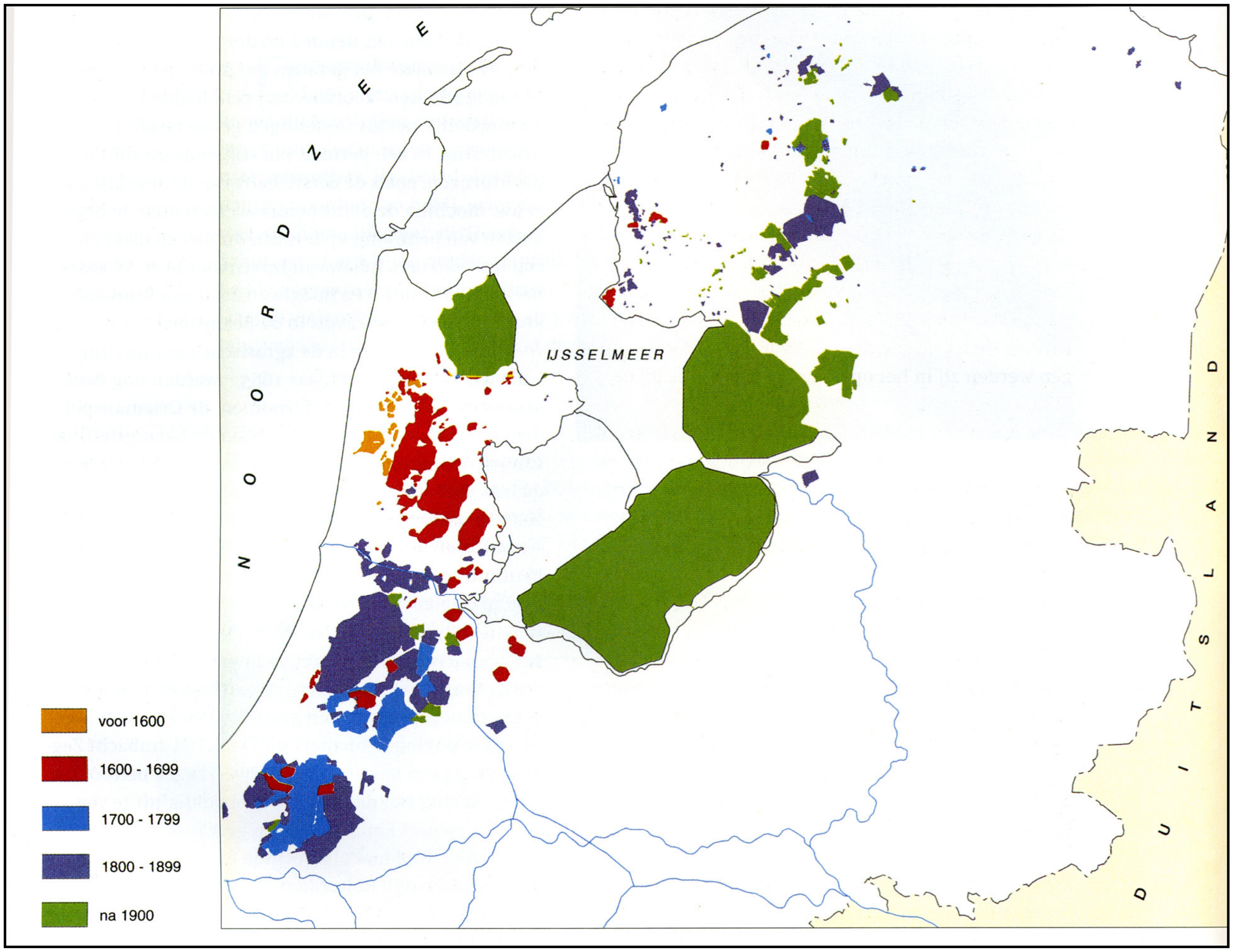

Figure 12: Summary of the drainage activities over several centuries: the different colored areas indicate surfaces gained on the water. The colors indicate the period in which a surface was drained (from: Tielhof & van Dam, 2006).

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Figure 11B: When there was a strong Southwesterly wind, the waves in the Haarlemmermeer were pushed up towards the northeast to such a level that the levees were in danger of breaking (from: Tielhof & van Dam, 2006).

Figure 12: Summary of the drainage activities over several centuries: the different colored areas indicate surfaces gained on the water. The colors indicate the period in which a surface was drained (from: Tielhof & van Dam, 2006).

Bio-sketch

S.E. van der Leeuw

An archaeologist and historian by training, he taught at the universities of Leyden, Amsterdam, Cambridge (UK), the Sorbonne and the Institut Universitaire de France. He held visiting positions at the University of Michigan, the University of Reading (UK), Australian National University, the University of Massachussetts at Amherst, and the University of Chicago, and lectured in many parts of the world.

His research interests include archaeological theory, ancient ceramic technologies, regional archaeology, (ancient and modern) man-land relationships, GIS and modelling, and Complex Systems Theory. He did archaeological fieldwork in Syria, Holland and France, and conducted ethno-archaeological studies in the Near East, the Philippines and Mexico. Since 1992 he has coordinated a series of interdisciplinary research projects (financed by the European Union) on socio-natural interactions and environmental problems. Up to 65 researchers from 11 European institutions were involved, ranging from theoretical physicists and mathematicians to historians and rural sociologists. The fieldwork spanned all the countries along the northern Mediterranean rim.

Since February 2004, he is Professor of Anthropology and Director of the School of Human Evolution and Social Change of Arizona State University. He is an External Professor of the Santa Fe Institute and a Corresponding Member of the Royal Dutch Academy of Sciences. Currently, he is treasurer of the International Human Dimensions in Global Environmental Change Programme. His publications include 16 books and over a hundred papers and articles on archaeology, ancient technologies, socio-environmental and sustainability issues, as well as invention and innovation.