Clio defeating Neptune: a pyrrhic victory?

Men and their influence on the evolution of coastal landscapes in the North Sea area.

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Abstract

In this article I tried to illuminate some of the most important aspects about the way human communities have influenced the natural coastal eco-system, often with disastrous long term results. It focuses especially on the human influence during the Middle Ages and the Old Regime. In its conclusion, it highlights arguments for a huge regional and temporal diversity of evolutions, since human influence was not everywhere identical. Moreover, because human activity often triggered natural phenomena and vice versa, and because we know from recent research (see e.g. Weerts and the many other articles in this volume) that natural phenomena causing changes in marine environments were also much more regionally different compared to what was believed some decades ago (see a state of the art in 1980: Verhulst and Gottschalk, 1980), it is logical that the regional component is crucial in the explanation of the evolution of coastal landscapes.

1. Introduction

Specialists increasingly agree that during the last few millennia the influence of mankind on the formation and change of coastal plains has been of huge importance. However, in most studies written by earth scientists, the human influence is rather superficially dealt with. Equally, in studies written by social historians and historical geographers is often only in a superficial way referred to the way humans influenced natural processes of land formation and/or degradation in coastal areas, often because on the one hand they do not know nor understand the natural

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1 I am very grateful to the colleagues Guus Borger, Tim Soens, Adri de Kraker and Henk Weerts for their very interesting comments on the initial version of this text.
processes, and on the other hand because many of them are not aware of the importance of changing social organization on landscapes as a whole (Thoen, 2011).

2. Natural phenomena and human action

Many natural phenomena influenced the formation and changes of natural landscapes in coastal zones. Apart from the sediment supply and structure, the main natural actors for coastal changes were the relative sea and tidal amplitudes, as well as the (changing) height (and composition) of the adjacent land mass. This determined the formation of shore lines, the composition and relative height of the upper soils with the geometry, shape and depth of tidal channels and natural rivers for drainage of the hinterland, sedimentation processes, peat formation, its disappearance as well as its stratigraphy, and the structure and the resilience of the under lying stratigraphy (e.g. compaction of soft sediments and oxidation).

All these phenomena are to a large extent either determined by or themselves determine the changes/evolution of relative mean high water level (MHW). The extreme high water level having often has cumulative effects on soil formation or destruction. In the very long term and on a very large scale, these MHW changes had natural causes like the growing or melting of ice caps, regional glacio- and isostatic rebound, long-term climatic changes, and composition and volume of marine sediments etc. (see Weerts, this volume). Here human action was hardly present. However, if one looks at previous centuries and millennia only, regional differences in tide storage and MHW were huge and changed a lot over time and area. Consequently, the same also happened with extreme high water conditions during storms. In addition, the drainage conditions of the hinterland changed drastically over time. The formation of tidal channels, tidal flats, sedimentation, and soil structure was to a large extent influenced by these more regional factors which made a lot of difference to humans for using the land as resource. These (relatively) more short term but especially more regional and ‘local’ natural factors were much more influenced by human action. The mentioned phenomena were regional but could also influence neighboring regions! Human action influenced the natural ecosystems and changed/adapted natural processes but were still partly influenced themselves by these changing
natural actions. This increases the complexity of a study of the evolution of coastal areas during the historical period.

For drainage reasons, rivers and channels discharged their water from the hinterland into the North Sea or in large deltas such as the Scheldt-Meuse or the Rhine. These tidal inlets had many moving side channels as well and created tidal flats mostly within a peat landscape that had formed since c.7000 BP. The landscape of these flats was changed in a natural way: new deeper tidal channels could be created and sedimentation could take place. However, since human communities were active in these coastal areas, to a large extent they steered these natural phenomena. This was true at different geographic levels: in the mean tidal inlets but also more inland in the side channels and in the peat areas.

One could make a global distinction between human influence on natural phenomena: on the one hand human action causing consciously wanted changes and on the other hand unconsciously created changes in natural processes. However, such a division is largely artificial since most consciously wanted changes also caused natural but often unexpected long-term side effects.

Direct human influence in the coastal landscapes especially happened in two ways: via overexploitation and via direct changes in the hydraulic system.
First, changes could occur due to human overexploitation of the landscape. This was especially true in coastal landscapes where the upper soil formed under marine influence and became intensively cultivated. Indeed, in areas in the (wide) vicinity of the sea or tidal channels, drainage often resulted in compaction of soft sediments (particularly peat). Also the fact that soils were literally removed at the upper layer (peat digging), but also by erosion and oxidation, caused subsidence of surface levels. Overexploitation and/or reclamation of much more inland situated areas, where the origin of the upper soils was often much older and not directly influenced by tidal erosive or sedimentation processes, could also cause changes in the coastal areas (see section 3).

Secondly, humans also influenced the coastal landscape directly through hydraulic systems: the reclamation of land, building of dikes, and canals or changing natural channels, the building of
sluices, and the creation of an artificial possible ‘man-made’ accommodation space. This direct influence had also accumulative (often negative) effects on natural hydraulic phenomena, as will be discussed in section 4.

The social context determined why and at which pace people directly influenced the natural ecosystem. It also determined the way they adapted and coped with the negative aspects of the changed ecosystem and how they could turn the balance in their favor. This will be dealt with in section 5.

3. Human action causing erosion and land subsidence.

3.1. Drainage and farming causing land subsidence.

One of the major natural phenomena influenced by mankind is subsidence of surface levels. This was particularly due to the compaction of soft sediments, especially peat but also underlying minerogenic sediments (Long, Waller, Stupples, 2006: 4). Compaction can have natural causes due to a change in natural drainage via natural channels and the deposition of heavy sediments on top. Nowadays, human action during the Roman and even more during medieval periods is also thought to be a causal factor. Although written evidence is scarce, in the last few decades, archeology has demonstrated that at an early point in time peat and intertidal saltmarshes (not having any dikes) could have been intensively used for cattle and sheep breeding, and also for grain cultivation, from an early period. For example, traces and remnants of Roman drainage activities were excavated in the area near Vlaardingen in S. Holland as well as in Zealand Flanders (see e. g. Lascaris and de Kraker, this volume; see also: Meier, this volume). In addition, large scale drainage took place during the Carolingian period (e. g. Vos et al. 2011 for the Netherlands, for coastal Flanders: Tys, 2003 and this volume; for Schleswig-Holstein: Meier, this volume). After embankments were built, drainage became even more intensive (see below). The systematic drainage which was necessary for cultivation caused land subsidence. It is well known that intensive drainage already occurred since the first occupation of these peaty areas (see many studies, inter alia Meier, this volume). The consequent subsidence must have been very important. In turn, it is obvious that land subsidence had far reaching societal consequences. It increased the amount of accommodation space and, after embankments, the risk of flooding!
So, land subsidence was to a high degree caused by man and had accumulative negative societal aspects. During the last years and decades, both archeologists and geologists have increasingly underlined the importance of the process (Bungenstock and Weerts, 2009). According to Long, Waller and Stupples, ‘this process is likely to have been a key driving mechanism behind rapid late Holocene coastal change, far exceeding the longer-term effects of eustatic change and uplift/subsidence’. In the Romney Marshes, compaction lowered the peat surface by at least 3m compared to the period before c.700AD when, in relation with this land subsidence, a saltmarsh was established in the area (Long, Waller and Stupples 2006: 2). Earth scientists such as Bungenstock and Weerts (2009) as well as Van Asselen et al. (2011) recently stressed that peat compaction may have been underestimated by geologists, stating that subsidence due to peat compaction is highly variable in time and space, with local rates of not less than up to 15mm per annum, depending on sedimentary sequence. Elsewhere, it was shown how important the phenomenon was for channel belt elevation, geometry, and configuration (Van Asselen, Stouthamer, Van Asch, 2009).

Moreover, due to drainage, gaseous CO\textsuperscript{2} flux associated with microbial oxidation must have been very important too for the lowering of the surface level. It is only since the mid-1970s that this phenomenon became apparent to investigators researching the North Sea area (see e.g. Borger, 2007: 30 referring to his own work of 1975 about Western Friesland). Its impact must have been huge if we contextualize it with well-documented recent data. In the Sacramento-San Joaquin Delta of Southern California it seems to have been responsible for 75\% of the current subsidence of surface level. There, subsidence made that the area, after the beginning of the farming practices in 1880, sink on average about 8m below a.s.l (Mount and Twiss, 2005: 4-5)!

Consequently, earth scientists’ well described phenomenon of land inversion (the apparent uplift of former tidal channels where an underlying peat layer was absent), which ensured that less or no compaction took place, was also, in an indirect way, to a much larger extent influenced by man than previously thought since it was directly influenced by land subsidence. It is well recognized how important these inversed zones were for historical geography as they were very suitable for settlement.
The variation in land subsidence due to compaction and oxidation also caused and partly steered the natural phenomenon of avulsion (the constant reposition of tidal channels) (Kiden et al., 2008: 59; Van Asselen et al., 2009). This way, aversion was also partly caused by human action. It was demonstrated that aversion could lead to local changes in average mean high water levels (id: 60) and in that way also influence the sea and channels via sedimentation and storm surges. Land subsidence was also influenced by drainage. Therefore, it is believed that subsidence was enhanced when drainage via windmills was introduced from the late fourteenth century onwards and in an accelerated pace from the sixteenth century when the practice became common (see e.g. van Tielhof and van Dam, 2006: 70). During the Early Modern Period, the intensive drainage of land via networks of mills in the polders sometimes caused problems in adjacent areas. This happened in parts of late eighteenth century Groningen. Too intensive water discharge made it necessary to make polders in neighbouring lands too and created structural problems in the Wolden area which could only be resolved in the 1870s (Ligtendag 1995: 249-50). Similar problems happened also in Rhineland and Noord-Holland in the Early Modern Period (an overview for the Netherlands in de Vleesschauwer, 2012:11-16).

Land subsidence increased the risk of flooding considerably. Not only were the consequences of flooding much higher due to the increased accommodation space in case of dike bursts, but the cumulative hydrostatic force acting on dikes is a function of the square of the depth of subsidence as has been showed by Mount and Twiss for the contemporary Sacramento-San Joaquin Delta (2005) (see also figure X). In other words, due to land subsidence, the construction of dikes had to be more solid to resist increasing water pressure. This required new investment, which in many areas was only realized in the second half of the Early Modern Period after a period of problems had arisen (see below).

3. 2. Peat cutting and salt making.
Since the mid Holocene period in most coastal plains, a considerable peat layer had formed on the surface. Since c.2500BP, when an ‘unstable’ period of marine influence began, even larger parts were covered with marine sediments or were taken by the sea. In other areas peat could continue to grow, such as in the quiet areas of the inland Scheldt area; this even continued until the high middle ages (Kiden, 2001). However, much of the peat was not covered with marine
sediments until the end of the medieval period and into the early modern period, not at least the areas which were situated further away from the sea and tidal channels. Although there are some indications that peat cutting for fuel was already practiced in Roman times, it was during the eleventh and twelfth centuries that it became very important in the North Sea Area. Across several centuries, vast amounts and large surface peat areas disappeared because of large scale peat cutting and the extent of areas where peat mining took place was enormous. Many studies have underlined the importance of peat digging for the economy of the Low Countries (see e.g. Cornelisse, 2008; van Tielhof and van Dam, 2006; Soens and Thoen, 2009a). Scholars were, and sometimes still are, divided in two groups: the ‘minimalists’ and the ‘maximalists’; the first minimalize the former presence of peat, the others do the opposite. The former group also minimalize the presence of raised peat bogs which were very useful for peat cutting. However, thanks to the development of new research, a lot of written data becoming available, and the intensification of studies on peat cutting, in most areas the maximalists won the dispute in the end. The presence and discovery of so-called daliegaten could prove the former presence of peat in some areas of the Northern Netherlands now covered with clay (e.g. Noord-Holland, Zuid-Holland, Utrecht and West-Friesland). As mentioned, at the beginning it was possible to cultivate crops on the well-drained peat soils. To improve the soil quality for arable farming, pits were dug through the peat to extract clay and sabulous clay from underneath. The clay was probably mixed with stable manure and used as fertilizer to improve the poor soil quality. However, although much of the peat has now disappeared due to erosion, oxidation or extraction, traces of these pits called daliegaten still can be found. Nowadays it is widely accepted that large amounts of peat were also once present in West-Friesland (Borger, 1975, Dekker 1981), the Campine area (Leenders,1989), deep in the Land van Waas as well as in the Meetjesland (for a state of the art The environmental consequences of peat digging are well known. Although it was mostly prohibited in the immediate vicinity of dikes, the resulting surface subsidence increased accommodation space in periods of flooding or when the dikes were broken. Vast areas, even as far as deep inland regions, increasingly became threatened by the sea and the possibility of being covered by marine sediments. Moreover, it was easy for sea water to penetrate an area where peat mining had previously taken place since such mining also created a network of ditches and canals for drainage and transporting peat. Exhausted peatlands also
suffered from under-investment in the maintenance of drainage systems and flood protection, as the land value often was low (see below). Peat districts also became even more prone to flooding, when the practice of peat cutting below water lever via dredging became common from the later middle ages onwards. Many artificial lakes were created that way such as in Holland, Utrecht and the NW part of Overijssel and in Friesland and (esp. the of the discussions between geologists and historians in Flanders: Soens and Thoen 2009a). In all these areas the peat that was located at the surface is now completely gone.

Southern part of) the Belgian coastal area (Van Tielhof, Van Dam, 2006: 120-151; Dekker, 1981: 63). From the late sixteenth century many of these lakes were again reclaimed and embanked using wind mills (these reclaimed lakes were called in Dutch droogmakerijen).

Since the eleventh century peat cutting for fuel was also carried out on a large scale and peat was sold in the many flourishing cities of the North Sea area. Salt making was also important. In the middle ages and the early modern times, salt was made in the North Sea area from salt peat. This was done in two stages: the burning of salt peat that was standing under the influence of marine salt outside the dikes (and sometimes covered with sediments that had to be first removed), and the process of refining for which also peat was used (Leenders, 2003). This practice was especially common in Zealand, South Holland, and West North-Brabant from the eleventh and twelfth centuries until the fifteenth century, when the import of foreign salt increased (id. and Mertens, 1963; De Kraker, 2007). There was some awareness of the environmental danger of peat digging outside the dikes, but prohibitive orders mostly were not effective (Leenders, 2003: 34; De Kraker et al, 2008)².

Peat mining happened at a different pace according the area. It can be demonstrated that in the northwestern part of Flanders (near the French border), peat cutting was undertaken in the twelfth and the first half of the thirteenth centuries, while along the Southern bank of the Western Scheldt it mainly took place between the thirteenth and fifteenth centuries (Soens and Thoen, 2009a). From the late sixteenth century large scale peat cutting stopped in the Southern

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² According to some, the salinity of peat -especially in not yet diked areas- probably also determined the date of reclamation (for arable!). Low salinity could have made reclamation easier and more rapid (see Oram, this volume).
Netherlands and the Western Scheldt area. In North Brabant and Holland and West Friesland (in both last mentioned regions, peat was especially used for farming) it started in the fourteenth century and reached its zenith in the seventeenth century. In Groningen and Drenthe, it was mainly a post-1600 activity that continued until recently (see e.g. Borger, 2007; Cornelisse, 2008; Van Tielhof and Van Dam, 2006, Leenders, 1989 and many more).

These regional and local differences in peat cutting of course influenced the locally different environmental consequences of this activity. In combination with the described land subsidence it must have created locally different environmental fragility and possibilities for water to reshape the landscape into a marshy area. Together with the phenomenon of inversion due to channel silting and peat compaction, the intensity of peat digging created local differences in altitude in apparently flat areas which had far reaching environmental consequences for the stability and limited sustainability of coastal areas. Nevertheless, it is likely that the flooding of peat districts was never inescapable: even though land subsided, and water levels increased, peasant small-holders in the central Holland peat districts managed to survive well into the late seventeenth century, thanks to a well-balanced combination of dairy farming and peat dredging, and a careful land and water management. Drainage only started to fail significantly in the latter half of the seventeenth century, at a moment when the economy of the Dutch Republic witnessed a severe recession (Van Dam and Van Tielhof, 2006; Soens 2008).

3.3. Erosion and increased land surface fragility?

**Erosion within the coastal areas.**

Drainage of peat areas was mostly done via a very dense network of canals and often rather deep parallel running ditches. This ‘network’ made the drained area very vulnerable to flooding. It is well known that due to storm surges large quantities of peat were destroyed and even large parts of the peat area were sometimes swept away to start drifting or were engulfed in the tidal canals or in the sea. As van Tielhof and van Dam could demonstrate, fragility of the peat surface caused by human intensive drainage was partly responsible for caving in of the river banks in the Rhineland area in the Netherlands during the later middle ages (van Tielhof and van Dam, 2006:...
Where peat was located in areas with clay in the subsoil, this fragility also often increased during storm surges because deep canals had been made to mix this clay with the less fertile upper layer to increase land fertility (Dekker, 1981; De Kraker, 1997, ch. 13).

Human-caused wind erosion was also co-responsible for changing landscape conditions in the coastal areas. This was particularly true in the dune barriers. Initially these barriers were in most parts of the coastal North Sea area not as high as they are sometimes today but wider, more craggy, and at the same time more robust and covered with plants too. They were mostly displaced (land inward) between the post-Roman period and the Early Modern Period and sometimes even until the twentieth century (Van Haperen, 2009: 10-16). Despite natural elements, it is likely that this dune destruction was to a large extend caused by overexploitation. This was the consequence of too intensive grazing of cattle and sheep and arable farming (see e.g. van Dam, 1999, and the literature in the notes). Destruction by rabbits - introduced by humans in NW Europe for the fur trade - was also problematic (Augustijn, 1995, Rentenaar, 1978) Moreover, wood cutting and deforestation, the cutting of sods, and even the founding of settlements in the dunes was destructive for this eco-system (see: Labarque, 2007; de Ceuninck, 1992; Klijn, 1987: 57 ff. gives many data out of spread literature; see also Oram, this volume).

The intensive use of the dune area was encouraged by the fact that dunes mostly had potable water in the subsoil (contrary to elsewhere in the coastal areas where salt water in the subsoil sometimes made arable farming and cattle breeding impossible) (Labarque, 2007: 83-84; Priester, 1998:37-41). Destruction often made the dunes, more barren and blown up, covering clay areas. The measures taken to limit sand erosion made them higher and often narrower (Labarque, 2007:25).

**Human induced erosion of the hinterland influencing land and seascapes.**

Because (often far away situated) hinterlands were linked with the sea via tidal channels and/or tidal estuaries, erosion under the influence of reclamation activities and improper farming within the hinterlands often had a serious influence on sediment transportation. This could have caused the silting up of tidal channels, the creation of sand banks, and changed the sediment supply in a general way. Moreover, it changed the tidal prism in the channels with different physical
consequences on the hydraulic system (see also below: the effects of direct human changes in the hydraulic system).

James P. M. Syvitski et al. (2005), stressed that today this is still a huge environmental problem. Indeed, it has been estimated that in the twentieth century, world-wide, humans have simultaneously increased the sediment transport by global rivers through soil erosion by $2.3 \pm 0.6$ billion metric tons per year.\(^3\)

In the first half of the Holocene soil erosion already seems to have been important (partly due to deforestation by hunter-gatherers?) (Joosten 2004). A recent study showed that erosion in the Rhine-Meuse delta caused by humans increased after 3000 BP. This caused a huge sediment supply and discharge from the hinterland (Gouw and Erkens, 2007) and meant that in the mouth areas of the Meuse and the Rhine, inland sedimentation could slightly counter the natural rise of the sea level (Vos et al., eds., 2011:44).

Human influence was probably even larger in more hilly or mountainous areas. In Eastern Scotland, for example, Richard Oram (this volume) suggests that deforestation and the loss of woodland cover, combined with an increased canalization and intensification of agricultural activity between the twelfth and fourteenth centuries increased the levels of discharge into the main river channels, especially the River Tay, causing the silting up of navigable channels with associated problems for shipping.

A secondary consequence of the silting up of river mouths caused by humans was that erosion also created problems in relation to the discharge of inland water across large areas. This certainly was the case in Holland when the Rhine mouth silted up before c.1200. The water in the peat areas behind the dunes could hardly be discharged. Therefore, already in the twelfth century, new canals needed to be constructed (see e.g. van Dam, 1999). Water discharge problems also enhanced flood risk due to heavy rainfall. This was the case in parts of Scotland during the fourteenth and fifteenth centuries (Oram, this volume).

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\(^3\) According to the same article referred to, the flux of sediment reaching the world’s coasts would have been reduced by $1.4 \pm 0.3$ billion metric tons per year because of retention within reservoirs. An opposite effect is caused by modern, large scale dredging techniques to deepen rivers. This way, sediments do not reach the sea anymore (personal communication H. Weerts).
4. Changes of the hydraulic system directly triggered by men.

In section 5.3., we deal with the chronology of embankments and their role in the – not necessary rectilinear- intensification process of land use. However, dike building and embankments themselves, as well as other infrastructural works, could have increased the vulnerability of a landscape and influenced natural phenomena. This is a complex matter and differs locally. However, here is a general outline along with some options.

Outside the dikes, particularly in delta areas, embankments have an important influence on the tidal rivers and channels. The regionally changed tidal influence could have weakened the embanked hinterland on a local scale as we will describe – not only at ordinary tide, but also at spring tides, in particular coinciding with gales. It was the different geometry of the tidal river and side canals that was at the core of these regionally different influences (de Kramer, 2002: 16 ff.). That is why, for example, in the North Sea itself, the amplitude is much bigger at Vlissingen (Eng.: Flushing) (3.8m) in the south than at Den Helder (c.1.4 m) more to the north (id.:18). If this natural geometry was either entirely or only partly artificially changed because a natural process had been triggered, the tidal amplitude could also have changed. That amplitude was influenced by the geometry of the bottom. When depth was decreasing, a process of shoaling increased the tide amplitude. The (due to embankments) increased tidal range as well as the increased flow rates could have deepened the tidal channel due to erosion. This might have caused higher high water levels with an increasing risk of flooding as a consequence and a need for still higher dikes. This was the case in the lower Scheldt basin near Rupelmonde from the middle ages onwards (Kiden and Verbruggen 2001:27). Even more than depth, it is the frictional resistance of the borders that influences tidal amplitude. A narrowing shape of tidal channel can result in an increasing process of reflection (rebound) and higher tidal amplitudes (de Kramer, 2002: 20). This ensures that the tidal amplitude in the more inland part of the Western Scheldt is still much bigger than at its mouth (Vlissingen c.4.6m, Antwerp c.5.9m; de Kramer, 2002: 21). When the river banks are more parallel (e.g. due to embankments), reflection as well as the tidal
amplitude can be lowered (de Kramer, ibidem). If this parallelism was due to embankments, flooding of one polder can change the whole geometry with new increases of tidal amplitudes as a result. More inward land frictional resistance can become so important that tidal amplitude progressively lowers again (the s.c. tidal bowl effect) (id.: 21), despite local differences still can occur due to local narrowing.

Changes in the geometry of the tidal channels can also cause changes in water speed during tidal activity, particularly in the volume of water displaced. Moreover, these elements determine tidal influence on the river banks and the adjacent polders.

The amount of water between the imaginary lines of high and low tides is called tide storage area (Dutch: ‘komberging’). If one is only focusing on the acreage of a tidal area between the tides, it is called the accommodation space. When large scale embankments took place and side channels either disappeared or were closed with dams, this area was reduced. This could then trigger a deepening of the river bottom, an increased water speed, a larger tidal amplitude, and thus could result in more pressure on the river banks (de Kramer 2002: 37). However, according to some this pressure would decrease again after a certain period (id: 42) due to the effect of deposition of marine sediments near the dikes in the second stage. This phenomenon occurring in intertidal environments is well known to earth scientists. The reduction of the s.c. tidal prism by embankments enhances sediment infilling and can even cause the closure of tidal inlets (Waller et al. this volume p. 7). This phenomenon is reported a lot in medieval charters. However, after a certain period, these alluvial deposits were often embanked as well, this way again neutralizing the risk reducing effect of the deposition of marine sediments.

Despite embankment or damming activities (of former tidal canals), human influence at the seaside of the dikes was also noticeable due to dredging activity in the tidal channels. Although this is a recent large scale phenomenon that became important from the late nineteenth century onwards, it was not uncommon in the middle ages either. So, we know that the former direct connection of the port of Bruges with the sea, the so called Zwin, was already dredged systematically during the fifteenth century (Augustyn, 1992). The influence could have been considerable because the activity might have changed the course of deeper tidal channels within
the estuary since there was a natural under water difference in ebb tide and flood tide channels and flood tide channels were normally more dangerous for the neighboring river banks.

For the River Elbe, it has been shown that modifications of the estuary in the second half of the twentieth century increased storm surge levels in Hamburg by 70 cm. Experts estimate that about three-quarters of this increase was related to coastal defense measures and one quarter to the deepening of the shipping channel from less than 11m to 14.5m (von Storch and Woth, 2006).

Understanding the relation between the building of human infrastructure and the effects on natural phenomena is very complex because human influence may have triggered the natural ‘morphodynamic’ system in different ways: consolidating it, disturbing it, or triggering a new unexpected phenomenon in an adjacent area (for the last statement see de Kramer, 2002: 47). The overview of some of the most important aspects of human influence on physical phenomena made by De Kramer and (in a simplified way) shown in figure 2 must therefore be interpreted with care since no ‘consequence’ is an absolute one. Everywhere and at any point in time the complete local context must be considered. This can be lead to an opposite result. (Idem: 48).

However, history teaches that in most cases and especially since the medieval period, human influence has complicated occupation in the longer term.

**Inside the dikes.**

The previous section focused on the influence of embankments on the seaward part of the coastal landscape, dominated by the sea and the tidal channels. However, even more importantly, changing the inland landward part of the coastal landscape - the area inside the dikes - had a major influence on the future sustainability of the area.

In some areas, the dike constructions themselves damaged the environment and made it more vulnerable: the constant digging of sods inside the dikes to repair them caused pits near the dikes to often fill up with salt mud. This weakened the area (de Vleesschauwer, 2012: 15).
However, land subsidence was a much greater risk! It has been already mentioned that (mostly) the process of peat compaction and land subsidence continued and even increased after embankments, as drainage and exploitation were intensified. This increased stress on dikes (see above) and asked for higher and more solid dikes and greater investment. Indeed, both the degree of investment and the degree to which the judicial and political organizations could ensure the maintenance of the infrastructure after embanking was very important for the sustainability of the area. The level of investment was determined by social organization and this will be dealt with in the next section.

5. The social organization as direct and indirect player determining the man-nature relation in coastal areas.

Above, we described the most important direct effects of human occupation on natural phenomena and environmental changes. However this influence was very different, both locally and temporally. This is not only due to different natural conditions but also to the way people organized the landscape. In turn, this was determined by the evolving social organization of society.

5.1. Why did social relations influence the geographical changes in coastal areas?

As everywhere (but to a larger degree in coastal areas because of the very high pressure of nature on living conditions), the man-nature relation is influenced by social organization in three ways.

1/ The social organization determined the occupation process as well as the degree of intensification of land use. As we will see below, occupation processes and embankments—and also the possible natural consequences described above—were directly related to changing social relations!

2/ Even in a society with apparently similar occupation phenomena, the influence of human settlement on the environment was different everywhere. This was due to different natural conditions. However, perhaps the different social organization was even more important and the
ability of this social organization to cope (e.g. via effective social control systems) both with changing natural conditions and natural disasters. Essentially, some specific social organizations would better handle the influence of natural changes than others. In the extreme, some types of social organization even managed to almost eliminate natural hazards or developed strategies to turn natural conditions to their advantage.

3/ A third point that needs to be made in this context is that the confrontation of certain social communities with negative natural phenomena and increased natural stress, could cause social changes that could have had in their turn (negative) cumulative effects on the influence of natural hazards.

For these reasons, it is necessary to study the social organization of the communities living in or influencing the coastal areas to understand the evolution of these landscapes. For so many decades this was only superficially taken into account, but in the 1990s this changed when historical geographers made serious attempts in this direction, not at least for coastal areas (Thoen, 2004; van Tielhof and van Dam, 2006, and in this volume Tys; Soens), although even today historical geography as a discipline still too rarely deals with former social relations to explain landscape changes (Thoen 2011).

However, in coastal areas different elements are complicating the study of the links between nature and social organization:

1/ Natural conditions, even on a regional scale, can have changed without direct and even indirect human influence. Climatic changes like the Medieval Warm Period and the Little Ice Age and their effect on the intensity of storm surges are good examples of this (De Kraker, 2008). For further causes we refer to the contribution of Henk Weerts (this volume).

2/ It is known that regional social causes for environmental change in the coastal area might have been caused by social or natural changes in a neighboring area, since the environmental cost of social or economic changes can be ‘externalized’ to neighboring areas. For example, bad maintenance within one polder can have consequences in neighboring polders as well, and land improvement through deep drainage in one area often results in increased drainage problems in the neighboring regions.
3/ It is likely that humans were not always aware of the damaging nature of their interference in the natural ecosystem, at least not at the moment of interference itself (e.g. concerning land subsidence due to compaction of peat; the consequences of deforestation on erosion and silting up of rivers...; see above), since it often took some time for negative consequences to appear. Even if people did become aware of some of the negative consequences of their actions it is unlikely they understood the mechanisms underpinning them.

Despite these difficulties, a study of social organization is necessary to understand the changes of many North Sea low coastal landscapes. In pre-industrial societies, the social organization that determined survival mechanisms was regionally organized. Why and how did this happen? It brings us to some methodological considerations about the concept of social agro-systems, first raised in 2004 (Thoen, 2004).

5.2. Social agrosystems in coastal areas.

As it has been stressed elsewhere, that during the middle ages and the old regime, regionally different ‘social agro-systems’ for decades determined the way people organized their production systems (Thoen 2004). This was due to the fact that in a pre-industrial society distance was still more important and fragmentation in many senses was the rule (politically, geographically, in social and market relations etc...). Combined with a large pre-capitalist tendency towards path dependency, people organized their survival strategies to ensure their income through regionally organized social relations, both formal and informal.

Regional social relations are determined by many elements such as natural conditions, property and power structures, family and market structures, cultural traditions, and supra regional elements (Thoen 2004). Since one of the elements is natural conditions there is a ‘bounce’- effect between social organization and natural environment. In particular, property and power structures are fundamental in vulnerable areas such as the coastal zones (van Bavel and Thoen, 2012). The social organization of production processes, the use and formation of the land, the cultural landscape, and the environment were to a large extent shaped and directed by property
arrangements. Property rights are understood as rights to land, such as the right of access, the right of sale and the right of inheritance, but also the right of use and the rights of profit, the rights of exclusion, the rights of management, and even the rights of prestige. These rights can be distributed between various persons and organizations (van Bavel en Thoen, 2012).

In pre-industrial societies, three types of social relations and property relations can be discerned. First, relations between local peasants who organized the production process locally. Second, relations between the local peasants ‘in the fields’ and their lords who did not cultivate land and often did not even live in the area under consideration. Third, there were the market relations inside and outside the region.

These described relations could be discerned on a regional basis. However, the social agro-systems in the coastal plain of the North Sea, also had a lot of similarities! Often rather identical changes in social relations happened, although not at the same pace. Indeed: in almost all areas there is a three stage evolution from a society and commons (and often with ‘terps’), towards a (commercial) peasant economy with a majority of small holdings and no commons, and from there towards a more commercial society with larger and middle sized farms.

Within this context it is impossible - not at least because a lot of research still needs to be done - to describe in detail how the coastal social agro-systems determined landscape evolution. However, some important aspects and trends that are mostly the result of recent research or new hypotheses can be discussed.

5.3. Towards dike building and embankments: resulting from and resulting in new social organization.

5.3.1. The social organization of before the dikes and embankments. A peasant society with commons.

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4 The original text of this section has been improved a lot thanks to important remarks of Tim Soens to which we are very grateful.
During the early and high middle ages, in almost all documented coastal areas on both sides of the North Sea area, rather small and free peasants seem to have been the majority of the people who colonized the areas (Soens, 2011; Rippon, this volume). Although this was not an ‘equal’ society (differences in landed property and wealth existed), these peasants were relatively free and mostly possessed their own means of production. In most coastal areas, local lordship was scarce (see the recent overview of the property and power relations in the Low Countries in: van Bavel, van Cruyningen and Thoen, 2011). It has been suggested that the absence of lordship in the early middle ages was the result of the late integration of many coastal areas in the Merovingian-Carolingian empire but, more importantly, it can be caused by the retreat of lords due to plundering by the Vikings between the ninth and eleventh centuries (idem 2011:171) and maybe even earlier by other Germanic tribes from the late Roman period onwards (for these invasions see e.g. H. Thoen, 1978). The Vikings were especially interested in the wealthiest layers of the society (d’Haenens, 1967). It is worthwhile investigating whether the Viking invasions could also have triggered the creation of trading mechanisms within these relatively free peasant societies.

Until the 1980s /1990s, it was generally accepted that before c.1000 the coastal plain was poorly occupied. Again in the eleventh century its occupation would have been considerably hindered, not at least due to the supposed increasing influence of the sea. More recent geological and historical research has shown, however, that in the coastal areas of the North Sea area, the Carolingian and post-Carolingian periods cannot be seen any more as a period of general abandonment and decline as one still thought in the last decades of the past millennium when this period still was seen as a period of ‘transgression’, land losses and settlement contraction (see e.g. Baeteman, this vol., Vos, 2011, Tys, 2003, van de Ven, 1993 et al.). Despite the fact that recent research is more focused on regional differences, the coastal area as a whole can be placed within the more pan-European optimistic vision on economic development of this period (McCormick, 2001). Lordship was in general weak and peasants could profit from it with large landed property rights, paying little or no rents. Settlements mostly coped well with the natural influence of the sea either via well-chosen Flachsiedlungen (un-raised settlements) (e.g. on river
banks, see Meier, this vol.) or by smaller (single house) or larger settlements on artificial hills (*terps*: see below). These coastal peasant societies could continue to grow relatively fast during the middle ages (van de Ven 1993; Tys, this volume; Soens, id.; Rippon, id.).

It is likely that in this social agro-system peasant society could still dispose of a huge amount of common lands: the still mostly un-diked freshwater peat lands and salt marshes. It has been demonstrated that peasant societies with commons were relatively stable. We know that also outside the coastal wetlands societies with a huge amount of common land to their disposal and dealing with only a limited amount of environmental and social changes, could survive very long (see e.g. Thoen, 2004)! Here, changes mostly occurred only when the communal system was changed which, as history has shown, occurred when new lordly (or governmentally) influence induced changes to property rights. This is actually what happened in many coastal areas in the course of the middle ages.

5.3.2. New social relations and embankments.

*Offensive or defensive dikes?*

In older literature embankments were thought to have occurred in two stages: a defensive stage, and an offensive stage. During the offensive stage, land would have been ‘conquered’ from the sea. This chronological ‘two stage model’ (which is still partly apparent in the standard works of Gottschalk, 1983 and Verhulst, 1995) is impossible to maintain. We now know that dikes were made in marshland and peat land that was already used by men (so that in this sense the ‘offensive ‘character can be questioned), and that there were always aspects of ‘defense’ (against tidal influence) in dike making – even if in different and changing degrees to that seen previously. On the other hand, many embankments were caused by need of developing societies to move towards more intensive land use (e.g. more grain cultivation, more intensive cattle breeding (compare remarks of Rippon, this vol.; see also Vervloet and van den Bergh, 2007:21). So, in certain aspects even low dikes built for temporary protection, could be seen as ‘offensive’. Moreover, as already mentioned, it was often the changed property rights of formerly un-diked areas that particularly triggered the earliest embankments. In that sense too, embankments can
often be considered as ‘offensive’. On the other hand, over exploitation of land between the twelfth to fourteenth centuries often meant that many (re-)embankments were progressively done for defense with higher and stronger dikes which again changed the property structures in the coastal lowlands. In sum, there is actually no clear cut periodization apparent between ‘offensive’ and ‘defensive’ embanking.

*Dike building and embanking as tools for population policy of lords and for agricultural intensification.*

Interventions in the hydraulic system of a tidal area initially occurred to protect settlements and newly reclaimed cultivated plots. Though some of these interventions date to the Roman period (Lascaris and de Kraker, this volume), most have occurred since the ninth and tenth century. The earliest dikes were built along and more or less parallel with the tidal channels in the neighborhood of settlements (and not as was thought along coast lines) as has been demonstrated by Henderikx for the Netherlands (1977) and by Tys for the Belgian coast (2003 and this volume).

Archeology showed that in coastal areas which were not yet protected with winter-resistant dikes (still used in a lesser intensive agrosystem), the oldest Flachsiedlungen (un-raised settlements) were easily replaced (see e.g. for Oost-Friesland, see van de Ven, 1993:51; for Noord-Holland: Besteman and Guiran, 1986; for Flanders: Van Doorselaer and Verhaeghe, 1974), adapting to changing (often human influenced) natural conditions. Elsewhere, structures variously known as terps, werven, vliedbergen, and Wurten (artificial mounds), in some areas going back to the Roman period or even earlier (as in Friesland and Groningen - see van de Ven, 1993: 39ff. or Schleswig-Holstein, see e.g. Meier this volume), were easily adaptable to counter change. Low dikes (also sometimes going back to the Roman period, see Lascaris et al., this volume) had a number of uses. They could often be used as additional protection or to make the surrounding salt marshes more useful for cattle and sheep breeding. They could even have been used for new forms of arable farming necessary to feed a growing population. For example, the building of so-called ‘summer dykes’ would produce more hay for animal feed which, in turn, would increase manure production (see Bazelmans et al. 1999:61; compare also Kiden and Verbruggen, 2001:26). Natural growing grasses in marine sediments are excellent fodder for cattle breeding
(including winter fodder), which was a precondition for mixed farming. So, in certain areas, intensification did not yet make it necessary to generally build high and robust dikes and complex sluice and locks in this first stage. However, the growing land pressure in the course of the middle ages, stimulated by a new social organization, must have created a higher need for the cultivation of bread cereals as well as a need for constant and protection from the sea. Tidal channels too would have required protection as well as the need for expensive sluice systems to drain the fresh water from embanked areas. In sum, the earliest settlements probably did not really need much dikes at all.

So, we can see embankments as a stage towards a more intensive use of land. This intensification of land use began before dike building. Settlement creation on artificial mounds was stimulated in many areas. A further stage in the intensification process was dike building and embankments which was actually a logical stage in this evolution. This intensification had a cumulative effect on dike building since it often caused additional ecological problems, which in turn demanded more and stronger embankments. Logically, these stages happened in different areas according to a different chronology.

Property and power structures and their role in occupation of tidal marshlands and dike building

But what triggered this intensification process leading to a more intensive land use and especially to the earliest embankments? Was it the large landowners and lords, or was it the peasants? This requires a nuanced answer.

A major role has been attributed to the changed power relations in the coastal areas and the role of the lords. It has been stressed that in (parts of) coastal Flanders the count played an important

\(^5\) Probably, in later stages cultivation of the cereals did not play such a large part in the embankments and re-embankments. Some peasant areas could develop a market system to import cereals, as it may have been in Holland from the 14th century on. In other areas the peasant society developed towards a more commercial society. Here cattle breeding often played a larger part. See below.
role in the reclamation process of the coastal area from the tenth century onwards (Tys, 2003, 2004), while for Holland the role of the count and of the bishop of Utrecht have also been underlined from the eleventh century (H. Vanderlinden and others see for a recent state of the art in this respect: Borger 2007: 59 and the literature there). In north-west Germany, the bishops of Bremen and Hamburg as well as the counts of Oldenburg played an important part in stimulating the creation of embankments (see Meier, this volume and the literature there)! In the English Fenlands, Glastonbury Abbey also had a strong role in shaping how landscapes were managed. However, for Rippon (this volume), who studied embankments in this area, it was locally different since in that neighborhood land shape and embankments were more influenced by local and peasant initiatives.

Certainly, the role of lords in early dike building can be proven. More than building dikes, their role was to encourage an intensification process. Therefore, collaboration with the local inhabitants and peasant land users was necessary.

Probably a major role must be attributed to changing property structures to explain the process of the earliest dike building. Lordship in preindustrial societies was build on two pillars: the seigneurie foncière (the possession of estates) and the (seigneurie banale) (the right to warrant and rule). These kinds of lordship were often in the hands of different groups. However, to change property structures in larger areas it was almost a pre-condition that the two pillars were in the same hands, or that the social groups controlling these pillars collaborated. To ‘reclaim’ land via dike building, one had to change the property structures of the peat areas and the marshlands that together comprised common lands. It was these groups who owned the seigneurie banale that could change the property rights. This was facilitated when they could collaborate with peasant property holders who were, since the early middle ages, found most frequently in coastal areas to encourage the reclamation process (or even better to stimulate intensification of that area).

How did this happen? Living outside or at the border of the (post-) Carolingian empire in a society with peasants possessing large property rights, a new class of (over-) lords could enhance their power so much that they probably managed to acquire (parts of) the formerly common lands which were huge in number. Some large estates were erected, but most of the land was given to
*coloni* (peasants) who got huge property rights over the land they were now allowed to privately cultivate. The gains were reciprocal. The lords got more inhabitants (who could also be used for military service and indirect gains via increased commercial activities), while the peasants often only had to pay a symbolic rent. So the major role of the lords was to attract people: in other words, they pursued an active population policy which could enhance both their income and their power and prestige in the region. These lords could profit from decreasing central power structures (particularly in the former Carolingian areas) and were stimulated by changing (growing) needs for inhabitants as well as for cash which they needed more in a growing commercial society from the 8th century and even more from the 11th century on. This evolution happened everywhere (Thoen, 1993) but in the coastal wetlands the role of lords was reserved to a very small powerful elite who had to take the traditions of private peasant property rights into account. These peasant societies were also to a relatively large degree protected by their overlords from the ambitions of lesser lords through the creation of exclusive power structures within those societies. To counter other seigniorial lords the overlords also collaborated with religious institutions who would not challenge their seigniorial power. These institutions were often gifted with land and rights over common lands where they could erect large holdings, priories, and they even got the right to stimulate colonization of the former commons. So, an increasing destruction of the common lands was the result. All of which meant that peasant society could continue to grow and increase intensification (and embankments) in the twelfth and thirteenth centuries when land pressure became apparent.

These lords, who in the early middle ages were still interested in the direct management of land not only played an indirect role in the intensification process via a population policy. It is likely that they also played a direct role as well via the organization of land use within these newly reclaimed lands, as the systematic and often geometric land divisions show. The reclamations named “cope”- reclamations described by van der Linden for Holland and Utrecht (Linden van der, 2000 refers to all his earlier publications) as well as the more recent studies of Tys for Camerlinc Ambacht seem to indicate this as well (Tys, 2003, 2004), though there were also huge differences: while he count of Flanders seems to have been especially interested in the

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6 In Flanders for example small territorial administrative units called *ambachten* were erected under the lead of an officer from the count (Koch, 1951).
colonization of marshlands, the count of Holland wanted to stimulate the intensive use and exploitation of peat lands. However, their general goals were similar. They both wanted to enhance population numbers and intensify land use through the privatization of former common lands, probably and especially to increase their power position in the county since tenants could also be recruited for the army. In some areas (like in Holland, see Linden van der, 2000), only symbolic rents to recognize their seigniorial power needed to be paid.

Whether these lords not only stimulated but really financed the dike making itself cannot yet be proven. What we do know is that the peasants living in diked areas were (at least from the 12th century) themselves responsible for the maintenance of this infrastructure and this could be an indication that they were actually co-responsible for the initial dike building as well. This suggestion does not preclude investment in these projects by their respective lords and without any doubt dike building in the reclaimed but former common lands was only possible with the consensus of the overlord who had appropriated the ‘seigneurie banale’ in these areas.

Towards a coastal area with a majority of small ‘commercial peasants’.

We mentioned already that the first dikes were often limited in size and height. They were often only protected parts of the areas adjacent to tidal channels. However, as a consequence of the tendency towards intensification, the first real ‘polders’ with a ‘closed’ ring dike mostly occurred between the eleventh and the thirteenth centuries (an early example can perhaps be found in tenth century Friesland. Van de Ven, 1993). We now know that in almost all the embanked and unembanked coastal areas of the North Sea area during 1100–1300 a society had developed with a growing population and a predominance of small peasant holders. Recent research demonstrates that the current polder landscape with a majority of large farms is to a large extend both a modern and early modern phenomenon. In the classic middle ages small scale farming was the rule, a social structure which almost everywhere goes back to the classic middle ages. These peasants were particularly interested in survival strategies. However, the growing needs of the overlords for money, caused by changing consumption patterns and growing urbanization (see Thoen, 1993), as well as the increasing network of waterways which was a precondition for drainage but was also very useful for transport of cash crops to the markets, stimulated these peasants to produce for the markets. Moreover, everywhere in the coastal areas towns of all sizes developed
in the coastal areas (from Dorestad to Bruges and the many small towns (see e.g. Stabel, 1996) erected in the coastal areas....) since the tidal channels and the man-made canals were of course also very useful for merchants. So, the growing commercialization was very present in the coastal wetlands, which stimulated, together with the already mentioned lordly colonization strategy, the fast colonization between the 11 and 13th century.

In sum, in many coastal areas the majority of peasants who owned small holdings were already producers of commercial products from an early stage in their existence. Salt making, peat digging, cloth production, as well as the cultivation of cash crops like dairy products, were huge. Accordingly, we could label this society at least from the Middle Ages onwards as a ‘commercial peasant society’, and this in a period when many inland sandy areas were still not as much commercially oriented (Thoen, 2004). Sometimes, like those from the fourteenth century in Holland, they already specialized in the production of dairy products and in peat extraction (van Tielhof, 2005).

New players in the occupation process...

In most areas, the role of important (over) lords to stimulate more intensive land occupation continued up to the twelfth century. The count of Holland, as well as the count of Flanders, are good examples of this. Later, in many areas, this kind of support disappeared since the overlords either re-aligned their interests towards supra-regional matters or suffered from impoverishment (like the Flemish counts in the thirteenth century).

In contrast, new social ‘upper-class’ groups could enhance their power in the area through typical medieval short-term profit seeking activities. This was the case with many religious institutions (see e.g. Mol, this volume), with new local lords (such as in parts of Zeeland, demonstrated by Dekker for Zuid-Beveland), but, often a bit later, also city burghers. In many areas they could also profit from the poverty of the peasants to acquire more property rights.

The role of the Cistercians and Praemonstratensians in the embankments is now clearer (see e.g. Verhulst, 1995:48; Mol, 1992). For a long period it was thought that these institutions were the initial settlers in salt marshes, but now we know that the coastal area already had a high
population density. Only through gifts of (already reclaimed) land, or when the peasants ran into financial difficulties, could they take over the initiative or create larger demesne centers, or even priories. Although active support from institutions and feudal lords most likely already dates from an earlier period, it was only apparent in Flanders since the twelfth century (Verhulst, 1995: 38), from the later middle ages in Zealand Flanders (van Cruyningen, 2012), and still later in the northern part of the Netherlands (XXX) that real entrepreneurs (private persons, institutions, lay lords) played a larger part in the embankments and that large scale embankment initiatives were taken. In particular, from the late thirteenth century onwards we can see more and more burghers of towns investing in the coastal rural estates, including peat digging centers (Thoen, 1988). The most important role of the increased influence of these large landowners was that the large estates that had often been created by them delivered, together with the increased peat digging activities, additional employment possibilities for the ever smaller peasant holdings (Thoen, 2003).

From the late thirteenth century on: the deficiency of a disrupted peasant society to cope with environmental problems and the change towards new social agro-systems.

From the late middle ages until the eighteenth century relatively the same type of evolution of social agro-systems took place in most coastal areas around the North Sea, although there was a huge chronological differences between them.

The smaller peasant societies increasingly came under pressure. Gradually more and more entrepreneurs financed embankments in areas where peasants had previously lived and who had abandoned their properties due to financial problems. These investors profited from the insolvability of these people to make ‘new land’ through the re-embanking of certain areas.

In this context it is important to know that from the thirteenth-fourteenth centuries new institutional structures became necessary. The embankments themselves had provoked greater investments for protection against the sea and to counter other increased water management problems. Indeed, the growing population also needed more protection. Moreover,
overexploitation had made the embanked areas more vulnerable for storm surges. To cope with these growing needs for maintenance, the first real water boards were installed. While, until the thirteenth century, peasants owning lands in the embanked areas and mostly living in the nearby holdings maintained the infrastructure themselves, from the thirteenth century onward it were organizations employing wage earners (paid through raising water taxes) who maintained the dikes, sluices, ditches and canals. The evolution of these institutions or waterboards (called: ‘waterschappen’, ‘wateringues’, ‘wateringen’, ‘everingen’, ‘hoogheemraadschappen’, ‘polders’, ‘Wassergenossenschafte’,…) developed between 1250 and 1600 all over the North Sea area (see: van de Ven, 1993:97). The judicial and social environment in which they functioned has been studied much more carefully during the last decades (see e.g. Soens, 2009 and 2011, van Tielhof, van Dam, 2008 and others). Initially, these organizations mainly dealt with the supervision of maintenance and repair works which remained the task of individual landowners. Only gradually, the water boards started to organize maintenance works themselves, financing their activities by levying a scot or geschot (uniform land tax) to be paid by all landowners. As we will see, for many small landowners, these costs became too much of a burden to survive….

Within these boards the peasants gradually lost influence (Soens, 2008). This might even have created additional problems for the sustainability of many coastal areas. When, as in Flanders or in Romney Marsh, the government of the water boards fell into the hands of the large landowners in the course of the later middle ages, things got out of hand since peasants no longer controlled their own safety (see: Soens: 2006, 2009b). A majority of ‘feudally inspired’ (read: interested in short term profit only) landowners took control of water management in wide coastal areas. It is no coincidence that in principalities where peasants remained influential on local water boards (like in Holland), water management seems to have been more effective and the peasant society could survive until the seventeenth century (see van Tielhof, 2005).

In itself, the transition towards monetary taxes to finance the water control system had an important impact on coastal society. On average, water taxes were not so high but they often were highly irregular. Many smaller peasant landholders became bankrupt and their land was in turn taken over by larger peasants. Furthermore, the water taxes were levied in cash, which already presupposes a level of commercialization.

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7 Today in the US these institutions are called, ‘levee boards’.
of the rural economy. In difficult years, peasant landowners could be faced with high water taxes, instantly to be paid in cash. As a result, the monetarisation of water management was clearly linked to the commercialization of coastal society, and with the transition from a society of peasant smallholders towards ‘commercial’ agriculture, where big landowners possessed the majority of the land. (Soens and Thoen, XXXX lease holding). Natural conditions slowly became less favorable for small peasants because the cultivation of heavier clay lands required more capital in terms of horses and plows. Only larger and mid-sized farmers could survive since they were able to expand and could make enough economies of scale (for more details see e.g. Soens 2012). In sum, there generally was a ‘forced’ evolution towards a more commercial society. Since the seventeenth century this evolution seems to have led towards a more sustainable landscape in most areas (see below). However, many regional differences occurred. The described evolution happened first in the Southern Low Countries and more later in the North. So while the deterioration of peasant society and the evolution towards larger holdings had clearly begun by the thirteenth century in the Belgian coastal area as well as in the Dutch river area (van Bavel XXXX), in Holland the process seems to have been slower. Here, peasants adapted in the later middle ages. This was thanks to a new boost of the proto-industrialization (peat digging, fishery, compare van Tielhof, 2005) and the increased demand for dairy products from booming towns. Peasants here specialized in such products and could profit from the grain supply of towns like Amsterdam. It was not until the seventeenth century that an evolution towards a more capitalist society with larger more specialized farms occurred here. Further north in the marine areas, this evolution did not take place until the eighteenth century (Groningen, parts of Friesland, Noord-Holland; Brusse et al. 2010: 204). These evolutions were not the only reason for the man-made increased environmental stresses that changed social conditions. Other factors were important as well, not least the importance of the balance between the different social players (owners, land uses, power elites). However, in general the natural pressure in the long term was in favor of the more powerful social classes. So, contrary to the more sandy areas, many coastal areas experienced major social changes in the course of the later Middle Ages and the Old Regime. What is important in this context is that the deterioration of peasant society since the late middle ages and the change/development towards a more commercial society did NOT immediately generate higher investments! In many areas the opposite took place! It has been demonstrated that for some regions like Flanders and Sealand the new, often absentee, powerful landowners who succeeded in taking over the landed property (due to the impoverishment of the peasants) and part of the judicial property (since they got more and more control over the water boards, Soens 2009), could not ensure the sustainability of the landscape for a long time between c.1250 and 1600). Apparently, short term profit making was the main goal of these elites. Even the larger farmers who took over from the former peasants (who degraded
towards wage earners), also struggled to survive and were not able to ensure the sustainability of the landscape. Farmer-elites who could support a more sustainable land use only emerged in the course of the early modern period in Sealand, Holland, Friesland, and Groningen.

Long term data series that can teach us more about the real investment level of the institutions are scarce. However, it is possible to get an idea of the investment rate for the Western Scheldt area (particularly the western part) from the later middle ages using water taxes as an index. As can be seen on figure 3, despite regional and temporal differences, in general the investment rate of the water boards was low (see: Thoen and Soens, 2001: 12 ff. and developed in Soens 2009 and Soens, 2012, table 5.5)! In many coastal areas during the late middle ages and into the sixteenth century, damages from storm surges and land losses were huge and many villages completely disappeared (see for the Western Scheldt area figure 3; compare also Soens, this volume). However, the biggest land loss in this area occurred during the Eighty Years War where the deliberate flooding of lands became accepted military strategy for both the rebel side and the Spanish (De Kraker, 1997). However, the fact that land and villages were often lost for ever proves that it this had been a vulnerable society before that war. For Sealand Flanders the loss of land cause by storm surges and warefare is estimated at roughly 75% of the late medieval landscape (De Kraker, 2002).

In general, until the seventeenth century, investments by the water boards represented no more than 10-50l wheat per hectare, which can be estimated as only a few percent of the yearly income of arable land in the polders (estimated at about 2000l per year of wheat per hectare).

5.5. Supra-regional support to regional social agro-systems in coastal areas and new attitudes of investment lead to increased sustainability in the Early Modern Period.

**Better techniques for sustainable landscapes?**
A new stage in draining and the new embankments was linked to the application of new drainage technology, in particular the general use of *poldermolens/hoosmolens* (drainage mills). Wind driven drainage mills had spread slowly since the late fourteenth century in Holland. They only became generally used during the second part of the sixteenth century when they replaced horse driven mills (see A. Bicker Caarten, 1990; see also. Zeischka, 2008; Borger, 2007: 55ff.). Initially, these (wind) mills were used for defensive reasons but their common use seems to be linked to a wider strategy of land reclamation. They also continued to be used for drainage via a pumping system of formerly flooded lands, as well as for making dry shallow lakes (Netherlands
s.c. “droogmakerijen”). Which were often created by dredging peat under the water table, a practice which had become common from the late middle ages on in some areas. Although these mill-steered reclamations fundamentally increased the tax burden, in certain areas like Holland the peasants themselves seem to have been able to support these additional costs for centuries.

**More sustainable investments**

In the second part of the Old Régime, the investment rate of the water boards alone was clearly growing, more than doubling in general! In some areas, this increased investment had already begun by the end of the sixteenth century. Elsewhere, the investments only grew post-1650. The local water boards were not the only financers of investments anymore! Indeed, in many areas like Sealand Flanders, the polders that needed money for investments after flooding or dike collapse were now subsidized on a more regular basis by higher institutions, governments, and/or neighboring polders to overcome financial problems (de Vleeschauwer, 2012: 96). The same was true for Holland (van Tielhof and van Dam, 2008:209). A new ‘absentee’ elite no longer just exploited the area (as seen in the period between 1200 and 1600); they also seem to have been more concerned with the general welfare of the landscape.

**And more sustainable results…**

From the second half of the eighteenth century onwards, provincial governments also took much more care in the construction and maintenance of ‘sea walls’ (de Vleeschauwer, 2012: 196)! It is very likely that this substantial growth of investments was responsible for the declining process of dijkvallen (dike erosion) - land losses due to storm surges and channel erosion caused by the ebb flow. While flooding caused by storms was very common in the late middle ages - a vast amount of land and many villages permanently disappeared- from the post-religious war period onwards these loses were relatively restrained. In the Western Scheldt and its adjacent tidal channels, a limited amount of polders still could be reclaimed. It is particularly important that a consolidation of the border line and the river banks took place (see figure 3). Only a small number of storm surges still caused damage, despite a continuously growing tidal amplitude upstream of the river towards Antwerp between 1650 and 1850 (de Kramer, 2002: 21). Even the
size and shape of the parcels cultivated since the seventeenth and eighteenth centuries is mostly still the same as today.

**What is the long term balance?**

Was anthropogenic influence in the coastal areas only negative for landscape evolution in the longer term? The above described influence of men on the nature of soils in the coastal area could give the impression that man’s influence on the coastal area was negative. If we view it in the long term, taking into account only the available size of land, we can indeed say that from the Roman period until the end of the Old Regime (although the embankments made with the aid of windmills of the Early Modern period can be to a certain extend be seen as ‘land conquests’) the acreage of the totally available land had shrunk considerably and it is likely that to a very large extent this was due to human distortion of the natural ecosystem. Moreover, the valuable peat soils in many areas (although there value was declining from the eighteenth century with the growing importance of coal) disappeared too. One can say that probably gradually less people could live in the same area since population pressure was often reversed due to social changes. In the middle ages and the early modern times, the most commercially oriented rural areas, such as the ‘forced’ commercial areas in the coastal landscapes of the North Sea, had the lowest population densities!

However, particularly since the Early Modern Period, one could sometimes reverse an environmental problem into an advantage by integrating it into a new ‘ecological balance’; this was, for example, the case in Holland, where many lakes which originated in the middle ages from peat dredging the underground water table and bank erosion were embanked again after the late sixteenth century. A large lake called the Haarlemmermeer also partly originated from peat digging got another function. It was transformed into a reservoir for drainage of the inland (van Tielhof and van Dam, 2006: 71).

More importantly, with the growing amount of clay soils as a result of the “battle of the sea against men and *vice versa*”, in general and in the longer term soils certainly became more valuable in terms of their nutrient content. The growing share of clay soils could produce the
highest yields for arable farming, as well as for dairy farming in areas under marine influence, the reciprocal relations between social relation and environmental stress, as described, eventually resulted almost everywhere in coastal societies where only highly productive, more specialized, and commercially oriented farming could survive. In the longer term and after many difficult times, this commercial agriculture in which new elites emerged has contributed to the evolution of a more modern society, at least according to some scholars. But this is of course another subject.

6/ Epilogue

In another article of part 1 of this volume, Henk Weerts brought together the major natural reasons for regionally different influence of the relative sea level movements. The text above focused on the influence of human social organization particularly during the last millennium. This influence was huge and the text illustrates why human action caused landscape changes to be different in regions which experienced similar natural conditions. Moreover, we tried to illustrate how and according to which mechanisms the changes into a cultural landscape often enlarged or changed natural phenomena. We also underlined the importance of ‘bounce effects’ between the natural and human causes of environmental changes.

On the other hand, recent research demonstrates a larger link with specific general economic and social tendencies on a supra-regional level. Until the later middle ages, coastal areas seem to have more followed general economic and demographic tendencies contrary to what was previously before c.1980, when researchers still believed in transgression and regression periods as the ‘engines’ for long term demographic movements. Today, with only minor differences compared to the rest of Europe, the Roman period until the third century is seen as a good economic and demographic period; the early middle ages as a period of low dynamics, while the economic revival seems to start in the Carolingian period until its zenith in the twelfth to thirteenth centuries. In older studies one considered the landscape in the period before 1000 (including the Roman period) as hardly being inhabited, and the period between 1000 and 1150 as one of low dynamics due to storm surges and sea level changes. Nowadays, the period
between the eleventh and the thirteenth centuries is seen as a period of intensive growth in most coastal areas, with increasing amount sof small holders, just as it was in most areas outside marine influence.

From the late thirteenth century onwards, the evolution of many marine areas started to diverge from the rest of Europe. Since the coastal regions were more fragile environments, these landscapes were vulnerable to changes in social relations like state formation and to on-going deterioration processes. In their turn, the environmental processes that occurred triggered new social relations where only the upper part of rural society could survive and in which non-local elites could take over the power in the area. Although, these elites managed to transform many North Sea coastal wetlands into regions of intensive agricultural development and economic growth, they could not ensure longer term sustainability; on the contrary, the changed social relations mostly worsened the relationship between man and nature for a long time. Only when one moved from a ‘feudal’ society - where individual and short term interests were still more important than the general interest - towards a more modern society, where central institutions limited personal interests in favor of the inhabitants, and where economic actors again collaborated in a more productive way, could a greater sustainability be realized post-1600.

However, despite these described general tendencies, local and regional differences remained huge. This is actually due to the same mechanisms: social relations did not everywhere evolve in the same way and did not interact in an identical way with locally different natural conditions. Therefore, we hope that the text above helps to understand locally different evolutions of the coastal wetlands around the North Sea.

As well these general long term tendencies, regional differences still deserve to be underpinned with more ‘in-depth’ research. At the same time it must remain the task of the historical geographer to increasingly study in detail the larger scale mechanisms of man-nature relations. Therefore, much more real inter and trans disciplinary research is still very necessary to further analyze and understand ‘the battle between Clio and Neptune’.
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thans verdwenen venen in het gebied tussen Antwerpen, Turnhout, Geertruidenberg en
Willemstad. 1250-1750, Brussel/Wageningen.

in het lage land ten oosten van de stad Groningen vanaf de volle middeleeuwen tot ca. 1870,
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**Figure 1. MOET VERVANGEN DOOR DE BUT (konijnen)**

**Figure 2 Natural versus human causes of historical change of the Scheldt river (zie ook aparte file)**

<table>
<thead>
<tr>
<th>Natural changes</th>
<th>Tide speed</th>
<th>Tide volume</th>
<th>Tide storage (Volume of water between high and low tide in a basin)</th>
<th>MHW</th>
<th>MLW</th>
<th>Height difference between low and high tide mode</th>
<th>Tidal flow rate (flood)</th>
<th>Tidal flow rate (ebb)</th>
<th>Maximum flow rates</th>
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</thead>
<tbody>
<tr>
<td>Silting</td>
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<td>Sea level up</td>
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<tr>
<td>Storm surges (enlarging and deepening)</td>
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<table>
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<tr>
<th>Human changes</th>
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<tr>
<td>Embankments: diking</td>
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<tr>
<td>Cutting of tidal channels with dams</td>
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<tr>
<td>Undiking</td>
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<td>Dredging on bars</td>
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<td>----------------</td>
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<tr>
<td>River bank protection</td>
</tr>
</tbody>
</table>

Source: Based on: de Kramer, 2002.
Figure 3 Water tax burden, storm surges and land losses in the Western Scheldt-Sealand (zie ook aparte file)
Important flood damages

1150-1250

Little amount of important storm damage

1250-1600

c. 12X important storm damages

and 2 periods of milt. inundations

Sealand Flanders c. 1300

1600-1850

c. 3 important storm damages

Cadzand

Burden of water taxes (litre per ha)

1150-1250

small burden (‘Verhoefslaging’)

1250-1600

Blankenbergse Watering  Yvene watering

c. 10-20 l.  c. 50/80 l.

1600-1850

Sealand Flanders c. 1600

1600-1650  c.32 l.  ?

1650-1700  c.35 l.  c. 14 l.

1700-1750  c.40 l.  c.116 l.

1750-1800  ?  c. 100 l.

1800-1850  ?  c. 75 l.

Sealand Flanders a round 1800

Sealand Flanders Today
**Figure 4: Drainage and land subsidence: conceptual diagram.**

This diagram is illustrating the evolution of Delta islands in the **Sacramento-San Joaquin Delta** due to levee (dike) construction and island subsidence in the nineteenth and twentieth centuries. The illustrated process is very similar to what has been happening in many coastal areas of the North Sea Area from the Roman period due to dry making and embankments.

**Source:** Mount, Jerrfey and Twiss, Robert (2005)
Pre-1880: Freshwater Tidal Marsh

- Anaerobic Decay
- CO₂, CH₄
- Vertical Accretion of Marsh Platform
- Main Channel
- Water Table

1900’s: Elevation Loss

- Microbial Oxidation
- CO₂
- Wind Erosion, Burning
- Compaction
- Main Channel

2000’s: Increased Levee Maintenance

- Decreased Levee Stability
- Increased Pumping Costs
- Increased Seepage Rates
- Main Channel
- Sea Level Rise
- Lateral Deformation

or Levee Failure