Medieval Settlement Research **32** (2017), 35–39

TRAVELLING THROUGH A RIVER DELTA: A LANDSCAPE-ARCHAEOLOGICAL RECONSTRUCTION OF RIVER DEVELOPMENT AND LONG-DISTANCE CONNECTIONS IN THE NETHERLANDS DURING THE FIRST MILLENNIUM AD

By ESTHER JANSMA[1 2 3], ROWIN J. VAN LANEN[1 2] *and* HARM JAN PIERIK[1]

Introduction

The collapse of the Western Roman Empire during the fourth and fifth centuries AD in many parts of continental north-western Europe coincided with severe depopulation as well as marked land-use changes and reforestation (see Jansma *et al*. 2014a, Par. 3, and all references therein). In addition, severe river-network reorganisation took place in the Netherlands, and coastal peat areas became flooded (*ibid*.). During the Early Middle Ages (EMA), general demographic and economic trends reversed. In the Netherlands this reversal took place earlier than in other parts of north-western Europe. Already during the seventh century, the rivers in this deltaic region had regained much of their transport-geographical importance and trade relations had intensified. This is expressed by the mid-seventh-century rise of Dorestad, which developed into an *emporium* located in the hub of an early medieval North Sea-based trade and exchange network. This early reversal makes the Netherlands a key region for understanding post-Roman revival of trade and economic prosperity in north-western Europe (Van Bavel 2010). Recent developments in digital data infrastructure in the domains of archaeology and physical geography in the Netherlands now enable the study of this transition from a trans-disciplinary perspective.

Against this background, this paper presents some results from the research project *The Dark Age of the Lowlands in an interdisciplinary light*, which aims to reconstruct the development of the physical landscape, settlement dynamics and land use, infrastructure, and long-distance relations in the Netherlands during the first millennium AD from three complementary perspectives: archaeology, geomorphology, and palaeoecology (Jansma *et al*. 2014a). From an archaeological/historical point of view, the results at present are descriptive rather than explanatory, due to the national scale and data-driven nature of this project.

The current summary spotlights river-bound long-distance relations starting with the Roman Period (RP), since river flooding and changing river courses (avulsions) during the RP had a major impact on the early medieval physical and cultural landscape in this region. The effects of geomorphological changes c on the cultural landscape were reconstructed by identifying settlement distributions and route networks and comparing these to detailed reconstructions of the changing physical landscape. The impact of landscape change on settlement distribution and long-distance connections was assessed using wood-derived datasets representing the archaeological remains of 'exogenous' construction timbers, shipwrecks and barrels excavated in the study region.

The Dutch riverine landscape and its habitation during the first millennium AD

In the Rhine-Meuse delta major geomorphological changes occurred during the late RP and EMA. These periods were characterised by a relatively high flooding frequency (Toonen *et al*. 2013), with the most extreme floods occurring in ca. AD 260/80, 680 and 780. The first of these floods coincided with the Roman abandonment of the Rhine-based frontier (*limes*; Fig. 1). During the same period several new river branches formed (Cohen *et al*. 2012; 2016). This caused the Oude Rijn (Old Rhine), which in the central/western Netherlands was a main corridor from the economic hinterland towards the North Sea, to gradually abandon its course after AD 800 (Van Dinter *et al*. 2017).

The new river branches established several economically important new connections (Figs. 1, 2). The Hollandse IJssel and Lek formed *c*. AD 1–300 and connected the northern Rhine branch to the Meuse estuary, crossing an extensive and formerly inaccessible expanse of peat and facilitating transport over water between the Rhine in the central part of the delta and the Meuse estuary (Pierik *et al*. in prep). The discharge of the river Linge downstream of Tiel was mainly taken over by the Waal around AD 220–450, which became the largest Rhine branch in the delta (Weerts and Berendsen 1995). After the RP, in the southwestern coastal plain new tidal inlets formed reaching towards the Meuse estuary and constituting a new inland water connection between the Meuse and Scheldt (Fig. 2; Vos 2015; Pierik *et al*. 2016; Pierik *et al*. 2017). Another important new connection was the Gelderse IJssel, after the seventh to eighth century branching off from the Rhine towards the north (Makaske *et al*. 2008; Cohen *et al*. 2009; Cohen *et al*. 2016). The maturation of this river linked the Rhine in the eastern part of the delta to the Almere lagoon, which in the north was connected to the Wadden Sea (Fig. 2). As a result economic activity shifted from

[1] Utrecht University (the Netherlands)
[2] Cultural Heritage Agency of the Netherlands
[3] Netherlands Centre for Dendrochronology: RING Foundation, Amersfoort

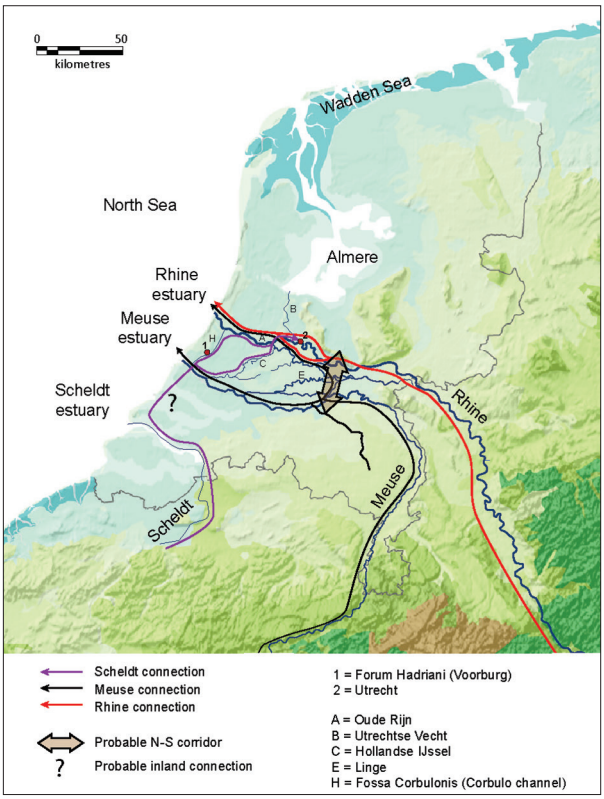

Figure 1 Long-distance transport routes in the Netherlands during the Roman Period. Background: map showing the Roman coast line (adapted from Vos and De Vries 2013). Figure prepared by Rowin J. Van Lanen.

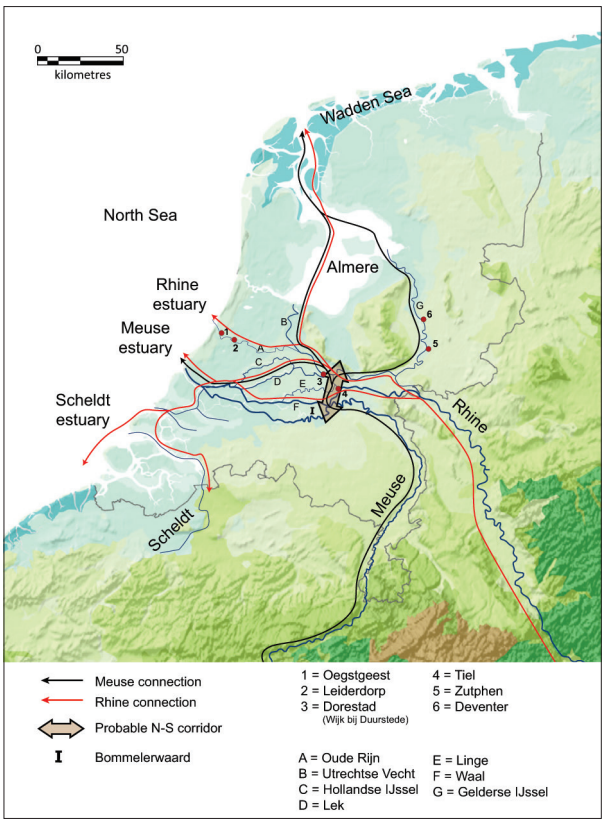

Figure 2 Long-distance transport routes in the Netherlands during the Early Middle Ages. Background: map showing the early medieval coast line (adapted from Vos and De Vries 2013). Figure prepared by Rowin J. Van Lanen.

the central and western parts of the delta to the east. In the ninth century, this facilitated the rise of important trade settlements in the eastern Netherlands such as Deventer and Zutphen (Groothedde 2013). In addition, increased flooding frequencies from the late RP onwards caused early medieval settlements located on the higher and dryer alluvial ridges of the Rhine-Meuse delta to relocate to somewhat higher areas (Pierik and Van Lanen 2017). This latter trend is especially visible in the relatively low-lying Bommelerwaard, where the large new river Waal formed (Fig. 2). This probably caused regular yearly floods to reach higher levels, causing a proportionally large abandonment of settlements in this area, with the few remaining settlements being raised on dwelling mounds. Although settlements shifted towards higher areas, most alluvial ridges remained inhabited and therefore land-based route networks hardly changed (Van Lanen and Pierik 2017).

Route networks in the Netherlands during the first millennium AD

During the RP an extensive route network developed, connecting many parts of present-day Europe. However in the Netherlands stone-paved Roman roads such as those present in southern Europe are non-existent. The construction of the most important road in this area, the Roman *limes* road, strongly varied per route section. In general this road, which followed the Rhine river system including the Oude Rijn (Fig. 1), was unpaved and consisted of a slightly raised central body hardened with gravel and often encased in wood, flanked by (drainage) ditches. With the exception of this road, built in AD 100 and rebuilt in AD 125, in the Netherlands there is little evidence for the existence of roads dating to the first millennium AD (e.g. Van Lanen *et al*. 2015a; Van der Heijden 2016). The main reason is that almost all land-based connections in this area were unpaved and therefore were not rigidly anchored in space (e.g. Horsten 2005; Van Lanen and Pierik 2017). Travellers moving through the landscape frequently shifted between lanes because of bad weather conditions (moisture) or general wear to the carved-in tracks (Van Lanen *et al*. 2016b). If we define roads as narrow, fixed communication and transport lines connecting settlements, Roman and early medieval land-based route zones were spatial zones that often were several hundreds of metres wide and included mostly unpaved bundles of tracks and paths. These route zones were an integral part of long-distance transport networks, which in the study region also structurally encompassed water routes (Van Lanen *et al*. 2016a).

Reconstructing ancient land-based route zones in the Netherlands is difficult, especially on a supra-regional scale, since their remnants are hidden or have vanished. Van Lanen *et al*. (2015a; 2015b) nonetheless have developed a method to reconstruct Roman and early medieval route networks, based on the hypothesis that in deltaic lowlands the orientation of such networks must

have been influenced to a high degree by environmental factors such as altitude, soil type, and relief. Based on past landscape settings, potential movement corridors were calculated and route zones between settlements were modelled for AD 100 and 800. By integrating detailed archaeological data from the national registration system ARCHIS (Roorda and Wiemer 1992; Wiemer 2002) and published research syntheses, land and water route zones could be calculated for among others a route-zone width of 500m (Van Lanen *et al*. 2015b). In order to test the accuracy of the reconstructions, the network was validated against archaeologically excavated infrastructural and isolated finds not included in the previous analyses. The results show that whereas the reconstructed 500m route zones together cover no more than 13.7% of the total surface area of the Netherlands, >81% of the Roman and >72% of the early medieval infrastructural and isolated finds originate from within these zones (Van Lanen *et al*. 2015b). This is in agreement with the hypothesis that in the Netherlands during the first millennium AD landscape settings had a significant impact on spatial patterns of human activity.

Roman and early medieval long-distance connections reconstructed from archaeological wood

Archaeological remnants of movable wooden objects are well suited for reconstructing past spatial connections because of the following characteristics:

- swift transport and direct application (construction timber);
- river-bound distribution (shipwrecks);
- direct geographical links with the economic hinterland (barrels); and
- high dating precision through dendrochronology.

Absolutely dated dendrochronological time series derived from such objects can be regarded as an integrator of environmental and cultural information, since archaeological wood is the residue of both the site conditions that governed annual tree growth and human activity such as the felling, transport and application of these trees. Using stringent statistical criteria Jansma *et al*. (2014b) showed that it is possible to trace the exact region of origin of oak timbers applied in Roman ships. This approach requires large and preferably international data collections for comparative research, identifying and using dendrochronological 'marker series' (i.e. distinct tree-ring patterns containing a strong environmental signal) while discarding patterns showing less region/site-specific variability. In addition this approach requires the application of GIS methods since it uses the spatial distribution of 'exogenous' wood versus the spatial layout of reconstructed route networks in order to determine timber provenance.

Wood use during the first millennium AD was analysed using dendrochronological time series representing 4,260 Roman and early medieval oak elements excavated in the Netherlands and Belgium and archived in the dendrochronological DCCD repository (Jansma *et al*. 2012; Van Lanen *et al*. 2016a, Appendix A: Supplementary Material A). The geographical results through time were verified using the provenance and distribution of common household goods (ceramics, stone) excavated in the Netherlands and dating to the RP and EMA (Van Lanen *et al*. 2016a).

The integration of dendrochronological, archaeological and geographical data

Combining the new findings with the results of previous studies we were able to identify several major, mainly river-based, transport routes operating during the RP and EMA. Although these routes vary through time, they have a strong common denominator: during the whole of the first millennium AD, a consistent south–north (and vice versa) directed transport corridor was present in the central part of the Dutch Rhine-Meuse delta (arrow in Figs 1, 2). This was one of the few locations in the Netherlands consistently enabling S–N directed transport between the Meuse and Rhine, linking the areas south and north of the Dutch delta (Van Lanen and Pierik 2017). Although not all watercourses in this corridor could be reconstructed with certainty by geomorphological studies, the dendrochronological data strongly support the hypothesis that in this area transport over water between the Meuse and Rhine was possible. In addition, abundant alluvial ridges in this area facilitated land-based transport crossing the delta along this axis. Given the fact that this persistent connection already must have existed well before the RP, this area might contain one of the richest archaeological records in the Dutch Rhine-Meuse delta.

Long-distance connections during the Roman Period
Dendrochronologically investigated elements of the Roman *limes* road and related structures dating to AD 125 were constructed with oak from the Ardennes (Fig. 1). These timbers were transported north along the Meuse (Van Lanen *et al*. 2016a) and therefore must have made their way to the Oude Rijn following the S–N transport corridor in the central Netherlands or the newly formed Hollandse IJssel. An alternative route may have been the *Fossa Corbulonis* (Fig. 1), a canal connecting the Meuse and Rhine directly behind the North-Sea beach barrier. This canal was dug in AD 37–41 (first phase) and AD 50 (second phase), and was fully functional until *c*. AD 100–150 (De Kort and Raczynski-Henk 2014).

Roman river boats excavated along the *limes* near Utrecht and constructed between *c*. AD 100 and 150, on the other hand, originated in the Scheldt region in current Flanders (western Belgium; Jansma *et al*. 2014b; Fig. 1). These vessels were unsuited for sea transport because they lacked a keel and therefore must have navigated north using inland water connections. Archaeological evidence (Van der Kroft *et al*. 2006; De Bruin *et al*. 2012) suggests that these vessels may have navigated from the Scheldt to the Meuse through a combination of natural inlets and a dug canal situated directly behind the beach barrier in the southwestern Netherlands. Since the segment of the *Fossa Corbulonis* north of *Forum Hadriani* ceased to function around AD 150 (De Kort and Raczynski-Henk 2014), these vessels most likely navigated from the Meuse estuary to the Rhine using the newly formed Hollandse IJssel towards Utrecht, or the S–N transport corridor in the central Netherlands, during their life span (which for at least one of these ships was

>50 years and lasted until at least *c*. AD 200; Jansma and Morel 2007).

In addition the Rhine river system was identified as a long-distance transport route, since building activities in *Forum Hadriani* in *c*. AD 160 and 205 utilised oak sourced upstream from the Mosel, a river running from the Ardennes to the Rhine near Koblenz (Germany), and from southern Germany (Domínguez-Delmás *et al*. 2014). The implication is that this timber must have been transported along the Rhine to the southern entrance of the *Fossa Corbulonis* along the S–N transport corridor in the central Netherlands or following the Hollandse IJssel (Fig. 1).

Long-distance connections during Early Middle Ages

Revetments and other water-management-related structures along the Oude Rijn during the Early Middle Ages mostly were constructed using locally grown oak (except in some cases involving the reuse of 'exogenous' ship's timbers). Examples are harbour-related structures in Dorestad (Jansma and Doeve, unpublished data), and revetments excavated at Oegstgeest (Doeve 2015) and Leiderdorp (Jansma and Doeve in press).

River vessels and water wells constructed from barrels excavated along the Oude Rijn, the North Sea coast (western Netherlands and Flanders, Belgium), and the Wadden Sea coast (northern Netherlands), and dating from the seventh to ninth centuries, were in most cases constructed from oak originating in the German Rhineland (Fig. 2). This indicates that the Rhine including the Oude Rijn during this time interval was the main long-distance transport corridor (Jansma and Van Lanen 2015; Van Lanen *et al*. 2016a). Given finds of re-used barrels with a similar provenance in Ipswich (United Kingdom) and Ribe (Denmark; Doeve 2015; Van Lanen *et al*. 2016a, Appendix A: Supplementary Material B), this Rhine-based network reached well beyond the Rhine river system and the Dutch/Belgian coastline.

Given a felling date in *c*. AD 612 of a dugout canoe sourced to the German Rhineland and excavated near Oegstgeest (Fig. 2), this Rhine-based connectivity system already was operational at the start of the seventh century (Jansma and Van Lanen 2015). This is earlier than expected and opens up the possibility that this system originated in the (late) sixth century. There is no dendrochronological evidence that this system still existed after *c*. AD 850 (Jansma and Van Lanen 2015; Van Lanen *et al*. 2016a). In this context it should be noted that Dorestad, after a final ransack by the Vikings in AD 863, was not rebuilt. This development coincided with a diminishing transport capacity of the Oude Rijn from *c*. AD 800 onwards, while the erosive capacity of this river branch increased (Van Dinter *et al*. 2017). Dendrochronological research of early medieval river revetments excavated at Leiderdorp (Fig. 2) has recently provided independent evidence of the erosive capacity of the Oude Rijn around this time, showing increased construction and/or reparation activities starting in AD 796 (Jansma and Doeve in press).

Given the marked absence in the Dutch archaeological record of 'exogenous' construction timbers, ship wrecks, and barrels dating between ca. 850 and 950, following this phase a century-long dip in long-distance transport of bulk goods may have occurred. This interval was followed by a significant shift of long distance connections: 'exogenous' oak used in ship wrecks and other objects excavated in the Netherlands and dating between *c*. AD 950 and 1050 without exception originated in the Ardennes. Given the spatial distribution of these finds, these objects probably were transported to the north following the Meuse (Van Lanen *et al*. 2016a; Fig. 2).

Acknowledgements

This research summary is part of the project *The Dark Ages in an interdisciplinary light: people, landscape and climate in the Netherlands between AD 300 and 1000*, funded by the Netherlands Organization for Scientific Research (NWO Humanities; project nr. 360-60-110; 2011-2019). For more information see: http://www.darkagesproject.com.

Bibliography

ARCHIS: Archaeological Information System of the Netherlands (ARCHIS). Available at https://archis.cultureelerfgoed.nl/#/login. Last consulted 25/3/2017.

Cohen, K.M., Stouthamer, E., Hoek, W.Z., Berendsen and Kempen, H.F.J. 2009. *Zand in banen: zanddieptekaarten van het Rivierengebied en het IJsseldal in de provincies Gelderland en Overijssel* [Sand-depth maps of the central and upper Rhine-Meuse delta, including the IJssel valley]. Arnhem: Provincie Gelderland.

Cohen, K.M., Stouthamer, E., Pierik, H.J. and Geurts, A.H. 2012. *Digitaal Basisbestand Paleogeografie van de Rijn-Maas Delta* [Rhine-Meuse Delta Studies' Digital Basemap for Delta Evolution and Palaeogeography]. Available at https://easy.dans.knaw.nl/ui/datasets/id/easy-dataset:52125.

Cohen, K.M., Toonen, W.H.J. and Weerts, H.J.T. 2016. *Overstromingen van de Rijn gedurende het Holoceen; relevantie van de grootste overstromingen voor de archeologie van het Nederlandse rivierengebied* [Rhine floods during the Holocene: the relevance of the most extreme floods for the archaeology of the Dutch riverine area]. Deltares report 1209091-000. Delft: Deltares.

DCCD (Digital Collaboratory for Cultural Dendrochronology). Available at http://dendro.dans.knaw.nl.

De Bruin, J., Besuijen, G.P.A., Siemons, H.A.R. and Van Zoolingen, R.J. (eds.) 2012. *Goedereede-Oude Oostdijk: een havenplaats uit de Romeinse tijd* [Goedereede-Oude-Oostdijk: a harbour from the Roman period]. Leiden: Sidestone Press.

De Kort, J.W. and Raczynski-Henk, Y. 2014. The Fossa Corbulonis between the Rhine and Meuse estuaries in the Western Netherlands, *Water History* **6**: 51–71.

Doeve, P. 2015. *The long journey of early medieval wood: establishing absolute dates and determining the provenance of timbers from the Oegstgeest-Rijnfront site*. Unpublished MSc thesis, Leiden University.

Domínguez-Delmás, M., Driessen, M., García-González, I., Van Helmond, N. Visser, R.M. and Jansma, E. 2014. Long-distance oak supply in mid-2nd century AD revealed: the case of a Roman harbour (Voorburg-Arentsburg) in the Netherlands, *Journal of Archaeological Science* **41**: 642–654.

Groothedde, M. 2013. *Een vorstelijke palts te Zutphen? Macht en prestige op en rond het plein 's-Gravenhof van de Karolingische tijd tot aan de stadsrechtverlening* [A royal pfalz at Zutphen? Power and prestige on and around 's-Gravenhof Square from the Carolingian period until the granting of town privileges]. PhD thesis, Leiden University.

Jansma, E. and Doeve, P. (in press). Dendrochronologische analyse van houtvondsten uit de opgraving Leiderdorp-Plantage [Dendrochronological analysis of wooden finds from the excavation Leiderdorp-Plantage]. In M.F.P. Dijkstra, A.A.A. Verhoeven and K.CA.J. van Straten (eds), Nieuw licht op Leithon: archeologisch onderzoek naar de vroegmiddeleeuwse bewoning in plangebied Leiderdorp-Plantage [New light on Leithon:

archaeological investigation of early medieval settlement in plan area Leiderdorp-Plantage]. *Themata* **8**.

Jansma, E. and Morel, J.-M.A.W. 2007 (eds). *Een Romeinse Rijnaak, gevonden in Utrecht-De Meern: resultaten van het onderzoek naar de platbodem 'De Meern 1'* [A Roman river barge excavated in Utrecht-De Meern: results of the investigation of barge 'De Meern 1']. Rapporten Archeologische Monumentenzorg 144. Amersfoort: Rijksdienst voor het Cultureel Erfgoed.

Jansma, E., Van Lanen, R.J., Brewer, P. and Kramer, R. 2012. The DCCD: a digital data infrastructure for tree-ring research, *Dendrochronologia* **30** (4): 249–251.

Jansma, E., Gouw-Bouman, M., Van Lanen, R.J., Pierik, H.J., Cohen, K.M., Groenewoudt, B.J., Hoek, W.Z., Stouthamer, E. and Middelkoop, H. 2014a. The Dark Age of the Lowlands in an interdisciplinary light: people, landscape and climate in The Netherlands between AD 300 and 1000, *European Journal of Post-classical Archaeologies* **4**: 471–476.

Jansma, E., Haneca, K. and Kosian, M. 2014b. A dendrochronological reassessment of three Roman vessels from Utrecht (the Netherlands): evidence of inland navigation between the lower-Scheldt region in Gallia Belgica and the limes of Germania inferior, *Journal of Archaeological Science* **50**: 484–496.

Jansma, E. and Van Lanen, R.J. 2015. The dendrochronology of Dorestad. In A. Willemsen and H. Kik (eds.), *Golden Middle Ages in Europe: new research into early medieval communities and identities*. Turnhout: Brepols, 99–144.

Horsten, F.H. 2005. *Doorgaande wegen in Nederland, 16e tot 19e eeuw. Een historische wegenatlas* [Main thoroughfares in the Netherlands, 16th to 19th centuries. A historical road atlas]. Available at: http://hdl.handle.net/11245/1.289095.

Makaske, B., Maas, G.J. and Van Smeerdijk, D.G. 2008. The age and origin of the Gelderse IJssel. *Netherlands Journal of Geosciences – Geologie en Mijnbouw* **87** (4): 323–337.

Roorda, I.M. and Wiemer R., 1992. The ARCHIS Project: towards a New National Archaeological Record in the Netherlands. In CA. Larsen (ed.), *Sites and Monuments: National Archaeological Records*. Copenhagen: The National Museum of Denmark, 117–122.

Toonen, W.H.J., Donders, T.H., Van der Meulen, B., Cohen, K.M. and Prins, M.A. 2013. A composite Holocene palaeoflood chronology of the Lower Rhine. In W.H.J Toonen (ed.), A Holocene Flood Record of the Lower Rhine, *Utrecht Studies in Earth Sciences* **41**: 137–150.

Pierik, H.J., Cohen, K.M. and Stouthamer, E. 2016. A new GIS approach for reconstructing and mapping dynamic late Holocene coastal plain palaeogeography, *Geomorphology* **270**: 55–70.

Pierik, H.J., Cohen, K.M., Vos, P.CA., Van der Spek, A.J.F. and Stouthamer, E. 2017. Late Holocene coastal-plain evolution of the Netherlands: the role of natural preconditions in human-induced sea ingressions, *Proceedings of the Geologists' Association* **128** (2), 180–197.

Pierik, H.J., Stouthamer, E., Schuring, T. and Cohen, K.M. (in prep). Human-induced drivers of avulsion success in the Rhine-Meuse delta, the Netherlands.

Pierik, H.J. and Van Lanen, R.J. 2017. Roman and early medieval occupation patterns in a delta landscape: the link between settlement elevation and landscape dynamics, *Quaternary International*. Available online 28 March 2017, http://dx.doi.org/10.1016/j.quaint.2017.03.010

Van Bavel, B. 2010. *Manors and Markets: economy and society in the Low Countries 500–1600*. Oxford: Oxford University Press.

Van der Heijden, P. (ed.), 2016. *Romeinse wegen in Nederland* [Roman roads in the Netherlands]. Utrecht: Matrijs.

Van der Kroft, P., Kranendonk, P. and Mullie, E. 2006. Resultaten per onderzoeksregio [Results per research area]. In P. Kranendonk, P. van der Kroft, J.J. Lanzing and M. Meijlink, (eds.), *Witte vlekken ingekleurd: archeologie in het tracé van de HSL-Zuid* [Filling in the blanks: archaeology on the route of HSL-South]. Rapporten Archeologische Monumentenzorg 113. Amersfoort: Rijksdienst voor het Cultureel Erfgoed, 21–84.

Van Dinter, M., Cohen, K.M., Hoek, W.Z., Stouthamer, E., Jansma, E. and Middelkoop, H. 2017. Late Holocene lowland fluvial archives and geoarchaeology: Utrecht's case study of Rhine river abandonment under Roman and Medieval settlement, *Quaternary Science Reviews* **166**: 227–265.

Van Lanen, R.J., E. Jansma, J. van Doesburg and B.J. Groenewoudt, 2016a. Roman and early medieval long-distance transport routes in north-western Europe: Modelling frequent-travel zones using a dendroarchaeological approach, *Journal of Archaeological Science* **73**: 120–137.

Van Lanen, R.J., Groenewoudt, B.J., Spek, T. and Jansma, E. 2016b. Route persistence. Modelling and quantifying historical route-network stability from the Roman period to early-modern times (AD 100–1600): a case study from the Netherlands, *Archaeological and Anthropological Sciences*: 1–16.

Van Lanen, R.J., Kosian, M., Groenewoudt, B.J. and Jansma, E. 2015a. Finding a way: modelling landscape prerequisites for Roman and early medieval routes in the Netherlands. *Geoarchaeology* **30**: 200–222.

Van Lanen, R.J., Kosian, M., Groenewoudt, B.J., Spek, T. and Jansma, E. 2015b. Best travel options: modelling Roman and early medieval routes in the Netherlands using a multi-proxy approach, *Journal of Archaeological Science: Reports* **3**: 144–159.

Van Lanen, R.J. and H.J. Pierik 2017. Calculating connectivity patterns in delta landscapes: modelling Roman and early medieval route networks and their stability in dynamic lowlands, *Quaternary International*. Available online 22 March 2017, http://dx.doi.org/10.1016/j.quaint.2017.03.009.

Vos, P.C. 2015. Flooding history of the Southwestern Netherlands. In P. CA. Vos. (ed.), *Origin of the Dutch coastal landscape: long-term landscape evolution of the Netherlands during the Holocene described and visualized in national, regional and local palaeogeographical map series*. Groningen: Barkhuis, 82–97.

Vos, P.C., De Vries, S. 2013. *2e generatie palaeogeografische kaarten van Nederland (versie 2.0)* [2nd-generation palaeogeographical maps for the Netherlands (version 2.0)]. Utrecht: Deltares.

Weerts, H.J.T. and Berendsen, H.J.A. 1995. Late Weichselian and Holocene fluvial palaeogeography of the southern Rhine-Meuse delta (the Netherlands), *Geologie en Mijnbouw* **74** (3): 199–212.

Wiemer, R., 2002. Standardisation: the key to archaeological data quality. In L. García Sanjuan and D.W. Wheatley (eds.), *Mapping the Future of the Past, Managing the Spatial Dimension of the European Archaeological resource*. Historia y Geografía 78. Sevilla: University of Sevilla, 103–108.