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research

Diverging decline. Reconstructing and validating (post-)Roman population trends (AD 0-1000) in the Rhine-Meuse delta (the Netherlands)

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Quantitative data on demography are vital building blocks for understanding cultural and landscape changes. This contribution highlights the making and testing of evidence-based population estimates based on archaeological data in the Roman and early-medieval Netherlands. The reconstructed demographic trends were validated by means of comparison, using multi-proxy data and evaluating data reliability. Results show a substantial late and post-Roman population decline. Regional differences however, were substantial as well. As this diversity may be crucial to explain manifestations of regional cultural differences during the late-/post-Roman period, demographic reconstructions require a multi-scale approach.
Keywords: Roman period, Early Middle Ages, the Netherlands, demographic modelling, landscape archaeology, population recontruction

I dati demografici quantitativi sono informazioni vitali per comprendere i cambiamenti culturali e paesaggistici. Questo contributo tratta della costruzione e verifica di stime basate su dati materiali archeologici nel territorio olandese di età romana e altomedievale. I trend *demografici ricostruiti sono stati validati tramite comparazione, usando dati* multi-proxy *e valutandone l'affidabilità. I risultati mostrano un sostanziale declino demografico in età post-classica. Differenze regionali erano comunque sostanziali. Dato che questa diversità potrebbe essere cruciale per spiegare fenomeni di differenze culturali regionali nel periodo tardo- e post-romano, le ricostruzioni demografiche richiedono un approccio multiscalare.*
Parole chiave: *epoca romana, alto medioevo, Olanda, modelli demografici, archeologia del paesaggio, ricostruzione della popolazione*

1. Introduction

Population density no doubt has a significant impact on the way societies and landscapes develop (e.g. Klein Goldewijk *et al.* 2010). Demography is essential for historians to understand the dynamics of, the

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change in, and the evolution of many different aspects of society over time. If you have no idea about a population's evolution, about population pressure, about migration, etc., there is no point in even trying to understand economic growth, political turmoil, the spread of culture, and many more interesting historical phenomena (De Moor 2016, p. 16). It is clear that archaeologists too have every reason to take into account demographic variables (e.g. Hassan 1981; Shennan 1998; Chamberlain 2006). Dutch archaeologist Frans Theuws (1988, p. 89) for instance, stated that the size and distribution of a population are crucial to understand how local communities were organized. Nevertheless, so far few archaeologists have dared to do so, in particular when it comes to quantification. Harsema (1980, p. 17) qualified calculating historical population numbers as a "precarious enterprise". According to Halsall (1996) "estimates of (pre-modern) population levels are notoriously unreliable" as no complete population censuses were taken until the 18th century.

Traditionally one of the main issues in European history is the transition between the Roman period and the Early Middle Ages (AD 3rd-6th centuries) (Gibbon 1776-1788). Many research questions revolving around this topic have a demographic dimension. Is it generally accepted that human populations (strongly) declined[1]. This is deduced from dwindling settlement numbers, the virtual disappearing of urban settlements (e.g. Louwe Kooijmans 1995; McCormick 2007; Wickham 2005, 2008, 2010; Cheyette 2008) and re-afforestation of abandoned arable land (e.g., Teunissen 1990; Roymans, Gerritsen 2002; Groenewoudt *et al.* 2007; Kalis *et al.* 2008; Kaplan *et al.* 2009). In our research area, the present-day Netherlands, the reconstruction of historical population numbers on the basis of data like this is not without problems. 'Dark Age' sites are probably underrepresented due to identification problems (Nieuwhof 2013; Heeren 2015; Van Lanen *et al.* submitted). And relations between demographic and landscape changes are not straightforward: reforestation for instance, may very well be the result not of depopulation but of agricultural change (Dark 2000) or (renewed) settlement mobility (Groenewoudt, Spek 2016). In a general sense, Wickham (2010) pointed to notable regional differences in the period under study, and stressed the need for a more regional research focus.

In the Netherlands several attempts have been made to generate multi-scale evidence-based reconstructions of population numbers and densities for both the Roman and early medieval periods (~AD 0-1000;

[1] E.g. McEvedy, Jones 1978; Daugherty, Kammeyer 1995. For a discussion of possible causes concerning our research area, see Heeren 2015.

Archaeological Period	Subperiod	Abbreviation	Age
Roman period (RP)	early Roman period	ERP	12 BC-AD 70
	middle Roman period	MRP	AD 70-270
	late Roman period	LRP	AD 270-450
Early medieval period (EMP)	early medieval period A	EMPA	AD 450-525
	early medieval period B	EMPB	AD 525-725
	early medieval period C	EMPC	AD 725-950
	early medieval period D	EMPD	AD 950-1050

Tab.1. Periods and sub-periods as specified by the Dutch Archaeological Basic Register (ABR).

tab. 1)[2]. In this paper these population estimates as well as the methods that were used are discussed. Special focus will be on recent work in the eastern part of the Rhine-Meuse delta (Eastern River Area), where a newly developed modelling technique was used (fig. 1; Van Lanen *et al.* submitted). We have tried to validate results by means of comparison (cross-checking), confrontation with proxy data on (predominantly) land-use intensity and applying source criticism. This study focuses on reconstructing population-size fluctuations, not on the cultural processes underlying these changes.

2. Estimating population numbers and densities

The underpinning of population estimates published so far varies and is not always very explicit. Only from the Late Middle Ages (ca. 14th century) onwards historical sources supply us with adequate demographic clues (Faber *et al.* 1965; Slicher van Bath 1957; Blockmans *et al.* 1980; Bieleman 1987; Arts 1993; 1999; Kossmann 1986; Lourens, Lucassen 1997; Spek 2004). Most estimates regarding earlier periods are usually based on archaeological settlement data. Burial data are rarely used,

[2] Most of this work was carried out within the context of two research projects: 1) *An Integrated Analysis of Twelve Small-scale Excavations representing the Period AD 0-500 in a River Valley in Overijssel,* funded by the Netherlands Organisation for Scientific Research (NWO) as part of the *Odyssee* programme; 2) *The Dark Age of the Lowlands in an interdisciplinary light: people, landscape and climate in the Netherlands between AD 300 and 1000*, also funded by NWO (Jansma *et al.* 2014). In the process of writing this paper some sources were derived from an unfinished text (c. 2007) by Jos Bazelmans (Cultural Heritage Agency of the Netherlands-RCE), titled: *Op glad ijs. Het aantal inwoners van Nederland in de pre- en protohistorie*.

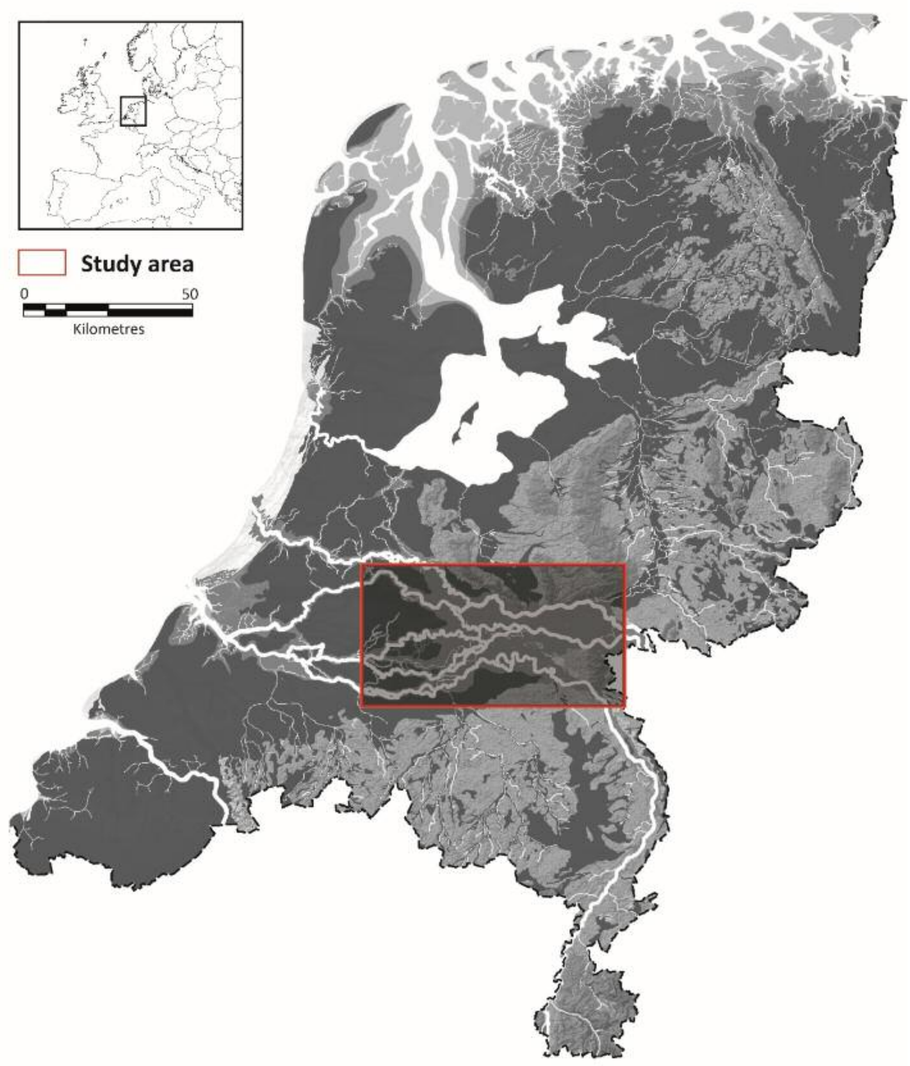

Fig. 1. The study area: the Netherlands and the eastern part of the Rhine-Meuse delta (red box). Reconstructed landscape AD 800 (Vos, De Vries 2013; figure derived from Van Lanen *et al.* submitted).

probably because varying burial practices cause substantial differences in archaeological visibility and consequently recovery rate. This impedes reliable (long-term) reconstructions. Settlement data are less problematical in this respect. In some cases population estimates relate to one specific period. Medieval archaeologist Heidinga (1987) for instance, estimated the 7th century population of the (present-day) Netherlands (excluding the very south: Zuid-Limburg), at about 20.000-30.000. This calculation was based on settlement densities within reconstructed early medieval settlement concentrations. However, knowing that much of Dutch archaeology is sub-soil archaeology (Deeben *et al.* 2006), it is in some areas difficult to judge to what degree current archaeological datasets are representative. What percentage of settlement sites have been discovered and recorded so far? Miedema (1983) had a relatively easy task calculating historical population numbers in the northern-Netherlands coastal lowlands. In this area from the Iron Age (ca. 600 BC) onwards people lived on artificially raised mounds that are either still visible in the landscape or historically known. In the same way calculations were made for the Northern-Germany coastal zone (Steuer 1988). Vos (2009) and Van Beek, Groenewoudt (2011) brought together and made estimations of Middle Roman settlement and population densities in archaeologically well-researched regions (tab. 2). Own estimates by Van Beek and Groenewoudt for the Eastern Netherlands Vecht region were based on:

1. The regional number of known Middle Roman settlement sites;
2. An estimate of the percentage of as yet undiscovered contemporary settlements (based on the results of large-scale surveys and excavations);
3. Estimated average number of contemporary houses/farmsteads per settlement;
4. Estimated household size.

Comparing these regional estimates allows some interesting conclusions. First of all it is clear that in general settlement density on (fertile) clay soils, both in the Dutch river area (Kromme Rijn and Tiel) and in the Northern-Netherlands coastal zone (Westergo) seems to have been much higher (17.4-19.1 p/km^2) than on (less fertile) sandy soils (4.0-6.9 p/km^2). Within sandy areas on the one hand and clay areas on the other estimated population densities are remarkably consistent. Some regions were Roman territory, others were not. Whether or not a region was part of the Roman empire seems not to have been a decisive factor with regard to settlement density (Van Beek, Groenewoudt 2011).

So far one attempt only has been made to use archaeological data to reconstruct the long-term demographic trend for the present-day Netherlands as a whole[3]. Louwe Kooijmans *et al.* (2005, pp. 696-698) created a population curve by interpolating a number of chronological reference points (fig. 2). The hunter-gatherer era (late Palaeolithic-Mesolithic) estimate is based on documented historical data from environmentally com-

[3] Evidently 'the Netherlands' is a debatable spatial entity when studying Pre-Modern times.

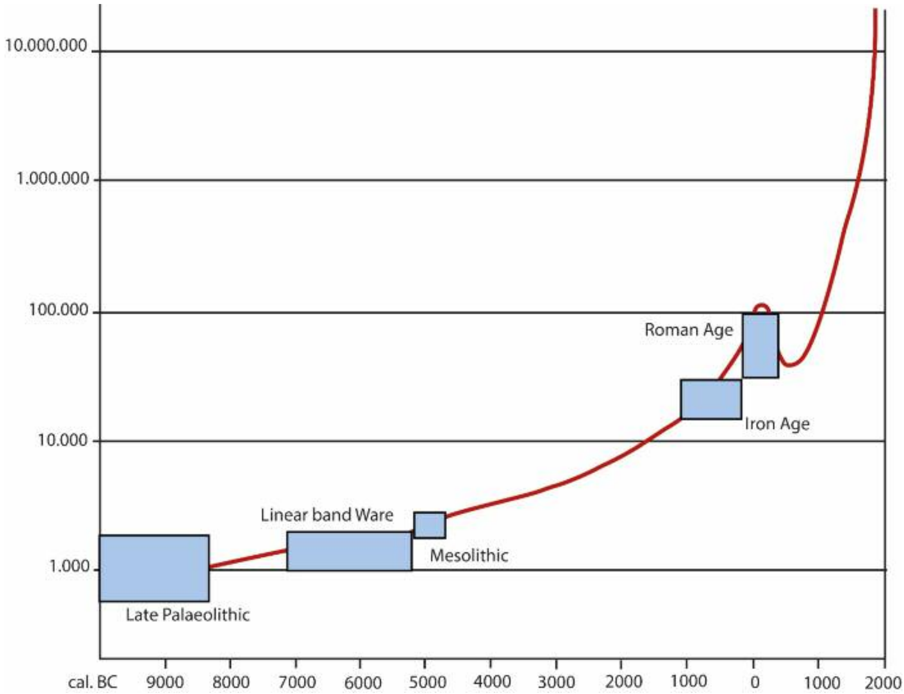

Fig. 2. Population curve for the Netherlands since the end of the last glacial (after Louwe Kooijmans *et al.* 2005, p. 697). The vertical scale is logarithmic.

parable areas. Early agriculture (Early Neolithic) numbers are based on settlement data and densities from one well-researched, but probably not representative, region (South-Limburg). Bronze- and Iron Age numbers too, are based on data from one specific area (Province of Drenthe). Building blocks in this case were the reconstructed territorial structure, established settlement density, settlement size and (estimated) household size. Estimated population numbers were tested by comparing them with large-scale excavation data from a micro region situated elsewhere (Oss-Ussen, Province of Noord-Brabant). The estimate for the Middle Roman period (150.000 = 7.5 persons/km^2) is deduced from published estimates, that are partly based on archaeology and on historically known military recruitment numbers. For the Late-/Early post-Roman periods the authors assume that population numbers dropped to the pre-Roman level. Between this last reference point and modern population levels gradually accelerating and uninterrupted population increase is hypothesized. In the population curve shown in fig. 2 the transition between Roman and Medieval periods clearly stands out as an anomaly. For the 4th

Region	Landscape	Surface (km²)	Population	Population density/km²
Westergo	Northern coastal	374	7150	19,1
Westergo (section)	Northern coastal	180	3254	18,1
Zuid-Holland	Western coastal	645	10000-16000	15.5-25
Texel	Western coastal	26	450-630	17-24
Kromme Rijn	River area	110	1950	17,7
Tiel	River area	105	1830	17,4
Vecht	Northern sand	294	1024	4,1
Bladel	Southern sand	175	800	4,6
Someren	Southern sand	72	500	6,9
Maashorst	Southern sand	100	400	4,0

Tab. 2. Estimated (rural) population size and density in different Dutch regions in the Middle Roman period (after Van Munster 2012). Based on Van Beek, Groenewoudt 2011, p. 21 and supplemented with data of Dijkstra 2011, p. 105 and Woltering 2000, p. 349. The results for Westergo and Oostergo are derived from Gerrets 2010, p. 72 and Taayke 1996, pp. 184, 190. Vecht region and Maashorst (Jansen *et al.* 2011) estimates by van Beek, Groenewoudt 2011, p. 21. The Zuid-Holland estimate is taken from Dijkstra 2011, p. 105. All other figures are based on Vos 2009, table 6.3, p. 213 incl. references.

and 5th centuries a substantial depopulation is assumed. Traditionally this period is one of the main mysteries in Dutch archaeology (Heidinga, Offenberg 1992; Groenewoudt *et al.* 2017).

Also Van Munster (2012) focused on the Netherlands as a whole but restricted herself to the Roman-medieval transition period. For six regions, delimited on the basis of palaeogeographical grounds population trends were reconstructed (fig. 3). Population estimates are based on Vos 2009 and Van Beek, Groenewoudt 2011 and single population estimates published in regional studies (tabb. 2 and 3). Not all these numbers are well-founded and rare larger (pre-urban) settlements were not included. Therefore their reliability probably varies.

Assuming that Van Munster's (2012) population curves are essentially correct, we can conclude that after AD 270 population decline occurred in all six regions. Timing (start and duration) and scale however, show considerable regional differences. Some areas seem to have been almost completely depopulated (Northern and Western-coastal Areas, Southern-sandy Area), others were not. In some cases population growth rapidly restarted (Northern Coastal Area: *Frisia*) whereas in others this took much longer.

Region	Landscape	Surface (km²)	Population	Population density/km²
Friesland	Northern coastal	900	6500-8700	7.2-9.7
Groningen/part of Oost-Friesland	Northern coastal	700	2700-3600	3.9-5.1
Zuid-Holland	Western coastal	645	1800-2400	2.8-3.7
Texel	Western coastal	18.5	390-570	21-31
Utrecht-Dorestad	River area	75	1500	20
Brabant	Southern sand	10400	5000-6000	0.5-0.6
Veluwe	Northern sand	1000	1250-2625	1-2.5
Drenthe	Northern sand	1300	3050-4270/ 4300-9030	2.5-7
Twente	Northern sand	1200	4450-9345	3.5-7.5

Tab. 3. Estimated (rural) population size and density in different Dutch regions in the Early Middle Ages (500-900 AD) (after Van Munster 2012). The figure is taken from van Dijkstra 2011, p. 107). The results for Veluwe, Drenthe, Twente and Texel are based on Woltering 2000, pp. 340-341 incl. ref. The estimates for Utrecht were taken from Kooistra 1996, § 3.3.2, those for Zuid-Holland, Friesland and Groningen/Oost Friesland from Dijkstra 2011, p. 105.

Region	Area (1000 km²)	AD 14 Population (millions)	AD 14 Density (per km²)	AD 164 Population (millions)	164 CE Density (per km²)	Population increase (%)
Gaul and Germany	635	5.8	9.1	9.0	14.2	55.2
Danube Region	430	2.7	6.3	4.0	9.3	48.1
Iberia	590	5.0	8.5	7.5	12.7	50.0
Italy	250	7.0	28.0	7.6	30.4	8.6

Tab. 4. Estimate of the Population of selected regions within the Roman Empire (after Frier 2000, p. 812, tab. 5, p. 814, tab. 6).

Recently Verhagen *et al.* (2016) applied Agent-Based modelling in order to model demographic dynamics along the Dutch part of the Roman *limes*[4]. The *limes* zone is situated for the largest part in the River Area indicated on fig. 3. Population dynamics was modelled on the basis of assumptions regarding a) reproduction and mortality and b) the ex-

[4] This work was carried out within the context of the NWO-funded *Finding the limits of the limes* project.

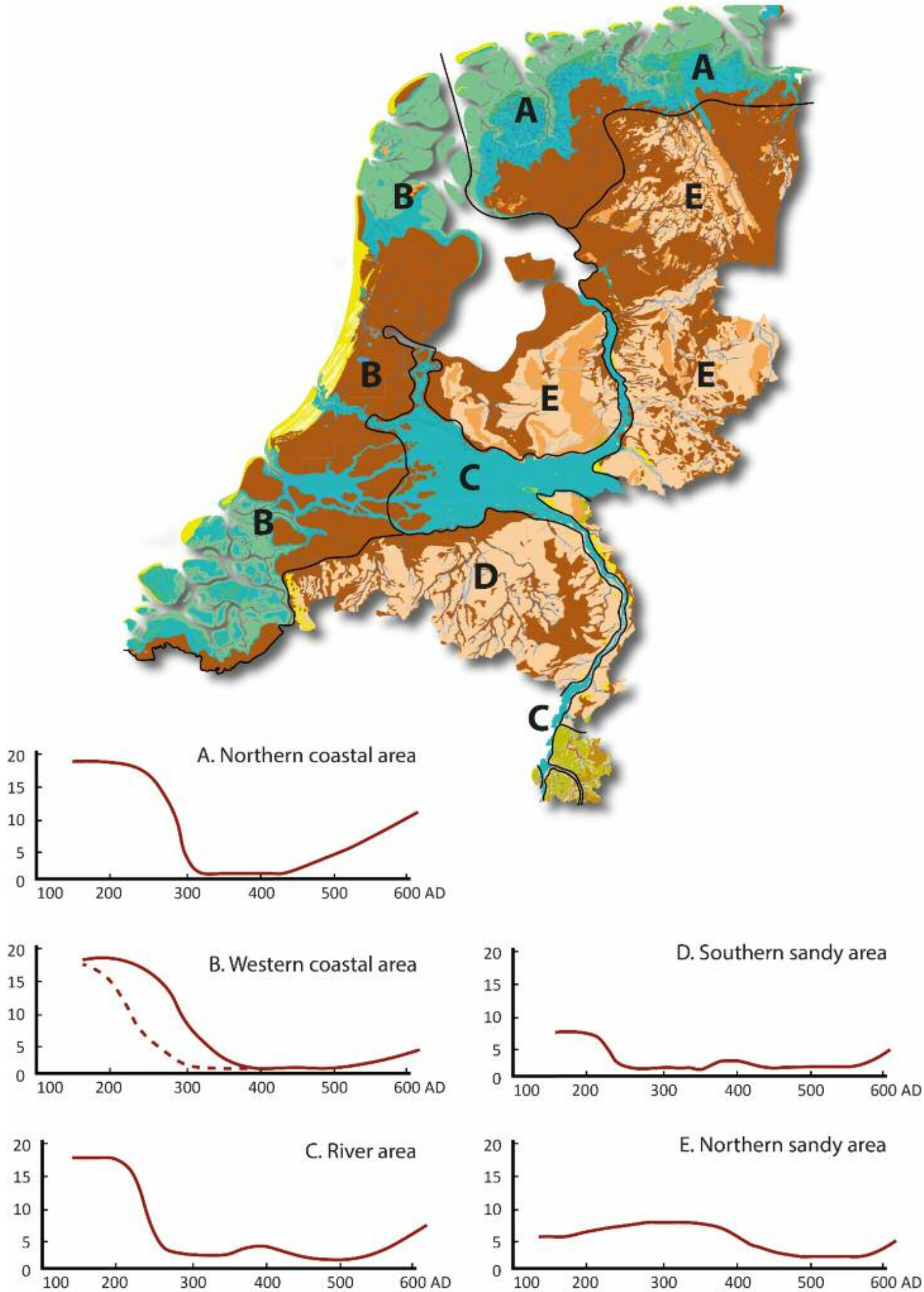

Fig. 3. Regional subdivision of the Netherlands adapted from Van Munster 2012. Regions are overlain on the reconstructed landscape around AD 800 adapted from Vos, De Vries 2013.

pected effects of recruitment by the Roman army. It is unclear to what extent the results reflect historical reality (e.g. Lo Casio 2001). The relevance of demographic data was demonstrated by Pierik *et al.* (submitted) who reconstructed population development in the Pleistocene sandy regions of the Netherland (covering ca. 50 % of the land surface) within a 800 BC-AD 1600 time span. Published population estimates were used, complemented by historical data (more details in Pierik *et al.* submitted: Appendix A). The conclusion that intensified land use resulting from population growth was the main driving force behind sand drifting was partly substantiated by these regional estimates (tab. 5).

Point of departure were the Roman-period estimations by Vos 2009 and Van Beek, Groenewoudt (2011) discussed before. AD 1500 and 1600 data are based on historical information summarized by Spek (2004). Numbers for other periods were estimated taking into account the number of known settlements for each period included in ARCHIS, the national archaeological database of the Netherlands (Zoetbrood *et al.* 2006)[5]. While doing so, period-specific differences in discovery potential of settlement sites were taken into account (Groenewoudt 1994; Deeben *et al.* 2006). Reconstructed developments in settlement density (again) point to large regional differences. Medieval population numbers in the Southern Sand Area grew by far the fastest[6].

	800 BC	**125 BC**	**AD 200**	**AD 500**	**AD 800**	**AD 1000**	**AD 1500**	**AD 1600**
Northern sand area	1.2	2.4	4.9	2.4	3.9	4.6	6.3	6.0-8.0 (7.0)
Eastern sand area	1.2	2.5	4.9	2.5	3.9	5.9	10.8	12.0
Middle sand area	1.2	2.4	4.9	0.5	3.9	7.6	17.0	15-25 (17.0)
Southern sand area	1.2	2.5	4.9	0.5	3.9	12.3	33.3	25-50 (37.0)
All sand areas	1.2	2.5	4.9	1.3	3.9	7.2	15.3	19.6

Tab. 5. Reconstructed population density in people per km^2 between 800 BC and AD 1600 in Pleistocene sandy regions of the Netherlands (after Pierik *et al.* submitted). The Northern and Eastern sand areas are subdivisions of 'Northern Sand', and the Middle and Southern sand areas of 'Southern Sand' on fig. 3.

[5] ARCHIS is maintained by the Cultural Heritage Agency of the Netherlands (RCE).

[6] This probably has to do with the proximity of the flourishing Flemish cities and the associated early rise (13th century) of a proto-capitalist market economy (Spek 2004, pp. 981-983; Vangheluwe, Spek 2008; Van Bavel 1999).

3. Post-Roman population decline

Well-underpinned *numerical* estimations of the scale of population decline starting at the end of the Middle Roman Period (AD 270) are scarce. Also the available data vary in terms of selected time intervals and methodology, which makes comparison problematic. There can be little doubt that in general the present-day Netherlands witnessed more severe depopulation, although researchers increasingly stress that the on-the-ground situation may have been differentiated[7]. No doubt both 'decline' and 'transformation' were historical realities (Nieuwhof 2013; Roymans, Heeren 2017). AD 500-900 population estimates presented by Van Munster (2012) (tab. 2-3 and fig. 3) are averages and the crucial AD 400-600 trajectory of her population curve essentially is based on *educated guessing* and interpolation. If we nevertheless use these numbers, Roman and Early Medieval (until AD 900) mean population densities can be calculated at 12.4 and 5.3-8.4 persons/km^2 respectively. This would mean that within this time-span population numbers almost halved. ARCHIS-based numbers presented in fig. 3 suggest that population numbers in the Netherlands dropped considerably more. This is confirmed by quantitatively analysing high-temporal resolution dated ARCHIS settlement sites only (tab. 6). Result show that in the Late Roman period the number of settlements drops by 73.1% and that decline continued into the initial phase of the Early Middle Ages (VMEA, minus 92.1%). After that time settlement numbers increase. ARCHIS-based decline estimates for the Eastern River Area only, range between 80% and 87% (see below).

Fig. 3 shows striking (intra)regional differences, both temporally and in terms of population density. As to the first: in three regions (Southern Sand, River Area, Northern Coastal Area) population decline starts early, around AD 250-270, in the Northern Sandy Area late, around AD 400-425. Some parts of the Western Coastal already seem te have become (largely) deserted in the 2nd century AD (Brandt *et al.* 1987), whereas other parts of the same area did so not before is the middle of the 3rd century (Van Heeringen, Van der Velde in press). Population decline in the Northern Sand Area seems to have been restricted, in the Southern Sand Area it was extreme (fig. 3). For the area last mentioned Heeren (2015, p. 283) critically re-evaluated the time span of excavated Roman-period settlements[8]. Of 50 settlements datable between AD 125-474 only 8-12 demonstrably were inhabited after AD 270 which im-

[7] E.g. Bitter 1991; Heeren 2015; Roymans, Heeren 2017; Roymans *et al.* 2017; Hendriks *et al.* in press. Research context: CLUE+ project *Decline and fall? Social and cultural dynamics in the Low Countries in the Late Roman Empire (AD 270-450)*, financed by NWO and FWO (Research Fund Flanders).

[8] Under investigation was the Meuse-Demer-Scheldt region, of which the Southern Sand area is part.

Period	N settlements	%	decline %
ERP	3710	53,2%	-46,8%
MRP	6971	100,0%	0,0%
LRP	1873	26,9%	-73,1%
EMPA	553	7,9%	-92,1%
EMPB	931	13,4%	-86,6%
EMPC	3317	47,6%	-52,4%
EMPD	2700	38,7%	-61,3%
Total	20055		

Tab. 6. Post-Roman population decline percentages for the present-day Netherlands based on high-temporal resolution dated settlement sites in ARCHIS (national archaeological database of the Netherlands)[9]. Periods cf. tab. 1.

plies a Late Roman decline percentage of 76-84%. This is only slightly less than an earlier settlement numbers-based estimate by Verwers (1998-1999, p. 318 and tab. I): minus 87%. According to Heeren (2015, p. 294) in this specific area not a single settlement was inhabited between the late 3rd and first half of the 4th century. In contrast, along the river Meuse a little to the east, clear evidence has been found of settlement continuity (Verwers 1998-1999; Van Enckevort *et al.* 2005). The Northern Coastal Area seems to have become virtually deserted in the 4th century AD, but this is not entirely uncontested (e.g. Bärenfänger 2001; Krol 2006; Nieuwhof 2013).

Combining ARCHIS-based decline percentages presented in tab. 6, Van Munster's Middle Roman regional population density estimates (tab. 2) and detailed AD 100 and 800 landscape reconstructions by Vos, De Vries 2013 allows estimating Roman and early medieval period population estimates for the (present-day) Netherlands as a whole. Also decline percentages can be transformed to actual population numbers. For both periods the surface area covered by (virtually) uninhabitable lands (marshes and mires mainly) was subtracted from the reconstructed total land surface. The remaining area was subdivided in 'sandy soils' (low population density: M=4,9 p/km^2) and 'clay soils' (high population density: M=17.5 p/km^2; tab. 7)[10].

This results in a total number of 167,133 Middle Roman inhabitants. Using a mean decline percentage of 83.9% (mean over LRP, EMPA and

[9] Selected were settlements producing solid evidence allowing high-resolution dating.

[10] Where Van Munster 2012 gives regional minimum and maximum figures, we used the minimum (see tab. 2).

Period	Land surface (km2)							
	Total	**Marshes**	**%**	**'Habitable'**	**Sandy soils**	**%**	**Clay soils**	**%**
AD 100	39194,690	19095,926	48,72%	51.28%	10172,996	25,96%	6702,325	17,10%
AD 800	37788,012	14698,765	38,90%	61.10%	10137,452	26,83%	8398,704	22,23%
Difference	-1406,678	-4397,161	-9,82%	9,82%	-35,544	0,87%	1696,379	5,13%

Tab. 7. Surface of 'habitable' land in AD 100 and 800 (based on landscape reconstructions by Vos, De Vries 2013)[11].

EMPB) for the period AD 270-725 a population number of 28,864 can be calculated. We have taken into account that the habitable land surface somewhat increased in the time interval between AD 100 and 800.

4. Roman and Early Medieval population numbers and densities in the Rhine-Meuse delta

Within the context of the *Dark Age of the Lowlands* research programme'[12] Van Lanen *et al.* (submitted) recently studied demographic fluctuations in the eastern part of the Rhine-Meuse delta: the Eastern River Area (fig. 1: box). Earlier attempts mainly focussed on (parts of) the Early Roman and Middle Roman periods (12 BC-AD 270). Bloemers (1978), Willems (1986) and more recently Vossen (2003), Vos (2009) and Verhagen *et al.* (2016) published Roman population estimates or trends for the Dutch *limes* zone. Most commonly two types of models have been applied: (1) the recruitment model (RM) which bases population estimations on the Roman-military requirement numbers known from historical sources (Bloemers 1978; Willems 1986) and (2) the settlement-density model (SDM) which bases calculations on settlement numbers, the average number of houses per settlement and average household size (Bloemers 1978; Willems 1986; Vossen 2003; Vos 2009; Dijkstra 2011). Van Lanen *et al.* (submitted) developed an adapted SDM for the Rhine-Meuse delta because: (1) probably most people lived in rural settlements, (2) good-quality settlement data are available, allowing an evidence-based approach and (3) it is impossible to make out if Roman

[11] Courtesy Menne Kosian (RCE).

[12] This research programme (*The Dark Age of the Lowlands in an interdisciplinary light*) by Utrecht University and the Dutch Cultural Heritage Agency (RCE) investigates how settlement dynamics, land use, infrastructure, demography and trade between AD 300 and 1000 were related to landscape and climate changes, focusing on the Lowlands' geomorphologically most sensitive regions.

army-recruitment numbers reflect ambition or reality. Additionally, such a model makes it possible to assess the relative contribution of low-level urbanisation and military presence.

For each archaeological period (tab. 1) population numbers were determined by first calculating the size of the rural population living in (common) small settlements and then adding the number of people living in (exceptional) large settlements or in military service. More details, including reference sites, are given in Van Lanen *et al.* (submitted: Appendix A). Rural-population numbers were calculated by multiplying the total number of rural settlements with the average number houses per settlement and household size for each period. The total number of settlements includes both excavated settlements and undiscovered settlements. Research by Bult (1983) and Deeben *et al.* (2006) suggests that in the Netherlands (at least) 50% of the number of settlements present are not (yet) discovered. The average number of houses per settlement and household sizes are based on published estimates (Bloemers 1978; Vos 2009; Heeren 2009, Dijkstra 2011; Hamerow 2002; Van Beek *et al.* 2015). Again ARCHIS settlement data were used. Population numbers for uncommonly large settlements (>5 ha) are based on settlement size, building density of houses and average household size. Quantitative data from well-documented large settlements (especially Roman Nijmegen and early medieval Dorestad) were used as a frame of reference to estimate population numbers in contemporaneous large settlements. Archaeological data on military presence is only available for the Roman period. During this period the area was part of the northern frontier of the Roman Empire, and had (at periods) a substantial military presence (e.g. Van Es 1981; Polak 2009). During the Early and Middle Roman Periods 15 Roman fortresses, i.e. 14 *castella* and 1 *castrum* with equally as many *vici* and *canabae legioni* were present. After the Early Roman Period, military presence declined significantly. The number of troops were estimated per sub-period. These estimates are based on historical (e.g. size of Roman legions, fortresses) and archaeological sources (e.g. excavated fortresses) (e.g. Hazenberg 2000; Ploegaert 2006; Blom, Vos 2007; Vos *et al.* 2012; Waasdorp, Van Zoolingen 2015). Again, building density, surface area and estimated population of well-documented military sites were used as a frame of reference for other sites. Based on Van Dinter *et al.* (2014) the average size of military presence in *castella* was set at 350 soldiers. Probably an equal number of people lived in associated *vici* (Van Dinter *et al.* 2014, p. 29). Numbers for the Nijmegen Roman *castrum* and *canabae legionis* (ca. AD 70-104; 14,000 inhabitants, Driessens 2007; Willems *et al.* 2004) were added separately.

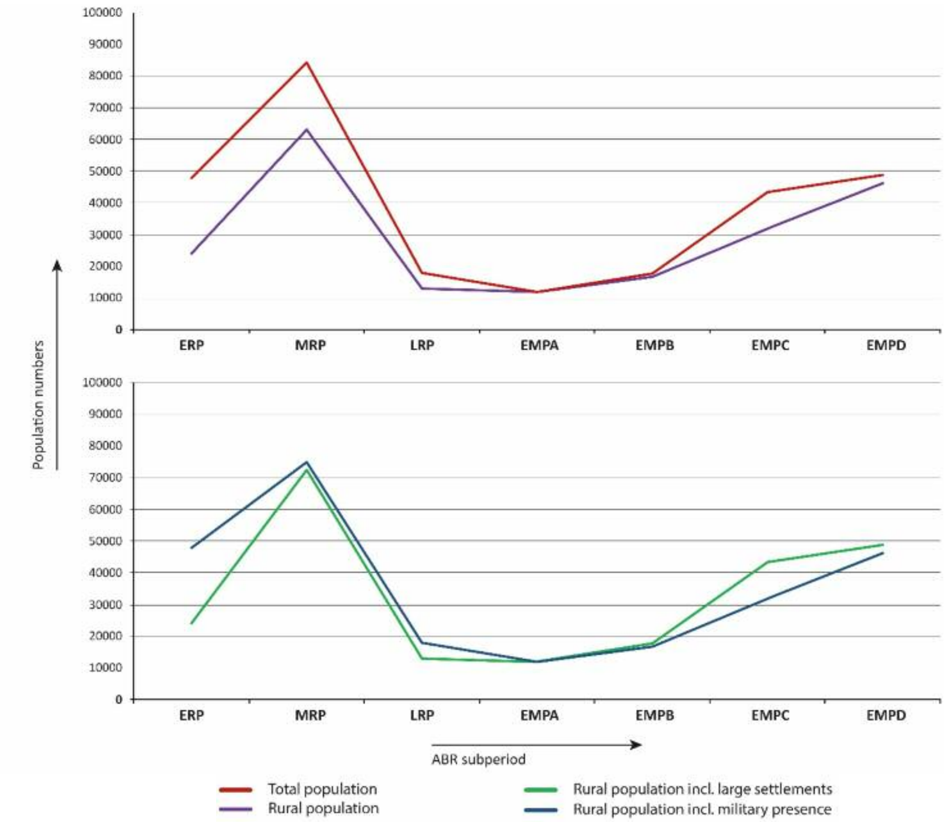

Fig. 4. Reconstructed population trends for the Eastern River Area during the 1st millennium AD. For each ABR subperiod the total population size, the rural population size, the military population size and the number of large settlement inhabitants are given (after Van Lanen *et al.* submitted).

5. Total-population estimates

Tab. 8 and fig. 4 summarize the modelling results. They show a strong population increase during the MRP, caused largely by rural population growth. Significant population decline is visible during the LRP, due to rural depopulation, diminishing military presence and the decline of large settlements. Compared to the Mid Roman maximum average population decline within the time span ROML-EMPB (270-725) amounts to 81.5%. Significant population growth re-occurs from the EMPC onwards. Low-level urbanisation was at its maximum during the EMPC, which largely reflects the rise of the international trading centre of Dorestad. Non-rural population groups never dominated, and Roman-military presence nor early urbanisation appears to have had much influence on total population numbers.

Period	Total population study area	Rural population + military presence	Rural population + large settlements	Rural population	% military	% low-level urbanisation
ERP	47863	47863	24063	24063	24.9%	0%
MRP	84316	74941	72516	63141	7.9%	11.1%
LRP	17948	17948	12948	12948	14.0%	0%
EMPA	11934	11934	11934	11934	0%	0%
EMPB	17692	16692	17692	16692	0%	5.7%
EMPC	43402	31902	43402	31902	0%	26.5%

Tab 8. Estimated total population Eastern River Area based on archaeological data, settlement size, structure and density. For each sub-period the relative contribution of military presence (i.e. active soldiers, not *vici* inhabitants) and urbanisation on the total population is provided (after Van Lanen *et al.* submitted).

Period	Total population	Surface area total study region (in km^2)	Surface area without flood basins (in km^2)	Population/ km^2 total study region	Population/ km^2 without flood basins
ERP	47863	3306.8	2409.1	14.5	19.9
MRP	84316	3306.8	2409.1	25.5	35.0
LRP	17948	3306.8	2531.3	5.4	7.1
EMPA	11934	3306.8	2531.3	3.6	4.7
EMPB	17692	3306.8	2531.3	5.4	7.0
EMPC	43402	3306.8	2527.5	13.1	17.2
EMPD	48815	3306.8	2527.5	14.8	19.3

Tab. 9. Reconstructed Eastern River Area population densities in the 1st millennium AD.

Population density was also reconstructed, separately for (a) the research area as a whole and (b) excluding (uninhabited) flood basins. Temporal differences in surface area were taken into account based on palaeogeographical data. Tab. 9 shows that during the Middle Roman period population density was very high (population/km^2 total): 25.5 persons/km^2. If we exclude uninhabited landscape zones (population/km^2 no flood basins) this number rises to 35.0. Both figures are significantly higher even than the population density-range for clay soils discussed before (17.4-19.1 persons/km^2). From tab. 9 maximum population decline percentages ranging between 80% and 87% can be derived.

Reconstructed population numbers were used to model the impact of demographic changes on past land use and landscape (Van Lanen *et al.* submitted). To do so, the PLUS modelling framework was applied (Past Land-Use Scanner, De Kleijn *et al.* submitted), allowing the integration of (digital datasets on) cultural and natural variables, which is essential for reconstructing spatiotemporal frameworks of past cultural-landscape changes. Also data on landscape structure, settlement location and agricultural potential and practices were taken into consideration. This also allows to test the feasibility of archaeological hypotheses regarding e.g. past human-landscape interaction. The landscape impact of reconstructed population fluctuations during the 1st millennium AD turns out to have been rather limited. A significant finding is that the substantial Early Roman military presence in the area did not exceed the areas food production potential (cf. Van Dinter *et al.* 2014; *contra* Groenman-Van Waateringe 1983; 1989). The large population of early medieval Dorestad could be supplied locally too. Both conclusions obviously do not imply that no food was imported. On the other hand, due to high overall population levels total self-sufficiency probably was not fully attainable in EMPD (Van Lanen *et al.* submitted).

6. Validation

The above reconstructions all point to, in some areas drastic, population decline starting in the 3rd or 4th century AD. A fundamental question remains to what extent we can trust the archaeological data on which demographic statements are based, in particular (fluctuations in) the number of settlements. Or are we faced with methodological restraints: our inability to identify (all) settlement sites, especially those dating to the early post-Roman period? We have tried to answer this question, and to validate the reconstructed population trends, by first comparing our outcomes (numbers and densities) with other estimations and then looking at proxy-data on human presence and activity: wood use, timber import, charcoal production, dress accessories (*fibulae*). Lastly, we will re-evaluate data reliability.

7. Comparisons

Numbers and densities. For the 7th-century Netherlands Heidinga (1987), calculated 20,000-30,000 inhabitants. Our estimate (average) for the period AD 270-725 is 29,000. A supraregional ('national') estimate by Louwe Kooijmans *et al.* (2005) for the Middle Roman Period (150,000) is in line with our (ca. 167,000). We have established that Roman-period population densities range between 17.4-19.1(25) p/km^2 (fertile clay soils) and 4.0-6.9 p/km^2 (less fertile sandy soils) and that in both landscape types population densities are remarkably consistent (tab. 2). This pattern is also visible elsewhere. Settlement numbers presented by Hansen (2015, pp. 246, 249) allow us to establish that both in terms of estimated population density (AD 200-600: ca. 8.3 p/km^2) and soil fertility (glacial clay mixed with sand) the Danish island of Funen takes an intermediate position. Exceptionally high population densities (up to 160 p/km^2!) are mentioned for the Northern Germany, an area comparable to the coastal clay area of Westergo (Jankuhn 1974, p. 357; Steuer 1988). Our archaeology-based regional population density estimates are in the same range as 'old' Roman-period estimates that are largely based on the fundamental work of 19th-century historian Karl Julius Beloch (1854-1929). He used planimetric estimates by contemporary military cartographers (Frier 2000, tab. 4). For the Roman Empire as a whole the given mean population density is 13.6 inhabitants per square kilometre in the beginning of the 1st century (AD 14) and 15.9 in the mid Roman period (AD 164). For 'Gaul and Germany' (of which the southern Netherlands were part of) Frier (2000) for both periods gives settlement densities of 9.1 and 14.2 respectively. Had we taken into account the demonstrated presence of population concentrations (areas with a far above average population density: Eastern River Area) then both estimates probably would even have been more similar. On the basis of the data brought together by Van Munster (2012) for the mid Roman Netherlands a only slightly lower mean population density of 11.2 p/km^2 can be calculated[13]. As to the Early Middle Ages: on the bases of data published by Steuer (1988) Merovingian population density in the German Breisgau region can be calculated at 4.3 p/km^2. This number is comparable with most estimates presented in tab. 3.

Post-Roman population decline: in his landmark paper on the Roman-medieval transition Cheyette (2008, p. 139) summarizes settlement evidence (largely qualitative) from different European regions suggesting "a radical thinning out of (…) habitation sites during the fifth and sixth centuries (…)" (North-Eastern Gaul, Western Eifel-Germany, Paris Basin,

[13] This is the average of estimated population densities of all five investigated regions situated within the Roman Empire. The figure that was used to establish this estimate was increased by 17.5 in order to balance the data in terms of sand- versus clay areas.

Danube Frontier etc.). Published decline percentages vary. On the basis of numbers presented by Klein-Goldewijk *et al.* (2010: tab. 2)[14] for Europe as a whole a ca. 12% decline can be inferred between AD 0 and 500 (AD 0: 4.1 persons/km^2, AD 500: 3.6 persons/km^2). Rough estimates by the historian Russel (1972) allow us to calculate a ca. 35% decline between AD 500 and 650. Adding (debatably...) both percentages results in a 47% population decline between AD 0-650. The data presented by Van Munster (2012) suggest that population numbers almost halved. High-temporal resolution ARCHIS settlement data (tab. 6) indicate that the number of settlements dropped much more: 73.1% and ultimately even 92.1%. ARCHIS-based decline estimates for the Eastern River Area range between 80% and 87% (see below). In Northern France Wickham (2005, p. 508) observed the number of sites declining by 50%[15]. According to Russel (1972) overall population decline in France and the Low Countries (the Netherlands and Belgium) between AD 500 and 650 amounted to approximately 40%. Interestingly, significant population decline also occurred outside (former) Roman territory, in Frisia[16] for instance (this paper), and further to the North, be it somewhat later. Following a population peak (AD 200-600) between AD 600-800 the Norwegian population declined by some 70%[17]. This estimate is based on numbers of graves, settlements and stray finds (see Solberg 2000; Iversen 2016; Vetrhus 2017). Estimated decline percentages, therefore vary strongly. This may reflect reality: regional variability, or scale-differences (generalisation) and methodological diversity as well (variation in reliability and accuracy). Pin-pointing causes is difficult. In the Northern France Aisne Valley for instance, on the bases of systematic fieldwalking, a ca. 50% decline has been established (Haselgrove, Scull 1995, p. 26), neatly corresponding with general, supraregional, estimates (ca. 40-50%) mentioned above. Aerial survey data from the neighbouring Somme-region, however, suggests 80% decline (Agache 1978). Regional diversity or methodological bias? Substantial (micro-) regional variability, as demonstrated in this paper, definitely was a general characteristic of the early post-Roman settlement landscape (see e.g. Ouzoulias, Van Ossel 2001).

[14] Their estimates per continent are averages based on previously published (methodologically varying) estimates.

[15] It should be noted that Wickham only dealt with the Merovingian Period (until AD 725). Van Munster on the other hand left out (pre-) urban centres (such as Dorestad).

[16] *Frisia* = Northern Coastal Area.

[17] Pers. comm Frode Iversen (Museum of Cultural History, University of Oslo).

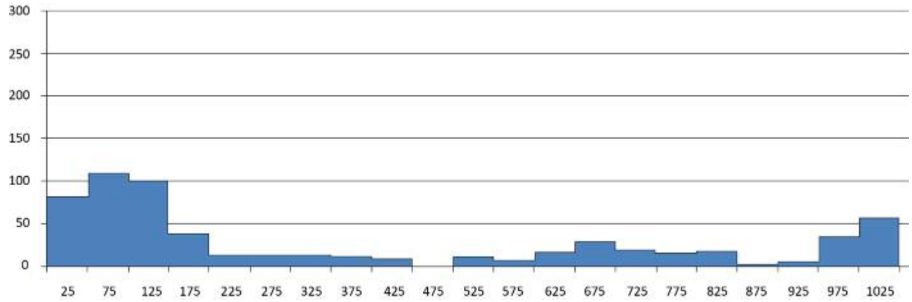

Fig 5. Histogram based on absolute cutting years of wood used by man AD 0-1000. Vertical scale: N-dated wood. Horizontal scale: dating (years AD). Figure courtesy of Prof. Dr. E. Jansma. These data were produced within the research project: The Dark Age of the Lowlands in an interdisciplinary light: people, landscape and climate in the Netherlands between AD 300 and 1000 (www.darkagesproject.com; Jansma *et al.* 2014) and were derived from the DCCD digital repository (dendro.dans.knaw.nl; Jansma *et al.* 2012).

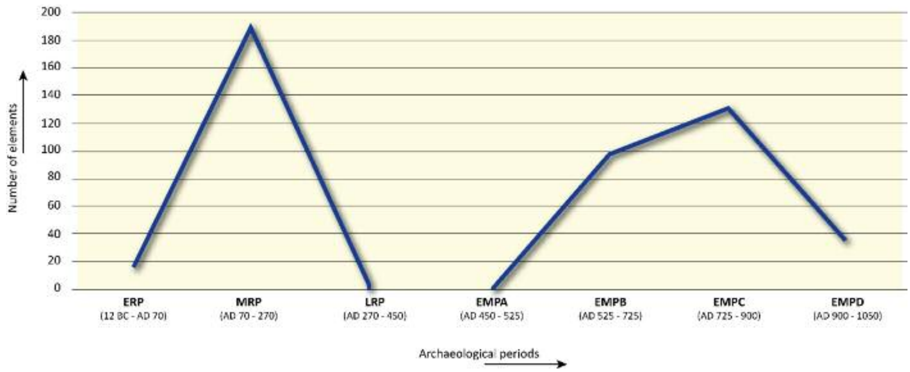

Fig. 6. Number of imported and dendrochronologically dated (individual) wooden elements (e.g. plank, stave, pile) per Roman and early medieval subperiod excavated in the present-day Netherlands (n=465). The reference collection contains measurement series from a total of 4260 wooden elements (after Van Lanen *et al.* 2016).

8. Proxy data

Wood

Variation in population numbers can be expected to be visible in the amount of wood that was used. If we look at the cutting dates of used wood found in archaeological contexts, we can observe a significant decrease from the mid-Roman period onwards (fig. 5). This conclusion is only valid for the River Area and the Western Coastal Area (fig. 3) as most wood included in the diagram comes from sites in these two areas. This is due to favourable conservation conditions and an above-average research intensity.

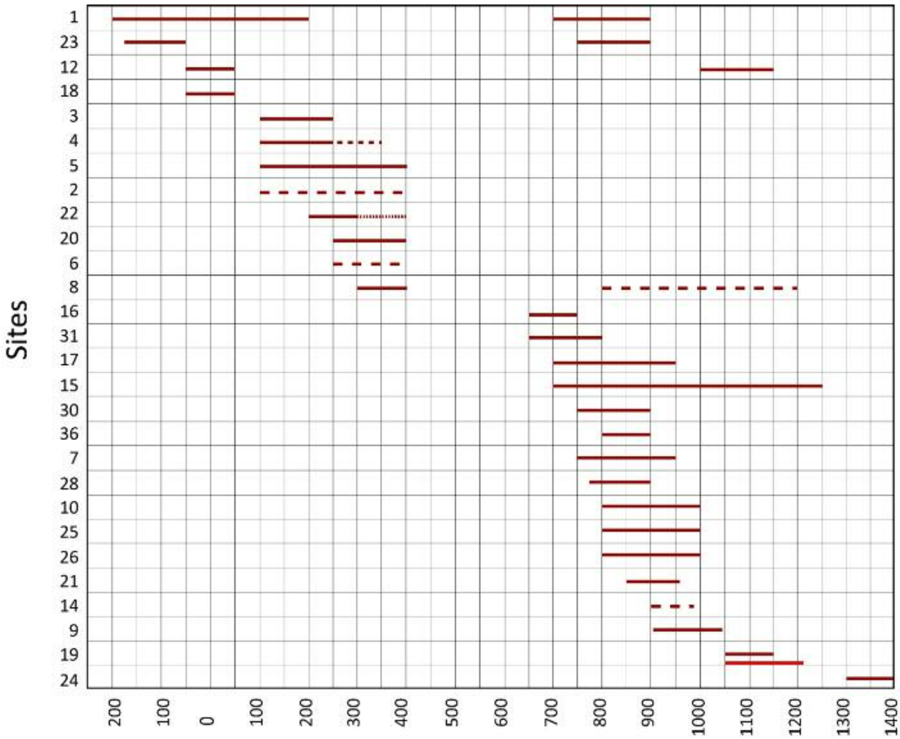

Fig. 7. Dated charcoal kilns ('pit kilns'). After Groenewoudt, Spek 2016. Vertical: site numbers. Horizontal: years BCAD.

The import of timber probably points to (1) much building activity, combined with (2) local shortage. To reconstruct Roman and early medieval long-distance transport routes in north western Europe the dating and provenance of imported timbers were investigated by Van Lanen *et al.* 2016. Fig. 6 shows that between AD 270 and 525 in contrast to earlier and later periods there is no evidence for the such import.

Charcoal kilns

Charcoal kilns demonstrate the presence of woodland, woodland exploitation and artisanal activity, especially the production and working of iron (for which charcoal was predominantly used; Groenewoudt, Spek 2016). Fig. 7 summarizes all reliably-dated charcoal kilns ('pit kilns' only) excavated in the Netherlands. So far these have only been found in the 'Southern Sand' and 'Northern Sand' areas (fig. 3). For these areas AD 400-650 dates lack, suggesting that during this time interval little or no charcoal was produced. Probably the same goes for the production and working of iron.

Fibulae

Very generally speaking, the quantity of archaeological features and debris reflects the number of people (e.g. Marsden, West 1992; Chamberlain 2006, pp. 128-131). *Fibulae* are of particular interest because both in the Roman Period and Early Middle Ages they were commonly used dress accessories: personal items (Heeren, Van der Feijst 2017, pp. 343-344, 397). Therefore we may expect numbers of *fibulae* to be indicative for numbers of people[18]. The largest numbers of Roman and early medieval *fibulae* have been found in the River Area (fig. 3; Heeren, Van der Feist (2017). Probably this at least partly reflects favourable conservation conditions and a high level of research intensity (Heeren, Van der Feist 2017, Chapter 8). Therefore, for the River Area only *fibulae* numbers and dates were brought together (tab. 10).

Period AD	time span (years)	N well-dated *fibulae*	Years/N	
150-270	130	1802	13,9	100%
270-450	180	806	4,5	32.4%
450-725	275	926	3,4	24.5%

Tab. 10. Numbers of well-datable (chronologically specific) *fibulae* AD 150-725 (based on data presented in Heeren, Van der Feist 2017)[19].

Although *fibula* numbers are much lower than before, the late Roman (AD 270-450) and early Post-Roman (Merovingian) periods (AD 450-725) clearly are not voids. Compared to the Middle Roman Period (AD 150-270) and taking into account time span differences the decline percentages for both periods are 67.6% and 75.5 respectively. This may suggest that late- and early Post-Roman population levels in the River Area were low, but almost certainly somewhat higher than estimated by Van Munster (2012, fig. 5) and Van Lanen (2017) (minus 80-87%).

9. Data reliability

The results of a recent regional study focussing on the Roman-Medieval transition (Eerden *et al.* 2017; Hendriks *et al.* in press) seems to confirm that the reliability of our demographic reconstructions may be

[18] Up to AD 400 both man and women usually wore one *fibula*. Afterwards few men used *fibulae*, women on the other hand usually had two minimum (pers. comm. Jan van Doesburg, RCE).

[19] AD 150-270: *fibula* types 47, 48, 56, 59-67; AD 270-450: *fibula* types 68-70, 72-78; AD 450-725: *fibula* types 79-87. Courtesy Stijn Heeren (VU University Amsterdam/ Coordinator PAN: Portable Antiquities of the Netherlands).

hampered by methodological limitations. Using up-to-date typo-chronological insights pointed out that settlement sites and stray finds dating to the period are not quite as rare as they were believed to be. For example, the abandonment of the well-known Roman period type site of Wijster is nowadays placed not in the beginning of the 5^{th} (Van Es 1967) but in the 6^{th} century AD (e.g. Hiddink 1999). Also the increased application of absolute dating methods has led to the conclusion that hiatuses may (partly) be an artefact of using inadequate or out-dated typo-chronologies. All in all, it is likely that renewed dating of 'old' sites included in the ARCHIS database will produce more evidence for 'Dark Age' settlement. Consequently also Van Lanen *et al.*'s (submitted) population estimates for the Eastern River Area (tab. 7) may indeed be somewhat too low (as already suggested by the *fibula* data, see above). We also have to take into account that "absence of evidence is no evidence of absence". Well-datable early medieval imports are very unevenly distributed throughout the Netherlands. The Western Netherlands Coastal Area stands out as a densely settled area in the Merovingian Period (AD 450-725) (Dijkstra 2011). Settlements could be dated here on the basis of numerous imports (predominantly pottery) from the German Rhineland. In contrast, in the Northern Sand Area well-datable imports are virtually absent. Here find complexes of the same period are dominated by hand-made 'Hessens-Schortens' pottery (Tischler 1954; Boon 2011), which is difficult to date with some precision (and is sometimes even believed to be prehistoric). In this situation, when absolute dates lack, it is very difficult to attribute sites to a specific early medieval subperiod.

10. Conclusions

We have discussed Roman and early medieval population numbers and densities reconstruction attempts for the present-day Netherlands (and specifically the Rhine-Meuse delta). Results show that such reconstructions are fairly accurately possible on the basis of archaeological data. This is demonstrated by the fact that methodologically different approaches result in comparable estimates. As to the proxy data validation: there are things to be said against each one of these proxies (in the Introduction we already mentioned that reforestation is not necessarily caused by population decline). Together however, they show a consistent pattern: they all point to significantly decreasing human activity. We believe this qualitatively supports our outcomes. An interesting observation is that the population density of fertile (clay) areas was consistently three to four times higher at least, than that of less fertile (sand) areas. Whether or not a region was part of the Roman empire seems not to have been a decisive factor with regard to settlement density. And notable population decline also occurred outside (former) Roman territory.

The Roman-Medieval transition was characterized by notable regional differences, both in terms of population density and temporality. Concerning Post-Roman population decline our research essentially confirms regional population trends reconstructed by Van Munster (2012). For the present-day Netherlands we estimate an average (maximum) population decline of 70-80%. This is less than our calculated 83.9% because it is likely that late- and early Post-Roman sites are underrepresented in the dataset that was used (ARCHIS). Regional decline percentages probably range between ca. 50% and almost 100%.

Especially for the Roman Period onwards it is important to systematically distinguish the normal rural population base levels from the exceptional local population concentrations (towns, military settlements). This allows more accurate estimations of population numbers. In combination with other datasets, such as detailed landscape reconstructions, evidence-based population estimates also allow quantitative testing of scenarios and hypothesis. In the Eastern River Area however, nor the influx of large numbers of Roman soldiers nor early urbanisation led to significantly increasing overall population numbers (Van Lanen *et al.* submitted). And neither demographic event caused overburdening the carrying capacity of the landscape in terms of food production.

The attempts that have been discussed represent two different approaches to calculate population numbers: region-based and *big data*-driven. The first approach involves collecting, interpreting and validating settlement data from intensively-researched areas/micro-regions. In terms of numbers and densities (settlements and population numbers) the results are subsequently extrapolated to larger areas, areas with similar landscape and culture-historical characteristics. Because regional variability may be substantial, extrapolation to larger areas should only be done if representative micro-regional datasets are available. The second method involves analysing large (digital) datasets. The larger, the better. One of the advantages of using large datasets is that a certain percentage of inaccurate information on site level is irrelevant when it comes to tracing general trends and patterns. Source criticism obviously remains essential, not on site-level but of the dataset as a whole. Important variables to evaluate are data representativeness and recovery rate. In this paper we additionally applied multi-proxy validation. Results essentially confirm our reconstruction of the magnitude of Post-Roman population decline.

To a degree calculating historical population numbers remains a "precarious enterprise". We cannot rule out that insights are distorted by archaeological inadequacies, including methodological biases. Dating possibilities have improved in recent decades however, and in our research area the time period that has been the focus of this paper has gradually become more 'visible'. This means that re-identifying and re-dating 'old' finds and sites could lead to new insights, insights that might contribute to forging more adequate tools for understanding social, economic and landscape dynamics. The established high degree of spatio-temporal population variation and dynamics stresses the necessity of a multi-scale approach. General, supraregional, estimates and trends may very well mask crucial regional differences. A better insight in demographic diversity therefore, may prove to be key to explain 'what exactly happened where' during the transition of the Roman Period to the Early Middle Ages. This requires evidence-based calculations. Because numbers do matter.

Acknowledgements

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