

# Could the local population of the Lower Rhine delta supply the Roman army?

## Part 1: The archaeological and historical framework

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### Abstract

*For a long time, historical sources and the marginal landscape have led to the assumption that the Roman army in the Rhine delta was mainly supplied with products transported over medium and long distances. In a diptych of articles, we will investigate whether this assumption is tenable for wood and food, based on archaeological, palaeo-environmental and geological research carried out in the past twenty years. The first article provides a review of the data, which leads to the argument that the Roman army also procured wood and food (especially cereals and beef) from agrarian settlements in the immediate surroundings. The second article will investigate the scale of local provisioning on the basis of a calculation model.*

**Keywords:** food and wood provisioning, limes, palaeo-landscape, Roman army

### 1. Introduction

In the 40s A.D. the Roman army built a series of wooden forts and watchtowers in the Rhine delta between Vechten and the North Sea coast (fig. 1). Publications have appeared on the relatively small forts (e.g. Glasbergen 1972; Haalebos 1977; Polak *et al.* 2004; Ozinga *et al.* 1989) and on the size and composition of the army (Bechert & Willems 1995; De Weert 2006; Polak 2009; idem in press). We also have information on the reason behind the military installations; in the first century they mainly functioned to protect shipping on the Rhine, and from the end of the first century also to mark the northwestern border of the Roman province *Germania inferior* (Graafstal in press; Polak *et al.* 2004, 249-250).

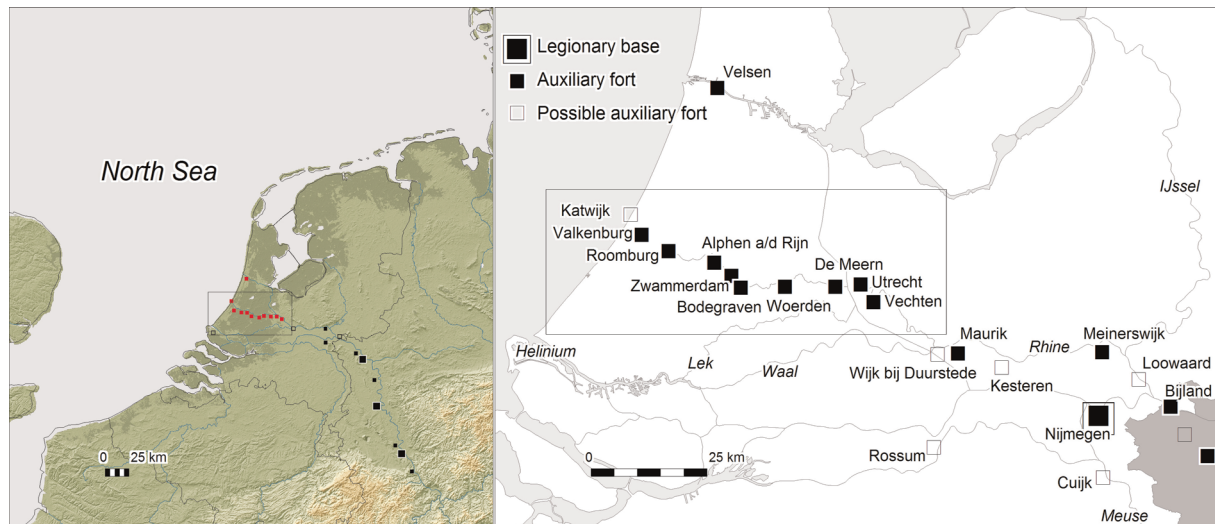


Figure 1 Research area in the Netherlands with Rhine delta forts projected on modern topography. Box indicates research area. (After Polak, 2009)

A sustainable frontier, however, requires a well-organised food supply (e.g. Groenman-van Waateringe 1989) and limitless supplies of building materials. It is precisely these two important aspects that are relatively little known. The accepted belief is that both a large part of the food as well as that of the wood for construction were imported. The arguments behind this belief are that the carrying capacity of the landscape was insufficient, and that the local population was not used to producing a substantial surplus (Bloemers 1983; Van Es 1981, 166-173; Whittaker 1994). Moreover, there are a number of historical and archaeological indications for the import of food, especially. Tacitus (Hist. IV, 26) described how in the first century, forts had to be supplied by cereal ships along the river Rhine. In Nijmegen, an inscription from the second/third century was found referring to a Nervian grain trader (Driessen 2007) and a ship filled with cereals was found near the fort of Woerden; the ship dates to the last quarter of the second century, and the cereals probably came from the loess area (Pals & Hakbijl 1992). Furthermore, there is a Late Roman source that mentions grain imports from Great Britain, destined for the Roman army (Mattingly 2006, 491, 505). The same seems to apply to animal food products for the army. The revolt of the Frisians in A.D. 28 is famous, and one of the reasons behind the revolt was the size of cattle hides that was demanded by the Romans (Tacitus: *Annales* IV, 72-73). An indirect deduction that has been made from this is that not only the hide but the entire animal was supplied. This is why the model pictured by Bloemers (1983) has been followed for a long time: the Roman army in the Rhine delta was supplied by cereals from the loess zone (northern France, Belgium, Dutch South Limburg and the German Rhineland) and meat from the *terpen* region (the northern Netherlands and northern Germany). However, this model is due for a revision.

Recent research has demonstrated that, contrary to what people used to believe, the local population around the northwest frontier was fully integrated into the Roman world (e.g. Derks & Roymans 2002; Heeren 2009; Vos 2009) and involved in supplying the army with food (Groot 2008; Groot *et al.* 2009; Kooistra 1996; *idem* 2012; Vos 2009). This, despite the fact that the population lived not in villas but in wooden byrehouses (Heeren 2009; Meffert 1998; Roymans 1996; Van Londen 2006; Vos 2009; Wesselingh 2000) in a dynamic landscape with an alternation of dry and wet areas and soils rich and poor in nutrients. In this context, an infrequently used quote from Tacitus in *Germania* (caput 5) is interesting:

'Their country, though somewhat various in appearance, yet generally either bristles with forests or reeks with swamps; it is more rainy on the side of Gaul, bleaker on that of Noricum and Pannonia. It is productive of grain, but unfavourable to fruit-bearing trees; it is rich in flocks and herds, but these

are for the most part undersized, and even the cattle have not their usual beauty or noble head. It is number that is chiefly valued; they are in fact the most highly prized, indeed the only riches of the people' (Tacitus *Germania*, caput 5, <http://www.fordham.edu/halsall/source/tacitus1.html>).

Excavations of military installations and rural settlements in the Rhine delta have produced a wealth of data on food and on wood as a construction material. All these data combined with detailed information on the landscape make it possible to investigate to what extent the local population was involved in supplying the Roman army in the Rhine delta, and what the carrying capacity of the landscape was with regard to food and wood.

The research is based on published and unpublished archaeological, palaeo-ecological and geomorphological data. Information from historical sources and ethnographical research has also been incorporated. The research area covers a zone of five kilometres to the north and to the south of the river Rhine, from a point eight kilometres to the east of the fort at Vechten to the estuary of the Rhine near Katwijk (fig. 1). The results are published in a diptych of articles. The current article, part 1 of the diptych, analyses the data in a descriptive way. To gain insight into the required amounts of construction and fire wood and food for the Roman army and their associates, as well as in the potential scale of the food production by the local population and the carrying capacity of the landscape with regard to food and wood, a conceptual model was developed. The model will be presented in part 2, by means of an example of calculations. The combination of descriptive and mathematical archaeology leads to new insights into the supply of food and construction wood – most importantly for the period A.D. 40 to 140 – to the Roman army in the Rhine delta.

## 2. The Rhine delta in the Roman Period

In recent years, Van Dinter (in press) has analyzed in detail LIDAR-data and geo(archaeo)logical, geomorphological and soil data of the Lower Rhine delta between Vechten and Katwijk. This has resulted in a palaeogeographical map for the Roman period which covers an area of more than 1,500 km<sup>2</sup> (fig. 2). This research has revealed that the Roman defence system, situated on the southern side of the Lower Rhine, was built in three different types of landscape. Each type has its own possibilities and limitations for living grounds, food production and the occurrence of wood.

The eastern part, with the forts Vechten, Utrecht and De Meern, the so-called river region, was part of the Dutch River Area. The river Vecht branched off in a northerly direction near the fort at Utrecht. In the Roman period, the Dutch River Area was characterised by active rivers flanked by levees, older alluvial ridges (levees formed by former rivers together with their residual channels) and flood basins (Berendsen 1982; Berendsen & Stouthamer 2001). Height differences were minimal in the Dutch River Area and the substratum was soft. The alluvial ridges and the levees of active rivers consisted of relatively fertile sandy to silty, clayey soils. They formed the highest parts of the landscape, which rarely flooded (fig. 3a). When levees and alluvial ridges were not used by man, mixed deciduous woodland developed. The composition of this woodland depended on the flooding frequency (Van Beurden 2008). The majority of the alluvial ridges and levees were already deforested before the Roman period, because these areas were the most suitable as living grounds and these woodlands delivered the best quality timber. The alluvial ridges and levees were also in use for arable farming and animal husbandry (Groot & Kooistra 2009). From the relict woodlands timber and wood for fuel could be collected. The flood basins were the lowest areas in the Roman riverine landscape. During every flood, flood waters brought fertile clay into the flood basins. This explains the nature of flood basin soils: fertile but wet and heavy. Water levels varied between different parts of the flood basins, and throughout the year. The highest water levels occurred during winter and in

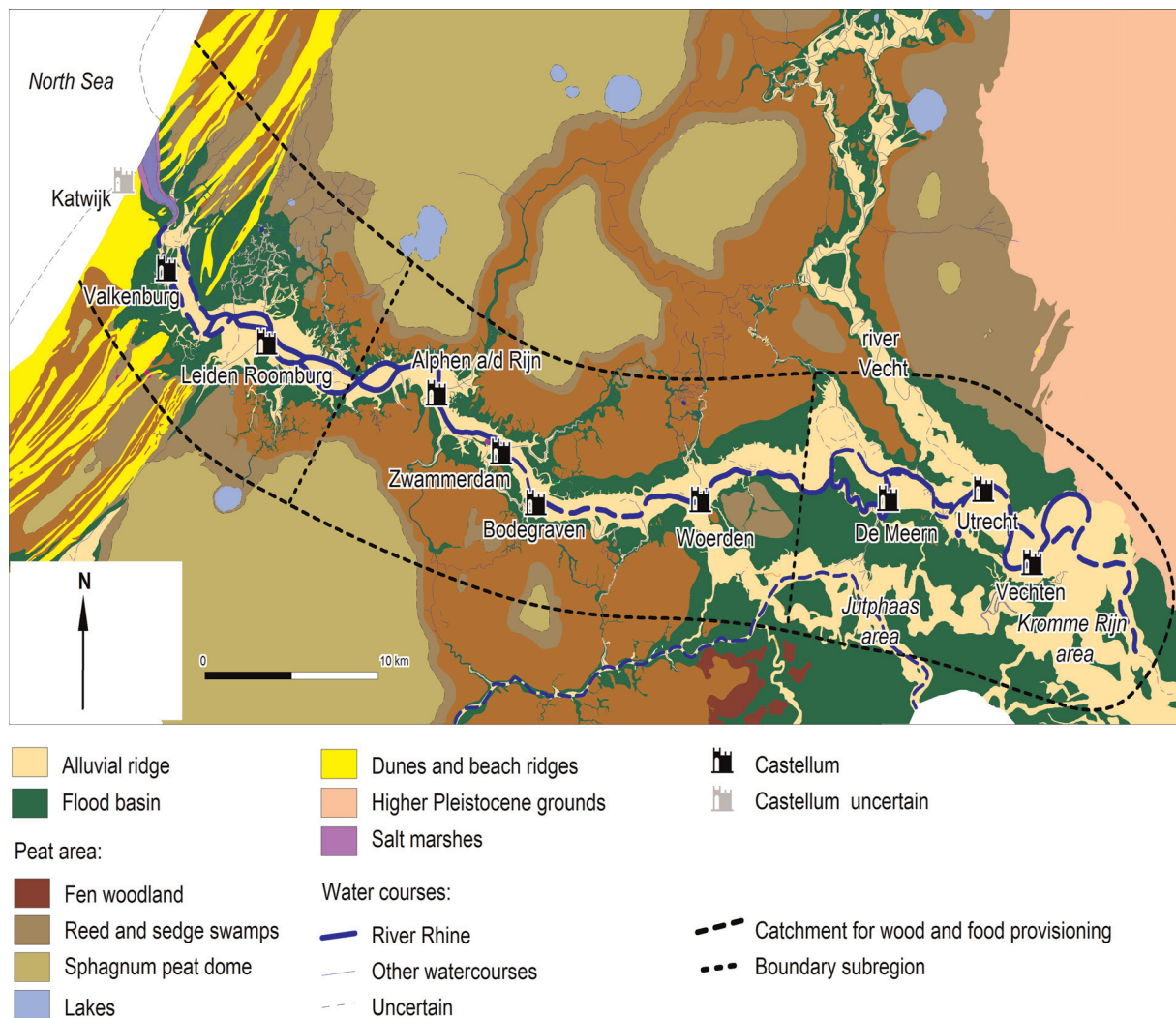


Figure 2 Palaeogeographical map of the western Lower Rhine delta during the Roman period. (After Van Dinter *in press*).

springtime. In a natural situation reed and sedge marshes covered the lower-lying areas. In drier places wetland woodlands occurred in which alder and willow dominated (Groot & Kooistra 2009; Van Beurden 2008). Due to the heavy clays and overall wet conditions, the flood basins were not suitable for arable farming, but were perfectly suited for pasture and hay meadows for cattle, sheep and horses. The wetland woodlands could be used to collect timber and wood for fuel.

The central part of the line of defence, with the forts Woerden, Bodegraven, Zwammerdam and Alphen aan den Rijn, was located on the southern levees of the Lower Rhine, which formed a narrow corridor of accessible terrain through extensive wetlands with active peat development (Van Dinter *in press*; fig. 3b). As in the river area, the levees in this peat region consisted of fertile sandy and silty, clayey soils and the low-lying flood basins of fertile, but heavy clays. In a natural situation, the levees were covered with mixed deciduous woodland and parts of the flood basins with wet alder woodlands (Van Rijn *in prep.*). It is likely that the low-lying parts of the levees and flood basins were covered with reed and sedges. Behind the flood basins Van Dinter (*in press*) reconstructed extensive eutrophic fen woodlands, mostly consisting of alder carrs. Further away from the river, the fen woodlands gave way to mesotrophic reed and sedge fields, followed by huge, dome-shaped, nutrient-poor *Sphagnum* peat bogs. Although these peat bogs were the highest places in the area (fig. 3b), they were very wet and not accessible. A complex, interconnected network of small watercourses received the



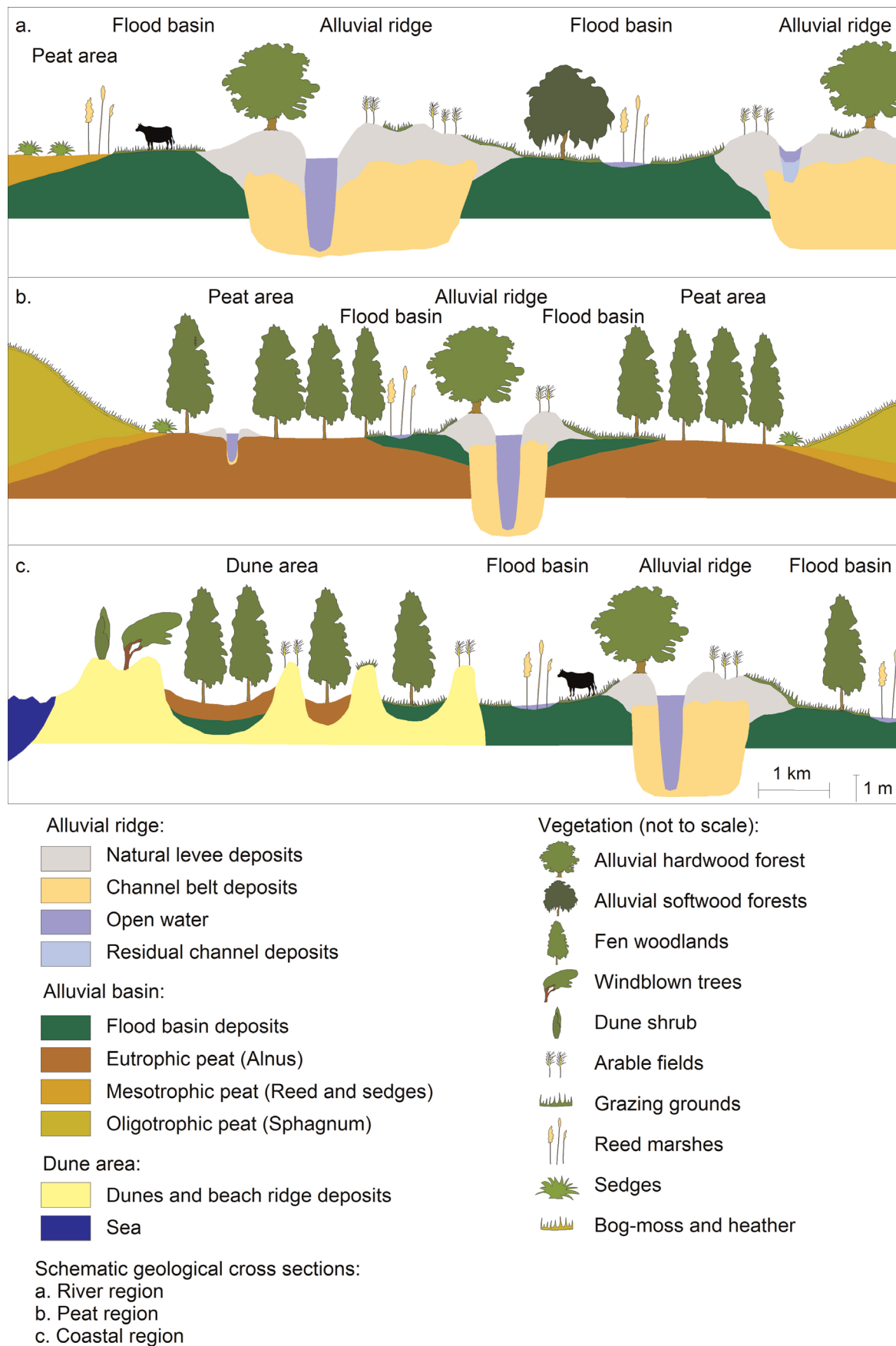


Figure 3 Cross-sections through the three types of landscape in which the Roman defence system of the Lower Rhine was built, a. river region, b. peat region, c. coastal region.

drainage water of these domes and transported it to the rivers Rhine and Vecht. The human activities were concentrated on the levees and flood basins in the same way as in the river region. The fen woodlands in the peat area were in use extensively, mainly for obtaining wood, as will be argued below.

The coastal region in the west forms the third type of landscape. The defence system with the forts Leiden Roomburg, Valkenburg and Katwijk was constructed there. This region includes a freshwater tidal district and the estuary of the Lower Rhine, which interrupted a series of parallel dune ridges and barrier plains (fig. 3c). In the estuary fresh water of the Lower Rhine was mixed with salt seawater. The extent of the reach of salt or brackish water lay just to the east of the fort at Leiden Roomburg (Van Dinter *in press*). The highest places were situated on the levees of the Lower Rhine, with a mix of fertile sandy and clayey soils, and the parallel dune ridges, which consisted of poor aeolian sand. In a natural situation, the dune ridges and the highest parts of the levees were covered with mixed deciduous woodlands of slightly different compositions. The dunes nearest to the sea and the estuary were free of trees, because of salt spray and flooding by brackish water. Various kinds of salt marsh vegetations were found in the flood basins and low-lying parts of the levees in the estuary. Reed and sedge marshes prevailed in the fresh-water tidal district. Peat accumulated in low-lying barrier plains, which existed in between the parallel dune ridges. These peat areas were normally covered with alder carrs (Kooistra 2008). The land use possibilities were more or less the same as in the other two regions. The dune ridges could have been used for the same activities as the levees and the salt marshes were excellent grazing grounds.

### 3. The Roman army in the Rhine delta

#### 3.1 *Timber for forts and other military structures*

In the first 150 years A.D. at least seven wooden forts, with sizes between slightly less than one and two hectares, was located in the Rhine delta (Chorus 2007). Little is known about the fort at Bodegraven, but this fort also seems to have covered circa 1 ha (Van der Kooij *et al.* 2005). Near Katwijk, a stone construction was located that has been interpreted as a fort, and for which the date is unknown (e.g. Bloemers & De Weerd 1984; De Weerd 1986). It is also unknown whether this construction had a wooden predecessor. However, it is likely that a fort was located near the mouth of the estuary in the first century (Bosman & De Weerd 2004; Van Dinter *in press*). The fort near Vechten was probably larger than the other wooden forts in the delta. This is the oldest fort of the series and was built in the first decades B.C. or A.D. (Polak & Wynia 1991; Zandstra & Polak 2012).

The forts are not the Roman army's only structures. Watchtowers were built and quays were constructed. In the late first century, a road was built, partly with a wooden foundation, which connected the forts (Luksen-IJtsma 2010). Although the building activities did not all take place at the same time, there would have been periods when a large amount of construction wood was required, for instance when the forts and quays were constructed in the 40s A.D., after the Batavian revolt in A.D. 69/70 when many of the forts had burned down, and when roads were built in A.D. 99/100 and 123/125. In between these moments, construction wood would have been needed for renovations and when regiments changed.

The excavations near and in the forts of Alphen aan den Rijn (Haalebos & Franzen 2000; Polak *et al.* 2004) and Valkenburg (Glasbergen 1972; Glasbergen & Groenman-van Waateringe 1974; Van Rijn *in prep.*) have provided much information on the use of wood in a military context. Moreover, the Roman road has been investigated in various locations, and wood data have become available for other forts and several watchtowers near the fort of De Meern

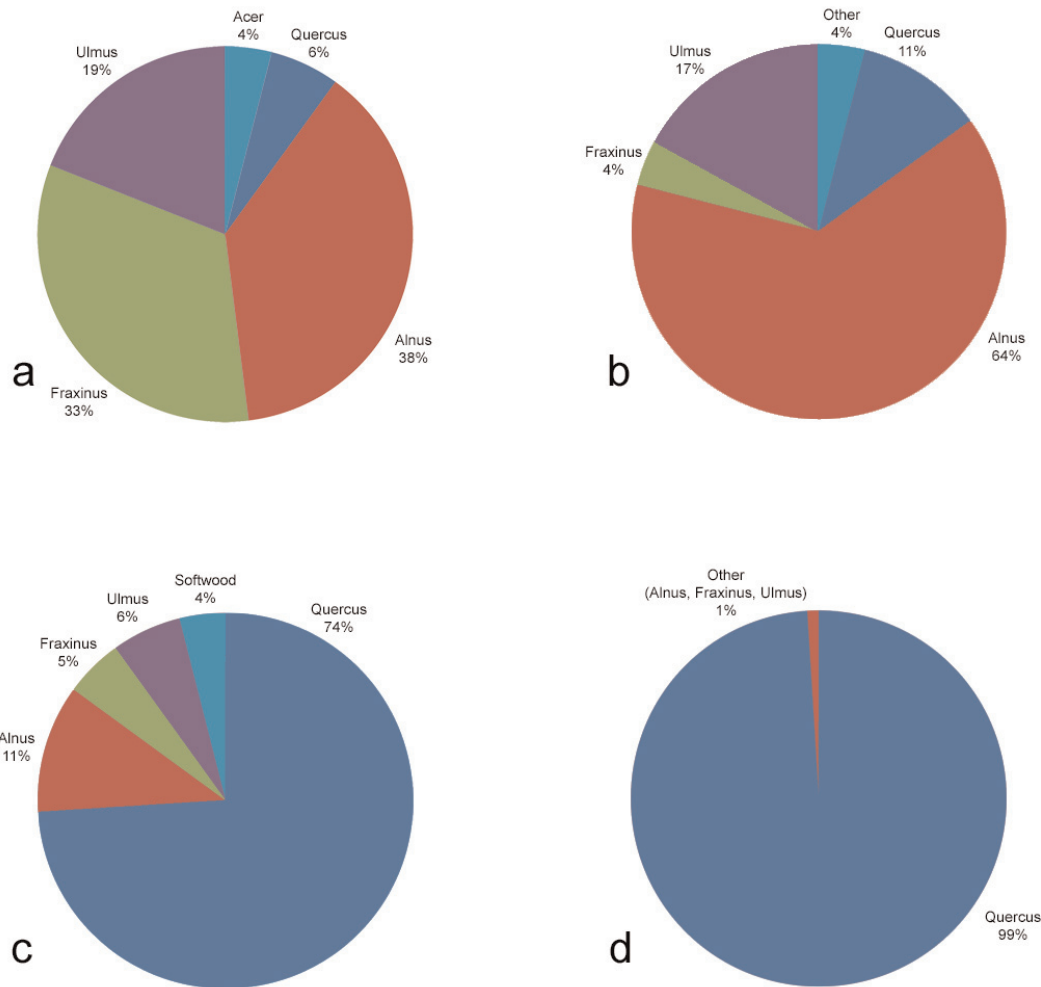


Figure 4a-d Relative amounts of wood taxa used for timber by the Roman army in the western Lower Rhine delta between A.D. 40 and 140, a. in the forts in the early Roman period, b. in the forts in the middle Roman period, c. in the road constructed in A.D. 99/100, and d. in the road constructed in A.D. 123/125. Legend: *Abies* = *A. alba* = silver fir; *Acer* = *A. campestre* = field maple; *Alnus* = alder; *Fraxinus* = *F. excelsior* = ash; *Pinus* = pine; *Quercus* = oak; *Ulmus* = elm.

(Langeveld *et al.* 2010; Van der Kamp 2007; idem 2009). On the basis of more than 6000 finds of wood, Van Rijn (in prep.) has gained insight into the use of wood in military constructions in the Rhine delta and on the origin of the building material.

The research on the wood reveals that a wide spectrum of species was used for the construction of the forts and the accompanying quays between A.D. 40 and 70. Alder (*Alnus*), ash (*Fraxinus excelsior*) and elm (*Ulmus*) are the most common species. Oak (*Quercus*) and field maple (*Acer campestre*) were used relatively little (fig. 4a). A range of nine species was used for wickerwork, wicker mats and faggots, which adds to the total wood spectrum. The spectrum of used species shows similarities with that of riverine woodland on levees. Because part of the wood that is used in constructions is gnarly and crooked – which would not be the case when it had been imported – it is assumed that construction wood from the local woodland on the levees was used for the layout of the military defence system, perhaps complemented with alder wood from the flood basins and fen woodlands.

The period after circa A.D. 70 shows a strong increase in the use of alder, while ash, elm and field maple have almost disappeared (fig. 4b). This leads Van Rijn (2004; idem in prep.) to con-

clude that the riverine woodland on the levees had become scarce. From the late first century onwards the construction wood of alder was made out of trees which had more or less the same diameters, and consisted of straight stems without side branches. Van Rijn assumes that this alder wood came from coppiced alder woodlands which were managed by man, and which were probably located on the low-lying parts of the levees, in the flood basins and the fen woodlands. This assumption is extremely interesting, since coppiced woodland provides more suitable construction wood per hectare than natural woodland. The assumption that production woodland occurred in the Rhine delta as early as the late first century indicates that the landscape was at that time already adapted to the increased demand for construction wood.

The selection of oak in the period after A.D. 70 seems to have been limited to the construction and maintenance of roads and the river infrastructure, especially in A.D. 99/100 and A.D. 123/125 (fig. 4c-d). Research into the numbers and pattern of year rings has demonstrated that part of the construction wood came from woodland that had been harvested for wood before. Wood with several hundreds of year rings also occurs, and some of it has been investigated dendrochronologically. This has revealed that these oaks have come from natural woodland located in what is now the western part of the Netherlands (Visser 2009; Visser & Jansma 2009).

Apart from the use in building, wood was the main fuel for various activities, such as domestic use (cooking, baking and heating), craft activities and for cremations. Until now, little was known about the use and origin of firewood in military contexts.

The research on wood reveals that the construction wood for the forts and other military constructions, as well as for the wooden foundations of the road, is mainly of local or regional origin. This result fits with the historical research carried out by Kehne (2007, 324). He writes the following:

‘The system of mobilizing material resources to provision the Roman armies in the form of taxes in money and kind was imposed on the new provinces of Gallia, Britannia and Germania. For several reasons the Roman empire never developed an uniform and universally military supply system. The Roman empire had to meet logistic needs of the armed forces on an ad hoc basis, with a lot of improvisation but constant improvement of the implemented institutions too.’

### 3.2 Timber for *vici* structures

It is likely that a camp village, or *vicus*, was located near each of the forts. Their remains have been found near the forts at Vechten (Vos 1997), Utrecht (Montforts 1995), De Meern (Langeveld in prep.), Woerden (Blom & Vos 2007), Zwammerdam (Haalebos 1977; Ploegaert 2006), Alphen aan den Rijn (Kok 1999), Leiden Roomburg (Brandenburgh 2006; Hazenberg 2000) and Valkenburg (De Hingh & Vos 2005; Vos & Lanzing 2000). However, our knowledge is fragmented, so that we know little about the size and chronology of the *vici*. Most of the *vicus* features, however, date from after circa A.D. 70 and from the second century A.D. (e.g. Blom & Vos 2007, 73, 414; Kemmers 2008).

Until now, traces of *vici* dating to the early or middle of the first century have only been found near the forts of Vechten and De Meern. A *vicus* seems to have been present at the fort of Vechten from the start (Hessing *et al.* 1997). The early *vicus* at the fort of De Meern seems to date to the middle of the first century. The structures consist of houses that have been built adjacent to one another, with yards at the back. The houses were inhabited for a maximum of ten years or so, and then abandoned (Langeveld in prep.). The absence of first-century *vici* near the other forts may be the result of lack of research or the many disturbances in the soil, which may have wiped out the oldest features. It is also possible that there were no permanent *vici* in the period from A.D. 40 until the end of the century, when the forts only served to protect shipping, with the exception of the large fort at Vechten (see below). Because only small sec-



tions of the *vici* have been excavated, their size is unknown. The inhabited area around the forts is estimated at several to several tens of hectares.

Unlike the forts, nothing is known about the use of wood in the buildings in the *vici* in the Rhine delta. Considering the wood use in the fort constructions, however, it seems likely that the buildings in the *vicus* were also mainly built with local wood. Wood for the early *vici* at De Meern and Vechten may have come from woodland on the alluvial ridges, although botanical research has shown that these were already largely deforested in the Late Iron Age (Groot & Kooistra 2009). Perhaps this is why alder from woodlands in the flood basins and fen woodlands was widely used in the first century, and oak – being a far better building wood – in a more restricted way.

### 3.3 Military population and their associates

An estimate was made of the size and composition of the Roman army and the associated *vicus* population, in order to gain an impression of the required amount of food. Based on their rather small size, it is assumed that the forts could house one cohort, circa 480 soldiers, but a number of soldiers per fort lower than 480 is likelier (Bechert 1983; Glasbergen & Groenman-van Waateringe 1974; Polak *et al.* 2004). De Weerd (2006) even argues that the forts were only occupied in the first century when it was necessary. The absence of *vici* in this period supports this hypothesis. Graafstal (in press.), however, has convincingly argued that the army controlled shipping on the Lower Rhine in this period. That means that the forts must have been occupied at least during the shipping season, from March to October (Fulford 2000, 42; Vegetius book IV, 39). From the end of the first century, the function of the forts changed, although the size of the forts stayed roughly the same. This makes it likely that the size of the army also stayed the same.

Only the fort Vechten was almost certainly larger. Indications for this exist especially for the period after A.D. 70 (Polak & Wynia 1991; Zandstra & Polak 2012). It is almost certain that the cohort I *Flavia Hispanorum equitata* (480 infantry plus 120 cavalry) was stationed there. There are some signs that possibly somewhere in the same period cohort II *Brittonum equitata milliaria* (800 infantry plus 240 cavalry) was associated with the fort. After A.D. 125, the *ala I Thracum* (500 men cavalry) was probably stationed in Vechten for a while. It is interesting to note that the occupation of the fort at Vechten consisted at least partly of cavalry units, because it is generally assumed that most of the forts in the Rhine delta were occupied by infantry units.

When we include Katwijk and Bodegraven, there were ten forts between Vechten and Katwijk (fig. 1). Based on an occupation of a maximum of 1 cohort, circa 480 men, per fort and possibly double that number for Vechten, the maximum size of the delta army is estimated around 5000 men.

It is generally assumed that from the late first century onward, it was mainly auxiliary units that were stationed in the forts. The finds of military diplomas indicate that the army units were not local (Polak 2009; idem in press). Less is known about the composition of the army between circa A.D. 40 and the mid-80s. Tacitus' mention that the Batavians were not allowed to be stationed in their own territory anymore after the revolt in A.D. 69 has led to the assumption that the auxiliary forts in the Lower Rhine delta were largely manned with local soldiers. However, there is no epigraphic evidence for this, although it is known that a large part of the Batavian and Cananefatian auxiliary units were stationed in Great Britain, for example, in the 40s and 50s (De Weerd 2006). Taking these considerations into account, it is likely that the size and composition of the army in the period from A.D. 40 to the mid-80s was similar to that of the following period.

However, there is a large difference in the size of the consuming population till circa A.D. 70 in comparison with the end of the first century onwards. As has been described above, most

*vici*, except those at Vechten and temporarily at De Meern, date after A.D. 70. The civilian settlements that arose around the forts had a military status and were inhabited by people related to the army (Sommer 1984; idem 1991): craftsmen, traders and family members of the soldiers. Although little is known about the size of the population of the *vici* near the forts in the Rhine delta, this is likely to have been similar to that elsewhere in Europe. That means that in later times the number of people living in the *vicus* was more or less equal to that of the garrison in the adjacent fort. The composition of the *vicus* population is a different story. While the people stationed in the forts were mostly men, men as well as women and children lived in the *vici*.

In short, the consuming population in the Lower Rhine delta from circa A.D. 40 until the end of the first century probably consisted of around 5000 soldiers and 500 to 1000 civilians, comprising men, women and children. It is possible that the number of consumers nearly doubled in the late first century to around 5000 soldiers and as many *vicus* inhabitants. Considering the presence of cavalry units, especially in Vechten but perhaps also small units in other forts, it is likely that horses, which may have required extra feeding, were kept in the forts.

### 3.4 Food for soldiers and *vicus* inhabitants

Various Roman authors have written about the quantities and the composition of the soldier's diet. In the second century B.C., Polybius mentions circa 840 grams (converted) of wheat per day for an infantry soldier, 1.7 kg wheat for an auxiliary cavalry soldier and his servant(s) plus circa 6.3 kg barley for his horse and pack animals (Polybios *The Histories* 6.39; converted to grams in Erdkamp 1998, 28). As far as meat is concerned, Polybius writes about special spaces within a Roman camp that were reserved for cattle (Polybios, *The Histories* 6.31). In the mid-first century B.C. Caesar wrote that he regularly supplied his soldiers with vegetables and meat, besides cereals (Caesar, *De Bello Civili* 3.47; see also the discussion in Erdkamp 1998, 31-32). Inventory lists for the army from other periods and regions show that the army was supplied with vegetables, fruit and nuts (Davies 1989, 198-199).

Nevertheless, cereals seem to have been the main part of the soldier's diet in all centuries of the Roman empire's existence. Under emperor Hadrian, a century and a half after Polybius, a soldier's diet consisted of cereals, bacon, cheese and sour wine (Aelius Spartianus, *Scriptores Historia Augustae Vita Hadriani* 10.2). Vegetius, living in the fourth century, but using sources from earlier centuries, stated that there should be enough supplies of grains, sour wine, wine and salt at all times (Vegetius, *De Re Militari* 3.3), and when a fort was threatened to be sieged, supplies should be stored within the fort, consisting of enough food for horses and for the soldiers enough cereals, fruit, wine and sour wine. Pigs and other animals should be slaughtered to obtain a good supply of meat (Vegetius, *De Re Militari* 4.7). Olive oil is not named in these sources, although it is likely that this product was part of the basic soldier's diet. A quote from Tacitus is interesting with regard to the necessary amounts of food that should be in store. Tacitus writes that every Roman fort in Great Britain under the governorship of Agricola (between A.D. 78 and 84) was to have enough supplies for a year (Tacitus, *Agricola* 22.2-3), which amounted to circa 333 kg of cereals per soldier per year (Davies 1989, 187). Quantities are also mentioned in the Egyptian papyri from the fourth century A.D. They describe that a soldier had a right to 969 grams of cereals per day (=3 Roman pounds); 646 grams (2 Roman pounds) of meat or bacon, 1.1 litres of wine and 0.07 litres of oil (Garnsey & Saller 1987, 83-104).

Whether the sources date to the second century B.C. or the fourth century A.D., each soldier had to be supplied with 800 to 1000 grams of cereals a day. Less is known about the quantities of the other required food products. When we consider that 1 kg of cereals provides 3000 to 3300 kCal of energy (Bloemers 1978; Bakels 1982), and that an active, young adult man uses between 3000 and 3600 kCal of energy (Den Hartog 1963, 78-79; Gregg 1988, 143; Roth 1999), it

becomes clear that cereals were the most important food for the Roman soldier (Kooistra 2012). This does not deny that meat products, fruits, nuts, vegetables, wine and olive oil were also substantial ingredients of the soldier's diet. Some of the ingredients belonged to the official soldier's diet. In addition, in times of peace soldiers could buy food themselves in the *vici* surrounding the forts. The now famous writing tablets from Vindolanda and other letters reveal that the soldiers also used family and relations to supplement their daily diet (Bowman 2003).

Analysis of the archaeobotanical and archaeozoological data from military sites in De Meern, Woerden, Zwammerdam, Alphen aan den Rijn, Leiden Roomburg and Valkenburg have given us insight into the food pattern of the military community in the Rhine delta. The archaeozoological research shows that in the start-up phase of a fort, relatively high amounts of pig and chicken were eaten (Cavallo *et al.* 2008). Once established, cattle became the main meat supplier. This applies to both the first and second centuries. Perhaps this can be explained by an insufficiently stable supply of animal products in the establishment phase of a fort. The soldiers would therefore have brought chickens and possibly pigs. Both these animals are fast breeders and require relatively little attention, which means that they could serve as temporary food until the supply lines had been established and the local population could take over (part of) the food production.

The archaeobotanical research (Kooistra 2009; idem 2012) shows that until the end of the first century (circa A.D. 70), there is a broad cereal spectrum in the forts, consisting of bread wheat (*Triticum aestivum*), emmer wheat (*Triticum dicoccon*), barley (*Hordeum*), spelt wheat (*Triticum spelta*), millet (*Panicum miliaceum*) and oat (*Avena*). The weeds found among the cereals indicate that part of the cereals was imported from Gaul. Since bread and spelt wheat are almost absent in agrarian settlements to the north and in the coastal, peat and river area south of the Rhine, it is assumed that these cereals were imported. Apart from remains of cereals, pulses, nuts, fruits and herbs have been found in the forts. Only Celtic beans (*Vicia faba* var. *minor*) could have been supplied by the agrarian settlements in the region. The other listed vegetable food products were not grown in agrarian settlements at this time, and must have been imported. At the end of the first century, the supply of cereals changed. In the forts, only bread wheat, spelt, emmer and barley are now found, with the first two cereals being imported, while the latter two could have been supplied by agrarian settlements in the region. From the second century, some Mediterranean herbs were grown in agrarian settlements to the south of the Rhine. Orchards for fruits and nuts can only be found in the southern and eastern parts of the province of *Germania inferior*. Both in the first and second centuries, part of the vegetable food products could have been sourced from the region, and part was imported. How much was imported and how much could have been local cannot be established purely by archaeobotanical research.

The food consumed by *vicus* inhabitants has not yet been discussed. Nothing is known on this topic from historical sources. The *vici* inhabitants were entirely dependent on the forts, since most of the population consisted of traders, craftsmen and relatives of the soldiers. There are no indications from archaeological research that there were any farmers living in the *vici*, growing cereals or breeding livestock. There are some indications for gardens where vegetables and herbs could have been grown (Van Amen & Brinkkemper 2009). However, it is generally assumed that the *vicani* were food consumers, and that means that they were also mainly dependent on the supply of food by the local agrarian population or on imports over longer distances. The relation between soldiers and *vicani* was probably so close that most of the *vicus* population would have moved when army units were transferred. This interconnection between soldiers and civilians makes it likely that their dietary habits were similar. This idea is supported by archaeozoological and archaeobotanical research. This has shown that the same food remains are found in the *vici* as in the military contexts (Kooistra 2009).

## 4. The rural population in the Rhine delta

### 4.1 Settlement distribution

Apart from the carrying capacity of the landscape, the size and composition of the local population determined the amount of food that could have been supplied to the army. The large-scale settlement excavations of recent years have provided a wealth of information on this topic. However, few settlements have been excavated completely and have been studied in enough detail to discover the number of farms per settlement and per period. Vos (2009) made an attempt to collect this information for the Kromme Rijn area, which is located in the north-western part of the Dutch River area, and was part of the *civitas Batavorum* in the Roman period. The north-western section of the Kromme Rijn area is part of our research area (fig. 2). Vos uses an average number of 2.5 farms per settlement for the Kromme Rijn area (Vos 2009, 215), but argues that there is a differentiation in rural settlements in this part of the Batavian region - in between the rivers Rhine and Lek and bordered in the west by coastal peat - varying from many small settlements of one or several households to a few large settlements with a minimum of four farms and a regional function (Vos 2009, 225-237). It also seems that the number of settlements in this region increased in the first two centuries A.D., combined with a developed settlement structure. Most of the settlements date to the second/third century.

Still little is known about the rural population in the peat and coastal regions of the research area, which were probably part of the *civitas Cananefatium*. Only one agrarian settlement, near Katwijk-Zanderij, located in the dunes of the coastal region, has been investigated extensively (Van der Velde 2008). Van der Velde assumes that the farmers settled there around A.D. 40, at the same time when the fort of Valkenburg was built nearby. The settlement was abandoned in the third century. During that entire time, the settlement consisted of two contemporaneously inhabited byre houses. The settlement thus seems to have been small, and the population seems to have remained unchanged.

Apart from the excavated settlements, there are numerous observations, obtained from mapping and stray finds. These are stored in the national database ARCHIS (Roorda & Wiemer 1992; the Archaeological Information System of the Cultural Heritage Agency, RCE). The ARCHIS version, updated to January 2009, has been consulted to obtain an impression of the number of agrarian settlements in the research area from the first and early second centuries. This approach has some drawbacks (see also Vos 2009, 29-30). For instance, most observations are not closely dated, and not every observation represents a rural settlement. Moreover, erosion has caused settlements to disappear in the course of history, and undoubtedly there are also settlements that have not yet been discovered. To estimate the number of rural settlements, observations have only been selected if they comprise multiple finds, if several observations occur within a radius of 200 m, if a cultural layer has been found, and if the observations are located on alluvial ridges, levees and parallel dune ridges. This exercise has yielded 210 possible rural settlements from the Roman period, most of which are located in the river region and the coastal region (fig. 5). The peat region seems to have been sparsely populated.

The question is to what extent the reconstructed number of settlements and the differences in density in the three regions of the research area match the actual situation. It is likely that erosion and sedimentation in the peat region is less or at the most similar to that in the river region. This could lead to the conclusion that the peat region was indeed less densely populated. However, the peat and coastal region have not been mapped in the same intensive and systematic way by field surveys and phosphate mapping. Furthermore, it is likely that the coastal region, where the Roman features may have been covered by the sand of the Young Dunes, harbours more undiscovered settlements than the other two regions.



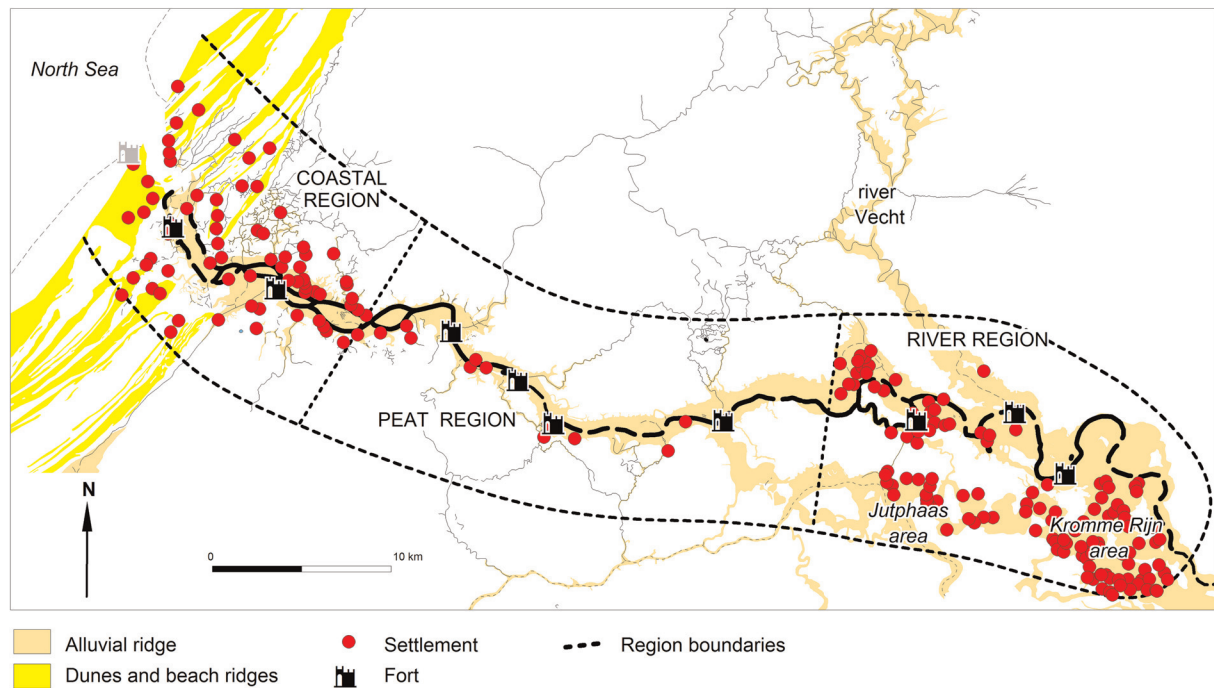


Figure 5 Reconstructed settlements in the western Lower Rhine limes zone based on ARCHIS database (2009).

It is unlikely that all 210 reconstructed settlements existed at the same time. It is generally assumed that the Early Roman period until circa A.D. 70 was less densely populated, although reality may have been distorted because pottery from that period is not always well recognised (Groot *et al.* 2009; Heeren 2009; Vos 2009). After the creation of the province of *Germania inferior* by emperor Domitian, in the 80s A.D., the countryside to the south of the Rhine developed quickly and the number of settlements increased (Groot *et al.* 2009; Vos 2009; Willems 1986). The settlement pattern to the north of the Rhine has not yet been investigated on such a large scale or with similar detail. As far as we can tell from the data, the number of settlements there does not appear to increase. It rather appears as if settlements were abandoned in the mid-first century (Den Hartog 2009) and that new settlements were founded at other locations in the second/third centuries (Stronkhorst 2004).

The rural settlements in the research area in the first and second centuries A.D. consist of wooden constructions. The discoloured features in the soil are the only remains that are left of these buildings, so that no information is available on the wood use and the origin of the wood. When wood is found, it comes from the lining of wells. It is self-evident that the farmers also obtained their wood from their immediate surroundings in the first and second centuries, just like the military.

#### 4.2 Rural population

The size of the rural population is deducted from the average number of farms per settlement and an average number of people per farm; the so-called settlement model. Based on ethnographic research, a household is assumed to have consisted of five to eight people of different ages and sexes (Bloemers 1978, 55; Willems 1986, 236; Vos 2009, 213). If we follow Vos's assumptions and take an average of 2.5 households per settlement, the agrarian population would have consisted of around 3400 people ( $210 \times 2.5 \times (5+8)/2$ ). The actual number will probably have been lower, since it is unknown how many settlements were contemporaneous. The settlements in the peat and coastal region were probably also smaller than those in the river

area. It does seem likely that the size of the consuming military population including the *vicani* was at least twice the size of the food-producing rural population. In other words, from the 40s A.D. onward, every production unit or farming family ( $=210 \times 2.5 = 525$ ) would have had to produce food for at least ten soldiers ( $=(9 \times 500) + (1 \times 500)$ ) and twenty soldiers and *vicani* ( $=[(9 \times 500) + (1 \times 500)] \times 2$ ) from the end of the 1st century onward.

### 4.3 Arable farming and animal husbandry

It is generally accepted that farmers in the research area only produced food for their own use before the arrival of the Romans (Kooistra 1996; Groot *et al.* 2009). The larger granaries found from the Roman period and the change in composition of the livestock in the Batavian region (but also in the rural settlement Katwijk-Zanderij) suggest that the farmers to the south of the Rhine produced a surplus of agrarian products (Groot 2008; Groot *et al.* 2009; Groot & Kooistra 2009; Kooistra 2009). Although surplus production is assumed, there is no clear specialisation in arable farming or animal husbandry (Groot & Kooistra 2009; Kooistra 2009). The farmers grew barley, emmer wheat, oat and sometimes also millet. It is unclear whether Celtic bean and flax/linseed (*Linum usitatissimum*) were common products. Mediterranean kitchen herbs have been found at several rural settlements from the second and third centuries; they are assumed to have been grown locally (Livarda & Van der Veen 2008). There are no indications for orchards in the Batavian and Cananefatian regions. The only fruits and nuts of which remains have been found in agrarian settlements could have been collected in the surroundings of the sites (Groot & Kooistra 2009; Kooistra 2009).

As far as livestock is concerned, cattle remained the main meat provider in agrarian settlements during the entire Roman period. The cited quote from Tacitus (*Germania*, caput 5) indicates that the local cattle were small in size. The appearance of larger cattle in the Roman period was the result of the improvement of stock-breeding practices to obtain a higher production of beef and/or for traction and other agrarian purposes (Lauwerier 1988). In the first century, more sheep may have been kept for meat (Groot 2008). Horses were bred in the Batavian region, probably for the Roman army, but not for their meat (Luff 1982; Lauwerier 1988). In the river area, botanical research has provided indications for the location of pastures. Some were located on the alluvial ridges and perhaps on fallow fields, but most botanical finds point to grassland vegetation in marshy areas (Groot *et al.* 2009; Groot & Kooistra 2009; Kooistra 1996; Kooistra & Van Haaster 2001).

Although the agrarian population to the south of the Rhine was integrated in the Roman empire to a high degree, hardly any imported food plants have been found in the agrarian settlements. Based on these results, it is assumed that in the Roman period the rural population produced its own food and did not import food from elsewhere. When we consider the agrarian products in the limes zone, it is likely that, as far as vegetable food is concerned, the rural population produced a surplus of cereals. For animal products, besides breeding horses, the emphasis seems to have been on the improvement of stock-breeding practices in case of cattle, although extra sheep were perhaps bred temporarily.

## 5. Did the local population supply the Roman army?

The dynamic and varied landscape of the limes zone has undoubtedly influenced the way it was used. Analysis of wood data has demonstrated that wood for the construction of the forts, but also for later building activities, was acquired from the woodland in the limes zone. Most of the wood used in the construction of the forts around A.D. 40 came from the woodland on the levees and alluvial ridges. From the second half of the first century onward, most of the wood

came from wetland woodland in the flood basins and the fen woodlands, where from the late first century production woodland was probably located. The bioarchaeological research has provided indications for the surplus production of cereals and the breeding of livestock. The fields for cereals would have been located on the levees of the Rhine, older alluvial ridges and dune ridges. Although the potential area for arable fields is limited, the requirements for wood and cereals do not appear to have been in conflict, because different parts of the landscape were used to obtain these products. Several landscape units could have been used for livestock. The required space for animal husbandry could therefore have conflicted with that for arable farming and forestry, but it is precisely because livestock was not tied to particular types of landscape that the animals could have been grazed in places where the other two space-consuming commodities did not grow, such as in the flood basins and the salt marshes. This would certainly not have been a second best option. Due to the regular flooding, the production of vegetation in the flood basins - the food for livestock - was higher than average.

An analysis of the many archaeological and bioarchaeological data has provided an impression of the layout of the landscape in the Rhine delta and landscape use by the military and rural population. The extensive research has provided information on the wood use by the Roman army and the food consumed by the soldiers and their associates. Most of the timber for military constructions came from local woodland, while part of the food was undoubtedly imported, as indicated by the written sources as well as the bioarchaeological research. There are also (bio)archaeological data and several written sources that indicate local food production for the army. It is unclear how important this local food production was. The next contribution will discuss this topic, on the basis of a theoretical calculation model.

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## References

### Classical sources

- Aelius Spartianus, *Scriptores Historiae Augustae Vita Hadriani*, transl. D. Magie 1961, London (Heinemann).
- Caesar, *De Bello Civili*, transl. J. van Gelder 1952, Haarlem (De Spaarnestad).
- Polybios, *The Histories*, transl. W.R. Paton 1999, Cambridge (Harvard University Press).
- Tacitus, *Agricola*, transl. J.W. Meijer 1992, Baarn (Ambo).
- Tacitus, *Annales*, transl. J.W. Meijer 1990, Baarn (Ambo).
- Tacitus, *Germania*, transl. M. Hutton 1963, London (Heinemann).
- Tacitus, *Historiae (Historiën)*, transl. J.W. Meijer 1991, Baarn (Ambo).
- Vegetius, *De Re Militari*, transl. F. Meijer 2002, Amsterdam (Athenaeum - Polak & Van Genneep).

### Modern literature

- Alföldy, G. 1968, *Die Hilfstruppen der römischen Provinz Germania inferior*, Düsseldorf (Epigraphische Studien 6).
- Bakels, C.C. 1982, Zum wirtschaftlichen Nutzungsraum einer bandkeramischen Siedlung. In: J. Pavuk (ed.), *Siedlungen der Kultur mit Linearkeramik in Europa*, Nitra, 9-16.
- Bechert, T. 1983, *De Romeinen tussen Rijn en Maas*, Dieren.
- Berendsen, H.J.A. 1982, *De genese van het landschap in het zuiden van de provincie Utrecht, een fysisch geografische studie*, PhD thesis Utrecht University (Utrechtse Geografische Studies 10).
- Berendsen, H.J.A. & E. Stouthamer 2001, *Palaeogeographic development of the Rhine-Meuse delta, the Netherlands*, Assen (Van Gorcum).
- Bloemers, J.H.F. 1978, *Rijswijk (Z.-H.), 'De Bult': Eine Siedlung der Cananefaten*, Amersfoort (Nederlandse Oudheden 8).
- Bloemers, J.H.F. 1983, Acculturation in the Rhine/Meuse Basin in the Roman Period: a preliminary survey. In: R.W. Brandt & J. Slofstra (eds), *Roman and native in the Low Countries*, Spheres of interaction, Oxford (BAR Int. Series 184), 159-209.
- Bloemers, J.H.F., & M.D. De Weerd 1984, Van Brittenburg naar Lugdunum. Opgravingen in de bouwput van de nieuwe uitwateringssluus in Katwijk, 1982. In: P.S. Anes, J.H.F. Bloemers, J.E.A. Boomgaard, W. de Leeuw, L. Sentis-Senden & M.D. de Weerd (eds), *De uitwateringssluizen van Katwijk 1404 – 1984*, Leiden (Hoogheemraadschap van Rijnland Leiden), 41-51.
- Blom, E. & W.K. Vos (eds) 2007, *Woerden-Hoochwoert. De opgravingen 2002-2004 in het Romeinse Castellum Laurium, de vicus en van het schip de 'Woerden 7'*, Amersfoort (ADC monografie 2).
- Bosman, A.V.A.J. & M.D. De Weerd 2004, Velsen: The 1997 Excavations in the Early Roman Base and a Reappraisal of the Post-Kalkriese Velsen/Vechten Dating Evidence. In: F. Vermeulen, K. Sas, & W. Dhaeze (eds), *Archaeology in confrontation: Aspects of Roman military presence in the Northwest. Studies in honour of Hugo Thoen*, Gent (Archaeological reports Ghent University 2), 31-62.
- Bowman, A.K. 2003, *Life and Letters on the Roman Frontier. Vindolanda and its People*, London (British Museum Press).
- Brandenburgh C.R. 2006, *Bodemonderzoek in Leiden 17. Archeologisch onderzoek Roomburg 2003*, Leiden.
- Cavallo, C., L.I. Kooistra & M. Dütting 2008, Food supply to the Roman army in the Rhine delta in the first century A.D. In: S. Stallibrass & R. Thomas (eds), *Feeding the Roman Army. The Archaeology of Production and Supply in NW Europe*, Oxford, 69-82.
- Chorus, J. 2007, Romeinse forten in de Rijndelta. Over stammetjes en staanders. In: M. Bergmans, T. Derks, R. Doreleijers, K. van der Veer & S. Willemsen (eds), *Vijfde symposium voor Onderzoek door Jonge Archeologen, 16 maart 2007, Groningen*, Amsterdam, 7-16.
- Davies, R.W. 1989, The Roman Military Diet. In: D. Breeze & V.A. Maxfield (eds), *Service in the Roman Army*, Edinburgh, 187-206.
- De Hingh, A.E. & W.K. Vos, 2005, *Romeinen in Valkenburg (ZH), de opgravingsgeschiedenis en het archeologische onderzoek van Praetorium Agrippinae*, Leiden (Hazenbergh Archeologie Leiden).
- Derks, T. & N. Roymans 2002, Seal-boxes and the spread of Latin literacy in the Rhine delta. In: A.E. Cooley (ed.), *Becoming Roman, writing Latin? Literacy and epigraphy in the Roman West*, Portsmouth, Rhode Island (JRA Suppl. Ser. 48), 87-134.



- De Weerd, M.D. 1986, Recent excavations near the Brittenburg: a rearrangement of old evidence. In: *Studien zu den militärgrenzen roms III, 13th Int. Limeskongress 1983*, Aalen (Konrad Theiss Verlag), 284-290.
- De Weerd, M.D. 2006, Repressie op afstand in een voorland zonder grenzen; De Romeinse limes in Nederland voor de opstand van de Bataven, *Westerheem* 55/1, 5-26.
- Den Hartog, C. 1963, *Nieuwe voedingsleer*, Utrecht (Het Spectrum).
- Den Hartog, C. 2009, *Sportpark Terweide 2; LR 41-42, Archeologisch onderzoek op Sportpark Terweide*, Utrecht (Basisrapportage Archeologie Gemeente Utrecht 18).
- Driessen, M. 2007, *Bouwen om te blijven. De topografie, bewoningscontinuïteit en monumentaliteit van Romeins Nijmegen*, PhD thesis Amsterdam University.
- Erdkamp, P. 1998, *Hunger and the Swort. Warfare and Food Supply in Roman Republican Wars (264 – 30 B. C.)*, Amsterdam (Gieben).
- Fulford, M. 2000, The Organization of Legionary Supply: the Claudian Invasion of Britain. In: R.J. Brewer (ed.), *The Roman Fortresses and their Legions*, London.
- Garnsey, P. & R. Saller 1987, *The Roman Empire, Economy, Society, and Culture*, London (Duckworth).
- Glasbergen, W. 1972, *De Romeinse castella te Valkenburg Z.H. De opgravingen in de dorpsheuvel in 1962*, Groningen (Cingula 1).
- Glasbergen, W. & W. Groenman-van Waateringe 1974, *The Pre-Flavian garrisons of Valkenburg Z.H.: fabriculae and bipartite barracks*, Amsterdam/London (Cingula 2).
- Graafstal, E.P., in press. River frontiers or fortified corridors? In: *Roman frontier studies 2009, Proceedings of the XXIIth International Congress of Roman Frontier Studies*, Newcastle.
- Gregg, S.A. 1988, *Foragers and farmers: population, interaction and agricultural expansion in prehistoric Europe*, Chicago (University of Chicago Press).
- Groenman-van Waateringe, W. 1989, Food for soldiers, food for thought. In: J.C. Barret, A.P. Fitzpatrick & L. Macinnes (eds), *Integrating the subsistence economy*, Oxford (BAR Int. Ser. 181), 135-162.
- Groot, M. 2008, *Animals in ritual and economy in a Roman frontier community. Excavations in Tiel-Passewaaij*, PhD thesis Vrije Universiteit Amsterdam.
- Groot, M., S. Heeren, L.I. Kooistra & W.K. Vos 2009, 'Surplus production for the market? The agrarian economy in the non-villa landscapes of Lower Germany', *Journal of Roman Archaeology* 20, 231-252.
- Groot, M. & L.I. Kooistra 2009, Land use and agrarian economy in the Roman Dutch River Area., *Internet Archaeology* 27.
- Haalebos, J.K. 1977, *Zwammerdam-Nigrum Pullum; ein Auxiliarkastell am niedergermanischen Limes*, Amsterdam (Caligula 3).
- Haalebos, J.K. & P.F.J. Franzen e.a. 2000, *Alphen aan den Rijn – Albaniana 1998-1999. Opgravingen in de Julianastraat, de Castellumstraat, op Het Eiland en onder het St.-Jorisplein*, Nijmegen (Libelli Novioma-genses 6).
- Hazenbergh, T. 2000, *Leiden-Roomburg 1995 – 1997: Archeologisch onderzoek naar het kanaal van Corbulo en de vicus van het castellum Matilo*, Amersfoort (Rapportage Archeologische Monumentenzorg 77).
- Heeren, S. 2009 *Romanisering van rurale gemeenschappen in de civitas Batavorum. De casus Tiel-Passewaaij*, PhD thesis Amsterdam Free University / Amersfoort (Nederlandse Archeologische Rapporten 36).
- Hessing, W.A.M., M. Polak, W.K. Vos & S.L. Wynia (eds) 1997, *Romeinen langs de snelweg: Bouwstenen voor Vechtens verleden*, Abcoude/Amersfoort (Uniepers, Rijksdienst voor het Oudheidkundig Bodem-onderzoek).
- Kemmers, F. 2008, Interaction or indifference? The Roman coin finds from the Lower Rhine delta. In: A. Bursche, R. Ciolek, R. & R. Wolters (eds): *Roman coins outside the empire; Ways and Phases, Contexts and Functions*, Nieborów (Collection Moneta 82), 93-103.
- Kehne, P. 2007, War- and Peacetime Logistics: Supplying Imperial armies in East and West. In: P. Erdkamp (ed.) 2007: *A companion to the Roman army*, Oxford (Blackwell Publishing Ltd), 323-338.
- Kok, R.S. 1999, *Archeologische inventarisatie Stadshart Alphen aan den Rijn*, Alphen aan den Rijn.
- Kooistra, L.I. 1996, *Borderland Farming. Possibilities and Limitations of Farming in the Roman Period and Early Middle Ages between the Rhine and Meuse*, Assen / PhD thesis Leiden University.
- Kooistra, L.I. 2008, Landschap, vegetatie en landgebruik in de Haagse regio. In: J.P. Flamman & E.A. Besselsen (eds), *Het verleden boven water. Archeologische Monumentenzorg in het AHR-project*, Amers-foort (Rapportage Archeologische Monumentenzorg 148), 47-72.
- Kooistra, L.I. 2009, The provenance of cereals for the Roman Army in the Rhine delta based on archaeobotanical evidence, *Beihefte der Bonner Jahrbücher* 58-1, 219-237.
- Kooistra, L.I. 2012, Die pflanzlichen Grundnahrungsmittel der Rheinarmee vor und nach der Gründung der Germania inferior. In: A. Stobbe & U. Tegtmeijer (eds), *Verzweigungen, Eine Würdigung für A.J. Kalis und J. Meurers-Balke*, Bonn (Frankfurter Archäologische Schriften 18), 171-188.

- Kooistra, L.I. & H. van Haaster 2001, Archeobotanie. In: M.M. Sier and C.W. Koot (eds) *Archeologie in de Betuweroute, Kesteren-De Woerd, Bewoningssporen uit de IJzertijd en de Romeinse Tijd*. Amersfoort (Rapportage Archeologische Monumentenzorg 82), 293-359.
- Langeveld, M.C.M. (ed.) in prep., *Vicuslaan (LR58)*, Utrecht (Basisrapportage Archeologie Gemeente Utrecht 32).
- Langeveld M., A. Luksen-Ijtsma & P. Weterings (eds) 2010, *LR46 en LR49: definitief archeologisch onderzoek naar de vicus, grafvelden, infrastructuur en een inheemse nederzetting in de omgeving van het Romeinse castellum in De Meern, deelgebied 'De Woerd'*, Utrecht (Basisrapportage Archeologie Gemeente Utrecht 19).
- Lauwerier, R.C.G.M. 1988, *Animal in Roman Times in the Dutch Eastern River Area*, Amersfoort (Nederlandse Oudheden 12).
- Livarda, A. & M. Van der Veen 2008, Social access and dispersal of condiments in North-West Europe from the Roman to the medieval period, *Vegetation History and Archaeobotany* 17, 201-209.
- Luff, R.M. 1982, *A Zooarchaeological Study of the Roman North-western Provinces*, Oxford (BAR Int. Series 137).
- Luksen-Ijtsma, A. 2010, *De limesweg in West-Nederland. Inventarisatie, analyse en synthese van archeologisch onderzoek naar de Romeinse weg tussen Vechten en Katwijk*, Utrecht (Basisrapportage Archeologie Gemeente Utrecht 40).
- Mattingly, D. 2006, *An Imperial Possession: Britain in the Roman Empire, 54 BC-A.D. 409*, London.
- Meffert, M. 1998, *Ruimtelijke Relaties in het Oer-IJ-Estuarium in de Romeinse IJzertijd met nadruk op de Assendelver Polders*. PhD thesis Amsterdam University.
- Montforts, M.J.G. Th. 1995, *Romeins Utrecht*, Utrecht (Matrijs).
- Ozinga, L.R.P., T.J. Hoekstra, M.D. de Weerd & S.L. Wynia (eds) 1989, *Het Romeinse Castellum te Utrecht*, Utrecht.
- Pals, J.P. & T. Hakbijl 1992, Weed and Insect Infestation of a grain cargo in a ship at the Roman fort of Laurium in Woerden (Province of Zuid-Holland), *Review of Palaeobotany and Palynology* 73, 287-300.
- Ploegaert, P.H.J.I. 2006, *Zwammerdam 'De Hooge Burch' en 'De Bruggen'*, Amersfoort (ADC-rapport 540).
- Polak, M. 2009, The Roman military presence in the Rhine delta in the period c. AD 40 – 140. In: A. Morillo, N. Hanel & E. Martín (eds), *Limes XX, XXth International Congress of Roman Frontier studies, Leon, (España), Septiembre 2006*, Madrid (Anejos de Gladius, 13-2), 945-953.
- Polak, M. in press, The Roman military presence in the Rhine delta in the pre-Flavian period. In: *Roman frontier studies 2009, Proceedings of the XXIth International Congress of Roman Frontier Studies*, Newcastle.
- Polak, M., R.P.J. Kloosterman & R.A.J. Niemeijer (eds) 2004, *Alphen aan den Rijn. Albaniana 2001–2002. Opgavingen Tussen de Castellumstraat, het Omloopkanaal en de Oude Rijn*, Nijmegen (Libelli Novioma-genses 7).
- Polak, M. & S. L. Wynia 1991, The Roman forts at Vechten, a survey of the excavations 1829 – 1989, *Oudheidkundige mededelingen uit het Rijksmuseum van Oudheden* 71, 125-156.
- Roorda, I.M. & R. Wiemer 1992, The ARCHIS Project: Towards a New National Archaeological Record in the Netherlands. In: C. Larsen C. (ed.), *Sites and Monuments: National Archaeological Records*, Copenhagen (The National Museum of Denmark), 117-122.
- Roth, J.P. 1999, *The logistics of the Roman army at war: (264 B.C. - A.D. 235)*, Leiden-Boston-Köln (Brill).
- Roymans, N. 1996, The sword or the plough. Regional dynamics in the romanisation of Belgic Gaul and the Rhineland area. In: N. Roymans (ed.), *From the Sword to the Plough. Three studies on the earliest romanisation of Northern Gaul*, Amsterdam (Amsterdam Archaeological Studies 1), 9-127.
- Sommer, C.S. 1984, *The military vici in Roman Britain Aspects of their origins, their location and layout, administration, function and end*, Oxford (BAR Int. Series 129).
- Sommer, C.S. 1991, Life beyond the ditches: Housing and planning of the military vici in Upper Germany and Raetia. In: V.A. Maxfield & M.J. Dobson (eds), *Roman frontier studies 1989, Proceedings of the XVth International Congress of Roman Frontier Studies*, Exeter, 472-476.
- Van Amen, I. & O. Brinkkemper 2009, De plantenresten uit de Romeinse sporen. In: M. Polak & T. de Groot (eds), *Vondsten langs de Limes*, Amersfoort (Rapportage Archeologische Monumentenzorg 167), 32-68.
- Van Beurden, L. 2008, *Vegetatie en ontwikkelingen in het rivierengebied in de Bronstijd*, Zaandam (BIAxiaal 331).
- Van der Kamp, J. (ed.) 2007, *Vroege Wacht. LR31 Zandweg: Archeologisch onderzoek van twee eerste eeuwse houten wachttorens in Leidsche Rijn*, Utrecht (Basisrapportage archeologie Gemeente Utrecht 16).
- Van der Kamp, J. (ed.) 2009, *Werk aan de weg; LR31 Zandweg: Archeologisch onderzoek aan de verspoelde sectie van de limesweg*, Utrecht (Basisrapportage archeologie Gemeente Utrecht 21).

- Van der Kooij, D., S. Sprey, M. Dijkstra & H. Postma 2005, Romeinen in Bodegraven. AWN-opgravingen in de periode van 1995 tot 2002, *Westerheem* 54-6, 275-306.
- Van der Velde, H.M. (ed.) 2008, *Cananefaten en Friezen aan de monding van de Rijn. Tien jaar archeologisch onderzoek op de Zanderij-Westerbaan te Katwijk (1996-2006)*, Amersfoort (ADC Monografie 5).
- Van Dinter, in press. The Roman Limes in the Netherlands: how a delta landscape determined the location of the military structures, *Netherlands Journal of Geosciences*.
- Van Es, W.A. 1981, *Romeinen in Nederland*, Bussum (Unieboek).
- Van Londen, H. 2006, *Midden-Delfland: the Roman Native Landscape Past and Present*, PhD thesis Amsterdam University.
- Van Rijn, P. 2004, Hout. In: M. Polak, R.P.J. Kloosterman & R.A.J. Niemeijer (eds), *Alphen aan den Rijn – Albaniana 2001-2002, Opgravingen tussen de Castellumstraat, het Omloopkanaal en de Oude Rijn*, Nijmegen (Libelli Noviomagenses 7), 216-36.
- Van Rijn, P. in prep., The timber supply for the Roman army in the western Lower Rhine from AD 40-140, PhD thesis Radboud University Nijmegen.
- Visser, R.M., 2009, De Romeinse houtvoorziening in de Germaanse provincies, *Westerheem* 58-1, 2-12.
- Visser, R.M. & E. Jansma 2009, Dendrochronologische analyse van het hout van de limesweg in Leidsche Rijn. In: J. S. van der Kamp (ed.), *Werk aan de weg. LR 31 Zandweg. Archeologisch onderzoek aan een verspoelde sectie van de weg*, Utrecht (Basisrapportage archeologie Gemeente Utrecht 21), 77-86.
- Vos, W.K. 1997, Sporen zoeken in de vicus. In: W.A.M. Hessing, M. Polak, W.K. Vos & S.L. Wynia (eds), *Romeinen langs de snelweg: Bouwstenen voor Vechtens verleden*, Abcoude/Amersfoort (Uniepers, Rijksdienst voor het Oudheidkundig Bodemonderzoek), 35-51.
- Vos, W.K. 2009, Bataafs platteland. Het Romeinse nederzittingslandschap in het Nederlandse Kromme-Rijng gebied, PhD thesis Amsterdam University / Amersfoort (Nederlandse Archeologische Rapporten 3).
- Vos, W.K. & J.J. Lanzing 2000, *De opgravingen in Valkenburg-Veldzicht 1994 – 1997*, Amersfoort (Rapportage Archeologische Monumentenzorg 78).
- Wesselingh, D.A. 2000, Native neighbours. Local settlement system and social structure in the Roman period at Oss (the Netherlands), *Analecta Prehistoria Leidensia* 32.
- Willems, W.J.H. 1986, *Roman and Batavians; a regional study in the Dutch Eastern River Area II*, Amersfoort (BROB 34), 39-331.
- Whittaker, C.R. 1994, *Frontiers of the Roman Empire, a social and economical Study*. Baltimore (Johns Hopkins University Press).
- Zandstra, M.J.M. & M. Polak 2012, *De Romeinse versterkingen in Vechten-Fectio. Het archeologisch onderzoek in 1946-1947*, Nijmegen (Auxiliaria 11).

