Surplus production for the market?
The agrarian economy in the non-villa landscapes of *Germania Inferior*

Maaike Groot, Stijn Heeren, Laura I. Kooistra, and Wouter K. Vos

The heyday of the Roman Empire was the first time in history that substantial parts of the population of temperate Europe were not directly involved in agricultural production. These people, both soldiers and inhabitants of towns, still needed to be fed. It is widely believed that most of their food was produced by villas. While this is undoubtedly true, a different situation is found along the NW frontier, in what is today the Netherlands (fig. 1), where the rural landscape was dominated, not by villas, but by settlements consisting of wooden byrehouses.[1] These settlements were situated on stream ridges and surrounded by low-lying and often wet floodplains. It has long been thought that the farmers of this frontier zone were unable to pro-

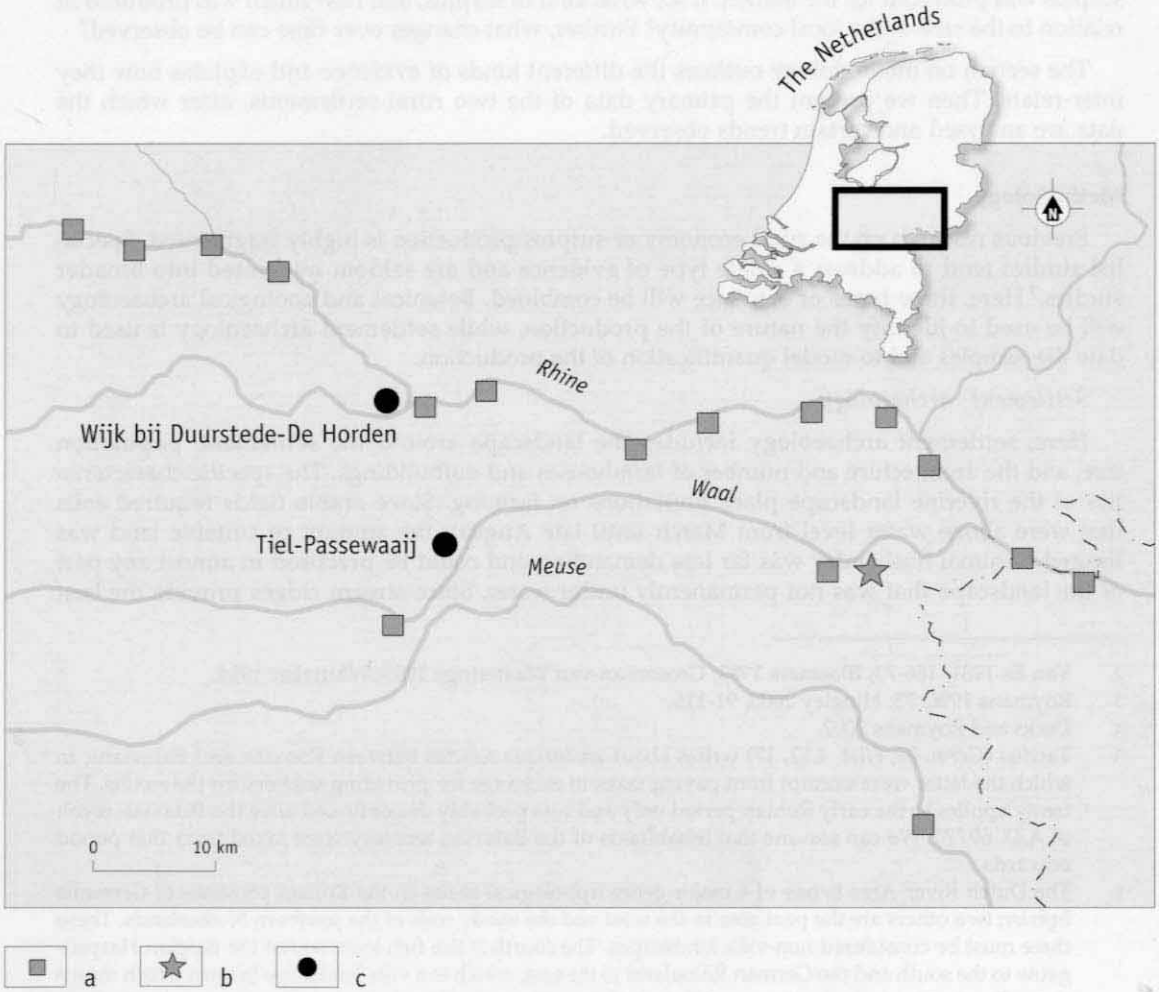

Fig. 1. The Dutch River Area and main sites mentioned in the text.
Key: a - military forts. b - the *civitas*-capital of Nijmegen. c - rural settlements.

1 Roymans 1996; Wesselingh 2000; Vos 2002; Heeren 2006.

duce a substantial surplus of food because of the limitations of the landscape,[2] but it has recently been argued that the near-absence of villas was not simply a matter of lack of wealth or underdevelopment, but also reflects a different set of cultural values.[3] New evidence from the settlements shows that a knowledge of Latin and literacy were widespread, indicating that rural communities were integrated culturally in the Roman world to a much larger extent than previously thought.[4] The abundant use of imported material culture (ceramics, metal items) evident on almost every rural site with good conditions of preservation shows that, apart from being able to pay their taxes,[5] the local communities also acquired large quantities of commodities from the market. Evidently the rural settlements were well integrated into larger economic networks, at least from the second half of the 1st c. A.D. onwards.

This suggests that there must have been a considerable agrarian production in the non-villa landscapes. We will investigate the agricultural surplus generated in the Dutch River Area[6] by focusing on two well-studied non-villa settlements: Wijk bij Duurstede-De Horden and Tiel-Passewaaij, two settlements which are believed to be typical of many others. A combination of settlement, botanical and zooarchaeological evidence is employed to arrive at a more sophisticated view of the agrarian economy in a non-villa landscape. The aim is to identify whether a surplus was produced for the market. If so, what kind of surplus, and how much was produced in relation to the size of the local community? Further, what changes over time can be observed?

The section on methodology outlines the different kinds of evidence and explains how they inter-relate. Then we present the primary data of the two rural settlements, after which the data are analysed and certain trends observed.

Methodology

Previous research on the rural economy or surplus production is highly fragmented. Specialist studies tend to address a single type of evidence and are seldom integrated into broader studies.[7] Here, three types of evidence will be combined. Botanical and zoological archaeology will be used to identify the nature of the production, while settlement archaeology is used to date the samples and to model quantification of the production.

Settlement archaeology

Here, settlement archaeology includes the landscape around the settlement, population size, and the architecture and number of farmhouses and outbuildings. The specific characteristics of the riverine landscape place limitations on farming. Since arable fields required soils that were above water level from March until late August, the amount of suitable land was limited.[8] Animal husbandry was far less demanding and could be practised in almost any part of the landscape that was not permanently under water. Since stream ridges provide the best

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2 Van Es 1981, 166-73; Bloemers 1983; Groenman-van Waateringe 1989; Whittaker 1994.

3 Roymans 1996, 73; Hingley 2005, 91-116.

4 Derks and Roymans 2002.

5 Tacitus (*Germ.* 29; *Hist.* 4.12, 17) writes about an *antiqua societa*s between Romans and Batavians, in which the latter were exempt from paying taxes in exchange for providing soldiers for the *auxilia*. The treaty applies to the early Roman period only and was probably discontinued after the Batavian revolt of A.D. 69/70. We can assume that inhabitants of the Batavian territory were taxed from that period onwards.

6 The Dutch River Area is one of 4 major geomorphological zones in the Roman province of *Germania Inferior*; two others are the peat area in the west and the sandy soils of the southern Netherlands. These three must be considered non-villa landscapes. The fourth is the rich loess soil of the Belgian Haspengauw to the south and the German Rhineland to the east, which is a villa landscape (a term which means that villas dominate the landscape, although the presence of other types of settlement is not ruled out; even when only *c.*40% of the settlements are villas, their conspicuous architecture, size, and choice of location dominate the landscape). Cf. Roymans 1996.

7 Thomas and Stallibrass 2008.

8 Vossen has produced (2007) a map of the central and eastern Dutch River Area that combines geological data with the locations of all known settlements from the Roman period.

location for arable fields, it is possible to estimate the amount of land suitable for growing crops that was available for each settlement. A complicating factor is that little is known about the extent of the territories of settlements. Assumptions about settlement boundaries need to be made before the available land can be estimated. An analysis of the amount of available land suitable for arable agriculture provides an upper limit for the production of crops. For animal husbandry, it is somewhat more difficult to estimate the size of grazing grounds, since floodplains may have been used as common grazing grounds by more than one settlement.

We need to be aware of the size of the populations of the two settlements, since the inhabitants had to be fed before any surplus could be traded. Following earlier research, it is assumed that in pre-modern times a normal family consisted of 5 to 8 individuals, which means an average family size of 6.5 people.[9] The number of simultaneously existing houses multiplied by 6.5 determines the estimated population size. This method presupposes that the excavated houses are more or less securely dated and that the settlement was (almost) completely excavated.

Since most buildings in a rural settlement have some economic function, the construction of farmhouses and outbuildings is another source of information on farming and surplus production. By comparing changes in the type and size of farmhouses with significant changes in the agriculture practised, we hope to establish whether changes in the construction of farmhouses reflect changes in the agricultural economy.

The dominant house type in the Dutch River Area is the byrehouse, which was inhabited by people and their livestock. Stable sections in byrehouses can be identified by the location of entrances and central roof-bearing posts.[10] One of the advantages of the good conditions of preservation in the Dutch River Area is the development of phosphate stains in places where manure seeped into the ground.[11] The presence of these stains can identify the stable section of a byrehouse. The development of phosphate stains is complex and dependent upon several factors; not every stable section will show a phosphate stain. But sometimes an internal division of the house plan can be recognized by small wall segments in the central part of the building. These wall segments probably represent cattle boxes and can be taken as evidence for a stable section. By analysing changes in the average size of stable sections per phase, we can draw conclusions about the numbers of animals regularly stabled.[12] Changes in average stable size may not only represent changes in the total number of animals kept in the settlement, but could also reflect changes in the way animals were exploited.

Outbuildings were used mainly for storage of arable crops and animal fodder. For the outbuildings, both the number of outbuildings per farmyard and the average size of each outbuilding are important. Changes in the way crops were stored or the space available for storage could reflect changes in crop production or changes in the organisation of production. Outbuildings cannot always be securely dated. It is also possible that the lifetime of especially the small outbuildings is much shorter than that of the farmhouses.

Botanical and zoological archaeology

Animal and botanical remains comprise the other sources of evidence for farming and surplus production. The interaction between arable agriculture and animal husbandry should not be underestimated. After the harvesting, livestock grazed stubble fields, feeding on arable waste products while fertilising the fields with their manure. Fodder to feed animals during the winter had to be grown, which means that not all arable fields could be used for crops for human consumption.

In trying to identify the production of a surplus of animal products, two methods are used to interpret the zooarchaeological data. First, changes in species ratios may indicate an increase

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9 Bloemers 1978, 55; Willems 1984, 236.

10 See Waterbolk 1975 for criteria for the identification of stable sections in byrehouses.

11 Van der Voort, Polman and Van Es 1979; Steenbeek 1983; Oonk 2006.

12 One of the main reasons for stabling livestock is the collection of manure, which was necessary for arable agriculture.

in the relative importance of one species. Although this can reflect a variety of causes, one is the response to a market by specialising in products from one species. Second, changes in the mortality profiles for a species can help identify a change in exploitation.[13] Again, this may reflect specialisation in certain animal products.[14] The underlying assumption is that the response of a rural settlement to the demand from a market will cause changes in animal exploitation.

Botanical data can be used only indirectly to identify surplus production. First, botanical research can be used to establish which cereals and pulses were produced as staple food in the rural settlements.[15] Second, as in zooarchaeological research, changes in crop ratios or specialisation in just one or in several crops can indicate surplus production. Changes in wild plant assemblages, especially of plants of arable fields, yards and gardens (*versus* plants of grasslands and meadows), could also be an indication for specialisation in arable farming or animal husbandry. In order to discover any changes in wild plant assemblages, wild plants found at Wijk bij Duurstede-De Horden and Tiel-Passewaaij were separated into several ecological groups.[16] The main indication for surplus production of crops, however, is an increase in storage capacity.

Farming was the core business of the inhabitants of Wijk bij Duurstede-De Horden and Tiel-Passewaaij. There is no difference between the food that was consumed by the local community and the food that it produced for the market. This is based on the fact that samples recovered from features connected to farmhouses show no differences in their assemblage of wild plants when compared to samples collected from large granaries of the same period. This means that all wild plant assemblages found in different features of the settlements are the result of farming activities, directly or indirectly.

Quantification models of production capacity

To obtain an idea about the possibilities of surplus production, the results from the above-mentioned sources were combined in quantification models for the local community, their livestock and arable crops. The landscape provides an upper limit for the amounts of land suitable for arable agriculture and animal grazing, while the number of farmhouses in existence at one time is an indication for the population size. The protein requirement per family of 6.5 people (men, women and children of different ages) is assumed to be 5219500 kCal per year.[17] Recent research on the percentages of animal and vegetable food in the Netherlands' diet of the Middle Ages led to the assumption that 70% of daily food consisted of cereals, 10% of meat, and 20% of other food products like pulses, milk, cheese, and fish.[18] The size of the byre-sections in farmhouses and of the outbuildings, both stables and granaries, yielded information on stable capacity for animals and storage capacity for crops, although it proved difficult to determine the number of outbuildings per period, since not all of them could be dated.

In order to quantify the possibility of surplus production of animals, population size is taken as a starting point. Assuming a fixed proportion of 10% meat in the diet will give the number of animals slaughtered per year for food. The energy yield per animal is assumed to be 293567 Kcal for cattle, 26370 Kcal for sheep, and 62999 Kcal for pig.[19] Since the proportions of the different species are known for each period, it is possible to calculate the number of animals killed for food for each species. To maintain a viable herd, no more than 1 in 4 animals may be

13 For zooarchaeological research at Tiel-Passewaaij, see Groot 2008a and b.

14 Specialisation here should be taken to mean relative specialisation: concentration on the production of certain animals or animal products after production for the settlement's own needs.

15 For the botanical archaeological research at Tiel-Passewaaij, see Fokma 2005 and Kooistra and Heeren 2007; for Wijk bij Duurstede-De Horden, see Lange 1990.

16 Based on Tamis *et al.* 2003.

17 Gregg 1988, 143.

18 Jobse-Van Putten 1996, 48.

19 Kooistra 1996, 67-68; IJzereef 1981, 184-86. IJzereef used different energy yields for calves and adult cattle. An average figure is used in our model, based on the mortality profiles from Tiel-Passewaaij periods 2 to 4.

killed each year. In this way we can reconstruct minimum herd sizes. These are calculated only for cattle and sheep, since the pig's ability to propagate quickly and the low number of pigs slaughtered per year means that just a single male and female pig could have provided all the pork consumed. By comparing the minimum herd sizes for each period with the total stable size, it is possible to determine whether surplus animals could be produced. When stabling capacity exceeds the minimum herd size, the extra animals could have been traded as a surplus. Stabling capacity for cattle is calculated by dividing 50% of the total stable length by 0.85 m (the average width of a stable box).[20] Since part of the stable sections was probably used for pigs, sheep and storage, we assume that only half of the total area was used for cattle. While it is possible that not all cattle were stabled, it is assumed here that they were stabled at least for some of the time.[21] The amount of land available for grazing livestock could not be determined due to the unknown number of settlements surrounding the floodplains, but it was probably not a limiting factor.

In quantifying the possibilities of surplus production of cereals, it is assumed that the Dutch River Area did not yield the highest quality of cereals. Therefore we begin with 1 kg of cereals delivering 3100 kCal of proteins. One must also realise that not all of the annual production of cereals could be used for consumption: reserve food and seeds for sowing were needed too. It is assumed that the inhabitants kept half of the annual requirement for food in reserve for bad years. The total amount of cereals needed comprised: private consumption + half of the private consumption in reserve + sowing-seed (which is $^1/_5$ of the total amount of cereals needed for consumption and reserve). Historical evidence and experimental research has demonstrated that 1 ha yielded 1000 kg of cereals if the amount of sowing-seed was 200 kg per ha. From experimental research it is also known that the average storage area was 280 kg cereals per m^2.[22]

Because of the shortage of manure, in antiquity arable fields could not be used permanently. That means that cereals were cultivated in different rotation systems with fallow years.[23] In our model we chose the classical variant, which is two-course rotation, by which every cereal production year was relieved by a fallow year.

The settlements

Despite some differences in location and size, Wijk bij Duurstede-De Horden and Tiel-Passewaaij share many similarities. Both sites were excavated almost completely.[24] The settlements were inhabited from the beginning of the Roman period onwards and show continuous habitation during the time-period of our study, the 1st and 2nd c. A.D. A detailed chronology could be established for both sites. Like most settlements in this river landscape, the sites were situated on a stream ridge.[25] The highest parts of the ridge and the sloping areas were suitable as living space and for arable agriculture. The lower areas were probably in use only as grazing land for livestock. Both settlements consisted of several farmhouses with associated buildings and do not show any strong evidence for élite residency. The surface area of arable fields available to the inhabitants of Wijk bij Duurstede-De Horden can be estimated as 50 ha at the most, while in Tiel-Passewaaij it was *c.*30 ha.[26]

Period 1 (A.D. 1-50)

Settlement archaeology

During the first period, a long twisting ditch divided the settlement of Wijk bij Duurstede-

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20 Waterbolk 1975, 392.

21 If only part of the cattle herd was stabled, the possible number of surplus animals would be even larger, so this assumption does not affect our conclusions on whether surplus production was possible.

22 Kooistra 1996, 66-68.

23 Slicher van Bath 1980, 76.

24 Hessing 1989; Hessing and Steenbeek 1990; Van Es and Hessing 1994; Vos 2002; Vos 2009; Roymans, Derks and Heeren 2007; Heeren 2009.

25 See the discussion in Hessing and Steenbeek 1990.

26 Hessing and Steenbeek 1990; Vossen 2007, 42.

Fig. 2. Excavations of Wijk bij Duurstede-De Horden. A - period 1. B - period 3.
Key: a - excavated area. b - ditches and farmhouses. c - graves.

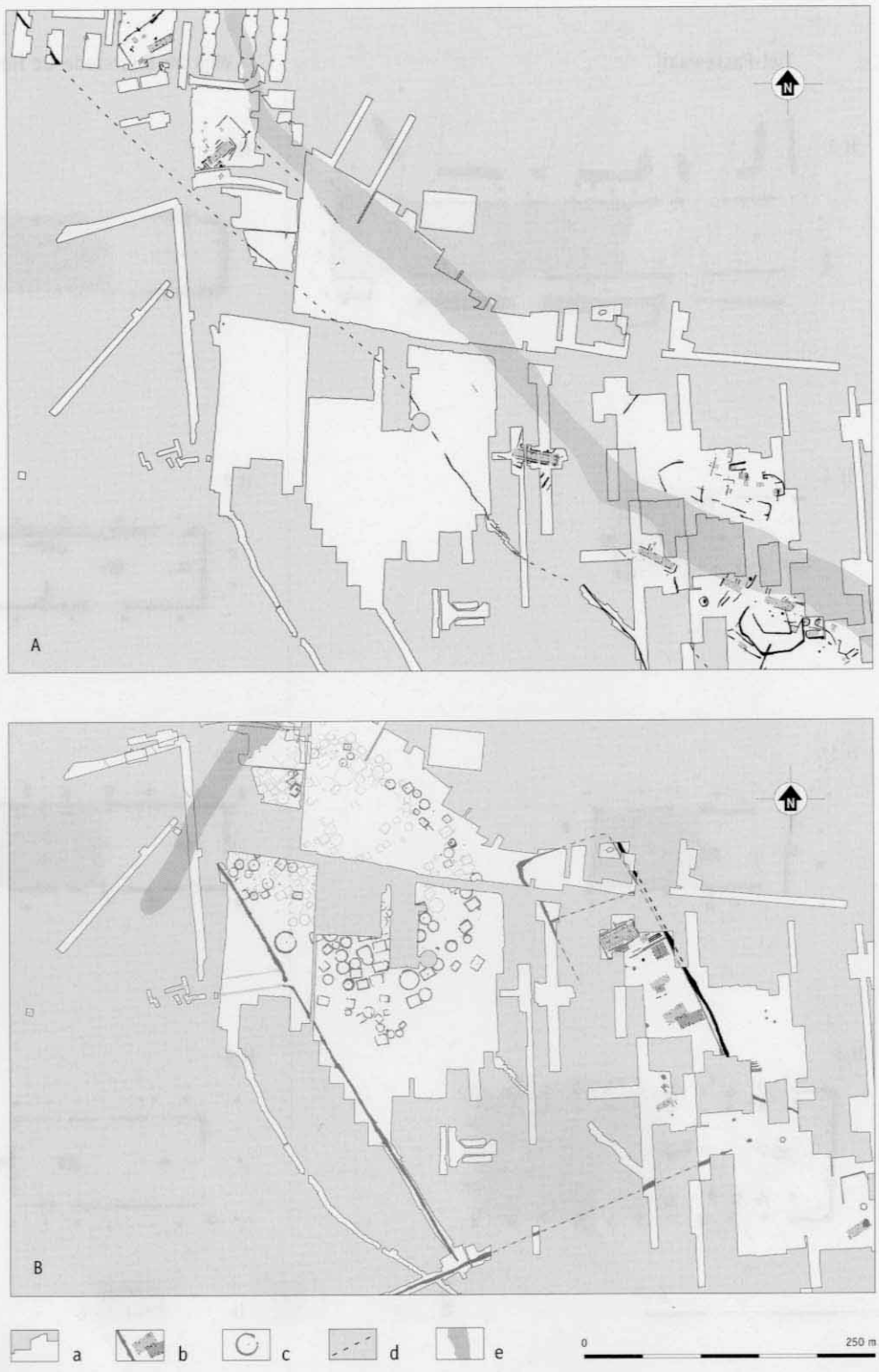

Fig. 3. Excavations of Tiel-Passewaaij. A - period 1. B - period 4.
Key: a - excavated area. b - ditches and farmhouses. c - graves. d - reconstructed ditches. e - residual channel.

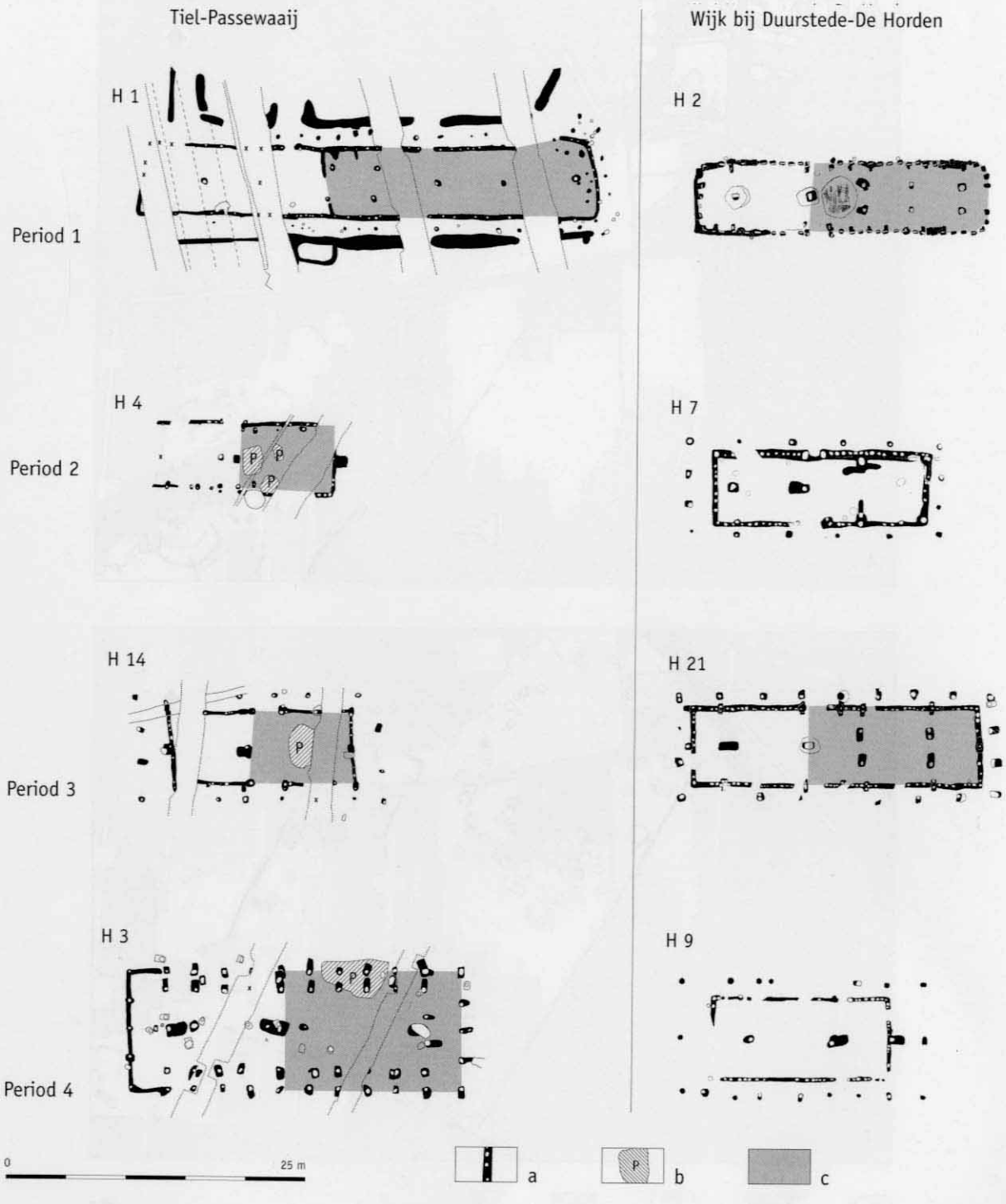

Fig. 4. Farmhouses at Tiel-Passewaaij and Wijk bij Duurstede-De Horden.
Key: a - features of the building. b - phosphate stain. c - byre sections within the farmhouse.

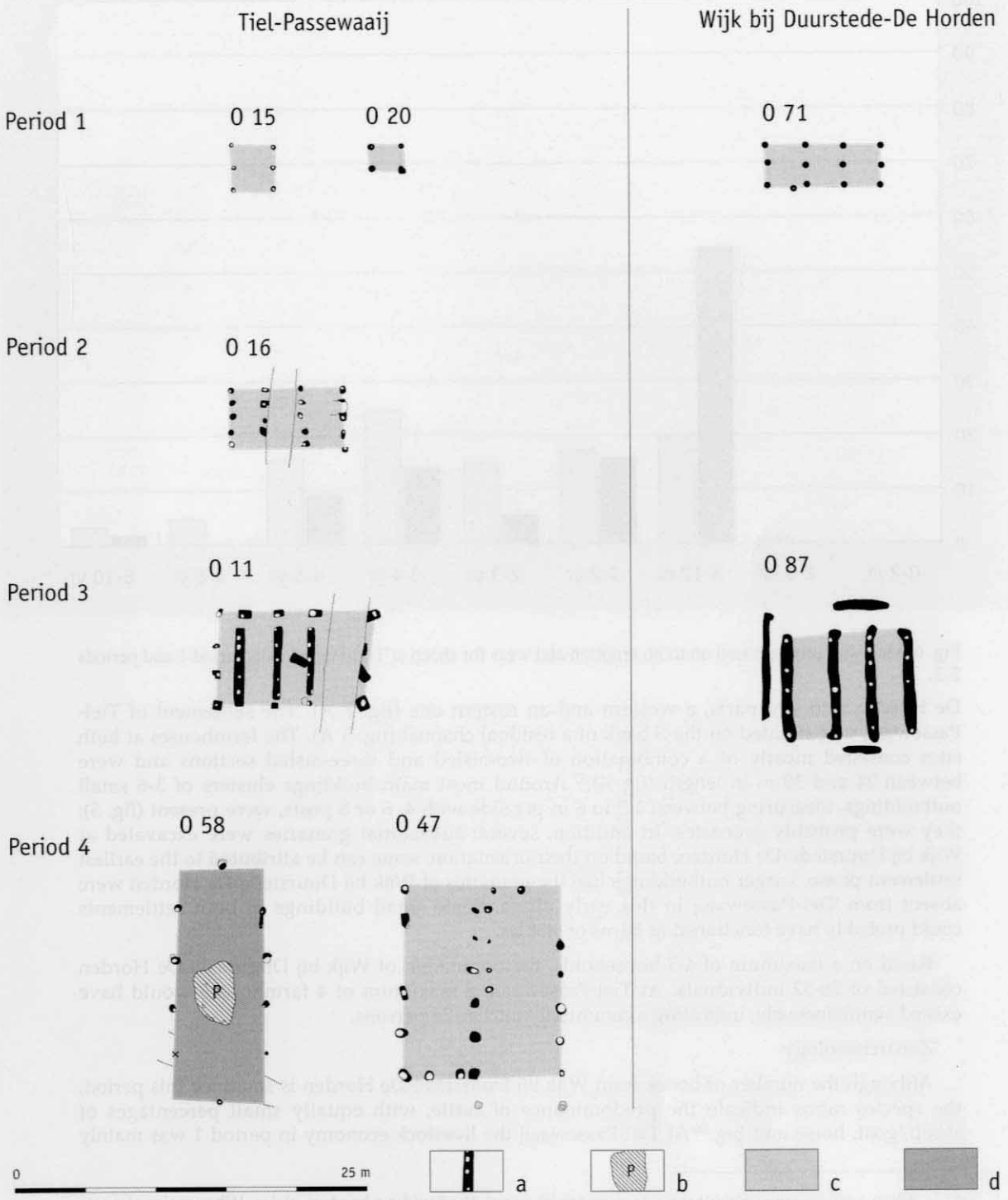

Fig. 5. Outbuildings at Tiel-Passewaaij and Wijk bij Duurstede-De Horden.
Key: a - features of the building. b - phosphate stain. c - storage buildings. d - stable.

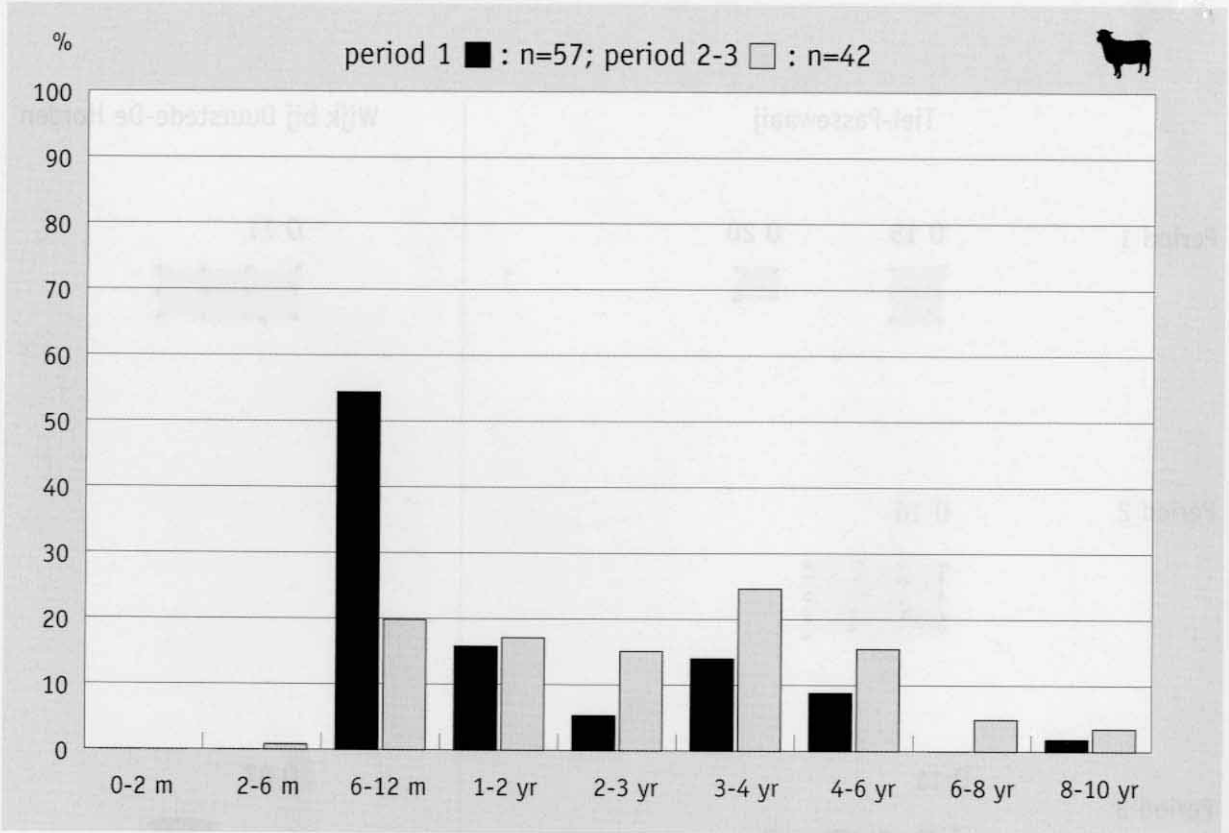

Fig. 6. Mortality profile based on tooth eruption and wear for sheep at Tiel-Passewaaij, period 1 and periods 2-3.

De Horden into two parts, a western and an eastern one (fig. 2 A). The settlement of Tiel-Passewaaij was situated on the S bank of a residual channel (fig. 3 A). The farmhouses at both sites consisted mostly of a combination of two-aisled and three-aisled sections and were between 24 and 38 m in length (fig. 4).[27] Around most main buildings clusters of 3-6 small outbuildings, measuring between 1.5 to 6 m per side with 4, 6 or 8 posts, were present (fig. 5); they were probably granaries. In addition, several substantial granaries were excavated at Wijk bij Duurstede-De Horden; based on their orientation, some can be attributed to the earliest settlement phase. Larger outbuildings like the granaries of Wijk bij Duurstede-De Horden were absent from Tiel-Passewaaij in this early phase. Some small buildings in both settlements could probably have functioned as barns or stables.

Based on a maximum of 4-5 households, the population of Wijk bij Duurstede-De Horden consisted of 26-32 individuals. At Tiel-Passewaaij, a maximum of 4 farmhouses would have existed simultaneously, indicating a community of 20 to 26 persons.

Zooarchaeology

Although the number of bones from Wijk bij Duurstede-De Horden is small for this period, the species ratios indicate the predominance of cattle, with equally small percentages of sheep/goat, horse and pig.[28] At Tiel-Passewaaij the livestock economy in period 1 was mainly

27 When a single row of central posts supports the roof, the building has two aisles. When pairs of posts support the roof, the two rows of posts divide the plan into three aisles.

28 Animal bone data from Wijk bij Duurstede-De Horden is taken from Laarman 1996, 369-80. One problem with the data is that the periods used by Laarman are somewhat different from the ones used here. The data for the early 1st c. A.D. actually dates to a transitional Late Iron Age/Early Roman phase, equated with our period 1.

based on sheep and cattle; together, they accounted for more than 80% of the animal bones.[29] The mortality profile for sheep, based on tooth eruption and wear, shows a very strong peak in the 6-12 month category (fig. 6). This peak reflects a system where lambs were slaughtered in the autumn and winter. The weaker individuals were culled from late autumn throughout the winter. Lambs were killed for meat either as food became more scarce or as their mothers' milk-production waned. Meat and milk were the main products of sheep. Almost 60% of cattle were killed before the age of 30 months; the remaining 40% reached adulthood or older ages. The 20% killed before 8 months could point to dairying, with calves slaughtered during winter as their mothers' milk-supply ended. The peak between 18 and 30 months represents animals that were not fully-grown, but would have provided a large amount of meat. The older animals were used primarily for other purposes, such as labour and manure, and would have produced calves to maintain the herd. Cattle were indeed multi-purpose, providing milk, meat, labour and manure.

Botanical archaeology

At Wijk bij Duurstede-De Horden 35 soil samples from 8 different features dating to period 1 have been analysed. No samples of plant macro-remains were collected for this period at Tiel-Passewaaij. The cereals present in the samples from Wijk bij Duurstede-De Horden are 6-row barley of the hulled variety (*Hordeum vulgare* subsp. *vulgare*, also known as hulled barley), emmer wheat (*Triticum dicoccon*), oats (*Avena*), and common millet (*Panicum miliaceum*). Among the wild plant species, those found in arable fields, yards and gardens are very common: almost 48% of all species belong to this category (fig. 7). No indications for non-local arable weeds were found. This confirms the hypothesis of local cereal production. Nearly 24% of species are typical for grasslands and meadows. Considering the location of Wijk bij Duurstede-De Horden in a low-lying part of the Dutch River Area, it is not surprising that water plants and plants growing on river banks are also well-represented (22%). Only 7% of all species are woodland plants. Storage capacity at Wijk bij Duurstede-De Horden varies from 5.5 to 25.5 m^2 per granary, with an average of 16.4 m^2 (based on 4 granaries). At Tiel-Passewaaij several dozens of small granaries were assigned to this period. If these granaries were used to store cereals, every household required several granaries at the same time (cf. the assumptions in Methodology above, and Table 1). At Tiel-Passewaaij storage capacity varies from 2.5 to 9 m^2 per granary, with an average of 5.4 m^2 (based on 10 granaries).

Period 2 (A.D. 50-100)

Settlement archaeology

The most important spatial development within the settlement Wijk bij Duurstede-De Horden occurred in period 2. It can be described as a fairly symmetrically-organised layout of two rectangular ditched enclosures. Inside the small W enclosure only one farmhouse was in use at the same time, while the larger E enclosure was occupied by several buildings. At Tiel-Passewaaij in this period the main orientation of the houses differed considerably from those of the previous period, which were aligned with the residual channel, indicating a different organisation. It is assumed that the residual channel had silted up almost completely by this time since it had lost its influence on the layout. Some of the farmhouses were long (between 20 and 25 m), but most were relatively short (less than 14 m). The internal division of the shorter ones is two-aisled or two/three-aisled. The shorter ones had only three central roof-bearing posts: two in the short walls of the building and one in the central space (fig. 4). Judging from the phosphate stains frequently encountered at Tiel-Passewaaij to the east of the central post, that post marked the division between the stable section and the living quarters. As a logical consequence of decreasing the length of the houses, the stable section became smaller too. At Wijk bij Duurstede-De Horden a new type of house is found, characterised by a partly one-aisled interior, in which the posts were placed almost directly against the long walls (fig. 4).

29 Groot 2008a and 2008b.

TABLE 1

PRODUCTION CAPACITY OF WIJK BIJ DUURSTEDE-DE HORDEN AND TIEL-PASSEWAAIJ
when 70% of the daily food consisted of cereals, 10% of meat, and 20% of other food products

* = some granaries of the previous period may have existed in this period.

Wijk bij Duurstede-De Horden: meat

Period in yr. A.D.	*N people*	*Kcal per yr*	*% cattle*	*% sheep*	*% pig*	*N cattle killed p/yr*	*N sheep killed p/yr*	*N pigs killed p/yr*	*min. herd size cattle*	*min. herd size sheep*	*total stable length*	*max. stable capacity cattle*	*stable length /cattle ratio*
1-50	29	2328700	77.5	11	11.5	7.6	1.1	1.1	30.4	4.3	51.3	60.4	1.7
50-100	29	2328700	81.1	15.7	3.2	7.7	1.5	0.3	30.9	6	54.6	64.2	1.8
100-150	36	2890800	77.7	16.8	5.5	9.5	2.1	0.7	38.1	8.2	66.6	78.4	1.7
150-200	26	2087800	77.7	16.8	5.5	6.9	1.5	0.5	27.5	6	30	35.3	1.1

Tiel-Passewaaij: meat

Period in yr. A.D.	*N people*	*Kcal per yr*	*% cattle*	*% sheep*	*% pig*	*N cattle killed p/yr*	*N sheep killed p/yr*	*N pigs killed p/yr*	*min. herd size cattle*	*min. herd size sheep*	*total stable length*	*max. stable capacity cattle*	*stable length /cattle ratio*
1-50	23	1846900	42.7	47.2	10.1	5.4	6.0	1.3	21.8	24	52	61	2.4
50-100	29	2328700	44.5	48	7.5	6.9	7.5	1.2	27.8	30	29.8	35	1.1
100-150	36	2890800	44.5	48	7.5	8.6	9.3	1.5	34.5	37.2	39.8	46.5	1.2
150-200	19.5	1565850	60.7	28.6	10.7	4.9	2.3	0.9	19.6	9.2	32.2	37.5	1.6

Wijk bij Duurstede-De Horden: cereals

Period in yr. A.D.	*N people*	*energy requirement Kcal per yr*	*cereal consumption (in kilo)*	*total kilo of cereals needed*	*storage capacity needed (in m2)*	*net ha arable field*	*rotation system 1:1 (in ha)*	*outbuilding capacity available (in m2)*
1-50	29	16300900	5258	9465	33.8	9.5	18.9	65.5
50-100	29	16300900	5258	9465	33.8	9.5	18.9	202.0
100-150	36	20235600	6528	11750	42.0	11.7	23.5	262.0
150-200	26	14614600	4714	8486	30.3	8.5	17.0	45.5*

Tiel-Passewaaij: cereals

Period in yr. A.D.	*N people*	*energy requirement Kcal per yr*	*cereal consumption (in kilo)*	*total kilo of cereals needed*	*storage capacity needed (in m2)*	*net ha arable field*	*rotation system 1:1 (in ha)*	*outbuilding capacity available (in m2)*
1-50	23	12928300	4170	7507	26.8	7.5	15.0	54.1
50-100	29	16300900	5258	9465	33.8	9.5	18.9	69.3
100-150	36	20235600	6528	11750	42.0	11.7	23.5	72.6
150-200	20	11242000	3626	6528	23.3	6.5	13.1	212.8

Outbuildings in this period vary from simple granaries to more elaborate ones with a larger number of posts and small two-aisled buildings. At Tiel-Passewaaij a possible Roman-style granary[30] is found in this period; the mass of small posts in the interior suggests an elevated floor and the area of the ground plan (8 x 4 m) shows that the building had a significant storage capacity (fig. 5).

Based on a maximum number of 5 inhabited farmhouses, the population size of Wijk bij Duurstede-De Horden does not seem to have changed during this period. At Tiel-Passewaaij 4 or 5 houses existed simultaneously, indicating a community of between 26 and 32 people.

Zooarchaeology

At Wijk bij Duurstede-De Horden in period 2 the percentage of horse fragments increased dramatically to 36%, while the proportions of cattle and pig decreased.[31] The proportion of sheep remained stable. Despite the decrease, cattle were still the species with the highest number of bones. Because of the lack of age data, no conclusions can be drawn on the exploitation of livestock. At Tiel-Passewaaij the animal bones from periods 2 and 3 were originally analysed as one; when they are split up between periods 2 and 3 the numbers are really too small, but certain trends can be recognised. While the animal bones from period 2/3 show similar percentages of sheep and cattle, the data from periods 2 and 3, separated out, indicate that the proportion of sheep was even higher in period 2 and started to decrease in phase 3. The increase of horse began in period 3. Mortality profiles are available only for the combined period 2/3. Although the economy was still based on sheep and cattle, the exploitation of sheep changed quite drastically: instead of killing most animals between 6 and 12 months, sheep were now killed between birth and 6 years in almost equal numbers for each year of life. Sheep were now mainly exploited for wool, with animals killed for meat only after they had provided several fleeces. Milk was still an important product, with 20% of lambs killed between 6 and 12 months; these lambs could also represent individuals culled during the lean winter months. Assuming that sufficient wool for the settlement's own use was already produced in the previous phase, the change in exploitation of sheep, from milk and meat to mainly wool, reflects production of wool as a surplus. Because the proportion of sheep declined in period 3, we can assume that wool production had its peak in period 2. There is no change in the exploitation of cattle when again a peak in slaughter is found between 18 and 30 months. A decrease in the relative number of calves killed before 8 months suggests that milk had become less important. The most important uses of cattle in this period would have been for meat, labour and manure.

Botanical archaeology

At Wijk bij Duurstede-De Horden 5 samples from postholes and a granary pit from period 1 or 2 were analysed. The granary burned down while hulled barley was being stored there. Cereals were also found in house ditches; again, hulled barley is the most common species. It is not surprising that in these cereal-rich samples plants from arable fields, yards or gardens are better represented than are the other categories. At Tiel-Passewaaij the fills of two wells and one pit were analysed. The cereals found in them are emmer wheat, hulled barley and oats.[32] Nearly 55% of wild plants are plants from arable fields, yards or gardens (fig. 7). Grassland and meadow plants are represented by 21%. The proportion of water plants and plants from river banks is equal, at 12%, to that of woodland plants. At Wijk bij Duurstede-De Horden the surface area of the granaries at this period varies from 1.8 to 36 m^2, with an average of 17 m^2 (based on 12 granaries). At Tiel-Passewaaij the large granary of this period offered storage capacity for more than one household. There the storage capacity varies from 4 to 23 m^2, with an average of 9.9 m^2 (based on 7 granaries). As in period 1, the small granaries did not have suf-

30 The term Roman-style granary is used because the ground-plan of these wooden buildings resembles the layout of stone granaries found in Roman forts and villas.

31 Period 2 is Laarman's Early Roman Period.

32 Kooistra 1996. However, it is uncertain whether cultivated oats were grown at Tiel-Passewaaij, since this type of cereal can only be identified by the chaff and no chaff was found.

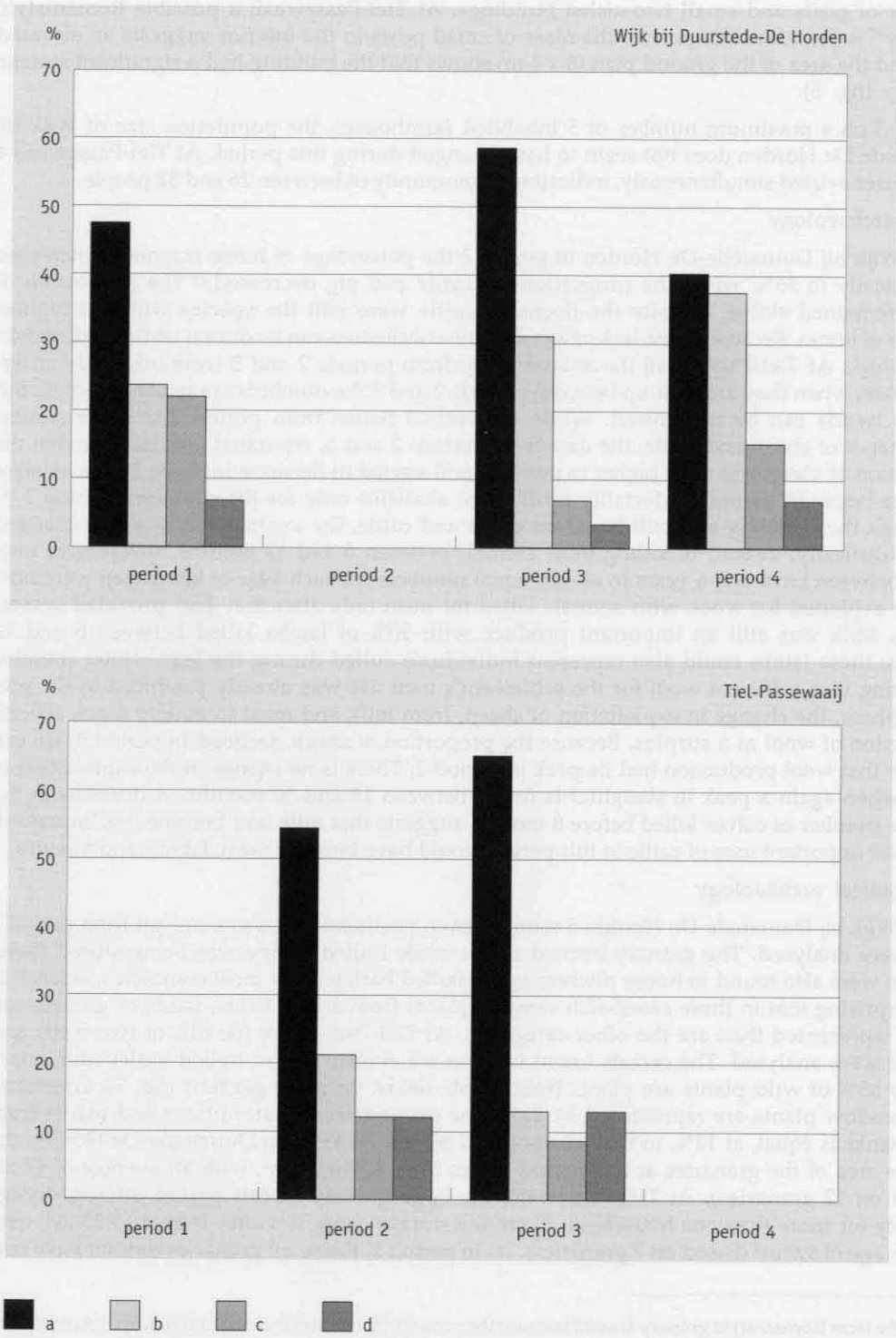

Fig. 7. Wild plant assemblages at Wijk bij Duurstede-De Horden and Tiel-Passewaaij.
Key: a - arable fields, yards, gardens. b - grasslands and meadows. c - water and river banks. d - woodlands.

ficient storage capacity for the cereals needed by a household: one household would have needed access to several such small granaries to store enough cereals for its own use.

Period 3 (A.D. 100-150)

Settlement archaeology

At Wijk bij Duurstede-De Horden the layout was at its most complex in period 3. The earlier difference in orientation between the two enclosures disappeared because new ditches were dug for the W enclosure, aligned with those of the E one (fig. 2 B). All buildings were now oriented on one of the two main alignments of the enclosure system. At Tiel-Passewaaij the most important change in settlement layout is the digging of long ditches from the settlement into the surrounding lands. Some were longer than 500 m (excavation did not reach their termination). Whether the ditches were intended to claim ownership of land or were purely functional (e.g., to divide arable fields from grazing grounds or for water management) is unknown. A comparable 'off-site ditch-system' has also been found at Wijk bij Duurstede-De Horden during this period.

At Wijk bij Duurstede-De Horden the internal division of the farmhouses varied: both a two-/one-aisled division and a two-/three-aisled division occur. Several buildings of a new shorter type were erected inside the large enclosure (fig. 2 B). At Tiel-Passewaaij the houses became larger in this period, although the construction that was introduced in period 2 (two-aisled buildings with a single roof-bearing post in the centre and two more in the short walls) was still used (fig. 4).

At Wijk bij Duurstede-De Horden there were now more granaries per farmhouse; at the same time several larger granaries were built. The trend observed earlier at Tiel-Passewaaij, showing an increase in the size of the outbuildings and a decrease in numbers, continued in this period. One outbuilding is clearly recognisable as a Roman-style granary: large postholes form the walls and foundation trenches with small posts support an elevated floor (fig. 5).

At Wijk bij Duurstede-De Horden the population size may have increased in this period, since 5 to 6 households (32-39 people) inhabited the settlement. Since Tiel-Passewaaij also has 5 or 6 houses existing simultaneously, the population size was about the same as that at Wijk bij Duurstede-De Horden .

Zooarchaeology

At Wijk bij Duurstede-De Horden the species ratios in periods 3 and 4 are almost exactly the same as those from period 2, with cattle and horse dominating the economy. Age data based on epiphyseal fusion show that 62% of cattle survived beyond the age of 4 years. This shows that meat was not the primary purpose of the cattle; traction, and probably manure, were more important. Of horses 80% lived beyond the age of 3.5 years.[33]

Botanical archaeology

At Wijk bij Duurstede-De Horden 4 samples from the floor surface of a house were analysed. The types of cereals found in these samples are similar to those found in period 1, with similar proportions per species. The category of plants from arable fields, yards or gardens is the most common, at nearly 59%. Thirty-one percent of all plant remains come from grassland and meadow plants. Woodland plants as well as water plants and plants from river banks are represented by less than 10% (fig. 7). At Tiel-Passewaaij, apart from one grain of barley, no cereals were found in two samples from a well. Plants from arable fields, yards or gardens are well represented at 65%. Thirteen percent of all plant remains are from grassland and meadow plants, and woodland plants are found in a similar proportion. Water plants and plants from river banks are represented by just under 9% (fig. 7). On average, the granaries at Wijk bij Duurstede-De Horden were slightly larger than in the previous period, with a surface area that varied from 4 to 42 m^2, and an average of 22 m^2 (based on 12 granaries). The large granary

33 Laarman 1996, 377. Laarman's Middle Roman Period represents our periods 3-4.

at Tiel-Passewaaij, with a surface area of 45.6 m^2, offered a storage capacity that exceeded the local needs by almost 100% (Table 1).

Period 4 (A.D. 150-200)

Settlement archaeology

No changes in settlement layout are found at Wijk bij Duurstede-De Horden in this period. At Tiel-Passewaaij the large off-site ditches still functioned, and new ditches closer to the settlement were added. The extensive system of ditches united the settlement and fields beyond the settlement (fig. 3 B). Close to the settlement's largest house one smaller field was separately enclosed, but whether it was used for agriculture, horticulture or animal grazing is not known.

At Wijk bij Duurstede-De Horden two buildings from this period have a two-aisled internal division and were very wide (up to 9 m) (fig. 4). These houses had surrounding posts that could be interpreted as a kind of Roman-style *porticus* or verandah.[34] It is doubtful whether these buildings actually functioned as ordinary farmhouses, especially since traditional stable sections for cattle cannot be recognised in the ground plan. No stable section was visible in a third building from the same period, but this house was long enough to have had a separate section for livestock. This farmhouse had a unique ground plan, with a partly two-aisled and partly one-aisled internal division. The final building, from period 4, had a two-/three-aisled interior and began in use during the preceding period. At Tiel-Passewaaij the houses continued to increase in length and even more so in width. House construction was now completely different from the earlier examples: central roof-bearing posts disappeared, to be replaced by pairs of posts close to the walls (fig. 4). One house is a blend between the traditional construction with central posts and the new style.

At Wijk bij Duurstede-De Horden in period 4 there are no changes in construction or size of the outbuildings. As far as the outbuildings in Tiel-Passewaaij are concerned, we find an increase in both the number and size of granaries. The largest one measured 14 x 11.8 m (fig. 5). The ground plan is not typical for Roman-style granaries, but large amounts of charred grain in the postholes indicate that crops were stored in this building. A second category of outbuildings became important in this period. One building is identified as a stable based upon an unusually large phosphate stain and a new design, one-aisled over the full length with posts placed individually in the walls (fig. 5). This construction is not found in farmhouses and differs from that of the buildings nearby. Although separate stables were now in use, contemporary houses still had a stable section. As a result, the total area for stabling increased considerably.

During period 4 the population size at Wijk bij Duurstede-De Horden decreased. Four houses were inhabited at the same time, indicating that the population consisted of some 26 people. The number of houses at Tiel-Passewaaij also decreased; only three existed simultaneously, suggesting a community of about 20 individuals.

Zooarchaeology[35]

Since periods 3 and 4 were analysed together at Wijk bij Duurstede-De Horden, no change is visible for this period. At Tiel-Passewaaij livestock composition changed in period 4: animal bone proportions show a decline in sheep (to 22%) and a substantial increase in horse (from 12% in periods 2-3 to 23%). The increase of horse remains had already begun in period 3. The percentage of cattle bones remains stable. Most sheep were killed during the first 4 years of life. The decrease in the percentage of sheep bones and a lower average slaughter age compared to the previous periods seem to point to a decline in the importance of wool. Meat must have been the most important product from sheep in this period. A first peak in slaughter of cattle between 30 and 36 months indicates culling for meat, while further peaks with adult and older cattle

34 Although this element is not entirely new (it is found in period 3 and probably also in period 2), the effect of an extensive 'verandah' is more pronounced in these buildings. Whether this phenomenon is an imitation of a villa with stone columns or an imitation of wooden military barracks is not clear.

35 Groot 2008a.

indicate the increased importance of products (manure and labour) from the living animals. Fifty percent of horses died before reaching 3.5 years. There are two possible explanations for this pattern. First, if horses were exploited for their meat, this mortality profile would not be surprising. There are indications that horsemeat was eaten at Tiel-Passewaaij, but not to the same extent as other domestic species. Horses were probably not bred to provide meat but their meat may have been consumed in some circumstances. The second possibility is that young horses are over-represented because young adult horses were sold or exchanged, and therefore died in a different location. In that case what we would expect to find are the non-survivors, foals and young horses that were weaker and died natural deaths, or that were culled deliberately, as well as the older breeding stock. The fertile floodplains would be the most suitable place to keep a herd of horses. The animals would be left there year-round, and only brought to the settlement when a selection of horses for sale or culling was made.

Botanical archaeology

At Wijk bij Duurstede-De Horden 64 samples from three features were analysed. In all samples hulled barley is the most common, followed by emmer wheat, oats, and common millet. As in the previous periods chaff remains are scarce. More than 40% of the plant species grow in arable fields, yards or gardens. The proportion of plants from grassland and meadows is high at nearly 38% (fig. 7). Most of the remains from grassland plants were found in the large E section of the settlement. Relatively few remains from wild plants were found in the W plot, but the composition shows the normal proportions, with more plants from arable fields, yards or gardens compared to grassland and meadow plants. At Tiel-Passewaaij a well and two ditches from this period were sampled, as well as 11 postholes from a granary that burned down. These postholes were filled with charred cereals, mainly emmer wheat and hulled barley with some oats and common millet. These crops were also found in other samples at this period. The number of wild plant species is too low to allow conclusions about the existence of arable fields and pastures.

At Wijk bij Duurstede-De Horden only one small and one large granary were assigned to this period, with a combined storage capacity of 45.5 m^2. The apparent increase in storage capacity may be misleading: although the storage capacity per building has increased, the total number of granaries may have been smaller than in the previous period. At Tiel-Passewaaij the burned granary, with a surface area of 165.2 m^2, was larger than needed to contain just the cereal harvest from the settlement itself (see Methodology and Table 1). Cereals were being stored in only half of the granary at the time it burned down, suggesting that the other half was used for the storage of other products.[36]

Discussion

At the end of the 1st c. A.D. the first villas were built in the fertile loess region in the S part of *Germania Inferior*. The agrarian economy of the villa landscape was mainly based on surplus production of spelt wheat (*Triticum spelta*). This remained unchanged until the late 3rd c.; only the volume of the surplus of spelt wheat varied.[37] As is known from previous work, the agrarian economy of the Dutch River Area differs from that of the villa region. It was long thought that farmers were unable to produce a surplus of any agrarian product. We hope to have made it clear that the agrarian economy in the Dutch River Area was far more dynamic than that of the villa region, with different products being important in different periods. The diversity itself is already an argument that farmers of the river landscape produced more than they needed for themselves. However, our main arguments come from combining results of settlement archaeology with botanical and zoological archaeology and applying this evidence to an agrarian production model. The outcome of this model is summarised in Table 1. The arguments are discussed below, starting with the surplus production of cereals and followed by the surplus production of animals.

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36 Kooistra and Heeren 2007.

37 Gechter and Kunow 1986; Kooistra 1996, 115.

Surplus production of cereals

No changes in the crop spectrum occurred during the Roman period at Wijk bij Duurstede-De Horden and Tiel-Passewaaij. Barley, emmer, oats and some common millet were found in both settlements. The same crops were found in Iron Age rural settlements in the Dutch River Area. Botanical information collected from 4 military sites and 3 *vici* in the Rhine delta shows that barley, emmer wheat and oats were found at all military and related sites, in addition to spelt wheat and bread wheat.[38] Some of the barley, emmer wheat and oats could be cultivated in the Dutch River Area.

At Wijk bij Duurstede-De Horden and Tiel-Passewaaij some indications were found for changes in arable farming with the goal of producing a surplus. One thread of evidence is the change in the wild flora at both settlements. Figure 7 shows that at Wijk bij Duurstede-De Horden the proportion of grassland and meadow plants increased, while the proportion of arable, farmyard and garden plants decreased. This result is even more remarkable since grassland and meadow plants are generally under-represented in settlement research, because these plants are not preserved as well as arable, farmyard and garden plants. The changes in the wild-plant spectrum at Tiel-Passewaaij are the complete opposite to those at Wijk bij Duurstede-De Horden. At Tiel-Passewaaij the proportion of arable, farmyard and garden plants increased during the Roman period, while the proportion of grassland and meadow plants decreased. These data could lead to the assumption that the emphasis of the agrarian economy at Wijk bij Duurstede-De Horden was increasingly on animal husbandry, while that of Tiel-Passewaaij was more on arable farming. This indicates that, despite the stability in crop cultivation, changes may have occurred in the ratio of arable farming to animal husbandry.

Changes in the construction and size of outbuildings are an important parameter for establishing surplus production of crops. One of the more pronounced changes in the settlements, especially at Tiel-Passewaaij, is the increase in the size of granaries. At Tiel-Passewaaij there is a clear development from a large number of small granaries to fewer larger granaries. At the same time total storage capacity increased. The situation at Wijk bij Duurstede-De Horden differs slightly: small granaries are found for all periods, but larger granaries are already present in period 1, as well as in later periods. The largest granaries date to periods 3 and 4. If granaries were used only for storing cereals produced by the settlement itself, the total capacity of the granaries at Wijk bij Duurstede-De Horden in periods 2 and 3 is much more than was needed by the local community and indicates surplus production (Table 1). The same could be concluded for Tiel-Passewaaij, but there the storage capacity in period 4 is much larger than in period 3. Since population size decreased in this period, it seems that a significantly larger surplus could be produced.

Was sufficient acreage of land available for growing this amount of crops? Table 1 lists a maximum of 50 ha for the arable fields at Wijk bij Duurstede-De Horden and 30 ha at Tiel-Passewaaij.[39] We assumed that 1 ha of arable land yielded 1000 kg of cereals (see Methodology). This means that when population was highest in the two settlements (in period 3) *c.*12 ha of land planted with cereals was needed to produce sufficient cereals for the inhabitants' own consumption. Assuming that a two-course rotation system was used, at least 24 ha must have been used as arable fields (Table 1). In the case of Wijk bij Duurstede-De Horden, surplus production was possible for all periods including period 3. At Tiel-Passewaaij surplus production of cereals was also possible for every period, but the potential amount of surplus for period 3 was low. While the population size and available arable land indicate that surplus production of cereals was possible, there is a discrepancy in the data: the storage capacity at Wijk bij Duurstede-De Horden for periods 2 and 3, and for period 4 at Tiel-Passewaaij, is much higher than the amount of cereals that could be produced on the arable fields of the settlements' own lands (Table 1).

38 Cavallo *et al.* 2008; Kooistra forthcoming.

39 Based on Hessing and Steenbeek 1990; Vossen 2007, 42.

Storage capacity is also affected by the life of granaries. If the life of the outbuildings was shorter than that of the farmhouses, the actual storage capacity is smaller than the capacity based on the size of the granaries. However, in the case of Tiel-Passewaaij, the exceptional storage capacity in period 4 is based on one very large granary only; that storage capacity is absolute rather than relative. Extra storage capacity can also be explained through centralised storage of all the cereals of the settlements. Since at both settlements Roman-style granaries are found in only one farmyard, local centralisation of cereal storage seems possible. While theoretically Wijk bij Duurstede-De Horden and Tiel-Passewaaij may have functioned as collection sites for the surplus from surrounding satellite settlements, more research is needed before conclusions can be drawn.[40] The final explanation is that the granaries were used for storing other products besides cereals. Vos suggested different functions for the storage buildings. He based his assumption on the differences in ground pressure per post for different types of storage buildings.[41] The ground pressure of the posts of the Roman-style granaries of period 3 (outbuilding 87, with a surface area of 42 m^2) and period 4 (outbuilding 88, with a surface area of 27.5 m^2) was high; that is why these buildings were probably built to store cereals. The extremely high storage capacities found in periods 2 and 3 at Wijk bij Duurstede-De Horden and in period 4 at Tiel-Passewaaij can only be satisfactorily explained when we do not continue to assume that granaries were used for storage of a surplus of cereals alone. It is likely that part of the outbuildings was used to store other products, such as animal fodder.

Surplus production of animals

The high percentages of horse bones at Wijk bij Duurstede-De Horden in periods 2 to 4 and at Tiel-Passewaaij in periods 3 and 4 are taken as an indicator of specialised horse-breeding. With up to a third of the animals being horses, this exceeds any local demand, especially since horse meat was probably not consumed on a daily basis in the Roman period. Surplus horses were almost certainly sold to the Roman army.[42] The Roman army had a constant need to acquire horses to replace those no longer functioning. A calculation based on what we know about the military presence in *Germania Inferior* leads to estimates of the number of serving horses ranging from 3700 to 5300.[43] A. Hyland suggested that horses lasted on active duty only for three years;[44] that would mean that over a thousand horses were needed each year to replace those retiring.

At Wijk bij Duurstede-De Horden the main development in house construction is that the central roof-bearing posts are replaced by posts in the wall from period 2 onwards. This creates a large open space. Since wattle partition walls separating cattle boxes have been found in byrehouses in the north of the Netherlands, it is assumed that they also existed in traditional byrehouses in the Dutch River Area. When stables were built without the central roof-bearing posts, it is possible that they did not contain cattle boxes. It is tempting to see a functional explanation behind this change in construction and connect it with the increase in the proportion of horses in period 2.

While Wijk bij Duurstede-De Horden focused on horse breeding early on, Tiel-Passewaaij shows a specialisation in wool production in period 2, before changing to horse breeding in periods 3 and 4.[45] Tiel-Passewaaij, a settlement that already depended on sheep in the Late Iron Age and Early Roman period, could respond to the demand for wool that existed in the second half of the 1st c. A.D. by changing the way the sheep were exploited. Whereas earlier the flocks were managed for meat and milk, and wool was produced only for the settlement's own use, age data from the second half of the 1st c. demonstrate that sheep were now mainly managed for wool (fig. 6). Since it is assumed that sufficient wool was already produced for the

40 The absence of Roman-style granaries in smaller settlements near Wijk bij Duurstede-De Horden and Tiel-Passewaaij could support this theory: Vos 2009.

41 Vos 2002, 54-56.

42 Hessing 2001, 162-63.

43 Bechert and Willems 1995, 23; Bogaers and Rüger 1974.

44 Hyland 1990, 86.

45 Groot 2008a and b.

settlement's own use, this increase in wool production is related to the demand from a market economy. When the demand for wool disappeared (perhaps because it was now imported from the Gauls, or due to *legio X* leaving Nijmegen), the emphasis on animal husbandry at Tiel-Passewaaij shifted from sheep to horses.

In period 3, a new type of outbuilding appeared at Tiel-Passewaaij, interpreted as a stable on the basis of phosphate stains. Since its appearance coincides with the proportional rise in horse numbers, and byrehouses with stable sections were still being built at this time in the farmyards which contained stables, it seems safe to assume that horses were the occupants of the new stables.

By focusing on horse-breeding and wool-production, we have ignored the most important animal throughout the Roman period, cattle. Cattle were the main meat producers at both Tiel-Passewaaij and Wijk bij Duurstede-De Horden. Since beef was also the most important meat in military forts and in the town of Nijmegen, it is assumed that the cattle were raised in local rural settlements. Age data suggest that cattle were not raised primarily for meat: traction and manure were the primary products. Older cattle that were no longer needed in the settlement were sold as a surplus. Our quantification model demonstrates the capacity for producing surplus cattle. Stabling capacity exceeds minimum herd size in all phases (Table 1). At Wijk bij Duurstede-De Horden stable capacity is twice the minimum herd size in periods 1 to 3, while it is only slightly larger than the minimum herd size in period 4. At Tiel-Passewaaij the difference between stabling capacity and minimum herd size is highest in period 1. Due to the decrease in average stable length, this figure is much smaller in period 2, but it increases again in periods 3 and 4. Another way to grasp the numbers of surplus cattle is to divide the total stable length by the minimum herd size for cattle (Table 1). When this ratio is around 1, there is no surplus production; the higher the ratio, the more surplus cattle were produced. At Wijk bij Duurstede surplus cattle could have been produced in periods 1 to 3, and at Tiel-Passewaaij in periods 1 and 4.

Conclusions

The data presented above show that it was possible for rural communities in the non-villa landscape of the Dutch River Area to produce a surplus of animals as well as cereals. Changes in settlement structure, size of the population, storage capacity and animal husbandry inform us about the nature and the relative amount of the surplus. Combining the observed changes in our two case studies with the large quantities of imported ceramics and metal objects that are found on almost every site in the Dutch River Area, it can be concluded that the surplus was delivered to a market and was (in part?) exchanged for portable commodities such as foodstuffs in ceramic containers, ceramic table wares, metal utensils, and personal adornments. Whether this market exchange took place in a military (the *vicus* of a fort along the Rhine) or civilian centre (the *civitas*-capital Nijmegen) is not known. In any event, it is clear that, from some point in the Early Roman period onwards, these settlements are integrated within larger economic networks.

In contrast to the villa landscape, animal husbandry was very important in the Dutch River Area. While the ratio between the different types of cereal remained constant, the ratio between the different species of domestic animal changed from period to period and from place to place. Thus, the agrarian economy of the Dutch River Area seems to have been more dynamic than that of the villa landscape.

Differences in type and density of settlements, as well as in small finds, between the Dutch River Area and other regions in the province of *Germania Inferior* may well indicate different economic mechanisms and consumer choices. A next step would be to investigate other regions and explain these differences further. The present article has uncovered a market economy in the non-villa-landscape of the Dutch River Area. The same is true, however, for the villa landscapes of the rich loess soils. How then can the difference in settlement types between these regions be explained? Why did the farmers of the Dutch River Area purchase large amounts of portable commodities but not invest their money in stone buildings (villas)? Clearly

we should not overestimate the volume of surplus in the non-villa landscapes. Of the absolute volumes hardly anything is known; here only the proportion of the surplus in relation to the size of the population was quantified. Identifying more absolute volumes of rural production in different regions would be an important step forward.

m.groot@let.vu.nl
w.vos@hazenbergarcheologie.nl
s.heeren@hazenbergarcheologie.nl
kooistra@biax.nl

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