Research Article

Daan Raemaekers*, Özge Demirci, Safoora Kamjan, Taravat Talebi, Mans Schepers, Hans Huisman, Hans Peeters, Canan Çakırlar

Timing and Pace of Neolithisation in the Dutch Wetlands (c. 5000–3500 cal. BC)

<https://doi.org/10.1515/opar-2020-0157>

received December 18, 2020; accepted June 16, 2021

Abstract: This article presents an overview of the current evidence on the process of Neolithisation in the Dutch wetlands. Over the years, several models have been proposed with different perspectives on the timing and pace of the process: a long transition, an early short transition, and a late short transition. The applicability of any of these models is, of course, dependent of the evidence. In this article, we briefly discuss recently obtained data from the Netherlands on vegetation disturbance (woodland clearing), soil disturbance (tillage), cereal cultivation, animal husbandry, and the use of ceramics. The data discussed involve palynological, sedimentary, micromorphological, archaeobotanical, zooarchaeological, as well as lipid analyses. Hence, it is concluded that from the mid fifth millennium cal. BC onwards, various aspects of a more “Neolithic lifestyle” become apparent in the archaeological record, including cereal cultivation on a structural, but small-scale basis in wetland environments. However, despite the “gradual” tendency that can be observed, the evidence is as yet inconclusive with regard to any of the models, due to persisting limitations of the datasets, potential regional variability, and aspects of scale. A new project, *the Emergence of Domestic Animals in the Netherlands* (EDAN), aims at a better understanding of animal husbandry through aDNA and isotope analyses, within a framework of statistical chronological modelling. We expect this project to enhance the debate greatly.

Keywords: Neolithisation, Swifterbant culture, northwest Europe, animal husbandry, cereal cultivation

1 Introduction

The Dutch wetlands has a standing international reputation as an area where, first and foremost, the transition to farming took extraordinarily long and, second, this transition started prior to that of neighbouring areas in northwest Europe, e.g. the British Isles and southern Scandinavia (e.g. Cunliffe, 2008, pp. 127–130; Shennan, 2018, p. 152; Zvelebil & Rowley-Conwy, 1986): After the Early LBK farmers of central Europe settled the loess zone at c. 200 km from the Dutch wetlands from c. 5300 cal. BC onwards, a stable

Special Issue: THE EARLY NEOLITHIC OF EUROPE, edited by F. Borrell, I. Clemente, M. Cubas, J. J. Ibáñez, N. Mazzucco, A. Nieto-Espinet, M. Portillo, S. Valenzuela-Lamas, & X. Terradas

* **Corresponding author: Daan Raemaekers**, Groningen Institute of Archaeology, University of Groningen, Groningen, Netherlands, e-mail: d.c.m.raemaekers@rug.nl

Özge Demirci, Safoora Kamjan, Taravat Talebi, Hans Peeters, Canan Çakırlar: Groningen Institute of Archaeology, University of Groningen, Groningen, Netherlands

Mans Schepers: Centre for Landscape Studies, University of Groningen, Groningen, Netherlands

Hans Huisman: Groningen Institute of Archaeology, University of Groningen, Groningen, Netherlands; Dutch State Agency for Cultural Heritage, Amersfoort, Netherlands

zone of contact between farmers and hunter-gatherers emerged, where LBK perforated adzes testify to the contact networks that developed in the area (Raemaekers et al., 2011; Verhart, 2000, pp. 33–42; Verhart, 2012). From c. 5000 cal. BC, Swifterbant ceramics were produced at hunter-gatherer wetland sites (Peeters, 2010; Raemaekers, 2011). The first bones from domestic animals date to c. 4500 cal. BC (Oversteegen, van Wijngaarden-Bakker, Maliepaard, & Van Kofschoten, 2001), while cereals were cultivated from c. 4300 to 4000 cal. BC onwards (Cappers & Raemaekers, 2008; Out, 2008, Table 1; Van Zeist & Palfenier-Vegter, 1981). The precise starting date of cereal cultivation is as yet uncertain due to the plateau in the calibration curve and the absence of modern high-precision dates.

These developments, indicating a *model of long transition*, have been questioned and two competing models are now available. The *model of an early, short transition* is based on two arguments (Raemaekers, 2003). First of all, in later phases of the Dutch Neolithic (Hazendonk group, c. 3800–3600 cal. BC and Vlaardingen-Stein group, c. 3400–2800 cal. BC), sites with a high proportion of bones of domestic animals (and in the case of Vlaardingen-Stein: also ard marks) are found on the coastal dunes, while contemporaneous sites in various wetland environments can be interpreted as seasonally occupied camps or hunting stations and have no evidence of the presence of cultivated fields. Second, dunes from the fifth millennium cal. BC have not been preserved due to coastal erosion. If one proposes a similar functional differentiation between coastal dune sites and inland wetland sites in the fifth millennium (as proposed for later phases of the Dutch Neolithic; Louwe Kooijmans, 1993), it follows that *if* Neolithisation occurred earlier than previously thought, we would expect coastal dune sites to be more agrarian in character than the known inland wetland sites from this period. This model has been criticised (e.g. Amkreutz, 2013, pp. 407–412), arguing that the model is based on a threefold division of the mammal bones (wild, domestic, and pig), which masks the underlying variation and that this model places too much emphasis on models of settlement systems.

More recently a third model has been proposed. Rowley-Conwy (2014) questioned the evidence of pre-4000 cal. BC animal husbandry in the area. He stresses that the distinction between wild and domestic cattle and pig has only been based on the size of the bones, while research in other regions has made clear that this method needs to be accompanied by aDNA analysis (e.g. Scheu et al., 2008 on northern Germany). Furthermore, the use of context dates, instead of direct dates on the bones from domestic animals, leads him to question the age of the assemblages involved. Therefore, his critique results in a model of a *late and short transition*, contemporaneous to the transition on the British Isles and southern Scandinavia.

To test the three competing models, this article discusses the current knowledge on the transition to farming in the Dutch wetlands (Figure 1). Here, we focus on the evidence of cereal cultivation, animal husbandry, and the use of ceramics based on the pollen, soil micromorphology, botanical macroremains, zooarchaeological data, and lipids preserved in ceramics. This article encompasses the period from c. 5000 cal. BC (when pottery was first produced in a hunter-gatherer setting) to c. 3500 cal. BC, when coastal sites of the Hazendonk group present fully Neolithic contexts. We focus on those sites that provide the starting date of aspects of the transition to farming, or where these aspects can best be illustrated.

2 Vegetation Disturbance

Crop cultivation involves the disturbance of vegetation and notably the clearing of woodland. The date and pace of the clearing of the primeval vegetation can be studied with the pollen analysis. Several palynological studies are available for our case study area. Out (2009a, especially 273–276) provides the most recent overview, concluding that deforestation occurred on a small scale, where forest vegetation was replaced by shrubs. Bakker (2003) concluded that at Gietseveentje the first – small-scale – deforestation occurred c. 4050 cal. BC (Bakker, 2003, pp. 214–217). In later periods, deforestation continued and gained an impact on the natural vegetation. Currently, additional palynological research is carried out at six small lakes in Friesland and aims to determine whether the Gietseveentje date for the beginning of deforestation is of local or regional relevance. A synchronous but small-scale deforestation across a large area could imply relatively intensive contacts across that area in which knowledge and motivation to deforest were exchanged.

Figure 1: Northwest Europe, with the distribution of the Swifterbant culture and sites mentioned in the text. Based on Teetaert, 2020 (Figure by E. Bolhuis, University of Groningen).

A diachronous deforestation would in contrast suggest more autonomous local communities or haphazard modes of landscape use, with local motivations to start deforestation at a moment of their own choosing.

The palynological investigation of these six new sites in Friesland revealed the vegetation history over the past 8,000 years. The pollen analysis and ^{14}C dating of key samples show the dominance of a dense forest in this area until the Late Mesolithic (Figure 2). The pollen diagrams show that first deforestation occurred across a time depth of c. 4000 years. While the forest was partly cleared in cores FRCP, FRCP2-9, and FRCP2-10 from c. 6000–5300 cal. BC, the vegetation remained almost undisturbed elsewhere. We are

Figure 2: Overview of pollen analysis results of pingo scars from northern Netherlands. Based on Talebi, Raemaekers, Cappers, & Maurer, 2018a, 2018b, 2018c, 2019; Talebi, Raemaekers, Maurer, & Cappers, 2020; Talebi, Maurer, Raemaekers, & Cappers, 2021.

confident that wildfire was not the primary agent for the forest clearing in all the locations because the presence of charcoal in the pollen samples does not correlate with the first palynological evidence for forest opening – an observation also made by Bakker (2003, p. 214). In addition, this observation may indicate the use of other methods for forest clearing than burning.

The appearance of secondary anthropogenic indicators (*Artemisia* and *Polygonum aviculare*) before the first signal of deforestation in core TYP2 and, in contrast, a delayed appearance of anthropogenic indicators in core FRCP2-10 can be the signs of different practices at each location. Although the pollen signals of vegetation disturbance were continuously present in the TYP2 sequence from the Mesolithic onwards, the dense forest of the area was not opened until later in the Neolithic. The recorded small-scale, but continuous, vegetation disturbance can be the result of the repetitive visiting of the area, not for cultivation *per se*. The scale of vegetation modification can register differently as well. The absence of anthropogenic indicators in core FRCP2-10 can be due to the small-scale vegetation modification that could produce weak pollen signals. This should be interpreted as a human influence (localised and recurrent signals with limited effects on the environment) rather than human impact (localised or widespread sequence of perturbation with measurable effects) on the natural environment (compared with the studies by Peeters et al., 2017, p. 197). We assess the current pollen data as evidence of small-scale deforestation aimed to create small cultivated fields – horticulture rather than agriculture.

3 Cereal Cultivation

The issue of cereal cultivation in the context of the Swifterbant Culture and wetland environments in general has been a matter of debate for years (e.g., Cappers & Raemaekers, 2008; Out, 2009a, p. 179; 2009b; Schepers, 2014, pp. 98–99). Out (2008, especially Table 2 therein) summarizes the main arguments to support or reject local crop cultivation. Her arguments include non-botanical archaeological phenomena, such as tillage marks and stone tools associated with cereal harvesting. The main issue with this perspective is that it represents an interpretive framework inspired on a full-blown agricultural context and avoiding mosaic-like wetlands that are considered less “optimal” nowadays. The archaeobotanical record does, however, provide ample evidence for the use of cultigens in wetland areas as of c. 4300 cal. BC. As yet, there is no evidence for this before this date (compared with the studies by Brinkkemper, Hogestijn, Peeters, Visser, & Whitton, 1999), with the intriguing exception of the Belgian Swifterbant site of Bazel-Sluis, where the presence of cereal grains, dated to c. 4850 cal. BC, has been interpreted as evidence for contact with neighbouring farming groups (Meylemans et al., 2018). A comparable interpretation was previously forwarded for the presence of cereal grains at the site of Swifterbant-S3 (Van Zeist & Palfenier-Vegter, 1981), but now, micromorphological evidence attests to local cultivation. Below, we review these lines of evidence – soil micromorphology and botanical macroremains – in further detail.

4 Arable Fields

Crop cultivation obviously involves the disturbance of soils. It is, however, far from straightforward to identify this in soil structures, notably by means of soil micromorphology (e.g., Carter & Davidson, 1998, 2000; Lewis, 2012; Macphail, 1998). Nonetheless, micromorphology is a powerful tool to interpret soil structures when integrated into a clearly defined archaeological and geo-biological contextual framework (Deak, Gebhardt, Lewis, Usai, & Lee, 2017). The first indications for local crop cultivation derived from micromorphological observations at the site of Swifterbant S2 in 2004, notably the presence of a layer consisting of variably sized and rounded aggregates (“clods”) of soil material embedded in homogeneous massive clay. Disturbance due to cultivation activities was considered a possible explanation, alongside trampling and rooting pigs (Huisman, Jongmans, & Raemaekers, 2009).

Subsequent fieldwork at Swifterbant S4 yielded unequivocal macroscopic evidence for cultivation in the form of a more or less regular pattern of sizable and well-delineated dark-grey humic clods, mixed with light-grey clay (Figure 3). It is probable that this pattern of phenomena results from the use of a hoe-like tool, suggesting the cultivation of relatively small-scale fields. Thanks to these observations, similar traces were identified in the documentation of neighbouring and contemporaneous sites S3 and S2 (Huisman & Raemaekers, 2014; Raemaekers & De Roever, 2020), excavated earlier.

Figure 3: The cultivated fields from S4 (top) and S2 (bottom) (after Huisman & Raemaekers 2014, Figure 4 and Raemaekers & De Roever, 2020, Figure 10.1).

Micromorphological analysis at Swifterbant S4 made it further possible to characterise the microscopic sedimentary manifestations of this particular type of cultivation in an alluvial floodplain environment. At this site, at least five discrete horizons with evidence of tillage could be identified, separated by midden and clay deposits (Huisman *et al.*, 2009). Moreover, features observed earlier in samples from the S2 site could now also be positively related to tillage (Huisman & Raemaekers, 2014). It has become clear that the site histories of S2 and S4 involve a complex alternation of cultivation and occupation, with evidence of cultivation both predating and postdating the use of these sites as settlements, and even intercalated between settlement phases.

It is important to note that none of these excavations were aimed at identifying cultivated fields. Rather, the goal was to excavate and research the archaeological settlement sites to which the fields are spatially and temporally connected. It is also important to realise that the tilled horizons are not only part of the archaeological settlement deposits proper but also that they extend into the overlying and underlying deposits. Taking this into account, we must ask ourselves how it is possible that, without looking for it, all three excavations on levees in the Swifterbant area uncovered horizons with evidence for tillage. The most logical explanation is that tilled horizons are a common feature on the levees in this river system and that crop cultivation therefore was a structural component of human land management and subsistence during this period. The Swifterbant cultivated fields indicate that river levees are important landscape zones for the study of the introduction of agriculture. These traces of arable farming preserved in the soil may be regarded to provide conclusive evidence for local farming on at least some of the Swifterbant sites.

5 Cereals

Next to the evidence for local arable fields, is the evidence for local cultivation provided by botanical macroremains. We centre our arguments around two key sites: “twin” sites Swifterbant S3/S4, and

Schipluiden and focus on the most abundantly available type of evidence: cereals. The Swifterbant sites were separated by a small creek, but probably functioned as a single settlement (Raemaekers & De Roever, 2020). Both Swifterbant S3/S4 and Schipluiden can be considered wetland sites, where marine influences are considerably more prominent at Schipluiden, especially in its early phases (Kubiak-Martens, 2006). The marine influence on the more inland located S3/S4 river system was negligible throughout its habitation (Schepers, 2014, pp. 94–95; Van Zeist & Palfenier-Vegter, 1981). The main crops available at these two, and basically all Neolithic Dutch wetland sites, are emmer wheat and six-row naked barley (Out, 2008). At both sites, cereal grains and chaff from both species were encountered, as well as cereal pollen and potential arable weeds (Figure 4).

Figure 4: Excavation at Swifterbant-S2 (2004). Top: spits of 50 cm × 50 cm × 5 cm were used as units of analysis. Bottom: the clay matrix was wet sieved using a mesh size of 2 mm with the aim to collect cereal grains from all spits (photo's University of Groningen/Groningen Institute of Archaeology).

A gradually increasing importance of emmer wheat with time can be observed at Swifterbant S3/S4 (Schepers & Bottema-Mac Gillavry, 2020). We interpret this trend as a reaction to subtle local environmental changes. An important message to take from the considerable variation in the ratio between these two crop plants is a continuous “crop awareness” throughout time. The crop selection process was characterized by a noteworthy degree of adaptability in response to changing local conditions. The rise in emmer wheat, clustering in specific strata, argues against an explanation of this phenomenon as a simple variation in crop performance over time. Changing habits of importation, an alternative hypothesis recently put forward by Raemaekers and De Roever (2020), seem unlikely. Bogaard (2008) already argues that most of the potential arable weeds encountered at Swifterbant S3/S4 are generalist species and should thus not be given too much importance as an argument supporting local crop cultivation. Recent vegetation analyses, however, have shown that it is not just the individual potential arable weed species that are of interest (see also Out, 2008, 2009), but rather *the combination of species* encountered that point toward arable weed vegetation (Schepers *et al.*, 2013; Schepers, 2014). Apart from the crop selection process, the lack of any other convincing botanical food imports at Swifterbant S3/S4 can finally be put forward as an additional argument for a society that was able to acquire or grow virtually all of its food sources locally. When these lines of reasoning are brought together, we propose small scale yet structural cultivation of emmer wheat and barley, in varying ratios, from c. 4300 cal. BC onwards.

At Schipluiden (3630–3380 cal. BC), a gradual transition from saline-brackish to fresh-water conditions went alongside increasing relative importance of emmer wheat as compared to barley (Kubiak-Martens, 2006). Barley is known to be the dominant crop in wet, coastal environments (Brinkkemper & Van Haaster, 2010; Out, 2008). Since both crops were well established at the time, this shift cannot be explained as “getting to know a new crop.” A correlation between changing local environmental conditions and crop species encountered can in itself be considered an argument for local cultivation. For Schipluiden, this was already suggested by Out (2008, p. 135, 2009, p. 421). With the recent Swifterbant S4 results in mind, which were not available at the time, it could be more explicitly acknowledged as a stronger argument than the emmer wheat vs barley ratio in itself. In Out’s valuable overview table of evidence for local crop cultivation (Out, 2008, p. 134 [Table 2]) for example, this argument is not included.

6 Animal Husbandry

Another aspect of the Neolithisation process involves animal husbandry, notably the domestication of bovines (*Bos*) and suids (*Sus*). Aurochs and wild boar are common in the area in the Early and Mid Holocene (Prummel & Niekus, 2011; Prummel, Niekus, Van Gijn, & Cappers, 2002; Zeiler & Brinkhuizen, 2015). Until recently, zooarchaeologists have been using individual specimen size as *the* criterion to determine the domestic status of large bovine and suid bones in fifth and fourth millennium BC assemblages (e.g., Kranenburg & Prummel, 2020; Zeiler, 1997). Archaeologists would then use the relative abundance of claimed domesticates as a measure of the relative importance of domestic animals and the contribution of animal husbandry to subsistence (Dusseldorp & Amkreutz, 2020; Raemaekers, 2003).

In pre-4400 cal. BC, assemblages of the Lower Rhine-Meuse area *Bos* are scarce and large (Louwe Kooijmans, 2003; Oversteegen *et al.*, 2001). The few domestic-sized *Bos* are represented by worked bone, not kitchen waste (Oversteegen *et al.*, 2001). Most *Sus* are large-bodied, large-toothed, suggesting a single wild population. Mortality data are in agreement with this suggestion (Çakırlar, Breider, Koolstra, Cohen, & Raemaekers, 2020). In the mid-fifth millennium BC, represented by a small assemblage from Brandwijk-het Kerkhof, *Sus* become somewhat smaller, or rather, smaller individuals start appearing (Çakırlar *et al.*, 2020). In the later part of this sequence, sheep or goat bones turn up in archaeological deposits at Hardinxveld-Giessendam De Bruin (Phase 3, c. 4500 cal. BC). These are very scarce in terms of relative and absolute numbers, but re-analysis and direct dates indicate that the Swifterbant people had access to sheep (and possibly goat) as early as mid-fifth millennium cal. BC (Çakırlar *et al.*, 2020).

In the Swifterbant area, the 4300–4000 cal. BC settlements contain higher ratios of morphologically domesticated cattle, pig, and sheep remains than in previous periods (Kranenburg & Prummel, 2020;

Raemaekers, 2003; Zeiler, 1997). *Sus* remains numerically important. An analysis of the mtDNA haplotypes in *Sus* remains from S4 allocates all probed specimens to European maternal lineages, finding no Near Eastern maternal ancestry (Kranenburg & Prummel, 2020; Krause-Kyora et al., 2013). The analysis of mtDNA alone cannot tell whether this is a result of the significant introgression of the Near Eastern pigs and rapid turnover of European lineages (Frantz et al., 2019).

Only after 4000 cal. BC, animal husbandry becomes a major activity in the Rhine-Meuse delta (Louwe Kooijmans & Jongste, 2006), manifested by high proportions of morphologically domesticated cattle (42% of the number of fragments in Schipluiden) in mammal assemblages (Zeiler, 2006) and mortality data, suggesting a sophisticated cattle husbandry, in which animals were managed for both meat and milk production (Kamjan, Gillis, Çakırlar, & Raemaekers, 2020). Stable carbon and oxygen isotope analysis of cattle tooth enamel reveal that calving seasons lasted approximately five and a half months; they were manipulated through foddering and regulated mating. This corroborates the inference that milk production was an important aspect of cattle farming at Schipluiden (Kamjan et al., 2020). The stable carbon and nitrogen isotopic ratios in bone collagen suggest that cattle mainly grazed at the salt marsh and the beach plain near the dune, where C_3 plants were abundant. Some cattle were fed with fodder from woodlands or grazed in these woodlands to maintain the herd during cold seasons (Kamjan et al., 2020). When these and other faunal stable isotopic data are used as a baseline for published human palaeodietary data from Schipluiden (Smits & Van der Plicht, 2009), it is possible to demonstrate the substantial contribution of cattle protein (meat and milk) to the human diet at the site. Collating these results indicates a high level of investment in cattle husbandry, highlighting the social and economic importance of cattle in Schipluiden. This, together with the special attention paid to cattle body disposition, reveals a new form of human–cattle relationship in the Rhine-Meuse Delta (Kamjan et al., 2020).

7 Use of Ceramics

Pottery is suitable to investigate the impact of cereal cultivation and animal husbandry in the diet, provided that pots were used as cooking vessels and that a change in diet is mirrored in these vessels. To this end, lipid residues of 111 vessels from seven Swifterbant sites were analysed (Figure 5) using gas chromatography-mass spectrometry (GC-MS) and gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS) to identify the content of the residues absorbed into the ceramics.

The lipid residue analyses of pottery from the sites of Hardinxveld-Giessendam Polderweg, Hardinxveld-Giessendam De Bruin, Brandwijk-het Kerkhof, and Hazendonk in the lower Rhine-Meuse area covering a time

Figure 5: GC-C-IRMS results showing isotopic values of $C_{16:0}$ and $C_{18:0}$ fatty acids of Swifterbant pottery collected from only ceramic matrices. 95% confidence ellipses indicate areas of authentic reference values for each group of origins from western Baltic.

span of c. 5000–3820 cal. BC showed that pottery was primarily used for the processing of freshwater fish throughout this long time period. In addition to the continuous exploitation of freshwater resources, the processing of ruminant foodstuff (domestic and/or wild) becomes an important part of pottery use in mid-fifth millennium BC, at De Bruin. The evidence for ruminant fat processing is replaced completely by the processing of porcine foodstuff (i.e., wild boar/pig) by the late fifth millennium BC, as evidenced in the Brandwijk and Hazendonk assemblages. Finally, the analyses demonstrate the first direct evidence for the processing of dairy products in Swifterbant pottery at Brandwijk c. 4100 cal. BC, albeit in small numbers (Demirci, Lucquin, Çakırlar, Craig, & Raemaekers, 2021).

The lipid residue analysis of pottery from three Swifterbant type sites S2, S3, and S4 (c. 4300–4000 cal. BC) also provided clear evidence for processing aquatic resources, almost exclusively freshwater fish (Demirci, Lucquin, Craig, & Raemaekers, 2020). Ruminant and dairy fats were absent in these pots, suggesting a specialised pottery use in these three sites. SEM analysis of a different set of vessels from S3 provided evidence for the plants processed in Swifterbant type sites. Noteworthy is the frequent presence of emmer wheat (Raemaekers, Kubiak-Martens, & Oudemans, 2013). It is proposed that the introduction of cereals at these sites correlates with a change in pottery characteristics (Raemaekers, 2015).

Although the analyses from Swifterbant and the Rhine-Meuse area sites suggest that freshwater fish processing was the main function of Swifterbant pottery, it is clear that there is a regional variation. As zooarchaeological and archaeobotanical records present a continuous exploitation of similar and diversified faunal/floral resources in all Swifterbant sites (see above), this kind of regional difference in the use of Swifterbant pottery suggest different culinary practices and cultural preferences on food preparation and consumption within the Swifterbant culture.

8 Conclusion

Recent fieldwork and post-excavation analyses, as well as revisiting legacy data from fifth to fourth millennium sites in Dutch wetlands “added flesh to the bones”: while the dominant/prevaling narrative of Neolithisation in the Dutch wetlands was based on the absence/presence of cereal remains and the proportion of bones from morphologically domesticated animals, we are now able to describe the developments in the period between 5000 and 3500 cal. BC in unprecedented detail (Table 1). Beginning c. 5000 cal. BC,

Table 1: Overview of the characteristics of ceramic use, animal husbandry, and cereal cultivation in the area of the Swifterbant culture

Cal. BC	Ceramic use	Animal husbandry	Cultivation
4000	Unknown	RM: cattle for milk and meat, fodder RM: some pig and sheep/goat	RM: emmer and barley Cultivation on structural basis
4300	SW: fish, some porcine, emmer wheat RM: fish, some porcine, one dairy	SW: small pigs with boar mtDNA SW/RM: some small cattle SW/RM: few sheep/goat	Friesland: small-scale deforestation SW: fields SW/RM: emmer and barley Cultivation on a structural basis
4500	RM: fish, some ruminants, one dairy	RM: pigs decrease in size RM: some small cattle, only worked bone RM: some sheep/goat	No evidence for cultivation
5000	RM: fish	Only wild animals	No evidence for cultivation
	No ceramics	Only wild animals	No evidence for cultivation

SW = Swifterbant area; RM: Rhine-Meuse area.

pottery in Swifterbant style is produced by hunter-gatherers. They use these ceramics to process food, of which freshwater fish was the primary ingredient.

From c. 4500 cal. BC we also have evidence for the processing of ruminant foodstuff in the pots and perhaps the first use of dairy products. While the plant component of the subsistence package apparently did not change, this period did yield the first bones from domestic animals. One directly dated sheep/goat bone is the clearest find, but sheep/goat remains of very limited importance throughout the period under study. Some worked bones from relatively small cattle might be from domestic animals as well, while the size of pig bones decreases.

From c. 4300 cal. BC, the use of pottery changes again. Ruminant fats are no longer found, but porcine fat now becomes visible in the food processing in pots. One pot with dairy fats testifies to the use of dairy products at this time. Noteworthy is that dairy fats were not found in the pots from the Swifterbant area, implying regional variation in pottery use or underlining the limited availability of dairy in this time in general. This period sees the start of cereal cultivation as well. It concerns small plots – horticulture – of emmer and barley. The plots were worked with a hoe. The number of fields identified at Swifterbant and the recurrent presence of cereal remains at all sites from this period indicate that cereal cultivation was a structural, small-scale aspect of the subsistence base.

In the centuries after 4000 cal. BC, we currently lack lipid analysis, but the zooarchaeological analyses strongly suggest that dairy fats are to be expected. At this stage, the importance of cattle exceeds that of the pig. Cattle were kept for milk and meat and were grazing but some were also fed fodder. Cereal cultivation in this period is based on the same crops, but we lack data to discuss the importance of this activity for the diet.

How to relate these processes to the three models presented in the introduction? One may propose that the data fit the traditional *model of long transition* very well. During a period of one millennium, we see the slow transformation of the subsistence base from hunting and gathering to one in which farmers focussed on cattle and made structural use of cereal cultivation. The *model of an early, short transition* would continue to stress that we lack coastal sites from the fifth millennium, an interpretation based on the unknown character of unknown sites. The advocates of the *model of a late, short transition* would stress the need to understand the zooarchaeological data from this period. The problem of scale, rather than origins, will be even more difficult to investigate.

A new project funded by the Dutch Research Council NWO (2020–2022), *the Emergence of Domestic Animals in the Netherlands (EDAN)*, re-considers the zooarchaeological evidence using old assemblages dating between 5000 and 3500 cal. BC, using a combination of high-resolution modelling of direct radio-carbon dates on morphologically distinct specimens, whole-genome ancient DNA analysis, and palaeodiet and mobility analyses using stable isotope analysis. This project will refine the chronological resolution and nature of the events and processes that led to the full-fledged establishment of animal husbandry in the Dutch wetlands. We expect this project to enhance the debate greatly.

Conflict of interest: The authors state no conflict interest.

References

- Amkreutz, L. W. S. W. (2013). *Persistent traditions. A long-term perspective on communities in the process of Neolithisation in the lower Rhine area (5500–2500 cal BC)*. Leiden: Sidestone Press.
- Bakker, R. (2003). *The emergence of agriculture on the Drenthe plateau*. Groningen: University of Groningen.
- Bogaard, A. (2008). Comment on R. T. J. Cappers & D. C. M. Raemaekers: Cereal cultivation at Swifterbant? Neolithic wetland farming on the north European plain. *Current Anthropology*, 49, 394–395.
- Brinkkemper, O., Hogestijn, W. J., Peeters, H., Visser, D., & Whitton, C. (1999). The early Neolithic site at Hoge Vaart, Almere, the Netherlands, with particular reference to non-diffusion of crop plants, and the significance of site function and sample location. *Vegetation History and Archaeobotany*, 8, 79–86.

- Brinkkemper, O., & Van Haaster, H. (2010). *Delfts groen. Archeobotanisch onderzoek aan Delft-Voordijkshoornse polder, een nederzetting uit 1075–1150 (=BIAxiaal 430)*. Zaandam: BIA Consult.
- Çakırlar, C., Breider, R., Koolstra, F., Cohen, K. M., & Raemaekers, D. C. M. (2020). Dealing with domestic animals in the fifth millennium cal BC Dutch wetlands: New insights from old Swifterbant assemblages. In K. J. Gron, L. Sorensen, & P. Rowley-Conwy (Eds.), *Farmers at the frontier: A pan European perspective on Neolithisation* (pp. 263–287). Oxford: Oxbow.
- Cappers, R. T. J., & Raemaekers, D. C. M. (2008). Cereal cultivation at Swifterbant? Neolithic wetland farming on the north European plain. *Current Anthropology*, 49, 385–402.
- Carter, S. P., & Davidson, D. A. (1998). An evaluation of the contribution of soil micromorphology to the study of ancient arable agriculture. *Geoarchaeology*, 13(6), 535–547.
- Carter, S. P., & Davidson, D. A. (2000). A reply to Macphail's comments on "An evaluation of the contribution of soil micromorphology to the study of ancient arable agriculture." *Geoarchaeology*, 15(5), 499–502.
- Cunliffe, B. (2008). *Europe between the oceans. 9000 BC – AD 1000*. Yale: Yale University Press.
- Demirci, Ö., Lucquin, A., Craig, O. E., & Raemaekers, D. C. M. (2020). First lipid residue analysis of Early Neolithic pottery from Swifterbant (the Netherlands, ca. 4300–4000 BC). *Archaeological and Anthropological Sciences*, 12(5), 105.
- Demirci, O., Lucquin, A., Çakırlar, C., Craig, O. E., & Raemaekers, D. C. M. (2021). Lipid residue analysis on Swifterbant pottery (c. 5000–3800 cal BC) in the Lower Rhine-Meuse area (the Netherlands) and its implications for human-animal interactions in relation to the Neolithisation process. *Journal of Archaeological Science: Reports*, 36, 105. [102812]. <https://doi.org/10.1016/j.jasrep.2021.102812>.
- Deak, J., Gebhardt, A., Lewis, H., Usai, M. R., & Lee, H. (2017). Soils disturbed by vegetation clearance and tillage. In C. Nicosia & G. Stoops (Eds.), *Archaeological soil and sediment micromorphology* (pp. 233–264). Hoboken: Wiley Blackwell.
- Dusseldorp, G. L., & Amkreutz, L. W. (2020). A long slow goodbye—Re-examining the Mesolithic–Neolithic transition (5500–2500 BCE) in the Dutch delta. *Analecta Praehistorica Leidensia*, 50, 121–142.
- Frantz, L. A., Haile, J., Lin, A. T., Scheu, A., Geoerg, C., Benecke, N., & Battista, V. M. (2019). Ancient pigs reveal a near-complete genomic turnover following their introduction to Europe. *Proceedings of the National Academy of Sciences of the United States of America*, 116(35), 14610–14611.
- Huisman, D. J., Jongmans, A. G., & Raemaekers, D. C. M. (2009). Investigating early Neolithic land use in Swifterbant (NL) using micromorphological techniques. *Catena*, 78(3), 185–197.
- Huisman, D. J., & Raemaekers, D. C. M. (2014). Systematic cultivation of the Swifterbant wetlands (The Netherlands). Evidence from Neolithic tillage marks (c. 4300–4000 cal. BC). *Journal of Archaeological Science*, 49, 572–584. doi: 10.1016/j.jas.2014.05.018.
- Kamjan, S., Gillis, R. E., Çakırlar, C., & Raemaekers, D. C. M. (2020). Specialized cattle farming in the Neolithic Rhine-Meuse Delta: Results from zooarchaeological and stable isotope ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$) analyses. *PLoS One*, 15(10), e0240464. doi: 10.1371/journal.pone.0240464.
- Kranenburg, H., & Prummel, W. (2020). The use of domestic and wild animals. In D. C. M. Raemaekers & J. P. de Roever (Eds.), *Swifterbant S4 (the Netherlands): Occupation and exploitation of a Neolithic levee site (c. 4300–4000 cal. BC)* (Groningen Archaeological Studies, 36, pp. 36–76). Groningen/Eelde: Barkuis.
- Krause-Kyora, B., Makarewicz, C., Evin, A., Flink, L. G., Dobney, K., Larson, G., ... Nebel, A. (2013). Use of domesticated pigs by Mesolithic hunter-gatherers in northwestern Europe. *Nature communications*, 4(1), 1–7.
- Kubiak-Martens, L. (2006). Botanical remains and plant food subsistence. In L. P. Louwe Kooijmans & P. F. B. Jongste (Eds.), *Schipluiden. A Neolithic settlement on the Dutch North Sea Coast, c. 3500 cal BC* (pp. 317–338). Leiden: Leiden University.
- Lewis, H. (2012). *Investigating ancient tillage an experimental and soil micromorphological study*. Oxford: BAR publishing.
- Louwe Kooijmans, L. P. (1993). Wetland exploitation and upland relations of prehistoric communities in the Netherlands. In J. Gardiner (Ed.), *Flatlands & wetlands. Current themes in east Anglian archaeology* (pp. 71–116). Norwich: Scole Archaeological Committee for East Anglia.
- Louwe Kooijmans, L. P. (2003). The Hardinxveld sites in the Rhine/Meuse delta, the Netherlands, 5500–4500 cal BC. In L. Larsson, H. Kindgren, K. Knutsson, D. Loeffler, & A. Åkerlund (Eds.), *Mesolithic on the move. Papers presented at the sixth international conference on the Mesolithic in Europe, Stockholm 2000* (pp. 608–624). Oxford: Oxbow Books.
- Louwe Kooijmans, L. P., & Jongste, P. F. B. (Eds.). (2006). *Schipluiden, a Neolithic settlement on the Dutch North Sea Coast c. 3500 cal BC*. Leiden: Leiden University.
- Macphail, A. I. (1998). A reply to Carter and Davidson's "An evaluation of the contribution of soil micromorphology to the study of ancient arable agriculture". *Geoarchaeology*, 13(6), 549–564.
- Meylemans, E., Bastiaens, J., Boudin, M., Deforce, K., Erynck, A., Perdaen, Y., & Crombé, P. (2018). The oldest cereals in the coversand area along the North Sea Coast of NW Europe, between ca. 4800 and 3500 cal BC, at the wetland site of 'Bazel-Sluis'. *Journal of Anthropological Archaeology*, 49, 1–7.
- Oversteegen, J. F. S., van Wijngaarden-Bakker, L. H., Maliepaard, R., & Van Kopschoten, T. (2001). Zoogdieren, vogels en reptielen. In L. P. Louwe Kooijmans (Ed.), *Archeologie in de Betuweroute. Hardinxveld-Giessendam Polderweg. Een Mesolithisch jachtkamp in het riviereengebied (5500–5000 v. Chr.)* (Rapportages Archeologisch Monumentenzorg, 88, pp. 209–297). Amersfoort: Rijksdienst voor het Oudheidkundig Bodemonderzoek.
- Out, W. A. (2008). Growing habits: Delayed introduction of crop cultivation at marginal Neolithic wetland sites. *Vegetation History and Archaeobotany*, 17, 131–138.

- Out, W. A. (2009a). *Sowing the seed? Human impact and plant subsistence in Dutch wetlands during the late Mesolithic and middle Neolithic (5500–4300 cal BC)*. Leiden: Leiden University.
- Out, W. A. (2009b). Reaction to “cereal cultivation at Swifterbant? Neolithic wetland farming on the north European plain.” *Current Anthropology*, 50, 253–254.
- Peeters, H. (2010). Early Swifterbant pottery from Hoge Vaart-A27 (Almere, the Netherlands). In B. Vanmontfort, L. Amkreutz, L. P. Louwe Kooijmans, & L. Verhart (Eds.), *Early pottery traditions in the lower Rhine area* (pp. 151–160). Leiden: Leiden University Press.
- Peeters, J. H. M., Raemaekers, D. C. M., Devriendt, I. I. J. A. L. M., Hoebe, P. W., Niekus, M. J. L. Th., Nobles, G. R., & Schepers, M. (2017). *Paradise lost? Insights into the early prehistory of the Netherlands from development-led archaeology* (Nederlandse archeologische rapporten, 62). Amersfoort: Rijksdienst Voor Het Cultureel Erfgoed.
- Prummel, W., & Niekus, M. J. L. T. (2011). Late Mesolithic hunting of a small female aurochs in the valley of the River Tjonger (the Netherlands) in the light of Mesolithic aurochs hunting in NW Europe. *Journal of Archaeological Science*, 38(7), 1456–1467.
- Prummel, W., Niekus, M. J. L. T., Van Gijn, A. L., & Cappers, R. T. J. (2002). A Late Mesolithic kill site of aurochs at Jardinga, Netherlands. *Antiquity*, 76(292), 413–424.
- Raemaekers, D. C. M. (2003). Cutting a long story short? The process of neolithization in the Dutch delta re-examined. *Antiquity*, 77, 780–789.
- Raemaekers, D. C. M. (2011). Early Swifterbant pottery (5000–4600 BC): Research history, age, characteristics and the introduction of pottery. *Berichte Römisch-Germanische Kommission*, 89, 485–500.
- Raemaekers, D. C. M. (2015). Rethinking Swifterbant S3 ceramic variability. Searching for the transition to TRB before 4000 calBC. In J. Kabaciński, S. Hartz, D. Raemaekers, & T. Terberger (Eds.), *The Dąbki site in Pomerania and the Neolithisation of the north European Lowlands (c. 5000–3000 calBC)* (pp. 321–334). Rahden: Verlag Marie Leidorf.
- Raemaekers, D. C. M., Geuverink, J., Schepers, M., Tuin, B. P., Van de Lagemaat, E., & Van der Wal, M. (2011). *A biography in stone. Typology, age, function and meaning of early Neolithic perforated wedges in the Netherlands* (Groningen Archaeological Studies, 14). Groningen/Eelde: Barkhuis.
- Raemaekers, D. C. M., Kubiak-Martens, L., & Oudemans, T. F. M. (2013). New food in old pots – charred organic residues in early Neolithic ceramic vessels from Swifterbant, the Netherlands (4300–4000 cal. BC). *Archäologisches Korrespondenzblatt*, 43(3), 315–334.
- Raemaekers, D. C. M., & De Roeve, J. P. (2020). Conclusions. In D. C. M. Raemaekers & J. P. De Roeve (Eds.), *Swifterbant S4. Neolithic occupation and cultivation in the Dutch wetlands* (Groningen Archaeological Studies, 36, pp. 107–113). Groningen/Eelde: Barkhuis.
- Rowley-Conwy, P. (2014). Foragers and farmers in Mesolithic/Neolithic Europe, 5500–3900 cal BC: Beyond the anthropological comfort zone. In F. W. F. Foulds, H. C. Drinkall, A. R. Perri, D. T. G. Clinnick, & J. W. P. Walker (Eds.), *Wild things: Recent advances in Palaeolithic and Mesolithic research* (pp. 185–201). Oxford: Oxbow Books.
- Schepers, M. (2014). Wet, wealthy worlds: The environment of the Swifterbant river system during the Neolithic occupation (4300–4000 cal BC). *Journal of Archaeology in the Low Countries*, 5, 79–105.
- Schepers, M., & Bottema-Mac Gillavry, N. (2020). Vegetation and exploitation of plant resources. In D. C. M. Raemaekers & J. P. De Roeve (Eds.), *Swifterbant S4. Neolithic occupation and cultivation in the Dutch wetlands* (Groningen Archaeological Studies, 36, pp. 51–75). Groningen/Eelde: Barkhuis.
- Schepers, M., Scheepens, J. F., Cappers, R. T. J., Van Tongeren, O. F. R., Raemaekers, D. C. M., & Bekker, R. M. (2013). An objective method based on assemblages of subfossil plant macro-remains to reconstruct past natural vegetation: A case study at Swifterbant, The Netherlands. *Vegetation History and Archaeobotany*, 22, 243–255.
- Scheu, A., Hartz, S., Schmölcke, U., Tresset, A., Burger, J., & Bollongio, R. (2008). Ancient DNA provides no evidence for independent domestication of cattle in Mesolithic Rosenhof, Northern Germany. *Journal of Archaeological Science*, 35, 1257–1264.
- Shennan, S. (2018). *The first farmers of Europe. An evolutionary perspective*. Cambridge: Cambridge University Press.
- Smits, L., & Van der Plicht, H. (2009). Mesolithic and Neolithic human remains in the Netherlands: Physical anthropological and stable isotope investigations. *Journal of Archaeology in the Low Countries*, 1(1), 55–85.
- Talebi, T., Raemaekers, D. C. M., Cappers, R. T. J., & Maurer, A. (2018a). *Palynologisch onderzoek aan een pingo-ruïne bij Oosterwold (OTJ02 - gemeente Ooststellingwerf; provincie Friesland)* (Grondsporen, 33). Groningen: Groningen University.
- Talebi, T., Raemaekers, D. C. M., Cappers, R. T. J., & Maurer, A. (2018b). *Palynologisch onderzoek aan de pingo-ruïne TYP2 (Burgum; gemeente Tytsjerksteradiel; provincie Friesland)* (Grondsporen, 39). Groningen: Groningen University.
- Talebi, T., Raemaekers, D. C. M., Cappers, R. T. J., & Maurer, A. (2018c). *Palynologisch onderzoek aan de pingo-ruïne TYPI2 in De Centrale As (gemeente Tytsjerksteradiel; provincie Friesland)* (Grondsporen, 47). Groningen: Groningen University.
- Talebi, T., Raemaekers, D. C. M., Cappers, R. T. J., & Maurer, A. (2019). *Palynologisch onderzoek aan de pingo-ruïne FRCP2-10 (Hurdegaryp, gemeente Tytsjerksteradiel, provincie Friesland)* (Grondsporen, 51). Groningen: Groningen University.
- Talebi, T., Maurer, A., Raemaekers, D., & Cappers, R. (2021). *Palynologisch onderzoek aan de pingo-ruïne FRCAP2 (Quatrebras; gemeente Tytsjerksteradiel; provincie Fryslân)* (Grondsporen, 65). Groningen: Groningen University.
- Talebi, T., Raemaekers, D., Maurer, A., & Cappers, R. (2020). *Palynologisch onderzoek aan de pingo-ruïne FRCP (Burgum; gemeente Tytsjerksteradiel; provincie Friesland)* (Grondsporen, 64). Groningen: Groningen University.

- Teetaert, D. (2020). *Routes of technology: Pottery production and mobility during the Mesolithic-Neolithic transition in the Scheldt river valley (Belgium)*. Ghent: Universiteit Gent: Faculteit Letteren en Wijsbegeerte.
- Van Zeist, W., & Palfenier-Vegter, R. M. (1981). Seeds and fruits from the Swifterbant S3 site. Final Reports on Swifterbant IV, *Palaeohistoria*, 23, 105–168.
- Verhart, L. B. M. (2000). *Times fade away. The neolithization of the southern Netherlands in an anthropological and geographical perspective* (Archaeological Series Leiden University, 6). Leiden: Leiden University.
- Verhart, L. B. M. (2012). Contact in stone: Adzes, Keile and Spitzhauen in the Lower Rhine Basin. Neolithic stone tools and the transition from Mesolithic to Neolithic in Belgium and the Netherlands, 5300–4000 cal BC. *Journal of Archaeology in the Low Countries*, 4, 5–35.
- Zeiler, J. T. (1997). *Hunting, fowling and stock-breeding at Neolithic sites in the western and central Netherlands*. Groningen: ArchaeoBone.
- Zeiler, J. (2006). Mammals. In L. P. Louwe Kooijmans & P. F. B. Jongste (Eds.), *Schipluiden, a Neolithic settlement on the Dutch North Sea Coast c. 3500 cal BC* (Analecta Praehistorica Leidensia, 37/38, pp. 375–420). Leiden: Leiden University.
- Zeiler, J. T., & Brinkhuizen, D. C. (2015). Fauna. In J. M. Moree & M. M. Sier, (Eds.), *Interdisciplinary archaeological research programme Maasvlakte 2, Rotterdam. Part 1 twenty metres deep! The Mesolithic period at the Yangtze Harbour Site – Rotterdam Maasvlakte, the Netherlands. Early Holocene landscape development and habitation* (BOOR-rapporten, 566, pp. 201–221). Rotterdam: Bureau Oudheidkunding Onderzoek.
- Zvelebil, M., & P. Rowley-Conwy. (1986). Foragers and farmers in Atlantic Europe. In M. Zvelebil (Ed.), *Hunters in transition. Mesolithic societies of temperate Eurasia and their transition to farming* (pp. 67–93). Cambridge: Cambridge University Press.