SOLE SURVIVORS: USING TREE-TRUNK WELLS FROM ARCHAEOLOGICAL EXCAVATIONS TO INFORM RECONSTRUCTIONS OF MEDIEVAL DEFORESTATION, AND FUTURE REFORESTATION

BERT GROENEWOUDT[1,2*], MENNE KOSIAN[1]

[1]Cultural Heritage Agency of the Netherlands, Smallepad 5, 3811 MG Amersfoort, The Netherlands
[2]University of Groningen - Centre for Landscape Studies, P.O. Box 72, 9700 AB Groningen, The Netherlands
[*]Corresponding author email: b.groenewoudt@cultureelerfgoed.nl

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ABSTRACT

This paper represents an attempt at a detailed analysis of woodland presence and dynamics during the Middle Ages (AD 500-1500), as a contribution to the current debate on large-scale reforestation in the Netherlands. Palynological data for this particular period are scarce and allow only global reconstructions. To widen our search for historical woodland proxies, we investigated the potential of archaeologically excavated tree-trunk wells. We carried out a nation-wide inventory of this type of well, in which the shaft is formed by hollowed-out tree trunks, typically large oak trees. Our suspicion that such trees indicate the local presence of (old) woodland in the past was confirmed by a marked positive correlation with spatial reconstructions based on other sources of information: archaeological (charcoal kilns) and non-archaeological (place names and historical references). The observed correlations suggest that mapping the distribution of precisely dated tree-trunk wells can indeed contribute to achieving fairly detailed reconstructions of medieval woodland cover.

Keywords: Middle Ages, woodland cover, deforestation, proxy data, landscape archaeology, tree-trunk wells

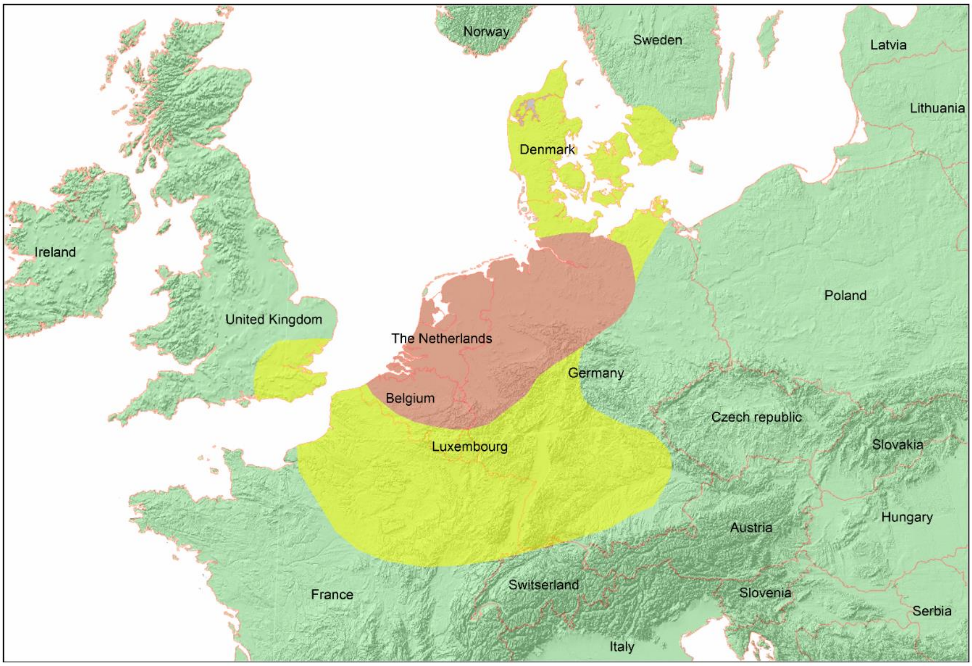
INTRODUCTION AND PROBLEM DEFINITION

Plans to expand the present woodland cover are at present being developed all over the world, with climate ambitions (carbon capture, climate adaptation), sustainable development and the preservation of biodiversity among the arguments being cited (UN, 2019; Di Sacco *et al.,* 2021). As part of the current debate on large-scale reforestation in the Netherlands (LNV, 2020), we set out to achieve a more detailed understanding of the presence and dynamics of woodland in the Dutch landscape during the medieval period (AD 500-1500) (Fig. 1).

Fig. 1: Research area - The Netherlands. Dark green: low-lying areas (peat, clay); light green: higher, predominantly sandy areas; yellow: coastal dunes

The main question is one of location: where to create new woodland? Suggested locations include those where woodland persisted for a long time; but how to find them? Woodland in the Netherlands has been mapped on a nation-wide scale and in detail only since about 1850. By then the deforestation of the nation was almost complete (Van der Meulen, 2003), a state which in fact had existed since *c.* 1650 (Dirkx, 1998; Groenewoudt, 2012). The presence of former woodland may be derived from historical sources. Generally speaking, the most commonly used tool for reconstructing historical vegetation patterns is pollen data, but due to unfavourable preservation conditions and a lack of research, palynological data for the period after *c.* AD 1000 are scarce. Moreover, the currently available large-scale reconstructions based on pollen data (e.g. Kaplan *et al.*, 2009, 2017; Zanon *et al.*, 2018) are insufficiently detailed to be useful for our purpose. We considered using the Dutch soil classification system (De Bakker & Schelling, 1966) to map soil types of which the name hints at the (former) presence of woodland. However, it soon became clear that a discrepancy exists between the spatial distribution of these soil types and that of the woodland-related place names associated with them (Eijgenraam, 2021). Another potential research venue, charting the 'potential natural vegetation' (PNV), likewise proved to be impractical while the concept is also debatable from a methodological point of view (Chiarucci *et al*., 2010), and its use would not add to the existing information on the actual presence of woodland at any specific moment in the past. Fortunately, there are still other options to explore. Recently we were able to demonstrate that a combination of the distributions of woodland-related place names and historical woodland references may yield important information on the presence and dynamics of woodland in the Dutch landscape during the medieval and early modern periods (AD 750-1650) (Eijgenraam *et al*., 2022; Groenewoudt *et al*., 2022).

Fig. 2: Indicative distribution map of medieval tree-trunk wells in north-western Europe. Brown: high density; light green: (probable) lower density



Extending our search for historical woodland proxies even further, we also explored the potential of archaeological data. Particularly in the last two decades the number of archaeological excavations in the Netherlands has greatly increased, resulting not only in a deluge of new archaeological data but also in distribution patterns that are more representative geographically.

TREE-TRUNK WELLS

Our research focussed on the most promising archaeological structures in terms of type (i.e. likely to be woodland-related), frequency (i.e. common), and spatial distribution (i.e. widespread). Earlier, we investigated archaeological remains relating to charcoal production (charcoal kilns), which led to the conclusion that such features are indicative of the former presence of woodland (Groenewoudt, 2007; Groenewoudt & Spek, 2016). In the present study we specifically looked at so-called tree-trunk wells: water wells made of hollowed-out tree trunks (German *Baum(stamm)brunnen/Baumstamm-Röhrenbrunnen*, French *puit à tronc évidé*). As far as we are aware, this is the first time this type of archaeological feature has been systematically studied from a landscape-historical perspective. To validate our results, we first looked at possible spatial-temporal patterns in the distribution and chronology of charcoal production sites (Deforce *et al.*, 2020). Next, we compared the results of our analysis with spatial reconstructions of the medieval distribution of woodland which draw on non-archaeological sources, specifically place names and historical sources (Groenewoudt *et al.*, 2022).

Wells made of large hollowed-out tree trunks are known in Europe from the Neolithic period onwards (e.g. Bernard *et al.*, 2008; Tegel *et al.*, 2012; Rybníček *et al.*, 2018), but in our research area this type of well first became common and widespread after *c*. AD 500 (Fischer, 2008). Outside the Netherlands, medieval tree-trunk wells are also known from Belgium (De Bruyne *et al*., 2013), Germany (e.g. Zoller, 1964; Zimmermann, 1992; Hopp, 2016), Denmark (e.g. Terkildsen & Andreasen, 2014), southern Sweden (Melin, 2011), north-eastern France (Peytremann & Tegel, 2007), and England (one specimen in London: Burch *et al*., 2011) (Fig. 2). In Bulgaria, such wells were (still) used in modern times (Zimmermann, 1992) (Fig. 3); the upper rim of these Bulgarian wells stood proud of the surface to about knee-high. This was also the case in 14th-century Germany, as a number of medieval manuscripts suggest (Zimmermann, 1992). In north-eastern France, the most recent tree-trunk wells appear to be 12th century in date (Georges-Leroy, 1995; Peytremann & Tegel, 2007).

Tree-trunk wells are constructed by splitting a tree trunk segment into two or more sections and hollowing them out before rejoining them into a large tube, which is then lowered into a deep pit and driven further down until below groundwater level. The trees, virtually always oak, tend to be very large in cross-section; diameters of one metre or more are fairly common, which would make these trees one or two centuries old. Often only one trunk segment is used but occasionally two or even three have been stacked or telescoped (Fig. 4). The selected trees tend to be straight, without side branches. Usually only the trunk section below the groundwater table has been preserved (Fig. 5).

Fig. 3: In Bulgaria, well shafts lined with hollowed-out tree trunks were (still) in use in the modern period; the trees protruded above the surface (after Zimmermann 1992, Fig. 236)

Fig. 4: Reconstruction of a tree-trunk well lining made by stacking two hollowed-out trunk sections (after Hiddink, 2008; Fig. 7.12)

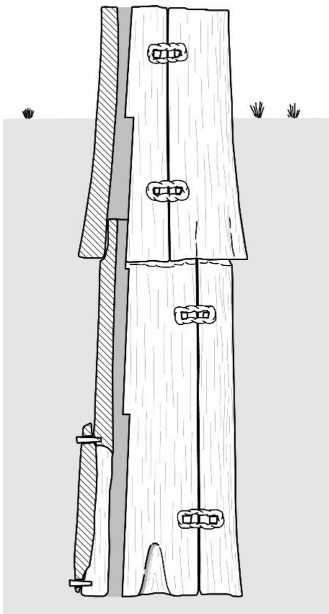


Fig. 5: Remains of a tree-trunk well shaft from the medieval settlement site Cothen-De Kamp, dating to the period AD 1150 to 1225. This oak was 115cm in diameter, suggesting that the tree was at least 150 years old (after Kramer, 2015; Fig. 94)

Trees from vanished woodland?

The general assumption is that tree-trunk wells ceased to be used in the Netherlands in the 13th century, and that their disappearance was associated with a growing scarcity of suitable trees (e.g. Groothedde, 1996; Verspay, 2007; Stoepker, 2015). Although there is no direct evidence for this assumption, the fact that tree-trunk wells stopped being constructed just when water wells with a turf or sod lining first made their appearance seems no coincidence. Significant from a woodland-historical perspective is the observation that most of the trees selected for the wells were not only large but – as said before - also straight and without side branches. This suggests that they grew in dense forest rather than in wood pasture or in isolation.

Equally relevant is the observation that in the early Middle Ages (AD 500-1000) at least parts of the Netherlands were still forested (Buis, 1985). Especially between AD 1000 and 1300, however, these forests rapidly disappeared as a result of large-scale reclamations (Van der Linden 1982; Thoen & Soens 2015) and over-exploitation (Buis, 1985; Dirkx ,1998). As a result, high-quality timber, particularly oak, quickly became scarce (e.g. Deforce, 2017). As early as the 13th and 14th century, the expanding Dutch towns had to resort to imported construction timber (Domínguez-Delmás & Van den Berselaar, 2009), although timber in the east initially still came from nearby regions (Weststrate, 2008). In the southern Netherlands, timber shortages became a serious problem in the 15th century. In the north, this happened in the 16th century (Buis, 1985). By *c.* AD 1650 nearly all woodland was gone.

METHODS AND DATA

Our inventory of tree-trunk wells was based solely on archaeological sources, mainly excavation reports. The inventory could be completed fairly quickly, since most tree-trunk wells were excavated within the last twenty years or so. Most of the resulting reports are accessible online and easily searchable. Excavation reports are published via *DANS-EDNA*, the e-depot for Dutch archaeology[1] and most of the relevant archaeo- and palaeobotanical reports could be easily traced and consulted online as well.[2]

For every well the wood type, date, and outer diameter of the trunk, and the depth of the well shaft were recorded, in addition to administrative information. Not every consulted report contained all information. If only an inner diameter was reported, the outer diameter was reconstructed by adding 0.15 m, or twice the diameter of the average well shaft (*c*. 0.075m). Furthermore, 0.20 m was added to all registered well depths to account for the minimum depth to which the former surface would have been eroded away due to later activities. Reconstructed depths do not account for the possibility that tree-trunk wells may have protruded above the surface (Fig. 3).

Tree-trunk wells can be dated by various methods: archaeologically (i.e. stratigraphy, objects from the infill), dendrochronological (or tree-ring) analysis, and radiocarbon dating or ^{14}C. The chronological span of a (medieval) ^{14}C date is often as wide as that produced by archaeological methods. Tree-ring dates tend to be the most precise, especially since the trees are likely to have been used within a few years after they were cut; bark is present on many of them. Moreover, oak is much easier to process in a fresh state than dried. Unfortunately many attempts to obtain a tree-ring date were unsuccessful, not only because the number of remaining growth rings from a hollowed-out trunk was insufficient (see below). Archaeologically obtained dates are often imprecise and moreover often date the (end of the) use life of a well, not its construction. Some wells appear to have been used for a long time; quite often the archaeological date of a tree-trunk well post-dates its tree-ring date by a century or more. In such cases the tree-ring date was recorded as being the most reliable.

Tree-trunk well dates were subdivided in five phases: A = AD 400-600, B = 600-800, C = 800-1000, D = 1000-1200, and E = 1200-1400. If a well's date range fell within two consecutive phases, the well was assigned to the phase that corresponded to the largest section of its range. Wells for which tree-ring dates were available were also classified by century.

We have mapped the data on a national scale. GIS software was used to model the spatial distribution of tree-trunk wells. This was visualised by showing the magnitude of distribution density in variations of colour intensity with the goal of suggesting spatial clusters. They do not necessarily have a uniform quantitative basis. We call these visualizations indicative distribution maps.

Source criticism and preliminary remarks

So the question is whether data on the distribution and chronology of tree-trunk wells can be a source of information on the presence of woodland in (in this case) the medieval landscape and on the process of deforestation. The use of tall trees, specimen with a large diameter, may even be indicative of woodland containing many old trees, i.e. woodland which was (at that time) extensively used. Most medieval woodland, however, was intensively exploited in various ways (e.g. Rackham, 1980; Peterken ,1993; Szabó *et al.*,

[1] https://doi.org/10.17026%2Fdans-xk5-n3me
[2] https://www.biax.nl/rapporten

2015). Oak trees likely to produce suitable timber were usually cut long before reaching the diameter observed in tree-trunk wells (e.g. Heneca *et al*., 2005; Aberth, 2012, 111). Timber diameters of 0.25-0.50m were most common by far (Knol *et al*., 1996, 298; Épaud, 2019)

Some comments as to the importance of validation are in order here. Firstly, a distribution pattern is also a reflection of regional variation in the intensity of archaeological activity. Secondly, since most of the trees in tree-trunk wells are oak, an analysis of tree-trunk wells has a bearing only on types of woodland that contain (much) oak. Such woodland was largely limited to higher ground. Especially the (mostly secondary) forests still to be found in the Middle Ages on the Pleistocene sandy soils were largely composed of oak (Groenewoudt & Spek, 2016). A local absence of tree-trunk wells may therefore mean that woodland no longer (or never) existed there.

The third comment concerns cultural aspects. Even if suitable trees were present, we must not automatically assume that people were also permitted to use them. During the later Middle Ages, many forests were subject to strict limitations as to which trees could be cut when and by whom (Buis, 1985). To what extent such regulations were actually enforced is difficult to establish.

Preference may also have played a role here in that otherwise suitable trees were simply never selected. Tree-trunk wells may have been customary in some places but not in others. The presence of alternatives such as barrels or casks may have been another factor, particularly in settlements close to important transport routes (Van Lanen *et al*., 2016). To summarize: the presence of tree-trunk wells is likely to be more instructive than their absence.

The fundamental question, however, is whether or not our assumption that the used trees were cut locally is correct. We believe that it is. As stated above, many of the growth-ring series match with others from the same site or locally but not with any of the available regional reference sequences. This seems to reflect local environmental conditions. Furthermore, given the size of these tree trunks and the modest means of the small rural settlements in which they occur, overland transportation over long distances seems highly unlikely; most timber was transported by water (Van Lanen *et al*., 2016). Settlements located near waterways may therefore form an exception to the rule. Even so, although most of the timber identified at early medieval Dorestad seems to have come from the German Rhineland, the origins of the wood from the Dorestad tree-trunk wells are as yet unknown (Jansma & Van Lanen, 2016). The most promising way forward for identifying the origins of timber on a regional scale, especially in problematic cases such as this, is to combine dendrochronological information with DNA analysis (Akhmetzyanov *et al*., 2020).

RESULTS AND DISCUSSION

General

The inventory identified 642 tree-trunk wells, from 173 different settlement excavations. The actual numbers will probably not be very much higher. The number of wells per site varies considerably. At present the highest number of wells identified at a single site is forty-eight (Dijkstra, 2015). At some sites tree-trunk wells are the predominant well type; at others, including contemporary sites, the range of construction methods is more diverse.

Of the 642 wells, 627 could be assigned to a particular phase. The date range of the remaining wells was too wide to be narrowed down to one specific phase.

The recorded diameters of the wells range from 0.30 to 1.52 m, the majority measuring 0.70 to 1.10 m across (Fig. 6). Registered depths vary from 0.75 to 7.40 m, with 2-3 m being the most common. In almost every case where identification was possible the wood turned out to be oak. Other tree species were rare (2 x beech, 1 x poplar, 1 x ash).

Fig. 6: Diameter distribution (cm) of medieval trees that were used to construct tree-trunk wells (n=397)

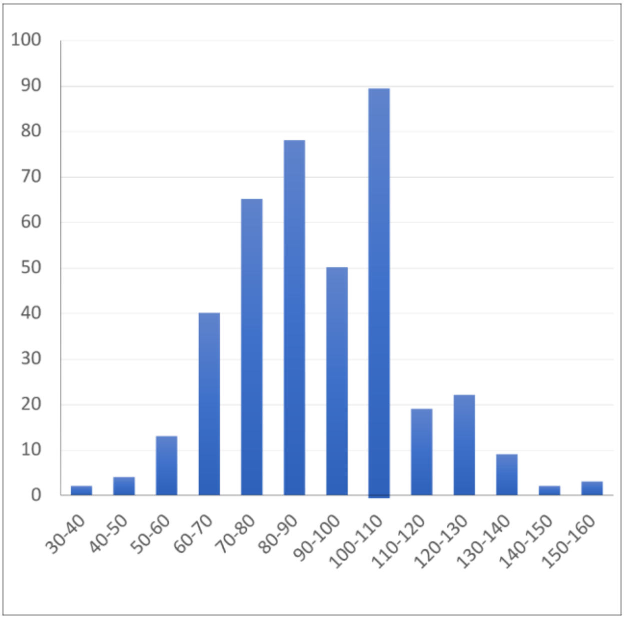


Fig. 7: Number of inventoried medieval tree-trunk wells (n= 627) per chronological phase. A: AD 400-600; B: AD 600-800; C: AD 800-1000; D: AD 1000-1200; E: AD 1200-1400

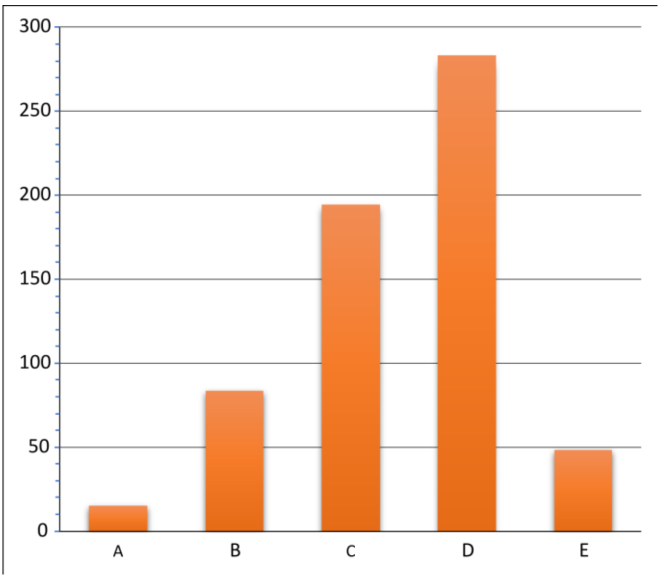
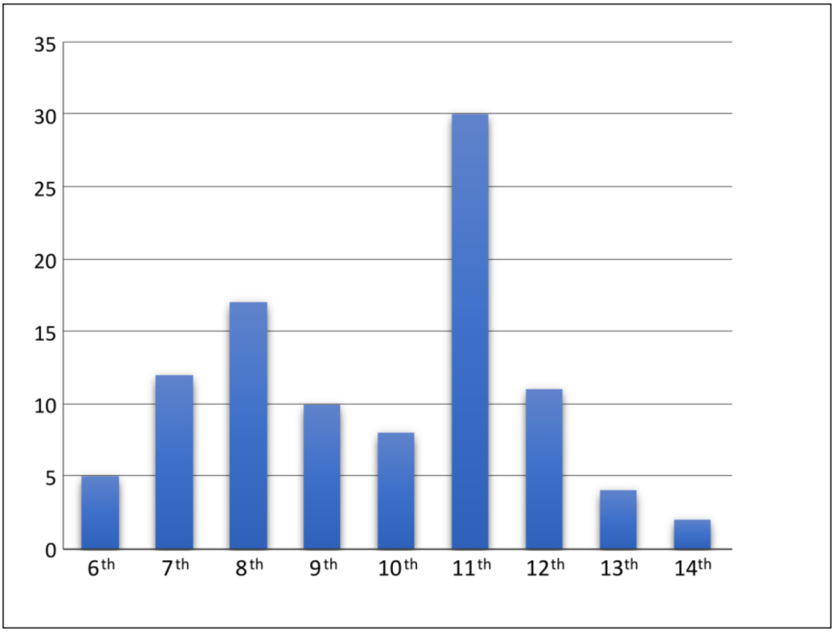


Fig. 8: Number of precisely dated (dendrochronology) tree-trunk wells per century (n=99)



Chronological patterns

In our research area tree-trunk wells occurred from the 5-6th to the 14-15th century. Tree-ring dates range from AD 524 to AD 1351-1352. This means that this type of well was used langer than what was previously thought (13th century). However, tree-trunk wells post-dating AD 1300 are rare. There are slightly more high medieval tree-trunk wells (N=325) than there are early medieval ones (N=309), but when the difference in length of the two periods (early medieval: AD 500-1000; high medieval: AD 1000-*c*.1300) is taken into account the high medieval period clearly dominates. A steep increase in the number of tree-trunk wells through time up to the period AD 1000-1200 (an increase which may be linked to a corresponding sharp increase in the number of settlements) is followed by an abrupt decrease (Fig. 7). Tree-trunk wells that are dated precisely (i.e. by dendrochronology) show a similar increase, but also a temporary decrease in the 9-10th century which is hard to explain (Fig. 8). The number of settlements in this period certainly did not decrease.

While tree-trunk wells dominate in some settlements, other sites – both early and high medieval – are characterized by a range of different well constructions which may or may not include the tree trunk type. In urban settlements, tree-trunk wells seem to disappear earlier than in rural areas. This may be due to the fact that the surroundings of towns soon became extensively deforested (Deforce, 2017). As already mentioned, the local availability of alternatives can also play a role.

Fig. 9: Distribution map of all medieval settlement sites (n=173) where medieval (AD c. 500-1300) tree-trunk wells have been documented (n=642). Large dots represent multiple settlements. Some settlements have produced only one well, others several or even dozens

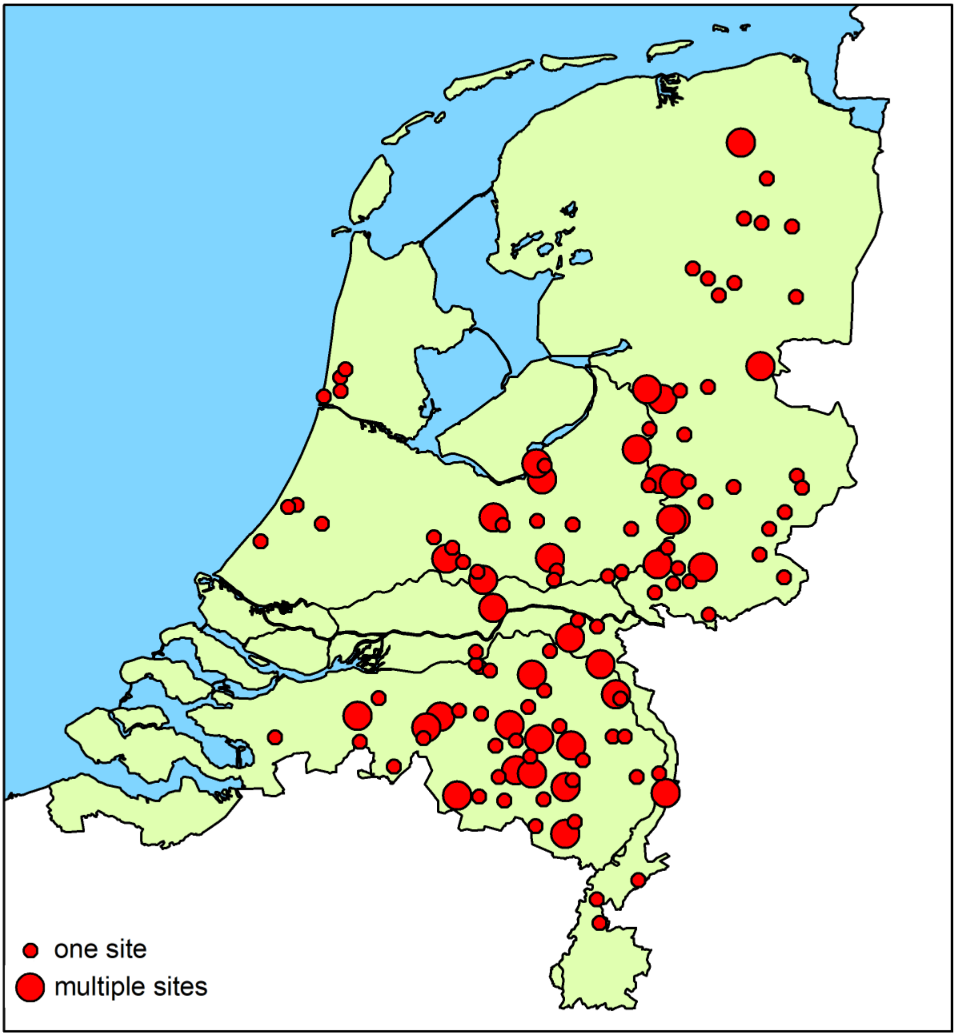
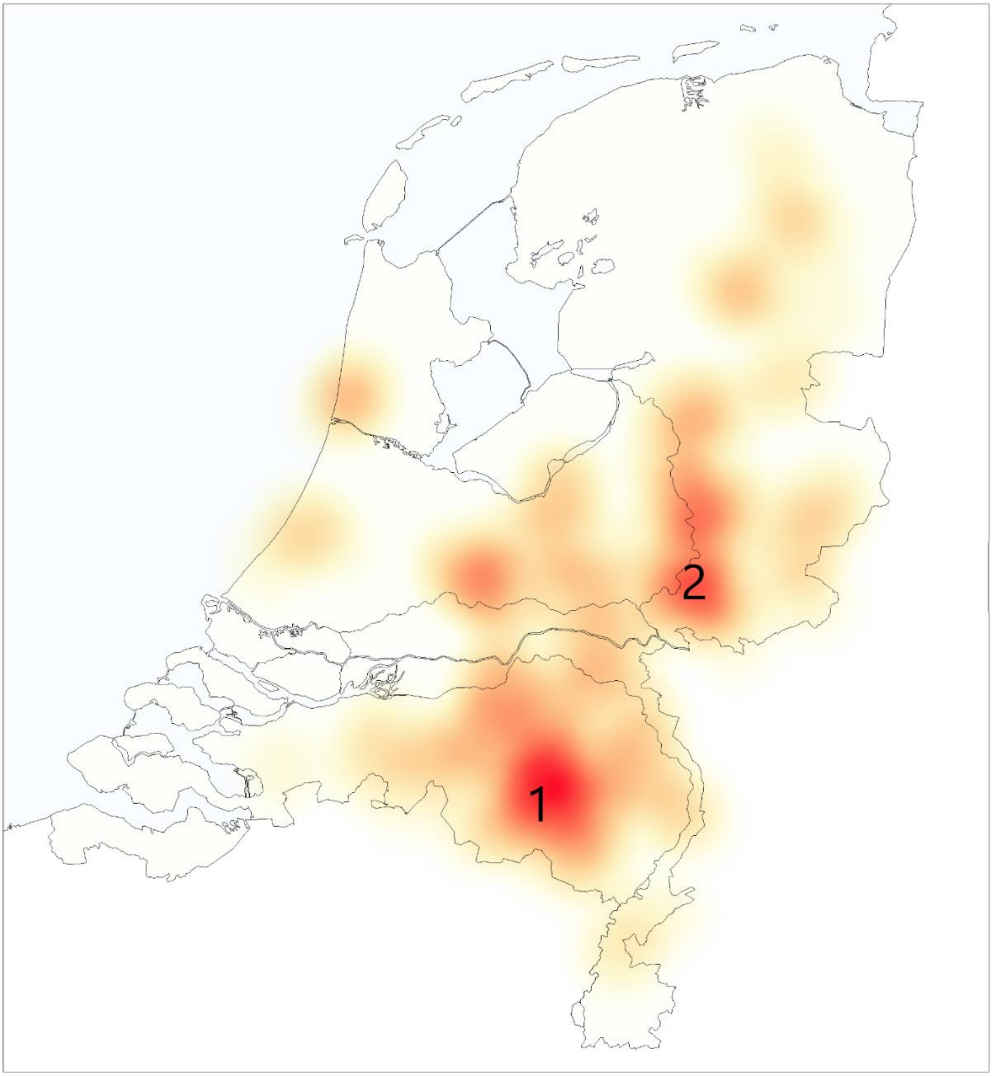


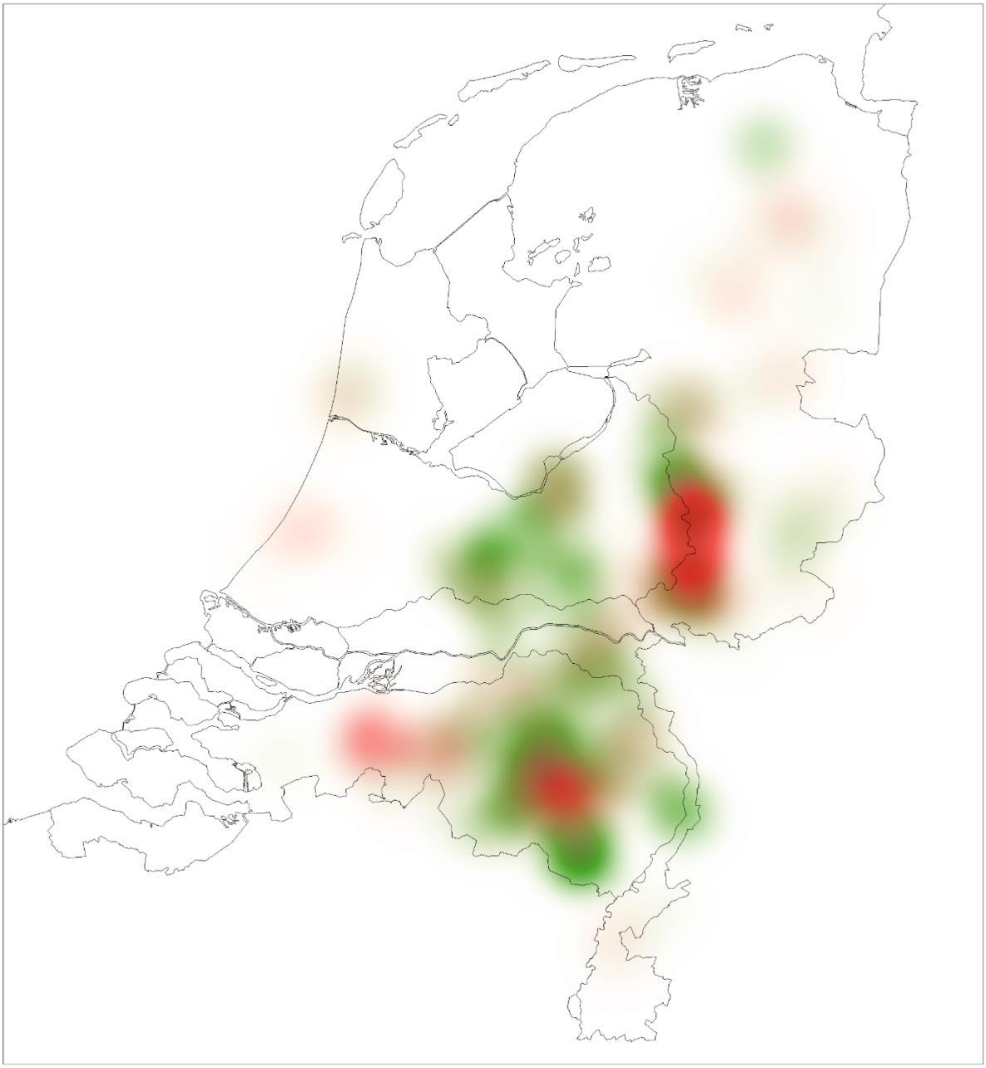
Fig. 10: Indicative distribution map of excavated medieval settlements with tree-trunk wells (n=173) (5/6th-14/15th Century). The most important clusters are numbered; these are discussed in the text



Spatial patterns

Tree-trunk wells are widespread in the Netherlands but there are nonetheless significant regional differences. This is apparent from the distribution map of the settlements where such wells were excavated (Fig. 9), but even more so when the density variation is modelled (Fig. 10). Two major clusters can be identified, one in the south, in the east of the province of Noord-Brabant (cluster 1), and a second cluster further to the north-east, in the IJssel valley and the nearby western part of the Achterhoek region (cluster 2). These are also the areas where tree-trunk wells with the largest diameters concentrate (>1.00 m). Smaller site clusters appear elsewhere, such as on the edge of the Veluwe area in the centre of the Netherlands. The coastal lowlands in the west and north as well as sections of the inland Pleistocene sandy soils further east are empty by comparison. In the west, and certainly in the province of Noord-Holland, this gap in the distribution of tree-trunk wells has been explained as resulting from the fact that the local landscape at the time was virtually treeless (De Koning, 2016), and also from the very high groundwater table which made complex well constructions redundant. The exact opposite was the case in the Veluwe area. There, groundwater levels are so low that digging a well is rarely an option.

Fig. 11: Combined indicative distribution maps of early medieval (AD 500-1000; red (n=92)) and high medieval (AD 1000-*c.* 1300; green (n=122)) settlements with tree-trunk wells



Modelling the density variation chronologically also reveals differences between the early and high medieval periods (Fig. 11). The main difference is a contraction of the area in which tree-trunk wells were used, specifically the north-east (province of Drenthe) and the western coastal area. Cluster 1, in the south, also seems to be significantly shrinking after AD 1000, particularly in the west. Cluster 1 coincides exactly with an area that was largely deforested in the Roman period, followed by substantial forest regeneration in the period AD *c*. 250-550 (Meures-Balke & Kalis, 2005; Van Haaster, 2018; Theuws, 2011) and subsequent reclamation in the course of the medieval period. Archaeological and historical evidence for this is complemented by the area's place-name 'landscape' (see below). Incidentally, the high medieval distribution pattern, both in the south (cluster 1) and in the Veluwe area, also seems to reflect settlement expansion. Cluster 2 in part encompasses an area which remained fairly densely forested until well into the Middle Ages (Slicher van Bath, 1944, 121; Groenewoudt & Keunen, 2008) and which has also produced some indications for local forest regeneration in de period AD *c*. 0-700 (Groenewoudt, 2006).

VALIDATION

In this section we will discuss the relation between these distribution patterns and others derived from other, established sources of woodland-historical information, followed by an assessment of the significance of tree-trunk well studies as a source of information on woodland history, and of the level of detail they can provide.

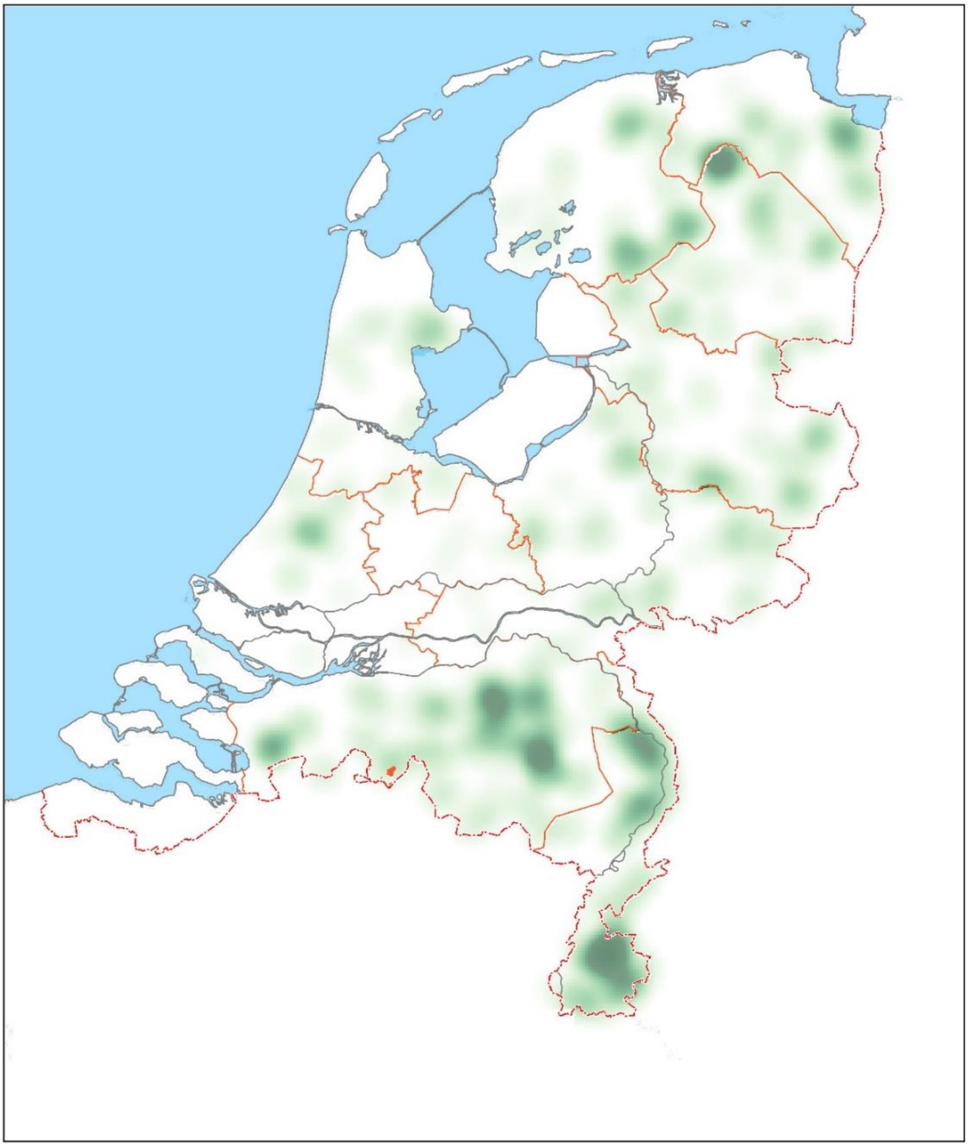
Charcoal production

Charcoal burning is a woodland craft (e.g. Rackham, 1980; Nelle, 2003; Bond, 2007; Ludemann, 2010; Warren *et al*., 2012; Raab *et al*., 2015), which means that archaeological remains of charcoal kilns point to the local presence of woodland in the past (Foard, 2001; Warren *et al*., 2012; Groenewoudt & Spek, 2016; Deforce, 2021). In the Netherlands pit kilns are the most wide-spread archaeological manifestations of medieval charcoal production. The most recent dates for this type of charcoal kiln (Deforce *et al*., 2020) coincide with the most recent dates for tree-trunk wells. Pit kilns mostly cluster in two regions, an eastern cluster (mainly 7th-9th century) in the west of the Achterhoek region, and a less clearly defined southern cluster (11th-13/14th century) in the east of the province of Noord-Brabant (Deforce *et al*., 2020, Fig. 8; Groenewoudt *et al*., 2023: Fig. 4). These two clusters roughly correspond to the core areas for the distribution of tree-trunk wells (clusters 1 en 2). At present there are far fewer archaeologically attested medieval charcoal production sites than there are settlements with tree-trunk wells, and the resulting distribution pattern is therefore likely to be less representative. Nonetheless, the fact that the clusters are mostly limited to southern and eastern inland areas on the map probably reflects the actual situation.

Place names and historical references

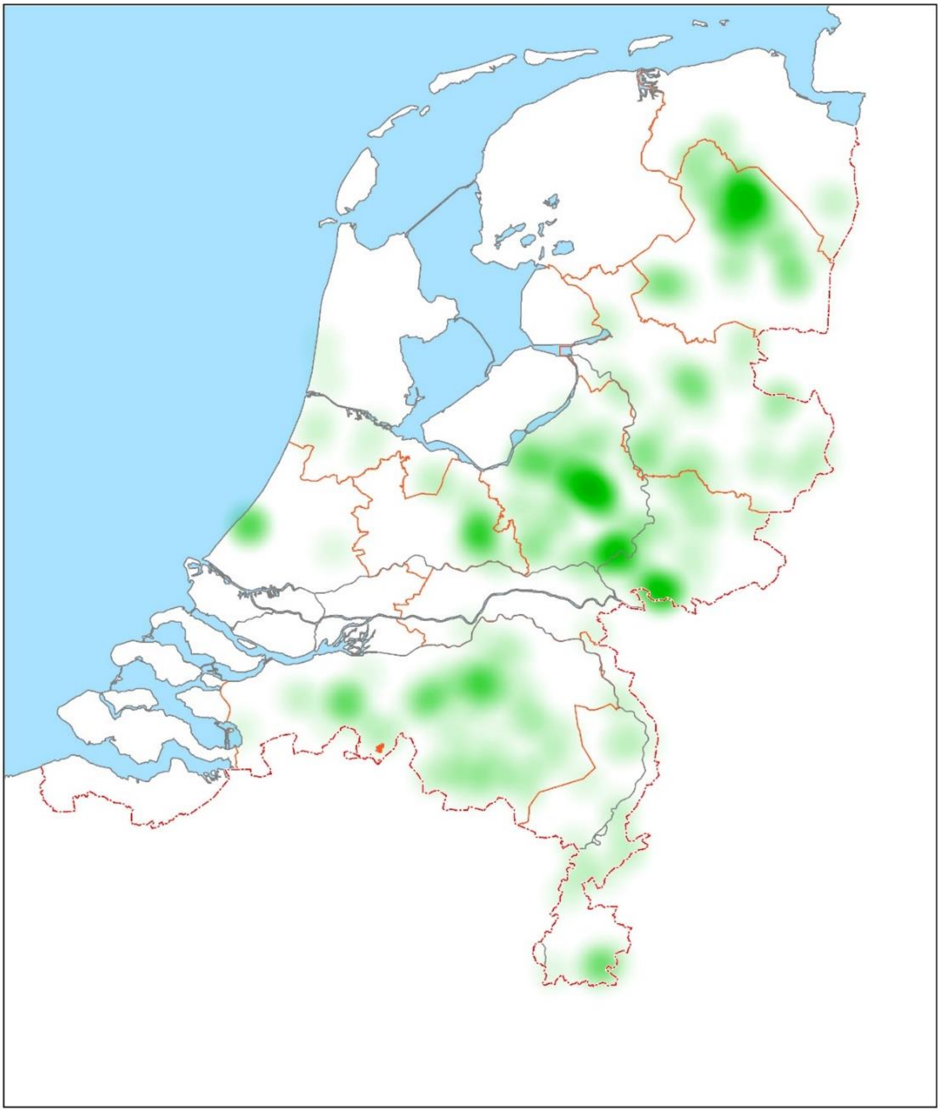
Toponym studies are also a promising venue for landscape-historical research. Many toponyms and especially place names refer to the local landscape and its exploitation by humans (see for instance Ter Laak, 2005; Higham & Ryan, 2011; Paulissen, 2018). About 10 % of the 6284 still existing Dutch place names originating in the period AD *c*. 500/1000-1500 (Künzel *et al*., 1988; Van Berkel & Samplonius, 2006), refer to the presence of woodland (Eijgenraam, 2021). However, it should be noted that the establishment of settlements in many cases will have resulted in deforestation. In fact, the woodland may already have disappeared some time before that, at least partially. In that case the woodland toponym first referred to existing woodland before continuing as a field name, which then became the name of the settlement established at that location. So presumably woodland-related place name data refer mainly to the situation before AD 1000.

Fig. 12: indicative distribution map of settlements with names referring to (the presence of) woodland. After Eijgenraam 2021



The distribution map of woodland-related place names shows a dense cluster which matches tree-trunk well cluster 1 (Fig. 12) but not the other well clusters. More detailed and comprehensive historical and toponymic studies, however (Slicher van Bath, 1944, 177-180; Slicher van Bath, 1949, 121) do bear out the presence of a forested landscape in the area of cluster 2. Combination with our data further suggests that tree-trunk wells are uncommon in specific areas where woodland was already relatively scarce in the medieval period (Drenthe and Twente regions). Also in these low-density areas this does not exclude variation at the local level. In a few settlements in the Drenthe region, tree-trunk wells were dominant until the 12th century, but in others, already in early Middle Ages wells were constructed differently. This may reflect local differences in the presence (or rather survival) of woodland, but it may also have other causes (see above).

Fig. 13: Indicative distribution map of woodland mentioned in historical sources (mainly dating between AD 1250-1650). After Groenewoudt *et al*. 2022



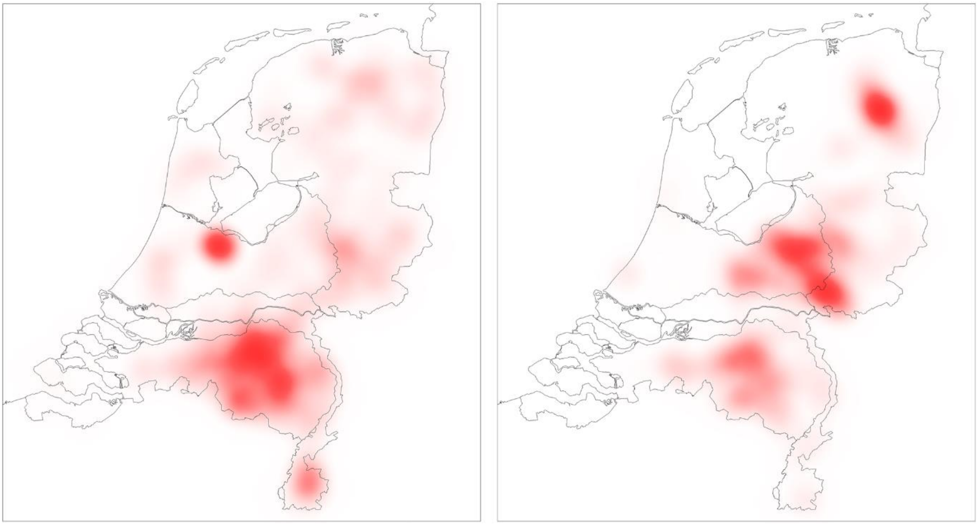
The distribution pattern of woodland mentioned in historical sources (Groenewoudt *et al*., 2022) largely conforms to that of the tree-trunk wells, although not at the level of individual clusters (Fig. 13). It is important to keep in mind, however, that relatively few historical sources pre-date AD 1250, which is the exact period when most of the tree-trunk wells were constructed. However, what is most likely not a coincidence, is that the youngest tree-trunk wells (14-15th century) were found in the immediate vicinity of historically known forest remnants (*Moftbos* and *Didammerbos*). On the basis of the above, we believe we can conclude that (clusters of) tree-trunk wells are indeed indicative of the historical presence of woodland. We consider this proven by the (overall) spatial correspondence with other forest indicators and moreover the association with specific forests known from historical sources.

There are various possible courses for further validation. Off-site anthracological research of well-dated charcoal assemblages from intact soils or charcoal kilns can be very useful, especially since it allows the identification of not only the presence of woodland but also of its composition at specific moments in time (e.g. Ludemann, 2003; Warren *et al*., 2012; O'Donnell, 2018; Bobrovsky *et al*., 2019; Deforce *et al*., 2021). Using the ecological requirements of specific tree species such as oak (*Quercus robur/petraea*) to develop ‘expectation maps’ for these species for specific periods in the past proved to be another promising method (Jansma *et al*., 2014). These are predictive models that show where certain species may have been present (to a substantial degree). A potentially significant proxy is settlement density, as woodland is much more likely to have occurred in sparsely settled areas (Hoevers *et al*., 2022).

COMBINING DATA

All (proxy)data indicating historical woodland that have been discussed are biased. For tree-trunk well data, this has already been discussed above. Medieval charcoal production sites are (still) relatively scarce and it is unclear to what extent the distribution of known sites gives a representative picture, at least on a supra-regional scale. Historical references are only partially preserved and, moreover, not all forests will have been mentioned in written sources. Not all stretches of woodland that were once present are reflected in place names, nor have all place names that do relate to woodland been preserved. What the datasets have in common is that they give an incomplete picture. But they are also complementary to some extent. One of the datasets may contain evidence that is missing in another. Therefore, combining them is likely to result in a more complete and accurate spatial impression of the historical presence of woodland than would be possible on the basis of any of the individual datasets. So that is what we did, choosing datasets with the highest information value, also in terms of chronology. For the early medieval ages (AD 500-1000), the distribution of early medieval tree-trunk wells was combined with place name evidence (Fig. 14, left; n-total:738). For the high and late medieval and early modern periods (AD 1000-1500/1650) the same was done with high medieval tree-trunk wells and historical sources referring to woodland (Fig. 14, right; n-total:423).

Fig. 14: Reconstructed distribution of medieval woodland in the Netherlands: combined indicative distribution maps. Left: AD 500-1000 (early medieval tree-trunk wells and place names referring to woodland); right: AD 1000-1500/1650 (high medieval tree-trunk wells and woodland mentioned in historical sources). Further explanation in the text



Comparison of both reconstructions clearly shows a decrease in woodland cover, especially in the north, west and extreme south. High medieval clusters do not point to reforestation but are (partly) the result of the fact that specific forests in this period are more often known historically. Moreover, these clusters do not indicate extensive areas of woodland, but rather concentrations of small relics. By AD 1650, almost all of them had disappeared, but in the relatively sparsely settled Veluwe and Drenthe areas some survived until the present day.

CONCLUSIONS

1. Studies of specific archaeological features may contribute to reconstructions of past vegetations, and specifically the past presence of woodland.

2. Our hypothesis that tree-trunk wells point to a local presence of (old) woodland is confirmed by a strong correlation between the distribution pattern of this type of well and spatial reconstructions based on other woodland-historical sources of information.

3. Nonetheless this source of woodland-historical information has its own biases, and a source-critical approach and cross-checking remain essential.

4. Complementing archaeological data on charcoal production sites, mapping precisely dated tree-trunk wells can place reconstructions of the medieval woodland cover on a sounder evidence-based footing.

5. High-density clusters of tree-trunk wells may also enhance the level of detail of these reconstructions.

6. It is plausible that the disappearance of tree-trunk wells is indeed related to deforestation, in particular of the higher and drier parts of the landscape suitable for settlement.

7. The observed contraction after AD 1000 of the area where tree-trunk wells occur appears to be related to increasing deforestation.

8. The digital availability of large numbers of excavation reports has proven to be a basic requirement to within a short period of time create large-scale and evidence-based spatiotemporal reconstructions. In our view, the same applies to other landscape archaeological or historical ecological contributions to current debates concerning environmental change.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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