The widespread occurrence of Celtic field systems in the central part of the Netherlands

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A B S T R A C T

The detailed elevation model based on airborne laser altimetry (AHN) proved to be a reliable tool to detect well-developed Celtic field systems, characteristic arable plots of the Iron Age. They were detected in the central part of the Netherlands, where only a limited number of Celtic field systems have been recognized in the past. Most of these previously detected systems were identified in the northern part of the Netherlands or in the southern part, but not in this zone. About 1200 ha of well-developed systems could be identified by AHN in the central part of the Netherlands, of which only 136 ha were registered as an archaeological monument. Another 335 ha of archaeologically identified Celtic field systems were not accepted or recognized by AHN, because they were morphologically less well-developed. Most of the around 1050 ha new discoveries occur in rough vegetations and forested areas, and can hardly be identified with previously used geodetic methods and aerial photography. Less well-developed or preserved systems were even more extensive and remnants were traced as fossil arable layers below plough soils or on lower slopes incorporated in mediaeval reclamations. The newly identified Celtic field systems, therefore, can be considered as remnants of much larger areas once covered with these arable plots. In the central part of the Netherlands, the estimated area once covered was at least around 4500 ha, more than enough to supply 10,000 people with cereals. Well-developed Celtic field systems started to develop in the late Iron Age with formation intensifying during the early Roman Period. The central part of the Netherlands is situated just north of the river Rhine, the former boundary of the Roman Empire, the Limes. The newly discovered extent of Celtic field systems will have influenced the interaction between different cultures on the border of the Roman Empire in the early Roman Period, about which very little is known. This perspective underscores the need for an integrated conservation policy and in-depth research through excavations in the near future.

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1. Introduction

At the start of the 21st century the last sheets of the geomorphological map 1:50,000 of the Netherlands had to be completed. The areas to cover were situated in the central part of the Netherlands. At that time the Actual Height Model of the Netherlands (Rijkswaterstaat, 2000), a detailed elevation model of the whole country using airborne laser altimetry, had just become available. With this model, relief patterns could be studied in much more detail and coherence than before. Therefore, the AHN was used to study the relief of the Pleistocene deposits in the central part of the Netherlands. In the process of geomorphological mapping, substantial areas with small, more or less rectangular patterns were recognized. They consisted of individual plots, varying from 25 to 45 m in length and width, marked by raised boundaries, varying between 10 and 100 cm in height. They strongly resembled Celtic field systems, a characteristic kind of field systems common in the Iron Age, occurring throughout northwest Europe. These patterns were checked with archaeologically registered Celtic field systems with known location and occurrence. They were identical.

Most of the Celtic field systems in the Netherlands have been identified in the northern and southern parts of the country. In the past, Celtic field research mainly focussed on the Dutch northern province of Drenthe where open landscapes prevailed. Using air photography many Celtic field systems could be identified (Brongers, 1976). The AHN survey of the Pleistocene area in the central part of the Netherlands, however, showed that in this area a substantial surface was covered with Celtic field systems, mostly located in rough vegetations and forested areas. The AHN appeared to offer new opportunities to study Celtic field systems.

This study focussed on the identification and characteristics of Celtic field systems in the central part of the Netherlands, a relatively...
Celtic field systems are found in the whole of northwest Europe, which consist of either sandy material or accumulations of stones of a large number of adjoining, small, more or less rectangular plots. The individual plots measure from about 20 to 45 m in length and width. These plots are generally bordered by low raised boundaries, which consist of either sandy material or accumulations of stones. The raised boundaries measure from several centimetres up to 1 m. Celtic field systems are found in the whole of northwest Europe, from Ireland in the west to Sweden and the Baltic states in the northeast (Klamm, 1993; Spek, 2004). In the sandy regions of the Netherlands, Germany, Denmark, Poland and the Baltic states, the raised boundaries generally consist of sand. High, sandy raised boundaries can be between 8 and 12 m wide (Spek et al., 2003; Harsema, 2005). In other countries where Celtic field systems are found, Ireland, Great Britain, and Sweden, rockier soils dominate and the boundaries of the plots generally are delineated by accumulated stones. The area covered by one Celtic field system may vary from a few to over 70 ha.

Celtic field systems formed a new development in the agricultural history of northwest Europe, starting in the late Bronze Age. Before that time, until ca. 1100 BC, shifting cultivation was practised, whereby every few years new fields were reclaimed from the forest by slashing and burning trees and their undergrowth to grow crops. Prehistoric farmers focussed on soils light enough to be tilled by means of hand-held digging sticks, the sandy soils. These soils tend to have a low fertility. Consequently, fields were soon deserted and new ones reclaimed. At the end of the Bronze Age, however, farmers remained in one area. They reclaimed a number of small rectangular plots, a Celtic field system, of which only a part was used at the same time. The dimensions of the individual plots, about 30 × 30 m, are thought to represent the surface that could be cleared in 1 day. Likewise, the size of these is believed to have enabled ploughing and sowing in 1 day (Brinkkemper, 1993; Van Wijngaarden-Bakker and Brinkkemper, 2005). When the soil was exhausted, the used plots were abandoned to recover and a different part of the plots within the Celtic field system was cleared and tilled. The farmers lived in farmsteads built on one of the plots and barnsteds were usually present in adjoining ones. After a few decades, generally coinciding with the reclamation of a new group of plots alongside existing ones, new farmsteads were built on another location in the same Celtic field system. Cattle were held, also on the plots. They provided the draught-power for ploughing and their dung served for manuring of the plots (Gehlhart, 1982; Spek et al., 2003). The abandoned plots became covered with vegetation, including shrubs and small trees. When reclaimed again, the vegetation was burned and waste material accumulated on the edges of the plots resulting in raised boundaries (Spek et al., 2003). After every fallow period more materials accumulated and distinct ridges separating the individual plots developed. Celtic field systems with well-developed and relatively high, raised boundaries are thought to have formed during the later stages of the Celtic field cultivation, viz. the late Iron Age up to the Roman Period (250 BC–AD 200). This can either be the result of (1) continuous clearing and accumulation on the edges during prolonged periods or (2) a more intensive agricultural system with an intentional raising of the walls with material from the surroundings, in which mainly the ridges were intensively cultivated and manured (Zimmerman, 1976; Behre, 2000; Spek et al., 2003; Harsema, 2005). Due to repeated burning of the vegetation, Celtic field systems often contain hardly any pollen nor botanical macro-remains and the reconstruction of grown crops is limited (Spek et al., 2003; Spek, 2004; unpublished data main author). Botanical macro-remains of grown crops, however, can be encountered in settlements, grain storage pits or offering pits and in some cases may be related to neighbouring Celtic field systems. Only in a few studies in the central part of the Netherlands (Buurman, 1986; Vermeeren, 1991; Van Zeist, 1968/1970) and comparable nearby locations (Bakels, 1998; Kooistra, 2008) cereals grown in these ancient field systems have been detected. They include Panicum miliaceum, Hordeum vulgare, Triticum dicoccum, Triticum spelta and Avena sativa.

In the Roman Period agricultural practices changed considerably, due to improved implements and intensified manuring. At the start of the Middle Ages more fertile land was reclaimed. Celtic field systems became abandoned and were incorporated into larger field plots or buried below a plaggen layer.

3. Identification of Celtic field systems in the past

Celtic field systems, together with burial mounds and megalithic tombs, are considered the best visible relics of the archaeological heritage in the landscape in the Netherlands. Burial mounds, due to the possible presence of gifts, and the appealing megalithic tombs got most attention. Nevertheless much research has been focussed on Celtic field systems, due to their conspicuous relief pattern. Klamm (1993) and Spek et al. (2003) have given excellent reviews of Celtic field research in northwest Europe.

Celtic field systems were first recognized as a particular type of ancient field systems during excavations in the first part of the previous century. The position and configuration of individual plots were commonly registered using various geodetic methods (viz. Van Giffen, 1928; Nielsen and Clemmensen, 1995). Due to their conspicuous relief in open, flat or rolling landscapes they belonged to the first archaeological features studied using aerial photography (Crawford, 1923). Thereafter, several air photo surveys of Celtic field systems were executed (Brongers, 1976; Zimmerman, 1976; Olesen, 1983). Brongers (1976), e.g., identified 95 possible Celtic field systems in the province of Drenthe. Field investigations using relief properties and soil profile characteristics of these locations resulted in 83 proper Celtic field systems and 12 uncertain systems (Spek et al., 2003). Even after modern reclamation activities, Celtic field systems commonly remain visible in aerial photographs, due to the difference in humus content between the plots and the base of the raised boundaries (Spek, 2004; Harsema, 2005). However, when the surface of the land is obscured, viz. in woodlands, aerial photographs were of limited use and thorough field surveys were needed to determine the presence and location of Celtic field systems (Jankuhn, 1956/57; Koster, 1970; Nielsen, 1984).

4. New identification method of Celtic field systems

At the start of the 21st century the Actual Height Model of the Netherlands (AHN), a detailed elevation model of the whole country based on airborne laser altimetry, became available. Laser scanners are hardly hampered by vegetation compared to aerial photographs or satellite images and better register the elevation of the solid ground. To eliminate the small remaining reflections of vegetation on the raw data, different filter techniques were developed to compensate for different types of vegetation structures. The resulting data is representative for the elevation of the solid ground. The elevation levels of the entire Netherlands were mapped with

a mean resolution of one measurement of every 4 \times 4 \text{ m}. This uniform, country-wide elevation data set was correlated with the X, Y and Z co-ordinates of the RD (national triangulation grid) and NAP (Dutch Ordnance Datum) data. A maximum standard deviation of 15 cm with a maximum systematic error of 5 cm applies to this detailed actual elevation model. This basic data set is too large to handle for different applications and is therefore generally transformed into a 5 \times 5 \text{ m grid} by means of the interpolation method: inverse squared distance weighting. The systematic errors do not change as a result of this transformation (Rijkswaterstaat, 2000).

With this elevation model, relief patterns can be studied in much more detail and coherence than ever before.

To optimise the identification with AHN of small-scale relief patterns the actual elevation model data set was transformed into a 2.5D relief map by using the Arcgis9 tool hillshade (McCoy and Johnston, 2001). This hillshade map was made transparent for 30% and draped over on a version of the elevation model in which discrete intervals of 0.25 m were presented by a specific colour range. This operation (Fig. 1) resulted in a digital map that was very suitable for the detection of characteristic small-scale archaeological phenomena such as burial mounds and Celtic field systems.

The optimised AHN elevation maps were used to calibrate the resulting relief patterns with those of archaeologically identified Celtic field systems. Two examples are given. The first one concerns probably the best-studied Celtic field system of the Netherlands, the Noorse Veld of Zeijen, province of Drenthe. In Spek et al. (2003) a figure is presented showing the position of the plots in this Celtic field system as mapped by geodetic methods by Van Giffen (1949), completed with those identified by Brongers (1976) using aerial photography. This figure is compared with the optimised AHN pattern of the same area (Fig. 2). The basic pattern in the central area, a nature reserve, is identical, but in the north and west more plots could be detected with AHN. They were not recognized in previous research and indicate that this Celtic field system once occupied a larger surface. The area consists of a rough heathland in which low relief changes are easily obscured and missed. In the first row of Table 1, a few AHN measurements of this well-studied Celtic field system are given, after deduction of the systematic error of 15 cm. According to this data, the height of the ridges varies between 15 and 50 cm. The real heights surveyed in the field, however, vary between 30 and 80 cm (Spek et al., 2003).

A second calibration example also concerns a well-studied extensive Celtic field system in Vaassen, Veluwe East, in the central part of the Netherlands (Fig. 3). The delineated archaeologically protected zone is taken from the Archaeological Monument Map (AMK) of the Netherlands (see also Section 5.2). The Celtic field system present in this area, mapped by Brongers (1972) using aerial photography refined with geodetic methods, covers 76 ha. The AHN map, however, clearly shows that the area in which a well-developed Celtic field system occurs occupies at least 87 ha: 11 ha more than identified in AMK. The plots are smaller than in the first example, about 38 \times 38 \text{ m}, and boundaries are, after the deduction of 15 cm, more than 20 cm in height (Table 1), in accordance with the field situation. Also in this case, neighbouring woodlands, local relief and rough vegetation have hampered the detection of the extent of this Celtic field system in the past.

A few more well-studied Celtic field systems incorporated in the Archaeological Monument Map (AMK) of the Netherlands were analysed in the same way with comparable results. The optimised AHN elevation maps appeared to be a reliable tool to identify these small-scale patterns and to study their characteristics.

5. Application of the new identification method (AHN)

5.1. Standard definition

Based on the results of the calibration of the detected patterns standard requirements for the recognition of a Celtic field system using the AHN were defined. The requirements are: at least eight adjoining plots of about 20–40 m in length and width in at least two rows. All four boundaries between the plots have to be distinctly present and be more than 20 cm in height. Such a basic unit corresponds with the primary reclamation units of Iron Age farmers as recognized by Brongers (1972) and used for identification by Harsema (2005). These patterns can hardly be mistaken for other small-scale patterns, such as reclamation boundaries, small parcelled out lots, embankments or small wood plots.

The defined standard, however, will exclude Celtic field systems in which less than 16 well-developed adjoining plots remained. Also excluded are systems in which boundaries are lower than 20 cm in height or are partly damaged. An example is given from the Grebbeberg, the southeast end of the Utrechtse Heuvelrug (Fig. 4, location Fig. 5). A remnant of only four well-developed plots is conserved on the southern slope (A). In the central zone a substantial area is covered with plots of which most boundaries are less than 15 cm high (B). Their pattern can still be recognized in the field. In the third delineated area (C), field terraces with raised boundaries occur, still in use for agricultural production. They are commonly attributed to regraduations of the Middle Ages following contour lines. However, several raised boundaries still delineate plots perpendicular to the isohypses. Because the dimensions of these raised boundaries are identical to those of identified Celtic Field systems in the neighbourhood, and the boundary of woodland and agricultural land follows the same angular pattern, it is very likely that all these are remnants of former Celtic field systems.

Although less well-preserved Celtic relief patterns can be recognized as such, they are omitted in this study. The only exceptions accepted are the officially registered Celtic field systems incorporated in the archaeological heritage of the Archaeological Monument Map (AMK) of the Netherlands.

5.2. Application combined with other digital data sets

In order to get a better insight into the choices the Iron Age farmers made for the selection of their farmlands the following digital data sets were compared and analysed.

1. The AHN map with identified Celtic field systems was compared with the information present in the Archaeological Monument Map (AMK) of the Netherlands. The AMK is a digital database using a detailed topographical map on which all identified and protected archaeological monuments in the Netherlands are registered. The archaeological monuments are subdivided by type of phenomena and attributed to specific periods (www.archis.nl). The AMK map comprising the registered Celtic field systems was projected at the same scale on
the AHN maps with the detected Celtic field patterns. The boundaries of both selected areas were compared and the differences analysed.

2. The same AHN data set was plotted at the same scale on the just finalized digitalized geomorphological map of the Netherlands (www.meetnetlandschap.nl; www.geodesk.nl; Kooimen and Maas, 2004). The position of the Celtic field systems in the landscape was analysed.

3. The same was performed with the digital soil map of the Netherlands (www.bodemdata.nl; www.geodesk.nl). The soil types occurring in the Celtic field systems were studied.

6. Selected study area

Scanning of the relief patterns in the central part of the Netherlands using the AHN data set resulted in a relatively high number of newly identified Celtic fields system patterns. After comparison with previously identified Celtic fields systems, using the standard requirements as discussed before, most of them could be considered as proper Celtic fields systems. Most Celtic field systems were supposed to be situated in the north of the Netherlands, viz. the province of Drenthe, and much research has been limited to that area (Brongers, 1976; Spek et al., 2003). Also in the southern parts of the Netherlands distinctive areas are covered with these (formerly) arable plots (Bakels, 1998; Kooistra, 2008; Van Wijngaarden-Bakker and Brinkkemper, 2005). A thorough investigation in the central part of the Netherlands and identification of Celtic fields systems in this region would be a welcome contribution and offer new insights into these Iron Age farmlands and their farmers.

Celtic fields systems are exclusively present on sandy Pleistocene deposits: ice-pushed ridges, outwash plains and coversands. These deposits were studied in the area situated south of the river Vecht (Overijssel) and north of the river Meuse, between 51°40’ and 52°35’N. The studied area was scanned using a scale of about

<table>
<thead>
<tr>
<th>Site</th>
<th>Mean area (m²)</th>
<th>Count (n)</th>
<th>Deducted height ridges (cm)</th>
<th>Max–Min (m²)</th>
<th>Mean size (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noordse Veld</td>
<td>1805</td>
<td>36</td>
<td>15–50</td>
<td>3462–687</td>
<td>42 x 42</td>
</tr>
<tr>
<td>Vaassen</td>
<td>1416</td>
<td>46</td>
<td>20–55</td>
<td>2241–835</td>
<td>38 x 38</td>
</tr>
<tr>
<td>Ede</td>
<td>1760</td>
<td>41</td>
<td>25–30</td>
<td>2956–721</td>
<td>42 x 42</td>
</tr>
<tr>
<td>Amerongen</td>
<td>2352</td>
<td>28</td>
<td>30–45</td>
<td>3360–1722</td>
<td>48 x 48</td>
</tr>
</tbody>
</table>

*Locations in Fig. 5.*
1:15,000, an optimal scale for the recognition of the selected patterns. East of the river IJssel only in three locations these patterns were recognized and around the town Nijmegen no Celtic field patterns could be detected. In the remaining sandy Pleistocene deposits in the central part of the Netherlands, however, many Celtic field patterns were found. Five sub-zones were distinguished: the Utrechtse Heuvelrug, Veluwe Northwest, Veluwe East, Veluwe South and Veluwe Southwest (Fig. 5). The Celtic field systems detected east of the river IJssel were dealt with as a separate group named Overijssel/Achterhoek (Fig. 6).

7. Results

7.1. Identification by using the AHN

The compiled data on identified Celtic field systems detected by AHN is presented in Table 2. In all, 33 well-developed Celtic field systems covering nearly 1200 ha were counted. The smallest area Celtic field system was 2.8 ha (Veluwe East) and the largest 155.5 ha (Veluwe Southwest). The latter sub-zone by far has the largest area covered by Celtic field systems (539.6 ha), followed by the Utrechtse Heuvelrug (248.6 ha). In Veluwe South, east of the river Rhine, the smallest area covered with these systems occurs (52.1 ha). In Table 1, last two rows, the same measurements as for the identified, well-studied Celtic field systems (first two rows) are given for two newly discovered strikingly well-developed systems. They are situated in Veluwe Southwest (Ede) and at the Utrechtse Heuvelrug (Amerongen, see Fig. 5). These and a few other newly identified Celtic field systems were checked in the field on relief features and soil profile characteristics (see also Fig. 7). All locations visited proved to be proper Celtic field systems and conformed to the selected requirements.

7.2. Occurrence registered in AMK (www.archis.nl)

In all, 21 Celtic field systems are registered in AMK, covering 471.1 ha (Table 3). In two sub-zones, Veluwe Northwest and South, no Celtic field system is registered. The smallest (0.2 ha) and the...
largest areas covered by a Celtic field system (185.5 ha) occur both in the same sub-zone (Veluwe East). The number of well-developed systems identified by using the AHN is more than twice as large. In Table 3 also the official AMK total surface area covered by Celtic field systems in Drenthe is given. Based on these data, in the past, the conclusion was drawn that most Celtic field systems occur in the province of Drenthe: 471.1 versus 1441.2 ha. Using the new information obtained from AHN of the central part of the Netherlands and taking into account that only well-preserved Celtic field systems are accepted, the conclusion has to be drawn that in the study area at least a nearly equal surface was occupied by Celtic field systems (Table 3). Comparing the number and sizes of registered Celtic field systems in Drenthe with those in the central part of the Netherlands it also can be concluded that most small systems occur in Drenthe and that most large field systems preserved are found in the central part of the Netherlands.

7.3. Comparison of AHN and AMK data

Celtic field systems registered in AMK, checked by field research, may not conform to the requirements of well-developed systems defined for AHN identification. Consequently, in AMK, Celtic field systems are included that are not accepted in AHN identification. On the other hand, well-developed Celtic field systems may be missing in AMK, viz. in rough heathlands or wooded areas. In Table 4 an overview of all obtained data is given. The area identified in AHN and AMK is given in a separate column and deducted from the original sources to avoid double counting. Table 4 reveals that in the core zone studied, only half the area present in AMK is also identified in AHN, 273.3 versus 136.4 ha. This means that only about 12% of the area with well-developed Celtic field systems in the central part of the Netherlands was registered in AMK.

7.4. Position in the landscape

Table 5 shows the geomorphological units in which the Celtic field systems occur. The identified Celtic fields in the central part of the Netherlands are mainly located on the upper slopes of the ice-pushed ridges. They cover 994 ha; 84% of the total surface of Celtic field systems in this area. The ice-pushed ridges were formed during the Saalian glacial period. They are composed of unsorted, slightly gravelly, coarse sands and have a distinct silt fraction. The top of the ridges is often gravelly due to selective erosion of fine fractions during the last, Weichselian, glacial period. Celtic field systems are accepted. The new information obtained from AHN of the central part of the Netherlands is given in a separate column and deducted from the original sources to avoid double counting. Table 4 reveals that in the core zone studied, only half the area present in AMK is also identified in AHN, 273.3 versus 136.4 ha. This means that only about 12% of the area with well-developed Celtic field systems in the central part of the Netherlands was registered in AMK.

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systems were not encountered in those gravelly zones. A substantial number of Celtic field systems are located on fluvioperiglacial alluvial fans, along the slopes of ice-pushed ridges (322 ha). Most fans are present in the sub-zones, Utrechtse Heuvelrug and Veluwe East. These fans have comparable compositions as the ice-pushed ridges. The Celtic field systems identified extend from the slopes of ice-pushed ridges onto these fans or occur solely on the latter. Lastly, a minor number of Celtic field systems is located on coversands. Coversand areas do occur on a large scale in the study area, but only in Veluwe Southwest some Celtic field systems are identified in coversand areas. Aeolian coversand deposits are composed of well-sorted fine sand and hardly contain any silt. As in the previous case, Celtic field systems identified on the slopes of ice-pushed ridges extend into coversand areas on lower parts of the slopes.

The Celtic field systems in Overijssel/Achterhoek follow the same pattern. Two are found on the slopes of ice-pushed ridges and one on a fluvioperiglacial alluvial fan with a thin layer of coversand.

The position of the Celtic field systems in the landscape is different in the province of Drenthe. Most Celtic field systems, 39%, are found on ice-pushed ridges, closely followed by those present on glacial till, 31%. Glacial tills do not occur at the surface in the central part of the Netherlands. About a quarter (27%) of the Celtic field systems in Drenthe are located on coversands, often covering glacial till. Celtic field systems often continuously extend across areas with and without glacial till in the subsoil, as is the case of the Noordse Veld (Fig. 2).

7.5. Soil types on which Celtic field systems occur

Soils occurring in the areas occupied by Celtic fields generally are podzolized soils (Table 6). Different types have developed due to variations in parent material, hydrology, vegetation and land use. Where the original composition of the parent material of the ice-pushed ridges is present the richest soils have developed, with relatively high moisture retentions. These were originally covered with a dense deciduous forest and had a well-developed moder humus and were typical brown podzolic soils. These soils were probably preferred by the Iron Age farmers, because they have most Celtic field systems. They are classified according to the Dutch soil classification (Ten Cate et al., 1995) as well-drained ‘holtpodzols’.
(gY30 or gY21); in the Soil Taxonomy, second edition (Soil Survey Staff, 1999), as sandy, mesic, Entic Haplortods. After the Iron Age the lower slopes remained in use as arable land. The upper gravelly slopes became reforested, some with oak coppice. In recent centuries they were often used for wood production. Less gravelly top zones and upper slopes remained in use as arable land and are generally covered with a much younger plaggan layer (viz. Overijssel/Achterhoek).

A second, smaller group of Celtic field systems is found in the upper zones of the fluvio-periglacial alluvial fans, where coarser sands occur, depleted of most fine material, especially near Vaassen (Veluwe East). On this poorer parent material, more acid podzols have developed. These soils were situated on the upper slope of the IJssel valley and moisture availability was relatively high, due to seepage from the Veluwe. They could easily be cleared and tilled, while moisture supply was secured. They are classified according to the Dutch soil classification (Ten Cate et al., 1995) as well-drained ‘haarpodzols’ (gHd30); in the Soil Taxonomy, second edition (Soil Survey Staff, 1999), as sandy, mesic, Typic Haplohumods. These soils represent poor arable lands that generally turned afterwards into rough heathlands with some trees or into forests plantages.

A minority of the Celtic field systems is found in the lower zones of fluvio-periglacial alluvial fans and in coversand areas. Here, more or less sorted, coarser and finer sands are present, in which even more acid podzols have developed. These podzols, however, occur below groundwater levels and have hydromorphic features. Also these soils could relatively easily be reclaimed and tilled by the Iron Age farmers. Afterwards these soils remained in use as arable land or grassland, as water shortages were limited. These soils are classified according to the Dutch soil classification (Ten Cate et al., 1995) as ‘veldpodzols’ (Hn30 or Hn21); in the Soil Taxonomy, second edition (Soil Survey Staff, 1999), as sandy, mesic, Typic Endoaquods.

On poor parent materials, as occurring in fluvio-glacial alluvial fans, sandy ice-pushed ridges, and coversand areas that are composed of more or less sorted, gravelly and/or coarser and finer sands,

<table>
<thead>
<tr>
<th>Region</th>
<th>Number</th>
<th>Mean area (ha)</th>
<th>Sum area (ha)</th>
<th>Min. area (ha)</th>
<th>Max. area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utrechtse Heuvelrug</td>
<td>10</td>
<td>24.9</td>
<td>248.6</td>
<td>3.7</td>
<td>97.7</td>
</tr>
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<td>2</td>
<td>39.6</td>
<td>79.2</td>
<td>11.1</td>
<td>68.2</td>
</tr>
<tr>
<td>Veluwe East</td>
<td>7</td>
<td>32.6</td>
<td>228.4</td>
<td>2.8</td>
<td>87.0</td>
</tr>
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<td>Veluwe South</td>
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<td>26.0</td>
<td>52.1</td>
<td>3.4</td>
<td>48.7</td>
</tr>
<tr>
<td>Veluwe Southwest</td>
<td>9</td>
<td>60.0</td>
<td>539.6</td>
<td>14.2</td>
<td>155.5</td>
</tr>
<tr>
<td>Subtotal</td>
<td>30</td>
<td></td>
<td>1147.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overijssel/Achterhoek</td>
<td>3</td>
<td>13.0</td>
<td>39.1</td>
<td>2.3</td>
<td>31.5</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td></td>
<td>1187.0</td>
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<td></td>
</tr>
</tbody>
</table>

Fig. 6. Area occupied by Celtic field systems in Overijssel/Achterhoek.

Table 2 Data on Celtic field systems detected and measured by AHN
and characterized by deep groundwater levels, no Celtic field systems are found. It is expected that Celtic field systems never developed on these deposits, viz. in the northern part of Veluwe East.

In the province of Drenthe, on the contrary, 64% of the registered Celtic field systems (Table 6) are found on ‘veldpodzols’ (Hn30 or Hn21). Here the situation is different. The presence of glacial till near the surface and many well-drained valleys offered ideal locations, easy to be reclaimed and tilled by the Iron Age farmers.

8. Discussion and conclusions

The optimised Actual Height Model (AHN) for identification of small-scale relief patterns proved to be very suitable for the detection of the Celtic field systems. A standard was defined to select all conserved well-developed Celtic field systems in the central part of the Netherlands. In all nearly 1200 ha of well-developed Celtic field systems were identified. About 136 ha had previously been registered as archaeological monument, but 1050 ha were newly discovered in this study. A different group of about 334 ha, previously identified Celtic field systems, was not included in the AHN selection as they were less well-developed. The sum of all identified Celtic field systems equalled those registered in the province of Drenthe, where most Celtic field systems were supposed to be located in previous studies.

In the central part of the Netherlands, however, the area once occupied by Celtic field systems certainly was much larger. The results can be summarized as follows:

1. During the AHN survey a large area of less well-developed Celtic field systems was detected. They were not counted as ‘real’ Celtic fields, but based on their position in the landscape and soil types occupied added to their conspicuous pattern, a substantial part of them are very likely Celtic field systems.  
2. The well-developed Celtic field systems, detected by using AHN, are mainly present on the upper slopes of ice-pushed ridges or fluvio-periglacial alluvial fans, on rough heathland or in forested land (Fig. 6). At these locations they could not be detected with air photography or routine field surveys. These Celtic field systems were afterwards abandoned as arable land and patterns were preserved. On lower slopes and plains the remaining detectable Celtic field patterns are less well-preserved: raised boundaries became discontinuous or partly levelled, or are less than 15 cm high. Here, the land generally remained in agricultural use and the original pattern disappeared partly or completely by changed agricultural practices. At several locations, transitions from the characteristic Celtic field relief patterns to larger plots were found. In a few hilly areas, elongated arable plots of about 25–35 m wide with

<table>
<thead>
<tr>
<th>Region</th>
<th>Number</th>
<th>Mean area (ha)</th>
<th>Sum area (ha)</th>
<th>Min. area (ha)</th>
<th>Max. area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utrechtse Heuvelrug</td>
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<td>13.4</td>
<td>80.5</td>
<td>3.5</td>
<td>40.6</td>
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<tr>
<td>Veluwe East</td>
<td>3</td>
<td>61.8</td>
<td>185.5</td>
<td>0.2</td>
<td>175.9</td>
</tr>
<tr>
<td>Veluwe Southwest</td>
<td>10</td>
<td>14.4</td>
<td>143.7</td>
<td>0.9</td>
<td>51.4</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>439.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overijssel/Achterhoek</td>
<td>2</td>
<td>30.7</td>
<td>61.4</td>
<td>18.3</td>
<td>43.0</td>
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<tr>
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<td>21</td>
<td>471.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drenthe</td>
<td>104</td>
<td>13.7</td>
<td>1441.2</td>
<td>0.3</td>
<td>146.8</td>
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<table>
<thead>
<tr>
<th>Region</th>
<th>Only in AHN (ha)</th>
<th>Only in Archis (ha)</th>
<th>Overlap AHN/Archis (ha)</th>
<th>Total area (ha)</th>
</tr>
</thead>
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<td>Utrechtse Heuvelrug</td>
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<td>323.8</td>
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<td>0</td>
<td>0</td>
<td>79.2</td>
</tr>
<tr>
<td>Veluwe East</td>
<td>166.9</td>
<td>124.1</td>
<td>61.4</td>
<td>352.4</td>
</tr>
<tr>
<td>Veluwe South</td>
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<td>0</td>
<td>0</td>
<td>52.1</td>
</tr>
<tr>
<td>Veluwe Southwest</td>
<td>470.0</td>
<td>74.0</td>
<td>69.7</td>
<td>613.7</td>
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<tr>
<td>Subtotal</td>
<td>1011.5</td>
<td>273.3</td>
<td>136.4</td>
<td>1421.2</td>
</tr>
<tr>
<td>Overijssel/Achterhoek</td>
<td>39.1</td>
<td>61.4</td>
<td>0</td>
<td>100.4</td>
</tr>
<tr>
<td>Total</td>
<td>1050.6</td>
<td>334.7</td>
<td>136.4</td>
<td>1521.6</td>
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</table>
Table 5
Geomorphological units on which Celtic field systems occur (%)

<table>
<thead>
<tr>
<th>Region</th>
<th>Geomorphology</th>
<th>Slope ice-pushed ridge</th>
<th>Fluvio-periglacial alluvial fans</th>
<th>Coversand deposits</th>
<th>Glacial till</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utrechtse Heuvelrug</td>
<td></td>
<td>67</td>
<td>28</td>
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<td>5</td>
<td></td>
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<tr>
<td>Veluwe Northwest</td>
<td></td>
<td>100</td>
<td>100</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Veluwe East</td>
<td></td>
<td>40</td>
<td>50</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Veluwe South</td>
<td></td>
<td>23</td>
<td>10</td>
<td></td>
<td>2</td>
<td></td>
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<tr>
<td>Total surface covered (ha)</td>
<td></td>
<td>964</td>
<td>322</td>
<td>126</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Overijssel/Achterhoek</td>
<td></td>
<td>75</td>
<td>6</td>
<td>18</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Total surface covered (ha)</td>
<td></td>
<td>30</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Drenthe</td>
<td></td>
<td>39</td>
<td>1</td>
<td>27</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>Total Surface covered (ha)</td>
<td></td>
<td>556</td>
<td>17</td>
<td>393</td>
<td>443</td>
<td>32</td>
</tr>
</tbody>
</table>

3. In several cases, e.g. on the Holterberg, Celtic field patterns border plaggen soils and remnants can be traced in the subsoil. Thin grey-brown agricultural layers are present below plaggen layers, which upon soil micromorphological research reveal characteristic features that are the result of Iron Age farming (Spek et al., 2003, 2004) and cannot be attributed to mediaeval agriculture, as is commonly done (Spek, 2004; Van Smeerdijk et al., 1995). Parts of Iron Age agricultural layers generally became incorporated in those of the Middle Ages or in younger plaggen layers. At the base of these agricultural layers, however, traces of Iron Age farming are common. As already stated by Adderley et al. (2006), our knowledge of these past land management practices can be greatly enhanced through examination of soil thin sections.

Not all the Celtic field systems need to have had well-developed raised boundaries. Well-developed raised boundaries are considered as a late development. In the well-studied Celtic field system of the Noordse Veld the raising of the surface started in the late Iron Age and intensified on the boundaries during the early Roman Period (Spek et al., 2003). Also Brongers (1976) presumed raised surfaces due to incorporation of allochthonous soil material in the Celtic field systems of Vaassen. The presence of a large area of Celtic field systems with well-developed raised boundaries in the central part of the Netherlands, therefore, can, besides an indication of exhausted soils that needed manuring, also be an indication of an intensified arable production at the start of the early Roman Period.

Based on all the data obtained, we estimate that the surface occupied by Celtic field systems in the central part of the Netherlands was at least three times larger than the 1500 ha identified hitherto. Using an estimation of 4500 ha for this part of the Netherlands it can be calculated how many people could be fed by this surface. Van Wijngaarden-Bakker and Brinkkemper (2005) state that generally on 2.7 ha, about 30 plots, enough cereals could have been grown to supply a family consisting of six persons. This means that from 4500 ha about 10,000 people could have been supplied. Kooistra (1996), however, concluded based on her data that during the Roman Period the production per hectare was at least 35–50% higher, which means that about nine persons could have been fed by the same acreage. Not included in this calculation is the fact that crops have been cultivated also on the ridges (Zimmerman, 1976; Behre, 2000; Spek et al., 2003), or that a substantial part of the diet could have been derived from other sources. There are strong suggestions that rye (Secale cereale) was a main crop in the final stage of Celtic field agriculture (Behre, 2000; Spek et al., 2003). Consequently, the population that could have been fed from this Iron Age agriculture is considerably larger than commonly thought.

The central part of the Netherlands is situated just north of the river Rhine, which was the boundary of the Roman Empire (the Limes). The Rhine functioned at that time as a main way of transportation and a cross-road for different cultures. The populations involved had to be fed and it seems probable that the arable production on Celtic field systems intensified at locations near this frontier, viz. the Utrechtse Heuvelrug and Veluwe Southwest and East.

Hardly any information on the scope and extent of the Iron Age agriculture, nor of their farmers in this part of the Netherlands, is available. Only very recently Kalis and Meurers-Balke (2007) published palynological data from a location in Veluwe South showing that Iron Age agriculture occurred at such an intensive level that the population density could have been much higher than generally supposed. In this perspective the information obtained from AHN stresses the need for an integrated conservation policy for the Celtic field systems in this part of the Netherlands, and for in-depth research through excavations in well-preserved areas that will offer new insights into the life of Iron Age farmers, the Roman occupation and the functioning of the Limes.

Acknowledgements

The authors like to thank Dr. Laura I. Kooistra, BLAX Consult (Zaandam), for her contributions on palynological data and botanical macro-remains to the discussion that enabled us to strengthen the focus of this manuscript. We are also much indebted to Dr. Bart Makaske, Alterra (Wageningen University and Research Centre), for his conscientious reading of the text and his comments for improvement.

References


