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Raised bed agriculture in northwest Europe triggered by climatic change around 850 BC: a hypothesis

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A sudden decline of solar activity around 850 calendar years BC caused a shift to a cool and wet climate in northwest Europe. Food production suddenly became problematic because of shorter, wetter growing seasons and increased night frost. This climate change triggered innovation and the development of a new agricultural system in continental northwestern Europe: arable farming on raised beds (Celtic field banks) laid out in a more or less checked pattern. This kind of agriculture mitigated the effects of the climate shift by providing better drainage and lessening damage by night frost and thus lengthening the growing season. Once the advantages of this kind of cultivation, soil enrichment and optimum root growth besides the hydrological effects, became obvious it will have been practised on a large scale and introduced when people thought it useful, independent of the local hydrological situation.

Keywords: Celtic field banks, Climate shift, Raised bed agriculture

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Introduction

The abrupt climate shift of ca. 850 BC was one of the most severe climate changes during the Holocene and the effects on people were considerable in areas that were marginal from a hydrological point of view (Magny 2004; Van Geel *et al*. 1996). At the transition from Bronze to Iron Age there was a major change in type of arable land in continental northwest Europe, viz. the introduction of 'Celtic fields', so named by Van Giffen (1928) after publications on checked arable field patterns in England. However, the continental Celtic fields were not surrounded by ditches or stone walls, but by earthen banks, ca. 40–60 cm high and between 3 and 16 m wide with, nowadays, gradually sloping sides. In 1911 Sophus Müller was the first to interpret this layout as old arable fields surrounded by banks, followed by A. E. van Giffen in 1928 and G. Hatt in 1931, cf. Brongers (1976) and Spek *et al*. (2003) for a detailed historical overview of the various interpretations. Hatt (1931) explained the formation of the banks by the accumulation of debris from the fields, Van Giffen (1944) as constructed by using the depleted and thus infertile topsoil of the fields. Modderman (1955) and Jankuhn (1957) opposed this because it would mean the removal of the most humic part of the arable. Brongers (1976) argued for formation of the banks by clearing stones and tree stumps, supplemented by material from the fields and humic material from outside to increase soil fertility.

We challenge conventional interpretations of the continental Celtic fields by arguing that arable farming did not take place in the lower parts between the banks, but right from the beginning on the banks. Iron Age farmers will have been well aware of the advantages of cultivation on high beds, thus counteracting the occurrence of adverse climatic conditions.

Solar forcing of abrupt climate change around 850 BC and the environmental impact

Holocene peat deposits, especially the rainwater-fed raised bogs of northwest Europe, are natural archives of climate change. Climate-related changes in precipitation and temperature are reflected in the changing species composition of the peat-forming vegetation and in the degree of decomposition of the peat. Blytt (1882) and Sernander (1910) subdivided the Holocene into alternating periods, which were supposed to represent differing climatic conditions. The so-called Subboreal–Subatlantic transition of the Blytt–Sernander scheme, which occurred around 850 BC, represents a consistently observed, abrupt and intense climate shift. In northwest Europe the climate changed from relatively dry and warm to

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cooler, wetter conditions (Van Geel *et al.* 1996, 1998) causing strong peat-stratigraphical and archaeological changes. The practice of dating peat samples using ^{14}C wiggle-matching has greatly improved the precision of radiocarbon chronologies since its application by Van Geel and Mook (1989). Applied to peat sequences it leads to high-precision calendar age chronologies, showing increased mire surface wetness occurring together with suddenly increasing atmospheric production of ^{14}C during the Subboreal–Subatlantic transition. Peat cores and lake deposits showing this phenomenon are known from the Netherlands (Kilian *et al.* 1995; Van Geel *et al.* 1998), the Czech Republic (Speranza *et al.* 2003) and Scandinavia (Berntsson *et al.* 2015; Mellström *et al.* 2015). The production of radiocarbon is modulated by solar activity. Therefore, the change toward strongly increased mire surface wetness of the Subboreal–Subatlantic transition has been interpreted as the effect of a sudden decline of solar activity.

The climate shift around 850 BC was one of the most important shifts during the Holocene in northwest Europe. It had a strong socio-economic impact in areas that were marginal from a hydrological point of view. In the Dutch lowland regions the climate shift caused a sudden, considerable rise of the ground water table so that arable land was transformed into wetland, where peat growth started. Farming communities living in such areas were forced to migrate because they could no longer produce sufficient food (Van Geel *et al.* 1996). Magny (2004) showed that during several millennia the presence of lakeside villages in southeastern France and adjacent Switzerland was strongly linked with lake levels and solar activity. No lakeside village occurred there after 850 BC. According to Jennings (2015) cultural and economic factors probably had been more important for relocation and abandonment of the settlements (see also Menotti 2015). However, in northwest and central Europe, the climate shift around 850 BC preceded a considerable rise in palynological indicators of human impact on the landscape. Van Geel and Berglund (2000) suggested a causal link between the climate shift around 850 BC and the evidence for a subsequent increase in human population density. They postulated that in the first instance the climatic crisis caused an environmental and social crisis. A collapse of societies resulted in a weakening of the position of dominant groups, which brought about a change in the social structure of farming communities. This facilitated the introduction of a new technological complex, creating further social change combined with a leap forward in production, food consumption and population density.

In south-central Siberia, archaeological evidence suggests an acceleration of cultural development and a sudden increase in density and geographical distribution of the nomadic Scythian population after 850 BC. Van Geel *et al.* (2004) proposed a relationship with an abrupt climatic shift towards increased humidity. This hypothesis is supported by palynological evidence. Areas that initially may have been hostile semi-deserts changed into attractive steppe landscapes with a high biomass production and carrying capacity. Newly available steppe areas could be utilised by herbivores, making them attractive for nomadic tribes. The Central Asian equestrian Scythian culture expanded, and an increase in population density was a stimulus for westward migration towards southeast Europe. For further evidence of climate change around 850 BC, for explanation of solar forcing of climate change and for additional, climate-related archaeological data, see Beer and Van Geel (2008).

Figure 1 Profile through a bank in the Celtic field of Øster Lem Hede. The small holes were made by taking samples for pollen analysis by the first author. (Photo W. Groenman-van Waateringe).

Celtic fields in prehistoric continental northwest Europe

The banks of the continental Celtic fields were built mostly of local material, coming from the depressions in between, sometimes supplemented with material from farther away (Arnoldussen and Scheele 2014; Gebhardt 1976). Manuring took place in the form of household debris and animal manure. Most of the household debris occurred in the banks, much less in the depressions in between (Arnoldussen and Scheele 2014). The phosphate content of the banks is

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highest, much less so in the soil outside the Celtic field and medium in between the banks (Arnoldussen 2012; Arnoldussen and Scheele 2014; Brongers 1976; Gebhardt 1976; Spek *et al*. 2003). Complete soil profiles with the old surface from before the construction of the bank can only be found in the banks (Fig. 1), not in the depressions (Fig. 2). The chequerboard pattern can have two different origins. At Vaassen (Fig. 3) Brongers (1976, 59–60) found that the area was originally divided in strips, measuring 230–300 m long by 35–40 m wide. He also found that the secondary cross banks were lower than the long, uninterrupted, primary banks. One may wonder if these were made when more cultivation space was needed. A second possibility is that the layout followed the pre-Celtic field pattern of parcelling and that the banks were simply superimposed on the original field boundaries. There is evidence for the existence of such earlier parcelling systems underneath the banks in the Celtic field of Hijken (Harsema 1991).

The continental Celtic fields are assumed on, a.o., stratigraphical evidence to occur during the Late Bronze/Early Iron Age (transition dated in the Netherlands around 800 BC, Louwe Kooijmans *et al*. 2005) and to have been in use into the Roman period (Harsema 2005). However, exact dating of the banks will always remain a problem, while the material used for building the banks can be from anywhere and from any depth. Moreover, there is evidence that the banks (not necessarily all of them) may have been used in the Early Medieval period for rye cultivation (Groenman-van Waateringe 2012). If this was the case the Iron Age pollen content of the banks is now overshadowed by younger pollen. So far there are just a few ^{14}C dates available (charcoal from household debris). These datings, however, are arbitrary because of the original, unknown, provenance of the charcoal (Brongers 1976; Lang 1994; Nielsen and Dalsgaard in press; Spek *et al*. 2003). From the Celtic field of Vaassen (Brongers 1976) there are no samples from the banks, just one *terminus post quem* (5th century BC) and one *terminus ante quem* (2nd century AD). From two Baltic Celtic fields (Lang 1994) four ^{14}C dates from underneath banks are available supposed to be from the vegetation burnt prior to the start of the system. These *terminus post quem* dates point to the Iron Age. From the Celtic field of Hijken (Spek *et al*. 2003) there is only one date from a bank: 4th–3rd century BC. From the Celtic field of Øster Lem Hede (Nielsen and Dalsgaard in press) there is only one date, a carbonised grain from a bank, also pointing to the Iron Age. OSL dates, so far known only from two sites, Øster Lem Hede in Denmark (Nielsen and Dalsgaard in press) and Wekerom, the Netherlands (Arnoldussen and Scheele 2014), show a more complicated picture. From the six dates of the Celtic field in Wekerom, two could be dated to the Middle/Late Bronze Age, four to the Iron Age. Five samples taken from banks in the Danish site are dated to the Iron Age, but one in the Mesolithic period. That result must be a warning that, when moving sods to raise the banks, older material apparently can be displaced without being exposed to light. Thus the OSL dating for the start of the Celtic field of Wekerom in the latter part of the Middle Bronze Age may also be questioned. Both in Øster Lem and Wekerom two OSL dates from above each other in banks have matched dates. This means that the banks were probably built up gradually, not in one phase. As a consequence of tillage and biological activity most profiles do not show separate phases or recognisable sods.

Figure 2 Profile in a depression between banks in the Celtic field of Øster Lem Hede. (Photo W. Groenman-van Waateringe).

Discussion

The current idea is that arable farming took place in the depressions between banks and that the banks were just boundaries. Some authors suggested that in a later phase agriculture may have taken place on the banks (Brongers 1976, 71; Zimmermann 1976). The pedologist Gebhardt (1976) proposed the term 'Celtic banks' instead of 'Celtic fields' for the Celtic field of Flögeln, Germany. Behre and Kučan (1994, 133; see also Behre 2000) consider the Celtic field of Flögeln with cultivation on the banks, following on a pre-Celtic field phase without banks, to be an exception. Their idea for cultivation on the banks is based on their width, up to 16 m, and their high phosphate content in comparison to the depressions.

Food production on raised beds is a well-known practice from all over the world and until modern times. Prehistoric garden beds, as they are called in America, are known from both South and North America (Moffat 1979; Riley *et al*. 1981). The width of the beds varies from 2 to 6 m, their height is ca. 45 cm. They are laid out in different patterns (Riley *et al*. 1981, Fig. 1). The advantages of this kind of agriculture are several. In the first place there is soil

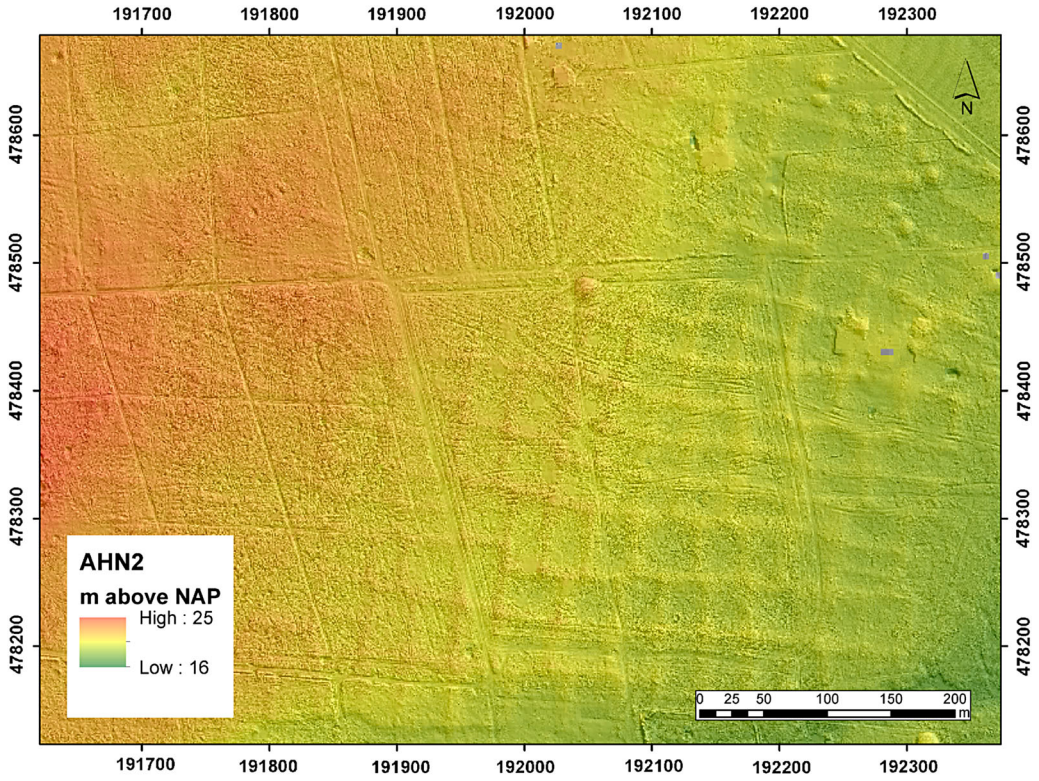

Figure 3 Composite map of part of a Celtic field west of Vaassen. Hill shade map overlain by an elevation model shown with 50% transparency. Data derived from Actual Height Model of The Netherlands (AHN2, see www.ahn.nl). Grid in Dutch RD New coordinate system.

enrichment, because of the addition of humic material from the topsoil besides the beds or from elsewhere. The second advantage is improved drainage because of higher storage capacity for water and a better drainage of water internally and externally towards the lower-lying areas. This will result in better aeration and optimum root growth for crop plants on the banks. In general, arable fields lying in between higher banks would suffer from local wetness, particularly under wetter climatic conditions and on less permeable soil types. Lowering of the level in between banks down to the impermeable loamy glacial till would have resulted in extreme wetness in the areas between the banks in the Celtic field of Zeyen (Spek *et al.* 2003). Reduction of frost damage is a third advantage of agriculture on the banks, as temperature readings between banks and lower parts of the arable system show temperatures 2–3°C higher on the banks (Moffat 1979), thus prolonging the growing season. This must have been highly important in a period with a wetter and colder climate.

Experiments with raised field agriculture were carried out in a lake basin on the border between Peru and Bolivia. Local farmers constructed raised fields with traditional tools with labour organised in a traditional manner. It was found that raised beds increased fertility, provided drainage and improved crop microclimate. The experiments also showed that the construction of the raised beds was laborious, but that in the long run they were very efficient, highly productive and inexpensive to maintain. Moreover, the complexity of social organisation to mobilise labour and plan activities was low, well within the means of small families or groups (Erickson 1992).

Conclusion

The solar-forced climate shift to cooler, wetter conditions around 850 BC was initially a disaster for farmers in northwest Europe, but 'crisis is the mother of invention'. We hypothesise that climate change forced the Iron Age farmer to adjust and to develop a new method of arable farming, i.e. on raised beds, with the advantage of better drainage and protection against night frost in spring and autumn, thus prolonging the growing season. Once the advantages of cultivation on raised beds became obvious, the system would be expected to have spread widely in the course of the Iron Age and been maintained for a long period, even if not forced by the hydrological situation, but because of all the other advantages of the new system. The new agricultural strategy and thus intensification of food production may have led to increased human impact as recorded in pollen diagrams.

The above may be characterised as 'environmental determinism'. But despite all the knowledge and modern techniques, one realises today that major climate changes can have far-reaching consequences

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for the existence of human populations. The Iron Age farmers apparently were able to cope with the new environmental conditions by adapting their arable practice, no longer on level fields, but on raised beds with all their advantages, thus mitigating the adverse effects of the climate change.

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