INDICATIONS OF SEVERE DROUGHT DURING THE 10TH CENTURY AD FROM AN INLAND DUNE AREA IN THE CENTRAL NETHERLANDS[1]

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ABSTRACT

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In the Kootwijkerzand on the Veluwe (The Netherlands) a settlement has been excavated that was buried beneath wind-blown sands and that was dated 750-1000 AD. For its water supply, this settlement depended on a nearby pool, which owed its existence to an impervious horizon in the subsoil. Since fluctuations in the water level of this pool could be reconstructed it could be established that the pool dried out relatively quickly in the 10th century. In addition a rainfall chart for the 8th-10th centuries was constructed. It appears that the first half of the 10th century heralded a period of drought, of a severity hitherto unknown, which must have affected large areas of Europe. A relationship, either direct or indirect, is sought between the lack of rainfall and features which appeared on the Veluwe and elsewhere around 1000 AD, such as:

1. turf-manuring and the shift in emphasis from summer cereals to winter cereals (rye) on the high, sandy soils;
2. sand-drifting, both inland and along the coast;
3. the reclamation of part of the high moor in the western Netherlands.

INTRODUCTION

From 1971 to 1974 several Roman and early Medieval settlements were excavated in the Kootwijkerzand on the Veluwe (The Netherlands). The work formed part of a large-scale archaeological project of the Albert Egges van Giffen Institute for Pre- and Protohistory, University of Amsterdam. One settlement was unearthed that dated to the period 750-1000 AD and that depended for its water supply entirely on a nearby pool (Fig. 1).

During the 10th century, this pool, which owed its existence to an impermeable horizon in the subsoil, dried out. Although ground-water was then still available from wells, the provision of water – especially for livestock – became so difficult that the inhabitants moved to other sites in the Kootwijk territory, not long afterwards. An additional factor in the abandonment of the settlement was the increasing problem posed by wind-blown sands, which eventually engulfed the entire area in the 11th century and which still form the core of one of the largest remaining inland dune regions in Europe.

Although other factors contributed to the loss of water from the pool (water consumption, leakage), it will be shown that the main cause can be attributed to climatological conditions. Quantifiable evidence for the fluctuation of the water level in the pool even permits the reconstruction of a rainfall curve for the 8th-10th centuries. This shows the advent of a period several decades long of hitherto unknown drought in the first half of the 10th century.
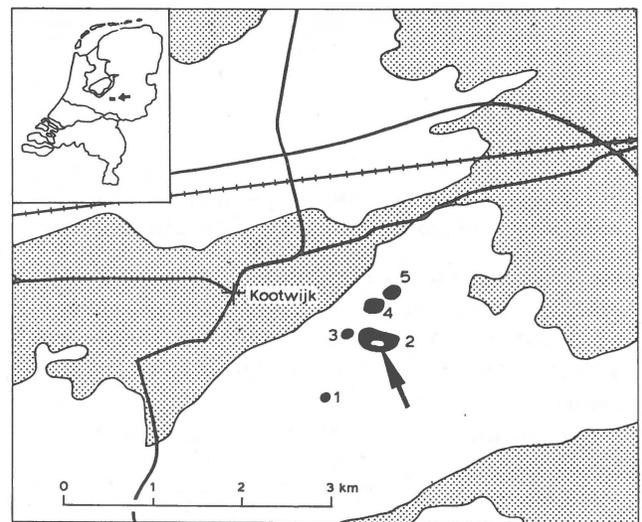

Fig. 1
The location of the pool (arrow) and the Roman and Medieval settlements revealed by excavation in the Kootwijkerzand. 1: 11-12th century; 2: 8-10th century; 3: 2-3rd century, 4: 6-7th century, 5: 7th century.
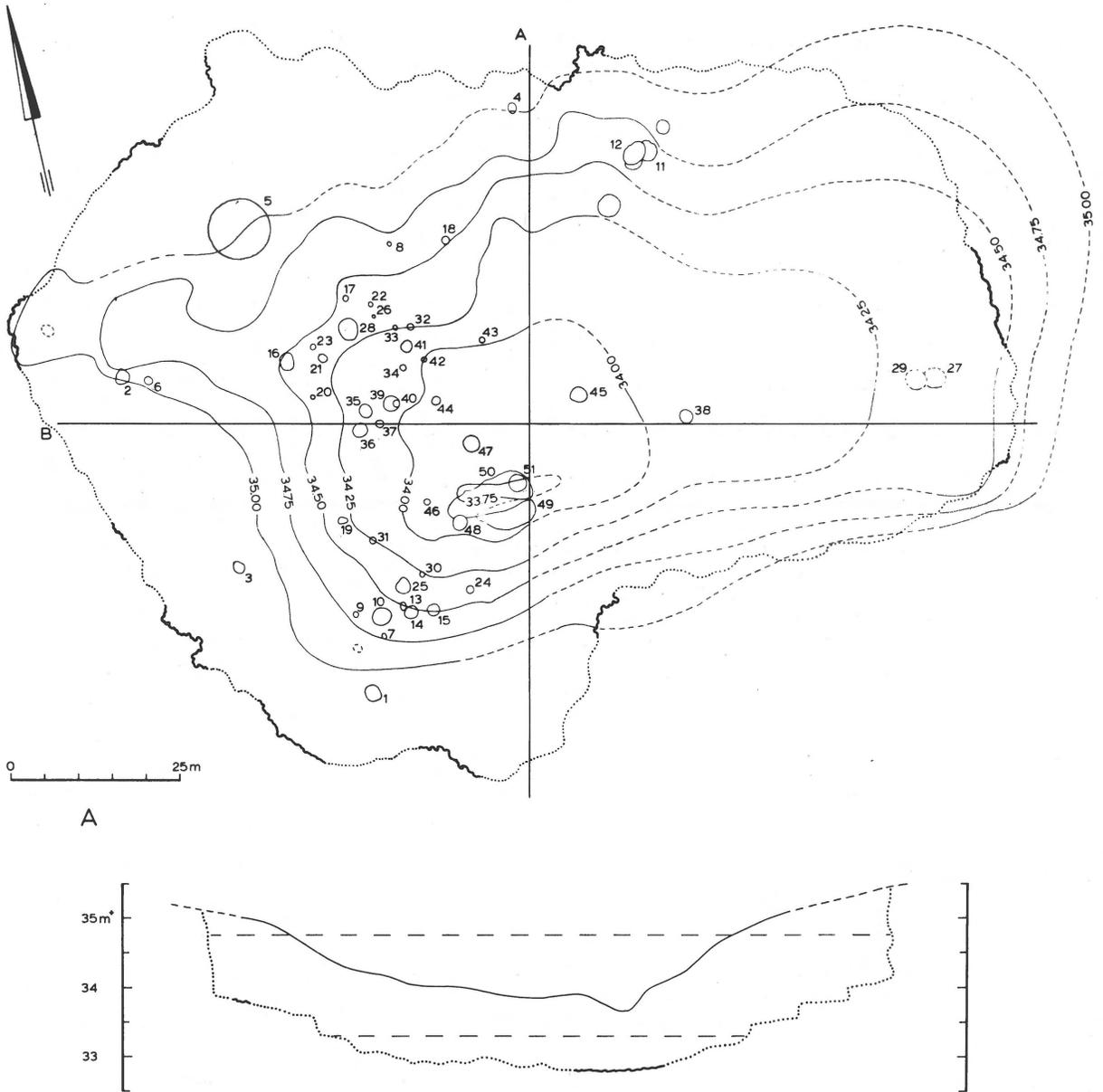
Fig. 2
Top: The pool. Heavy line: surface exposure of iron pan (dotted: reconstructed). Thin lines: contour lines (dashed: reconstructed). Numbers: wells. Bottom: section (A) of the pool with highest and lowest water level marked (broken lines).

First the method used to obtain this rainfall curve is described. Then a discussion is given of certain phenomena which make their appearance around 1000 AD in the Veluwe and elsewhere and which can be linked to the exceptional drought:

– turf-manuring and a shift in emphasis from summer to winter cereals on the high, sandy soils
– sand-drifting, both inland and along the coast
– the reclamation of part of the raised bogs in the western Netherlands.

For more detailed information reference is made to HEIDINGA (1984).

THE WATER SUPPLY

The majority of pools on the high sandy soils in The Netherlands was formed in depressions on a strongly developed B-horizon of a humic podzol. The water in the pool at Kootwijk, however, collected on an impermeable bank some 75-150 cm below the surface (Fig. 2). An iron pan developed here leading to the formation of an almost impenetrable "bath tub". The water regime depended entirely on local precipitation. Within the basin in which the water collected, we may envisage – prior to the 10th century at least – a small lake, that fluctuated in size and that was ringed by land with a high (pseudo) ground water table.

Fig. 3
Well sealed by blown sand (hollowed treetrunk) in the deepest part of the pool basin.

From the second half of the 9th century onwards, wells were dug near the pool, probably because the surface water became polluted. Later, after the pool had fallen dry, wells were also dug in the lowest parts of the basin. With an odd exception, the wells were not dug through the iron pan under the pool. If the iron pan was punctured, a new iron pan developed rapidly. Other evidence also suggests that leakage in such cases was minor and of short duration. Fifty-one wells were dug, most were lined, either by a hollowed-out tree trunk (Fig. 3) or with a plank revetment. Apart from these wells, for prolonged use, there were smaller pits apparently only for temporary use. However, a number of the larger wells could also be shown to have been exploited for only a limited period of time.

From the level from the wells were dug and the depth to which they reached, it is possible to deduce that they were never exploited all at the same time. From Fig. 4 it may be concluded that the water level fluctuated between 34.75 and 33.30 m + NAP (Dutch Ordnance Level), during the period in which wells were dug. Considering the relief of the area and the course of the iron pan, the maximum water level may have measured 35.00 m + NAP. Whether this level was ever reached, however, is uncertain. From the archaeological datings of several of the wells and the spatial relationship between the fen and particular phases in the settlement, the general trend of the water level can be reconstructed with reasonable accuracy (Fig. 5). A slight decrease in water level is observed from as early as the beginning of the 9th century, but it is only in the first half of the 10th century that a strong lowering of the water table took place. Still, the process is too gradual to justify the supposition that the pond drained suddenly as a result of a rupture in the iron pan.

On the basis of a calculation of the water storage capacity of the pool at various water levels, it can be shown that between circa 800 and 950 AD some 6000-7000 cubic metres of water must have "disappeared". Strictly speaking, the rainfall surplus – i.e. the amount of rain-water remaining after evaporation – should be added to this loss. Under present climatic conditions, this surplus represents about 8% of the annual precipitation which falls on open water and about 30% of what falls on land that supports vegetation of the type which could be reconstructed for the margins of the pool. (Here, an annual precipitation of 76 cm and evaporation of 70 cm/a is assumed over open water – figures taken from SCHIMMEL & TER HOEVE, 1952). Evaporation in the land surrounding the pool is estimated from lysimeter readings in the Provinciale Waterleidingduinen in North Holland. It is suggested, that 90% of the land was grass covered, that 5% supported deciduous woodland and that 5% was bare. If evaporation were the only loss, the pool would have overflown each winter. Inevitably, it must be concluded that evaporation was not the only cause for the lowering of the watertable. Of course, evaporation decreased as the water level dropped, since the surface area of the pool decreased (Fig. 6).
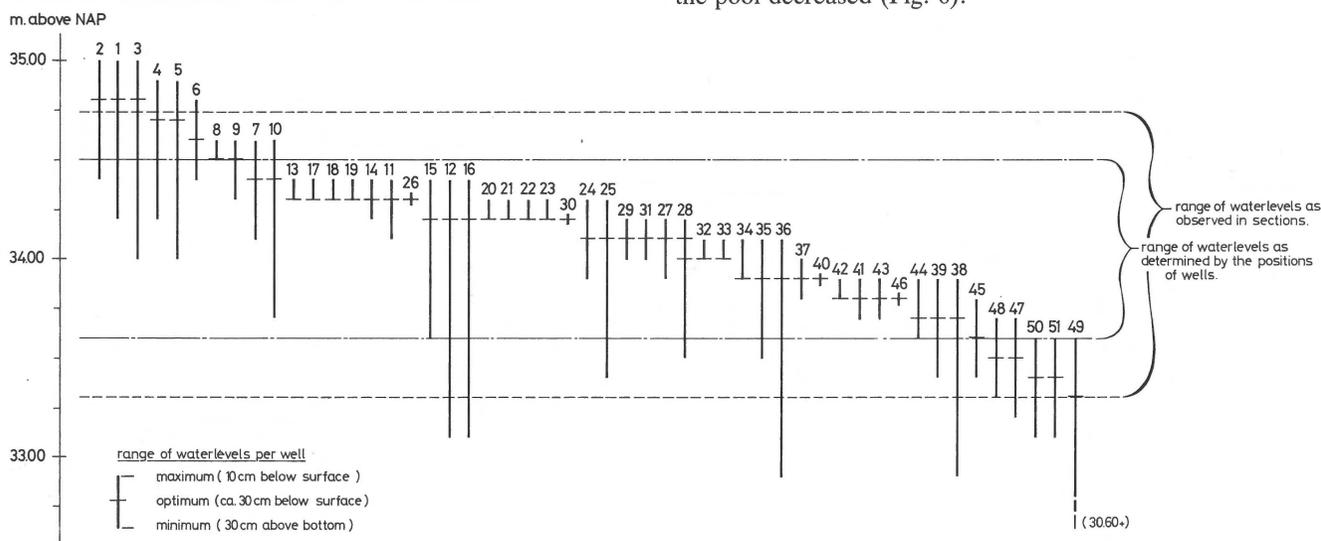

Fig. 4
Minimum and maximum levels per well, arranged from high to low: also the minimum and maximum level in the pool from other observations.
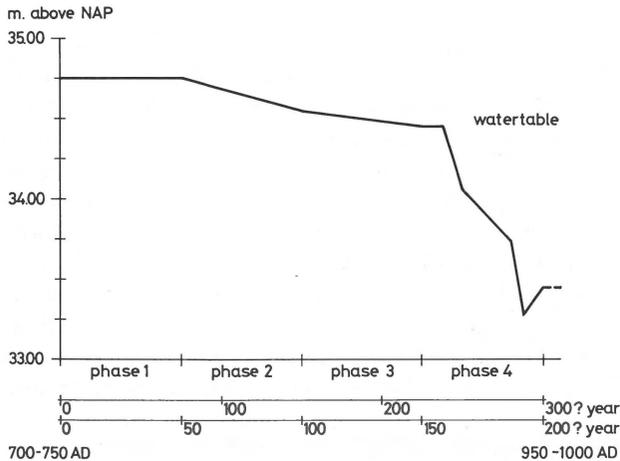
m. above NAP

Fig. 5
The fluctuation in water level in the pool in the 8th, 9th and 10th century. Since it is impossible to fix the beginning or the end of the settlement exactly, two time scales are given the maximum and the minimum duration of settlement.

WATER LOSS

Water is lost from the pool by 1. evaporation; 2. consumption by man and beast; 3. and by seepage.

That precipitation was no longer able to balance these losses may have been caused either by decreasing rainfall or by increasing loss of water or by a combination of both. At first, it was supposed that the pool had been literally "drunk dry", but an estimate of the maximum water usage in the period concerned shows that in stead there must have been a considerable surplus (see Fig. 7). This estimate is based on the population present in each phase with livestock being calculated from the size of the byre in each house. It is possible that additional livestock was kept permanently outside, but in view of the extensive farming methods of the time, these animals were probably kept at some distance from the settlement and had their own drinking places (possibly transhumance was practised; see HEIDINGA, 1984). Since even the
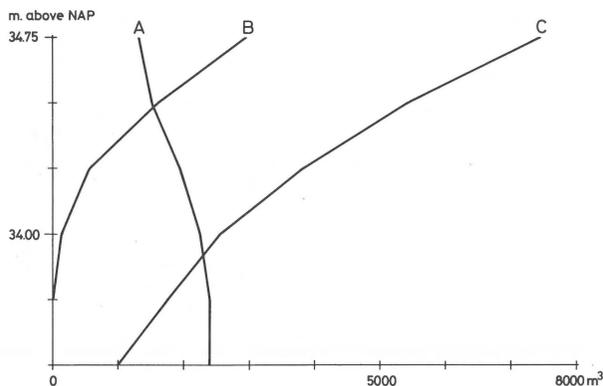

Fig. 6
Water surplus (rainfall minus evaporation) of the pool per level if the climatic conditions were the same as today (A), compared with the volume of surface water (B) and the total quantity of water in the pool (C).
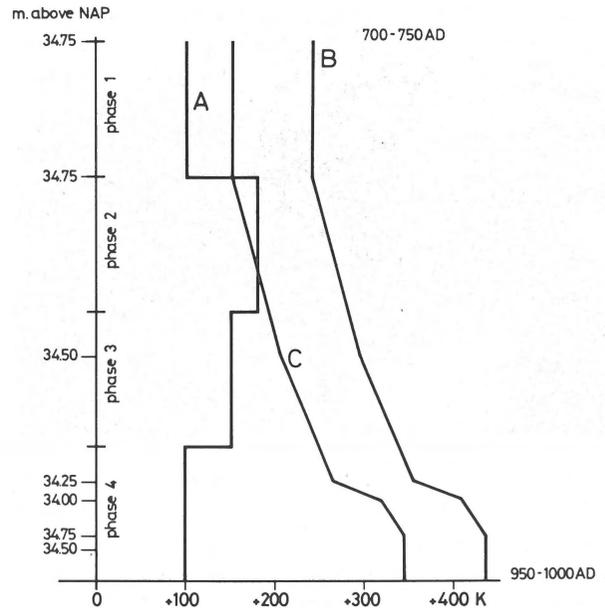

Fig. 7
Estimated water consumption by man and beast (A), compared with the surplus after evaporation only (B) and the surplus after evaporation and seepage (C). 1 K on the horizontal scale represents the average consumption of 1 cow per year (approx. 5,5 m³/a).

stalled livestock would only have been kept in or near the settlement periodically, the estimate of water consumption is probably too high rather than too low.

Loss of water through seepage is more difficult to quantify. What is certain is that a rupture of the pool bed would result in only temporary leakage, while the study of a similar pool by SCHIMMEL & TER HOEVE (1952) indicated that the bed is comparatively water-tight. Nevertheless, a permanent seepage of about 7 cm per year at the highest water levels should be accepted (for calculation see HEIDINGA, 1984). Even if these amounts are added to the volume consumed, there ought to have been a reasonable surplus under the present day rainfall and evaporation conditions.

The implication is, therefore, that precipitation and evaporation at that time were *not* comparable to the present; it must have been dryer, with less rainfall and possibly also increased evaporation.

THE CLIMATE IN THE 8TH, 9TH AND 10TH CENTURIES

Since the pool lies in an impermeable basin and the amount of water lost annually by evaporation, seepage and consumption can be estimated, it is also possible to calculate the amount of the annual precipitation required to produce the observed deficit:

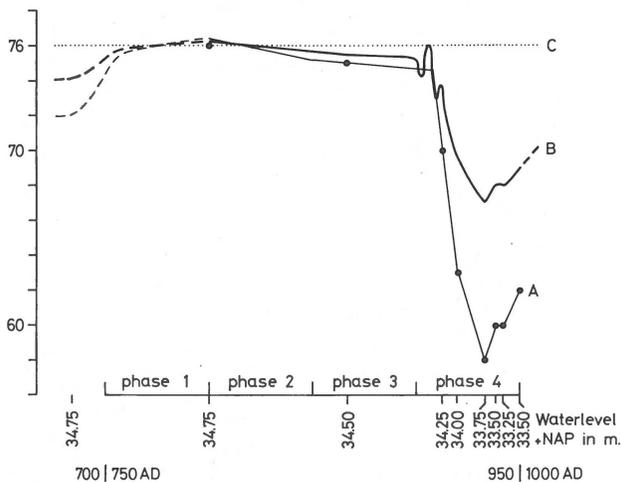$$P = E + C + L + D/S, \tag{1}$$

PRECIPITATION IN CM PRO YEAR

Fig. 8
Estimated annual precipitation between 700/750 and 950/1000 AD
A: minimum (evaporation rate as at present); B: maximum (symmetrically increased evaporation); C: present-day quantity.

in which P = precipitation; E = evaporation; C = consumption; L = leakage, D/S = deficit/surplus of water in the pool area, all per year. In fact the calculation of annual precipitation is considerably more complex than this simple equation suggests. Problems which can only be mentioned here are the difficulties of expressing the various factors in annual terms, the inconsistent evaporation rates as a result of the fluctuations in surface area of the pond, the overflow from the land zone (with its reduced capacity for moisture retention) towards the pool, the consequences of a potentially higher water level than the observed maximum of + 34.75 m (NAP, and the seepage factor (for full details see HEIDINGA, 1984). A fundamental drawback is the assumption in this equation of a constant rate of evaporation. It is likely that irregularities in the pattern of rainfall will be reflected in a variation in the absolute quantity of evaporation. In Fig. 8, curve A represents the annual precipitation from about 700-950/1000 AD if the evaporation rate of present climatic conditions is accepted. In curve B, the deviation from curve C is attributed for 50% to an increase in the rate of evaporation. In this case, the extremes in the level of annual precipitation do not differ to any great extent from those recorded during the severest drought in the recent past, between 1800 and 1810, when the annual rainfall fell some 10-12 cm below the present average

(LABRIJN , 1945). Nevertheless, because the ratio between precipitation and evaporation is variable, Fig. 8 should be regarded only as an illustration of a trend and not as a reconstruction of actual yearly rainfall.

It appears that at the beginning of the 8th century it was possibly somewhat dryer than at present, that climatic conditions throughout the late 8th and 9th centuries were about the same as at present, and that the first half of the 10th century heralded a period of drought of hitherto unknown severity, which possibly lasted until the beginning of the 11th century. If a higher rate of evaporation than at present is accepted the dryness must have been accompanied by high temperatures and cloudless summers. As winters will also have been much dryer than now, the climate must have had a much more continental character throughout the entire year: hot, dry summers and very cold, but also dry, winters.

Whether this conclusion is compatible with previous information concerning the climate of the early Middle Ages, is not easy to assess; the palaeoclimatological sources and methods are exceedingly heterogenous, the margins of uncertainty inherent in each are great, and the degree of mutual agreement is low. A major problem is whether and how local evidence may be translated into general trends.

The analysis of the bog stratification ought to provide evidence for any periods of wetness or drought since these conditions are reflected in the composition of the peat (OVERBECK 1975). On the basis of such analysis in Cumberland (U.K.) BARBER (1978) concluded that the first half of the 10th century was dominated by a distinctly wet and/or cold climate. In the same period in Denmark, however, there is evidence for stagnation in peat growth, and thus, presumably, for dryer conditions (AABY, 1976). LAMB (1977, p. 428) also suggested that it was too dry rather than too wet during the 10th century: "the most remarkable sequence of drought in Britain and Germany was reported in the AD 900's, particularly in the 920-940's and 980-990's". LAMB pointed to the chronological correspondence between these periods of drought and the sequence of year rings in the Spessart-oak series, which display severe growth retardation in the same periods, probably attributable to a shortage of water (LAMB 1977, Table, app. V. 22). In LAMB's (1982) synopsis of the past climate, he was quite explicit on the evidence for drought in the 10th century, and characterized the climate of this period in England, Germany and S. Scandinavia in terms entirely consistent with the description obtained from the Kootwijk
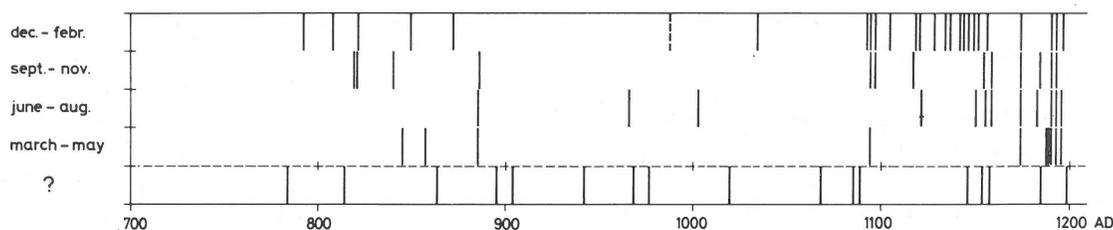

Fig. 9
River flooding in western Europe till 1200, according to Gottschalk (1971).

evidence: hot dry summers and cold dry winters. The remarkably few river floodings recorded in the 10th and 11th centuries (GOTTSCHALK, 1971) may also be an indication of the relatively dry conditions which prevailed in this period (see Fig. 9).

CONSEQUENCES OF THE DROUGHT

Just as certain changes in economy, shifts in settlement patterns, famines etcetera are regarded by palaeoclimatologists as symptoms of climatic change, so many an historian or archaeologist holds established climatic fluctuation responsible for concomitant events and changes in society. Such associations are only justified, however, when the reconstructed climatic conditions have predictable consequences (PARRY, 1978). For example, the mere fact that Denmark's economic and political apogee in the 10th century occurs in a period of relatively high annual temperatures is a totally inadequate reason for ascribing the former to the latter, as RANDSBORG (1980) does. The consequences of extreme aridity are in fact to be expected in those regions which are by nature either already exceptionally dry or, at the other extreme, exceptionally wet.

In The Netherlands, we see the culmination of several significant changes around 1000 AD in just these regions – the rather wet *and* the rather dry – which can be linked to the consequences of a period of aridity. These changes were to have a major effect – both positive and negative – on the course of Dutch rural life.

CHANGES IN THE AGRICULTURAL SYSTEM ON THE SANDY SOILS

On the high sandy soils, such as those on which Kootwijk is situated, the risk of crop failure as a result of lack of rainfall is high, especially in the case of summer cereals such as wheat and oats.

A dry spring in particular is disasterous not only for the young sprouts but also for the field itself: as the unprotected tilth dries out the threat of erosion and sand-blows increases, as the events of 1947 in Lower Saxony confirm (STECKHAN, 1950). Since summer cereals formed a considerable proportion of the arable, similar problems must have occurred on a large scale in the 10th century.

In the 10th century important changes in the agricultural system on the sandy soils were probably stimulated by these problems. For the first time, a new method of manuring was introduced, a method whereby the field was raised by bringing humic material from elsewhere (heather turves, leafmould etc.), with or without a mixture of animal manure. BEHRE (1976) established that turf-manuring was first practised in Lower Saxony in the second half of the 10th century. In Kootwijk too, the first raised soils date from the 10th century

(HEIDINGA, 1984). According to PAPE (1970) the principal advantage of such soils over non-raised fields is enhanced moisture retention and a tilth which encourages root development: properties of great importance in periods of drought. Thus, the extreme dryness of the 10th century when, no doubt, fewer crop failures were seen to occur on relatively thick fields with high humus content than on thin, poor soils, may well have led to this artificial deepening of the plough soil.

It this supposition is correct, we must assume that in this primary phase of turf-manuring relatively large quantities of humus were applied. It could be shown that in Kootwijk the farmers at first only improved those fields which were being covered by drift sand. Later humus was added to raise the plough soil above its customary thickness. Since turf-manuring offered several additional advantages, such as preparing soils for cultivation which were naturally not suited, this system was maintained into the late 19th century in extensive areas of The Netherlands and Northern Germany, where it exerted a profound influence on economy and settlement.

The increasing dominance of rye to the detriment of wheat and barley which is evident on the sandy soils from the 10th century onwards (BEHRE, 1976; HEIDINGA, 1984; GROENMAN-VAN WAATERINGE & VAN WIJNGAARDEN-BAKKER, in press) may also be viewed in terms of a general shortage of rainfall; rye, which is cultivated as a winter cereal, has greater chance of success than the summer cereals. Furthermore, the field surface was protected from erosion in early spring by a cover of young growth. Together with turf-manuring, the success of rye cultivation on this type of soil was permanent: it is not the first time in history that progress was the outcome of dire necessity.

WIND EROSION

We have seen that, by the 10th century, the entire situation on the Veluwe was highly susceptible to large scale wind erosion: extensive tracts of the cover sands had been deforested as a result of agricultural clearance, grazing, fuel gathering and, last but not least, of the huge demand for charcoal for use in the local iron industry (HEIDINGA, 1984). Fields lying fallow, drove roads and other places which lacked their protecting mantle of vegetation as a result of human activity, were thus exposed to the full force of the wind. During dry spells, wind erosion must have increased considerably as the soil surface dried out and as the extent of bare soil increased due to the withering and slow regeneration of some types of vegetation.

In addition, a lower nutritional value of the available fodder plants will have increased the pressure of grazing, while withering vegetation would suffer more from trampling. Furthermore, it is at just at such periods of stress that the removal of the humus cover for use in fields begins – in itself an indirect consequence of drought. This picture alone is sufficient to conclude that severe wind erosion and sand

drifting should already have occurred by the 10th century. These sand drifts would, no doubt, have formed the centre of the extensive drift sands which were eventually to cover about one fifth of the higher Veluwe (KOSTER, 1978). It is well-known that aeolian sand transport takes place under such conditions, especially in the spring with dry, sunny weather and bleak, easterly winds (STECKHAN, 1950; KOSTER, 1978; HEIDINGA, 1984).

On the basis of the dating of bogs sealed by drift sands KOSTER (1978), however, arrived at a somewhat later date for the beginning of the Veluwe sand drifts, namely the 12-13th century. From the morphology of the sand drifts he concluded that southwesterly winds were responsible for the major part of the sand transport.

However, it is advisable to distinguish between the genesis of the sand drifting (the primary drift phase) and its later extension (the secondary drift phase). Arid conditions are essential for the formation of the drift sands in the first place, but once the sands are established they may extend even under moist conditions, provided the wind is strong enough. The pools studied by KOSTER (1978)may have been covered only in the secondary phase. Whatever the truth in this matter, the evidence from Kootwijk proves that here at least, severe wind erosion was taking place as early as the 10th century.

The formation of the Younger Dunes (YDI) has much in common with the formation of the drift sands on the Veluwe. Along the coast, an older landscape of dunes, marked by traces of human activity, was covered by new drift sands. The debates on the cause and dating of both events run parallel courses. Even though JELGERSMA ET AL. (1970) still dated the first phase of Young Dune formation (YD la) in the 12th or 13th century, RENTENAAR (1977) opted for the 10th century on the evidence of written historic evidence. This agrees with KLIJN's (1981) dating of the beginning of the process. KLIJN based his conclusion on the calculation of the amount of time it takes for dunes formed along the seashore to reach dated sites inland (see also ZAGWIJN, 1984, this volume). It seems to be generally accepted that the dunes were formed along the seashore. Be that as it may, their extension inland must have taken place in the same fashion as that of the inland dunes. The contemporaneity of the two landscape developments suggests a common cause, namely extreme aridity which upset delicately balanced environments, both along the coast and inland.

PEAT RECLAMATIONS

The loss of agricultural land on the high sands in consequence of dune formation was to some extent compensated by the gradual extension of cultivation into the great peat bogs of the western Netherlands. Although these areas had been occupied sporadically before, systematic, large-scale reclamation only began in the 10th century (DE COCK, 1965; HENDERIKX, 1983). In the west, the occupants of the Old Dunes, now threatened by the advancing drift sands, played a major role in this process of reclamation (see HALLEWAS, 1984, this volume).

Quite apart from general demographic factors there arose a definite urge to utilize this formerly virgin land with its rainfed cushions of high moors. These areas are only fit for agricultural purposes if the surface is already drying and humification is taking place, and when the growth of the moisture-dependent *Sphagnum* species stagnates. Such conditions are achieved when natural or artificial drainage takes place or when there is a rainfall shortage.

It is inconceivable that in every place where 10-11th century cultivation is in evidence, the bog should have been drained by natural agencies, as for instance, when water is syphoned off by the intrusion of rivers or the sea. The inhabitants of these areas certainly became highly skilled in artificial drainage techniques, but whether they penetrated the bogs in the 10th century, already equipped with that know-how is open to question. It is more likely that these techniques were developed by the force of circumstance, namely when land already cleared became liable to flooding as a result of shrinkage and oxydation.

The dry phase described in this article coincided more or less with the earliest stages of the reclamation and that makes it likely that the peat was already suitable for exploitation as a result of rainfall shortage. That the greatest extent of the high moors was only reclaimed long after these dry years is in no way contradictory, for the reduction in surface level of the cultivated lands leads to drainage of the surrounding peat, which would facilitate cultivation. Cultivation would also tend to stimulate the development of a drainage system.

We thus see that the drought only stimulated the start of the process; it would not have been necessary to maintain or extend it. Reclamation of the peat bogs is no more "caused" by the drought of the 10th century than turf-manuring or rye cultivation: drought goaded man to adjust. He would ultimately have reclaimed bogs anyway, even without the climatic stimulus.

CONCLUSIONS

A small pool in the Kootwijkerzand covered by windblown sand provides definite evidence for dry conditions in the 10th century postulated by LAMB (1977, 1982). Calculation of the approximate annual deficit of water in the pool shows that at that time there must have been not only higher evaporation but also lower annual rainfall than at present, an indication of warm dry summers and cold dry winters. In the dryest years, which can be dated between circa 925-975, precipitation must have been at least 10 cm/a less than at present. Such climatic conditions must have had the greatest impact on vegetation that directly depends on rainfall, i.e., the vegetation on the sandy soils with a low groundwater table and on the *Sphagnum* peat bogs. Thus severe agricultural problems arose on

the high sandy soils. These problems were countered by raising the humus cover of arable fields, thereby increasing the moisture holding capability and by turning chiefly to winter cereals which are more resistant to drought than are summer cereals. The high moors in the western Netherlands on the other hand were rendered suitable for cultivation thanks to stagnation in *Sphagnum* moss growth and changes in the surface soil. These factors may have contributed to the beginning of large scale peat bog reclamation in the western Netherlands during the 10th century. Finally, it is suggested that the general aridity may have stimulated sand drifts on the Old Dunes along the coast, on the cover sands of the Veluwe, and elsewhere. For none of these features drought was a *conditio sine qua non:* they all are still in evidence long after the drought had passed.

ACKNOWLEDGEMENTS

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