SKRIFTER UTGIVNA AV SVENSKA INSTITUTET I ATHEN, 4°, XLII
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Agriculture in Ancient Greece

Proceedings of the Seventh International Symposium at the Swedish Institute at Athens, 16–17 May, 1990

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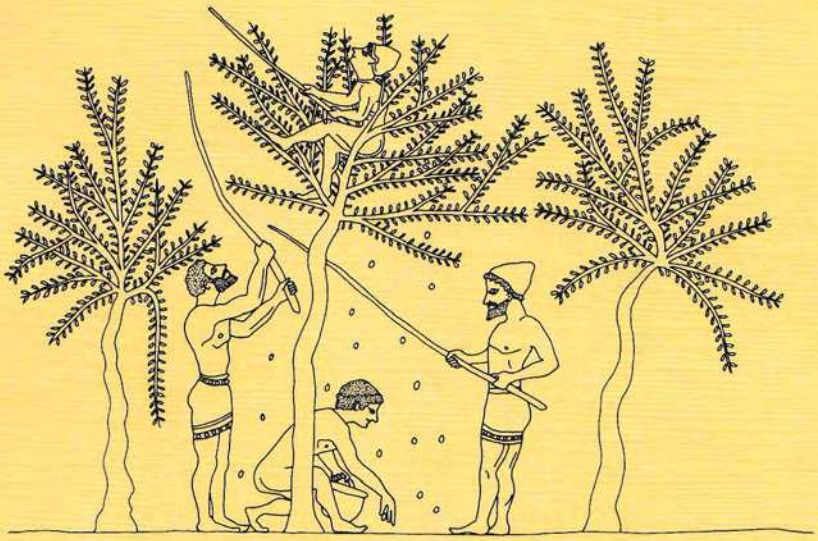
Berit Wells



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Abstract

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These fourteen papers on ancient Greek agriculture were read, or emanated from the discussions during, an international conference in Athens; the papers are followed by transcripts of the discussions of the symposium. Two main themes are addressed: (1) production—how do we recognize a farm and what could be, and what was, produced on it? (2) and the organization of agriculture—who owned the land, who worked it and how, and how much did it yield?

Key words: Agriculture, barley, farm, grape, labor, land, olive oil, olive tree, pulses, vine, wheat, wine, yield.

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Prehistoric and Historic Soils in Greece:

Assessing the Natural Resources for Agriculture

by
Eberhard Zangger

Abstract

Although paleofertility and -climate cannot be directly determined from the soil record, geoarchaeological reconstructions of landscape stability and destabilisation in Greece have been able to reveal the history of soil quality and its use and abuse. Studies of the Argive Plain, the Southern Argolid and Thessaly show how the rapid climatic change at the end of the last ice age did not result in any landscape destabilisation. Widespread soil erosion began only within 1000 years after the introduction of agriculture in these areas and thus appears to be human-induced.

Introduction

Although the term 'soil' may have different meanings to people with different background e.g. engineers, geologists, or gardeners, everybody would recognize the soil as the bearer of all life on dry land. Soil is the uppermost epidermis of the earth, averaging one metre in thickness; a loose accumulation of inorganic and organic matter that is of extreme importance for agriculture and thus for the global food production. The soil is a dynamic system undergoing constant changes depending on climate, parent material, relief, vegetation, hydrology, fauna and man. It evolves over thousands of years but is extraordinarily fragile and can rapidly erode. The soil records the history of a landscape but also determines its future to some extent. Studying soils thus also means studying the past, present and future environmental evolution.

Quaternary environmental oscillations

Understanding the natural long term oscillations of the earth is imperative for the reconstruction of recent environmental processes such as climatic change or soil erosion, because the human factor in environmental change can only be estimated when the character, extent and speed of natural fluctuations are known. Thus an examination of the prehistoric and historic Greek environment requires a look much further back in time.

During the Quaternary the earth was plunged into an ice age about every 100,000 years (*Fig. 1*). The causes of these glacial/interglacial cycles are still not fully understood, but the most widely accepted model is based on changes in the earth's orbit. The Quaternary glacial/interglacial cycles reveal a remarkable steadiness of frequence and amplitude, although the transitions from full glacial to full interglacial conditions occurred extremely rapidly. The most recent cycle was at its coldest at 20,000 bp, began to warm up rapidly at 15,000 bp and reached the postglacial maximum as early as 9000–6000 bp. The temperature had then risen about 4°C on a global scale and up to 12°C at the poles. At that time, 6000 bp, the Thames and Rhine valleys, having just represented the southern edge of the Arctic ice sheet, now housed lions and hippopotamuses.[1]

The termination of the last glacial period, 10,000 years ago, also roughly coincides with the introduction of cultivated crops and domesticated animals, perhaps implying a link between cultural and environmental evolution. If these two are linked indeed, one question we may want to contemplate in the future is why civilisation emerged during the most recent interglacial period and not during any of the previous twenty-five.

Marine cores from the North Atlantic show an extremely rapid increase in ocean temperature perhaps taking as little as 30 years.[2] However, the change from full glacial conditions to full interglacial conditions took 6000 years (15,000–9000 bp), because of the retarded response of the polar ice caps. The periodic accretion and depletion of these ice masses is accompanied by shifts of vegetation and faunal belts and by substantial sea level fluctuations. During the peak of the last glaciation, 20,000 years ago, sea level was 120 m lower than today.[3] Large coastal plains then provided the grazing grounds for herds of mammals such as wild ass hunted by Paleolithic tribes.[4] The Argive Plain, for

[1] A. J. Stuart, 'The history of the mammalian fauna during the Ipswichian/last Interglacial in England', *Phil. Trans. R. Soc. Lond.* B276, 1976, 221–250; J. J. Lowe & M. C. J. Walker, *Reconstructing Quaternary Environments*, Harlow 1984, 211.

[2] W. S. Broecker & G. H. Denton, 'The role of ocean-atmosphere reorganizations in glacial cycles', *Geochemica et Cosmochemica Acta* 53, 1989, 2465–1501.

[3] R. G. Fairbanks, 'A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas', *Nature* 342, 1989, 637–642.

[4] Tj. H. van Andel & J. Shackleton, 'Late Paleolithic and Mesolithic Coastlines of Greece and the Aegean', *JFA* 9, 1982, 445–454.

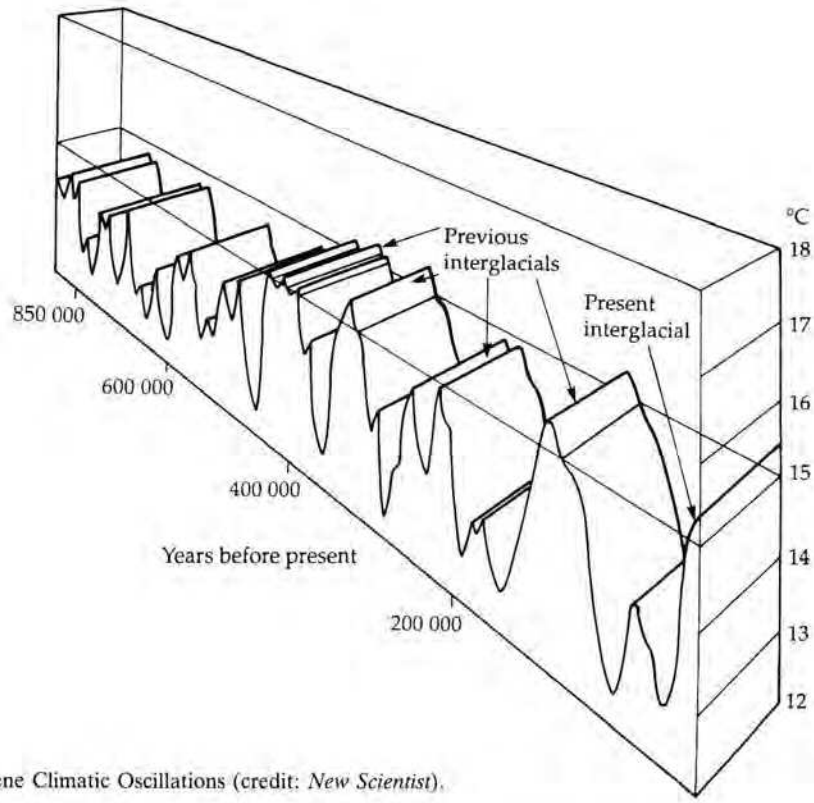

Fig. 1. Late Pleistocene Climatic Oscillations (credit: *New Scientist*).

instance extended 10 km farther south 18,000 years ago.[5]

According to pollen cores taken from Franchthi Cave[6] and elsewhere in Greece,[7] the glacial steppe vegetation was rapidly displaced during the early Holocene by forest of deciduous oaks possibly covering up to 95% of the surface.[8] The character of these forests may have varied spacially and temporarily between open wood with grassy ground flora and dense woodland.[9] Geoarchaeological studies in Thessaly and in the southern Argolid, however, have revealed long intervals of landscape stability spanning the Pleistocene/Holocene transition despite the rapid and far-reaching changes in climate and vegetation. No floodplain alluviations occurred in Thessaly between 27,000 and 7000 bp,[10] while the landscape of the Southern Argolid remained stable from 32,000 to 4500 bp.[11] Paleosols of this period are only sustained in topographically low areas where they have been preserved by burial under Holocene deposits. The parent material of such more recent alluvia must have been a soil cover higher up on the slopes which may not have been very thick. However, even a thin soil of 10–20 cm would suffice to provide the ground for a diversified vegetation.

To summarize the events before the introduction of agriculture and the rise of civilisation: far-reaching environmental changes at the end of the last ice age included rapid increases in temperature, a significant rise of global sea level, and broad shifts of vegetation belts. The soil, however, appears to have been uneffected by this environmental metamorphosis. Widespread erosion and redeposition occurred only after the natural climatic changes had regained a ± stable stage.

Soil characteristics

Subsurface exposures often show parallel, nearly horizontal layers which might have been formed by either sedimentation or by soil formation. Sedimentation occurs when loose material is eroded, transported, and deposited. Physical and chemical properties of the sediments reflect parent ma-

[5] E. Zangger, *Geoarchaeology of the Argolid* (= *Argolis* 2), Athens, in press; Tj. H. van Andel, E. Zangger & C. Perissoratis, 'Late Quaternary history of the Gulf of Argos, Greece: soil horizons and transgressive/regressive cycles', *Quaternary Research*, 1990.

[6] M. C. Sheehan & D. R. Whitehead, 'The Late-Postglacial vegetational history of the Argolid peninsula, Greece', *NatGeogrRes* 13, 1981, 693–708.

[7] J. Turner & J. R. A. Greig, 'Some Holocene pollen diagrams from Greece', *Review of Paleobotany and Palynology* 20, 1975, 171–204; J. Turner, 'The vegetation of Greece during prehistoric times: the palynological evidence', in *Thera and the Aegean World* 1, London 1978, 765–773.

[8] W. Rothmaler, 'Die Waldverhältnisse im Peloponnes', *Intersylva* 3, 1943, 329–343; A. Beuermann, 'Die Waldverhältnisse im Peloponnes unter besonderer Berücksichtigung der Entwaldung und der Aufforstung', *Erdkunde* 10, 1956, 122–136.

[9] O. Rackham, 'Land-use and the native vegetation of Greece', in *Archaeological aspects of woodland ecology* (BAR-IS, 146), eds. M. Bell & S. Limbrey, Oxford 1982, 177–198.

[10] A. Demitrack, *The Late Quaternary geologic history of the Larissa Plain (Thessaly, Greece)—tectonic, climatic, and human impact on the landscape*. Unpublished Ph.D. diss. at Stanford University, Stanford 1986.

[11] K. O. Pope & Tj. H. van Andel, 'Late Quaternary alluviation and soil formation in the southern Argolid: its history, causes and archaeological implications', *JAS* 11, 1984, 281–306.

terial, transport and depositional environment and associated fossil remains indicate the former biological regime. Times of enhanced sedimentation reflect landscape instability and vertical changes of sediment properties record the environmental evolution. Soil horizons are in many respects very similar to sedimentary layers. The generation of soil horizons takes place only on stable surfaces and requires a long time. The temperature gradient and the movement of water and ions through the surface layers of any natural deposit gradually cause the formation of horizons. The time needed for the development of a mature soil depends on the climate and the bedrock. A one-metre thick soil on a marl in Greece would probably form within a few thousand years. Thus soils record times of landscape stability. Soil development may occur independently of sedimentary units and is frequently discordant with the stratification.

The resource value of a soil in the sense of agricultural productivity is described by its fertility, which is a measure for the capacity of the soil to produce satisfactory yields of cultivated plants.[12] Limiting factors for the agricultural productivity of a given area are controlled by the environment and by socio-economic factors. The natural factors are climate, soil properties and site properties, whereas socio-economic factors are for example the farming system and the location of the arable land with respect to markets. The socio-economic component is generally assumed to be a more important factor than the physical state of the land.[13] Physical and chemical soil characteristics are thus by no means the only or decisive parameters determining the value.

Amongst the physical properties of soils are their depth, texture, structure, stoniness and drainage. These attributes are today regarded as more difficult and more expensive to change than chemical properties.[14] Thus, coastal plains and flat inland basins have always represented preferred places for agriculture, because their drainage is excellent and their stoniness is limited. Soil texture is described by grain size and a floodplain alluvium generally consists of up to 80% silt (0.002–0.063 mm), an ideal basis for agriculture. Soil structure measures the aggregation state of individual soil particles based on their shape and size. The soil structure is important to the movement of water and air through the soil and to prevent surface erosion.[15] The development of soil structure can be used as an indicator for relative ages, because it reflects the soil's maturity.

Chemical status is an important parameter of soil fertility, especially because many of the most important elements are rapidly depleted during agricultural use. Nitrogen, phosphorus and potassium are considered to be major elements for the soil fertility while sulphur, calcium and magnesium are of secondary importance. Nitrogen has a positive correlation with crop yield, but it is also easily leached or taken up by the vegetation. Therefore nitrogen is the most important fertilizer in modern agriculture. The next important element, phosphate becomes fixed in the soil as compounds not directly usable by plants. These compounds are stable and cumulative, thus long-used fields and occupation sites can be identified by high amounts of phosphate. Potassium and calcium are provided to the soils by weathering of minerals, and sulphur is derived from the atmosphere by precipitation and from plant residues.

Attempts to determine the paleofertility of soils were made during the Southern Argolid Survey,[16] but failed because chemical analyses can only determine present compositions, not show the chemical history of the soils. Thus, high values of a certain element cannot be attributed to a moment in the past because they could reflect the most recent manuring. So far, only phosphate analyses have been carried out successfully to determine human impact on disturbed strata.[17]

Precipitation and vegetation

Although the paleofertility of the original Pleistocene soils remains unknown, there is no reason to assume that it lacked essential elements. Today's agricultural productivity of southern and central Greece is not restricted by soil fertility but by a lack of precipitation.[18] Thus, discussing the agricultural productivity of southern Greece requires a consideration of precipitation, something which is possibly the most important factor of fertility.

To the present day no indisputable methods have been found to determine precipitation patterns for prehistoric and historic times. Because of the sensitive marginal climate of Greece, such methods would have to be extremely accurate. On the other hand, no conclusive evidence supporting a considerably different rate of precipitation has been found either; thus most scholars assume the rate to have remained more or less the same over the past few millennia.

Weather records have only been taken routinely for the last 150 years. Some of the earlier measurements (1894–1926) of the precipitation in Nafplion were presented by Lehmann[19] and also discussed by Balcer, Nordquist and van Andel.[20] A comparison of these values with the most

[12] J. G. Cruickshank, *Soil Geography*, Newton Abbot 1972, 198.
[13] Cruickshank (supra n. 12), 198f.
[14] Cruickshank (supra n. 12), 213.
[15] P. Birkeland, *Soils and geomorphology*, New York 1984, 17.
[16] Tj. H. van Andel, pers. com. 1990.
[17] R. C. Eidt, 'Detection and examination of anthrosols by phosphate analysis', *Science* 197, 1327–1333; *idem*, 'Soil phosphate as a diagnostic feature in Abandoned Settlement Analysis', in *Man, culture and settlement*, eds. Eidt *et al.* New Delhi 1977, 216–227; *idem*, *Advances in Abandoned Settlement Analysis*, Milwaukee 1984, 1–159; *idem*, 'Theoretical and practical considerations in the analysis of anthrosols', in *Archaeological Geology*, eds., G. Rapp & J. A. Gifford, New Haven 1985.
[18] Tj. H. van Andel, E. Zangger & A. Demitrack, 'Land use and soil erosion in prehistoric and historic Greece', *JFA* 17, 1990.
[19] H. Lehmann, *Landeskunde der Ebene von Argos und ihrer Randgebiete* (= *Argolis 1*), Athen 1937, 31–49.
[20] J. M. Balcer, 'The Mycenaean dam at Tiryns', *AJA* 78, 1974, 143; G. Nordquist, *A Middle Helladic village. Asine in the Argolid* (Boreas 16), 18–19; Tj. H. van Andel, 'Landscape and people of the Franchthi region', in *Excavations at Franchthi Cave, Greece*, ed. T. W. Jacobsen, Bloomington 1987, 5–8.

recent data (1948–1987) shows no significant difference for the past 100 years.[21] A stable rate of precipitation for the last one hundred years, however, does not provide grounds to argue that rainfall was the same over the past 3000 years. Even if the prehistoric precipitation was as low as today, the original forests of the early Holocene would have raised transpiration and thus humidity. Moreover, the vegetation cover would have protected the ground from splash erosion and the clay-rich surface soils would have retained the water for a long period, permitting perennial rivers as opposed to the present ephemeral flash floods. These tempering effects of dense vegetation and stable soil had already been recognized in Classical Greece as Plato's report in *Critias* shows.[22]

The vegetational cover may thus represent an important link between natural vegetation, agriculture, and soil erosion.[23] Preliminary results of pollen data from the former Lake Lerna in the Argive Plain have produced an as yet undated record of the vegetational history for this diversified landscape.[24] Most prominent in this pollen diagram are the abrupt increase and decrease in water plants, sedges (*Cyperaceae*), and grasses (*Poacea*) reflecting wet phases which have already been recorded from the depositional history of the area[25] and the bones of Lernaean graves.[26] A proliferation of deciduous oak during the early Holocene ended suddenly giving way to hornbean (*Carpinus*) and evergreen shrubs and trees. The hornbean, however, soon disappeared again while the evergreen vegetation including the olive further increased with time. The olive's increase coincides with its group, the evergreen trees, although the olive was presumably cultivated. Juglans, too, represents an introduced tree which increased in the more recent past. The last stage of the Lake Lerna pollen diagram reflects a disruptive grazing community, as indicated by the appearance and survival of juniper which accompanies overgrazing.

The pollen diagram presents a distinct record of events during and after the introduction of agriculture. Initially the valley bottoms were cleared to allow the simplest method of agriculture, where crops were harvested in one place only as long as they produced a satisfying yield. Cultivation was then shifted to obtain a better harvest in a different area, thus requiring the farmers to be mobile and affecting a relatively large area of land compared to the number of inhabitants. The system was successful as long as the population and the inherent agricultural demands were small enough to rest the land between uses and to restore soil chemical fertility. The subsequent introduction of fallow or dry farming allowed farmers to become stationary. In this system a part of the permanently farmed land was left unused each year to conserve nutrients and moisture. The transformation of woodland into farmland was probably largely completed in the Early Bronze Age.[27] Already in Mycenaean times the vegetation community looked similar to the present one.[28] Some dense forests may have remained in the back country, providing a biotope for boars, Mycenaean hunters, and perhaps the occasional lion.[29] Certainly by the Classical period,[30] the full agricultural potential of the land had been reached.

Soil erosion

What impact had the introduction of widespread agriculture on the inherited Pleistocene soils? Comparisons with other parts of the world demonstrate the effect of the rapidly spreading civilisation on soil stability. In Maryland, USA, for instance, an original soil loss of 0.2 cm per 1000 years increased fifty-fold through the spread of farming in the 19th century. Later reforestation of this land lowered the erosion rate to 5 cm/1000 yrs.[31] Clearing land, farming, deforestation for timber, grazing, and man-made fires are the most important causes of accelerated anthropogenic soil erosion.[32] The resultant loss of soil in the uplands and catastrophic sedimentation in valleys and coastal plains are obvious today in many parts of the world.[33] Particularly in the Mediterranean the consequences of farming, overgrazing,[34] timber cutting for shipbuilding, and the effect of firewood and industrial charcoal-making have been examined carefully.[35]

Soil erosion is by definition exceeding the natural degree of erosion and thus anthropogenically triggered or enhanced. It can come about as splash erosion through the

[21] Lehmann (supra n. 19), 41.

[22] Pl., *Critias* 111.

[23] Tj. H. van Andel, C. Runnels & K. Pope, 'Five thousand years of land use and abuse in the Southern Argolid, Greece', *Hesperia* 55, 1986, 103–128.

[24] S. Jahns, 'Preliminary notes on human influence and the history of vegetation in South Dalmatia and South Greece', in *Man's role in the shaping of the Eastern Mediterranean landscape*, eds. S. Bottema, G. Entjes-Nieborg & W. van Zeist, Rotterdam 1990.

[25] E. Finke & H. Malz, 'Der Lernäische See: Auswertung von Satellitenbildern und Ostracodenfaunen zur Rekonstruktion eines vergangenen Lebensraumes', *Natur und Museum* 118 (7), Frankfurt a. M. 1988, 213–222; E. Zangger, 'Prehistoric coastal environments in Greece: the vanished landscapes of Dimini Bay and Lake Lerna', *JFA* 17, 1990.

[26] J. L. Angel, *Lerna. A preclassical site in the Argolid*, 2: *The people of Lerna. Analysis of a prehistoric Aegean population*, Princeton 1971, 1–159; *idem*, 'Ecology and population in the Eastern Mediterranean', *WorldArch* 4, 1972, 88–105.

[27] Turner (supra n. 8).

[28] H. J. Kroll, 'Zum Ackerbau gegen Ende der mykenischen Epoche in der Argolis', *AA* 1984, 211–222.

[29] J. Boessneck & A. Driesch, 'Ein Beleg für das Vorkommen des Löwen auf der Peloponnes in 'herakleischer' Zeit', *AA* 1981, 257f.; *idem*, 'Ein Löwenknochenfund aus Tiryns', *AA* 1979, 447–449.

[30] Rackham (supra n. 9).

[31] M. G. Wolman & R. Gerson, 'Relative scales of time and effectiveness of climate in watershed geomorphology', *Earth Surface Processes and Landforms* 3, 1967, 189–208; J. R. Borchert, 'The dust bowl in the 1930's', *Annals of the Association of American Geographers* 61, 1971, 1–22; van Andel, Zangger & Demitrack (supra n. 18).

[32] K. W. Butzer, *Archaeology as human ecology: method and theory for a contextual approach*, Cambridge 1982, 123–145; C. C. Park, 'Man, river systems, and environmental impacts', *Progress in Physical Geography* 5, 1981, 1–31.

[33] Butzer (supra n. 32).

[34] H. A. Forbes & H. A. Koster, 'Fire, ax, and plow: human influence on local plant communities in the Southern Argolid', *Annals of the New York Academy of Science* 268, 1976, 109–126.

[35] T. A. Wertime, 'The furnace versus the goat: The pyrotechnologic industries and Mediterranean deforestation in Antiquity', *JFA* 10, 1983, 445–452.

impact of rain drops on the ground, which would largely be prevented by a dense vegetation. Soil erosion can also appear as sheet erosion where whole surface layers creep or flow downslope at once. Most abundant, however, is gully erosion, where deep channels are cut into the ground and rapidly grow in width and depth.

Holocene soil history of Greece

As was shown before, the sea level of the Argive Plain extended 10 km farther south 18,000 years ago. It had a stable soil surface at that time and deposition was limited to the shelf. The coastal plain was occupied by man in the early to middle Holocene as is recorded by Neolithic sites and disturbed soils in the subsurface. One auger core penetrated a Middle Neolithic site in the floodplain, which was buried under 5 m of alluvium. An auger core cross-section through this site and the coastal plain shows the depositional history of this area (*Fig. 2*). The large Middle Neolithic site rests on Pleistocene deposits and replaces parts of the Pleistocene surface soil. Thus, there has been no deposition in this area during the Late Pleistocene until the abandonment of the site. It is dated by sherds and a radiocarbon accelerator to be 6240±125 bp (uncalibrated). The settlement was established on the foot of the small Profitis Ilias 1 km south of Tiryns. At that time there was still a wide coastal plain between the hillock and the sea. The postglacial sea level rise, however, gradually submerged the coastal plain. Before it had reached the maximum transgression the first Holocene landscape instability occurred, resulting in the deposition of the alluvial unit marked LN/EH. This alluvium partly covered the site and prohibited any further inhabitation of the place. Thus the accelerator dates and pottery from the site securely date the first phase of Holocene landscape stability to have been between the Middle Neolithic and the peak of the maximum transgression, because both the site and the alluvium became eroded by the advancing sea at around 2500 BC (*Fig. 2*: arrows). This date was derived from another cross-section in the Argive Plain again by radiocarbon dating. Soon after, the maximum transgression sedimentation took over (*Fig. 2*: EH) resulting in an early regression of the coast and subsequent land stability. The final phase of deposition (*Fig. 2*: LH) was triggered in the Late Bronze Age by the diversion of the creek north of Nea Tiryns which caused enhanced deposition along this cross-section. A Mycenaean figurine from the LH IIIB period which was found at the bottom of the LH-alluvium gives a maximum date for the construction of the dam. In this profile, like in any other area of the Argive Plain there has been no considerable deposition during the last 3000 years.

Thus, the most pervasive environmental changes in the Argive Plain occurred in the Late Neolithic and Early

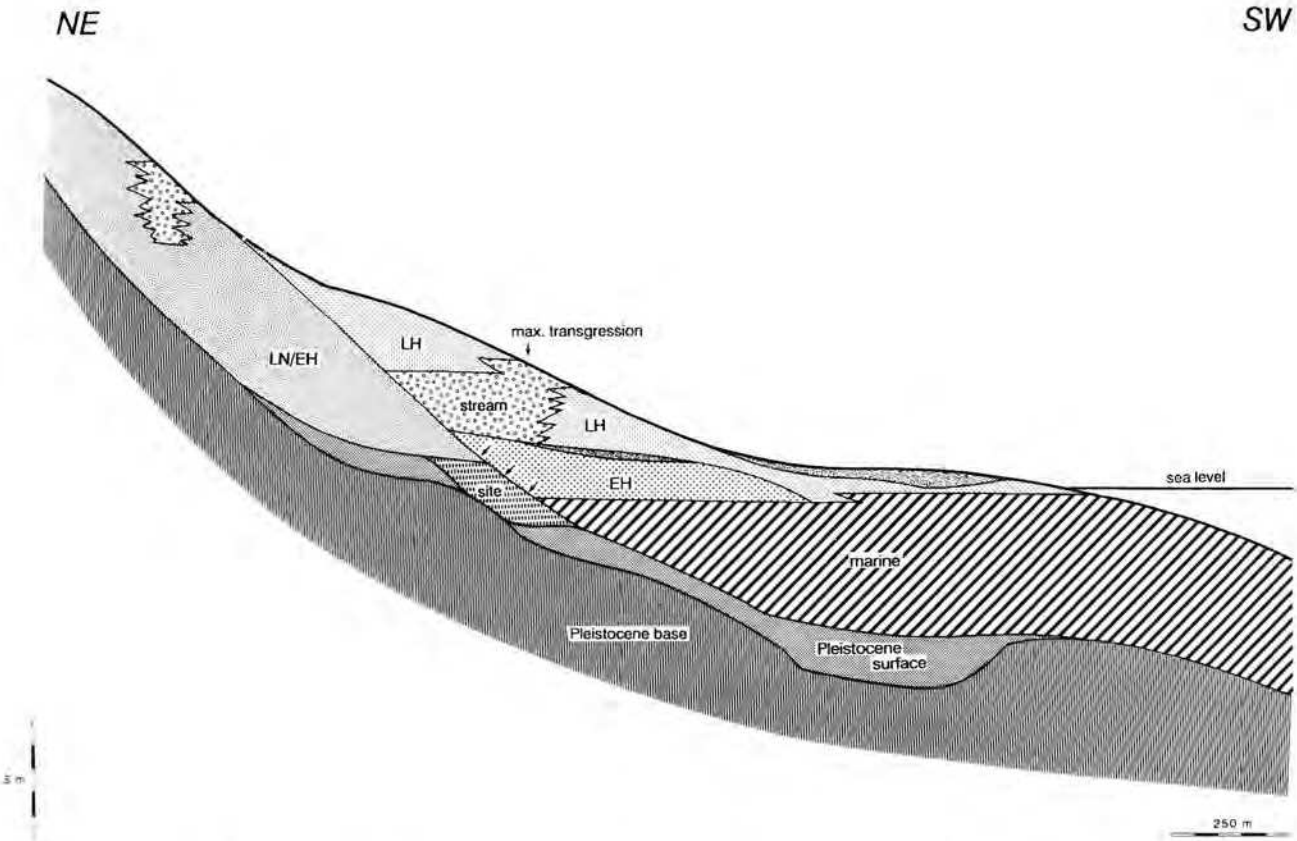

Fig. 2. Auger core cross-section north of Nafplion (Greece) showing phases of Holocene soil instability in the form of enhanced coastal deposition. The maximum marine transgression which occurred around 2500 BC shifted the coastline about 1 km inland of its present location.

Bronze Age. The massive alluviations which occurred at that time resulted from soil erosion that stripped the Pliocene marls and Pleistocene fans of the foothills of most of their brown woodland soils. The Early Bronze Age floodplain deposits spread across the early Holocene plain and today form most of its surface. This alluvium is most extensive on the inner plain and along its streams, but thickest in the coastal zone. Slope stability then returned and lasted until the Late Bronze Age, long enough for a soil to form on the Early Helladic alluvium.

Another phase of soil erosion with at least locally disastrous consequences took place in the later part of LHIIIB at Tiryns. Up to 4.8 m of mud were then deposited in one event, possibly burying parts of the lower LHIIIB town east of the citadel.[36] After this flash flood, the dam in its present form was built at the LHIIIB/C transition and has been effective ever since.

The present appearance of the Argive Plain has thus been shaped by regional soil erosion and alluviations in the later Neolithic and in the Early Helladic period. Except for episodic progradation of the coast and the intermittent deposition of overbank loams along the Inachos River and its tributaries, landscape changes since about 1000 BC have been of minor extent.

This Holocene depositional history agrees largely with the ones of the Larissa basin and Southern Argolid.[37] The landscapes of all three regions have remained stable from the late Pleistocene through the early Holocene. The most significant alluviation in Thessaly, named Girtoni alluvium,[38] is dated to ca. 4500–4000 BC by a number of superimposed Bronze Age sites. Thus the deposition occurred within 1 000 years after the Thessalian plain began to be farmed.[39] During those 1000 years the number of sites and presumably the population had increased steadily without serious loss of soil.[40] As in the case of the Argive Plain, this first Holocene alluviation was also the most extensive and voluminous; its regional extent and influence on the landscape exceed that of all later episodes. — In the Southern Argolid the earliest phase of soil erosion occurred at 2500 BC followed by brief alluviations between 300 and 50 BC and around 1000 AD.

The degree of maturity of the late Pleistocene and all but the latest Holocene soils shows that the episodes of stability and soil formation have lasted thousands to tens of thousands of years. Overall, stability appears to have been the prevailing state of the Greek landscape during the last 100,000 years or more, with destabilization a rare event. When it occurred, however, it brought destructive consequences for agricultural productivity and archaeological site pattern.

Conclusions

Even in the absence of data about paleo-fertility and precipitation, the history of soil formation and erosion can be reconstructed rather accurately. The drastic climatic changes of the glacial/interglacial transition between 20,000 and 10,000 bp took place without causing any soil erosion. At the beginning of the Holocene and the dawn of civilisation, Greece was covered with a stable fertile soil which had matured for 20,000–30,000 years. The glacial steppe vegetation was rapidly replaced by deciduous oak forests which disappeared again during the Neolithic and Early Bronze Age. At the same time widespread soil erosion occurred in many parts of Greece resulting in the removal of the thin but valuable soil cover on the bedrock slopes and its redeposition in valleys and coastal plains.

In Thessaly, the Argive Plain and the Southern Argolid, the most widespread soil erosion occurred within 1000 years after the introduction of agriculture. Soil erosion was at least locally still a problem in Mycenaean times as the torrential flood at Tiryns shows. There are no indications that the landscape of the Classical period looked much different than today's. By that time people had evidently realized the significance and fragility of the soil and had terraced mountain slopes. Some of these terraces, although hardly recognizable as such, remain efficient to the present day. In addition, new terraces were built during the last few centuries keeping the Greek soils stable at least until the introduction of the bulldozer.

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[36] Zangger (supra n. 5); *idem*, 'Tiryns Unterstadt', *Archaeometry '90*, Basel 1990.

[37] Tj. H. van Andel & E. Zangger, 'Landscape stability and destabilisation in the prehistory of Greece', in *Man's role in the shaping of the Eastern Mediterranean landscape* (supra n. 24).

[38] Demitrack (supra n. 10).

[39] P. Halstead, *Strategies for survival: an ecological approach to social and economic change in the early farming communities of Thessaly, N. Greece*, Diss. at the University of Cambridge, 1984; *idem*, 'From determinism to uncertainty: social storage and the rise of the Minoan palace', in *Economic Archaeology* (BAR-IS A96), eds. Sheridan & Bailey, 1981, 187–213.

[40] P. Halstead, 'The economy has a normal surplus: economic stability and social change among early farming communities of Thessaly, Greece', in *Bad year economics: cultural responses to risk and uncertainty*, eds. P. Halstead & J. O'Shea, Cambridge 1989, 68–80.

Discussion

O. Rackham (to E. Zangger): What fraction of Greece was covered with fertile soil in the early Holocene?

E. Zangger: I can only speak about the areas I have looked at which are the Volos basin, the southern Argolid, the Argive plain in particular, Thessaly, the Larisa basin and now the Skourta basin, and this is true for those areas. My opinion is that each part of Greece must be studied individually because the environmental histories vary from place to place.

O. Rackham: How far up the limestone hills do you suppose the soil went?

E. Zangger: I do not think the soil cover reached to the top of the limestone hills. But this is a question of opinions, where you want to draw the line.

O. Rackham: The question of the stability of climate might be answered by the pollen record in Greece of north European trees, particularly *Tilia*. Before the Bronze Age, *Tilia* was a good deal farther south than it is now. It seems to have been quite abundant even in southern Crete, but as far as we know it no longer grows in Crete at all. What caused it to disappear? You may say mankind destroyed it in some way; but if that were so, why does *Tilia* not now grow in Crete on cliffs where it cannot be got at? It survives in south Greece only at high elevations and on north-facing cliffs, which shows that it requires a less arid climate than there is in southern Greece today. I suggest that this points to a change in climate between the early Holocene and the present. The evidence indicates that climate changed in the Neolithic or Early Bronze Age.

E. Zangger: We know that there were drastic climate changes at that time and my point is that they did not leave any record in the soil history. We know that they left a major record in the vegetation history; they must have, and as I said, the peak of the interglacial warm period was 6000 years ago when, for instance, the Thames and Rhine valleys contained completely different faunas than today. But, as far as I know, there are no indications for climate changes in Greece during the last 3000 years.

A. Ammermann: Some evidence from several Neolithic sites in southern Italy suggests that the analysis of charcoal fragments from archaeological sites rather than pollen (which can be blown over considerable distances) may be a more sensitive guide to a local biotic community and its changes over time. In the Acconia area of Calabria, for example, the same 23 tree species appear again and again through the Neolithic, and these are the same species that are found in the area today. This suggests at least in the case of Calabria (I am less familiar with the situation in Greece) that you already had in place in the Neolithic period the complex of vegetation that has lasted to the present time.

E. Zangger: That could be quite true. As I said, it varies from area to area and I had to draw a general picture.

A. Ammermann: It is against the notion that there is some huge major difference in the past.

H. Lohmann: You have shown us the pollen diagram and divided it into four phases but you gave no absolute dates.

E. Zangger: No, I said there are no absolute dates yet. We expect to have them in a few weeks.

M. Munn: You referred to the anthropogenic soil erosion which usually falls in the later Neolithic or the beginning of the Bronze Age as being due to cultivation of slopes and the erosion of slope material. Is the conclusion that should be drawn from this that only slopes, or primarily slopes, are being cultivated or is there a fundamental difference in the way that slope cultivation will show up in the study of the soils versus cultivation of bottom land? In other words, can you say that bottom land was equally cultivated and the destruction effects are only felt on the slopes?

E. Zangger: No, I cannot say that. I can only say that cultivation of the bottom lands would not have resulted in soil erosion and redeposition of material at the shore.

M. Munn: So the nature of the process means that the evidence only shows up in the case of cultivated slopes.

E. Zangger: That is right.

M. Jameson: Over what period, over how long a period, do you think that this catastrophic event took place?

E. Zangger: I can say from the geological record and also from the archaeological record that it must have happened within 30 years. But it is very likely that it was one event.