**Article:**

Halstead, P. (2018) Forest clearance and land use by early farmers in Europe: insights from north Greek oral history. Quaternary International, 496. pp. 42-50. ISSN 1040-6182

https://doi.org/10.1016/j.quaint.2017.04.010

# Forest clearance and land use by early farmers in Europe: insights from north Greek oral history

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## 1. Introduction – historiography and current state of the debate

Early palynological research revealed that the first farmers in temperate Europe (and also, as we now know, at least the northern parts of Mediterranean Europe) faced a more or less wooded landscape. Experimental and ethnographic observations have demonstrated the feasibility of felling these trees with stone axes or of defoliating their canopy by stripping bark from the trunk, but debate has continued regarding the use-life of Neolithic clearings. Were they sown for just a year or two in a regime of shifting slash-and-burn cultivation, with minimal tillage and seed scattered in the ash from burnt vegetation? Or were they sown more or less continuously as 'permanent' gardens or fields subject to more or less intensive tillage? This debate is important *per se* to our understanding of early European agricultural history, but also has wider implications: for the potential abundance of domestic and wild animals with different browsing and grazing habits (e.g. Arbogast and Jeunesse, 2013; Saqalli et al., 2014); for the likely scale and severity of environmental impact by early farmers (e.g. Innes et al., 2013; Robinson, 2014; Salavert et al., 2014); for the ways in which the latter enculturated and laid claims to the landscape (e.g. Barrett, 1994); and for the probable influence of tenurial claims and residential mobility on social relationships and identities (e.g. Bogaard et al., 2011; Kotsakis, 2006). The cases advanced for both shifting and permanent cultivation have claimed two rather different forms of support: empirical, based on more or less (in)direct archaeological proxies (cf. Halstead, 2014a) for Neolithic crop husbandry practices; and circumstantial (what 'should have happened'), based on recent ethnographic, historical and experimental analogues.

The classic early syntheses of Clark (1952) and Childe (1957) illustrate how sparse was the empirical evidence then available and how indirect were the proxies used. For Clark (1952, 92) 'there can at first have been no question of initiating systematic, permanent clearance and the formation of settled fields. . . . Patches of forest would be cleared, sown, cropped and after a season or two allowed to revert to the wild, while the farmers took in another tract. In this process burning played a vital role, since it converted timber into ash and so provided a potash dressing for the virgin soil'. In empirical support of this reconstruction, Clark cited a pollen diagram from Denmark, in which Neolithic burnt clearance was ostensibly followed by cereal growing and gradual regrowth of trees (1952, 94 fig. 44), but this sequence is now regarded as an artefact of palynological formation processes and analytical methods and anyway spanned perhaps three centuries, if anything suggesting permanent rather than shifting cultivation (Rowley-Conwy, 1981). To Childe (1957, 60), while long-lived earlier Neolithic tell settlements in central Greece implied permanent cultivation ('a rural economy advanced enough to maintain the fertility of the fields'), thin early Neolithic occupation levels in the north Balkans implied temporary habitation and thus 'shifting agriculture and pastoralism combined with hunting and collecting' (1957, 86). Likewise with early (LBK) farming across central Europe, apparent lack of prolonged occupation reflected a 'crude agricultural technique, one still illustrated by some hoe cultivators in Africa today. They cultivated a plot till it would bear no more and then another, and so on until they had used up all the land round the hamlet; thereupon they shifted bag and baggage to a new site on fresh virgin soil' (1957, 106). Leaving aside what have proved to be empirical errors or over-simplifications, the thickness of habitation levels is, at best, a very remote proxy for crop husbandry regime. Neither author explicitly justified his choice of analogy. Clark, citing very high returns on seedcorn (*not* yields per unit area) in recent north European slash and burn, argued that early farmers will have preferred shifting cultivation until clearance outstripped the capacity of woodlands to regenerate (1952, 92-93). Conversely, Childe seemingly regarded shifting cultivation as necessity rather than opportunity, highlighting shared limitations of technology/knowhow between early European farmers and recent African hoe-cultivators. Both Clark and Childe thus relied heavily on circumstantial arguments, although they must be judged against the then scarce direct empirical evidence for early farming practices (Isaakidou, 2011).

Over the following decades, far more information on the contexts, methods, performance and impact of slash-and-burn cultivation became available from small-scale experiments by archaeologists in northern Europe (e.g. Reynolds, 1977; Steensberg, 1979; Luning and Meurers-Balke, 1980; Meurers-Balke and Luning, 1990; Rösch et al., 2002; 2004) and from collations or syntheses of ethnographic observations and historical descriptions from 'backward' parts of Europe, European colonization of North America, and tropical regions (e.g. Boserup, 1965; Coles, 1976; Sigaut, 1975; Steensberg, 1980). Much of this literature supported the view that shifting slash-and-burn farming offered good yields for modest labour inputs under conditions of simple technology and abundant forest/low human population density, making it the most plausible model for early farming in Europe.

Circumstantial arguments were also mounted in favour of early permanent cultivation. Rowley-Conwy (1981) convincingly questioned the relevance to Neolithic temperate Europe of recent shifting cultivation in the far north of the continent, where usually it exploited very infertile soils (as also in most tropical analogues) and grain harvests were neither its primary purpose nor reliable. Conversely, long-term agricultural experiments in southern England unambiguously indicated the capacity of permanent clearings on fertile temperate soils, especially if manured, to sustain continuous grain production. He concluded that 'slash and burn would have been an unlikely option' in Neolithic temperate Europe (Rowley-Conwy, 1981, 95), claiming empirical support for permanent cultivation in faunal spectra dominated by domestic sheep, cattle and pigs that would have maintained fertility on cultivated land with their manure and retarded forest regeneration on any abandoned plots by grazing/browsing. As with a similar argument for permanent cultivation by early farmers in Greece (Halstead, 1981, 324), however, the taxonomic composition of domestic livestock was a rather indirect proxy for crop husbandry regimes.

The debate has continued, with both sides citing circumstantial arguments and indirect evidence, but recent methodological and empirical advances in the archaeobotanical record from Neolithic Europe have provided two direct proxies for early cultivation regimes. First, ecological analysis of the weeds accompanying Neolithic grain crops, especially in temperate central Europe (Bogaard, 2002; 2004; Jacomet et al., 2016) and more tentatively in the Mediterranean (Bogaard and Halstead, 2015; Antolin et al., 2015), reveals a prevalence of taxa indicating cultivation of long-established rather than recently cleared plots and also suggesting intensive disturbance of the soil rather than the perfunctory harrowing more typical of slash and burn. Secondly, stable nitrogen isotope values in Neolithic charred grains from southeast to northwest Europe widely indicate sowing of intensively manured plots (Bogaard et al., 2013; Fraser et al., 2013; Kanstrup et al., 2014; Styring et al., 2016; Vaiglova et al., 2014), that would have no place in a shifting slash-and-burn regime (Rowley-Conwy, 1981). Both weed and isotope studies are as yet patchy in geographical and temporal coverage and exhibit some variability in results, but they provide direct proxies for crop husbandry methods and support permanent rather than shifting cultivation as the norm for early farming in Europe. Conversely, recent empirical counter-arguments for shifting cultivation (e.g., Schier, 2009; Rösch et al., 2014 – in the context of later Neolithic 'marginal colonisation) are heavily dependent on less direct off-site proxies (e.g. pollen evidence for vegetation change, charcoal indications of burning). The thorny issue of the use-life of agricultural clearances in Neolithic Europe has thus been, or soon will be, resolved empirically, leaving neither need nor justification for circumstantial arguments in identifying early crop husbandry practices. Analogy-based assessments of the costs and benefits of shifting and permanent cultivation can now be redeployed from identifying *what* Neolithic farmers did to understanding *why* they did so (e.g. Baum et al., 2016), with any failure of cost:benefit analysis correctly to 'predict' the predominant, empirically documented early farming regime potentially revealing factors affecting this choice that have hitherto been overlooked. Analogical studies may also highlight characteristics or consequences of either regime that have heuristic value for future research into early forest farming in Europe.

A major obstacle to analogical assessment of the alternative regimes is that ethnographic and historical accounts of recent shifting cultivation in Europe are overwhelmingly, if not entirely, derived from 'marginal' clearance of poor soils, often supporting birch, alder or pine in the far north (Montelius, 1953) and evergreen maquis or garrigue in the Mediterranean (Sigaut, 1975, 26-28; Sereni, 1981; Halstead, 2014b, 264-7). For information on shifting cultivation of mixed deciduous woodland, we are largely dependent on very incomplete accounts of pioneer clearance in North America and on a few small-scale archaeological experiments. To supplement these sparse sources, this paper presents oral historical testimonies from elderly retired farmers in northern Greece with first-hand experience of non-mechanised clearance of mixed deciduous woodland for cultivation of annual crops. As well as extending to the north Mediterranean our knowledge of clearance for cultivation in mixed deciduous woodland, these testimonies also offer complementary insights to those from recent experimental slash and burn at Forchtenberg in southwest Germany (Ehrmann et al., 2009; 2015). The following sections first summarise the results of the Forchtenberg project, then present the north Greek oral historical evidence, and finally consider the implications of both datasets for understanding of crop husbandry in Neolithic Europe.

## 2. The Forchtenberg experimental project

The Forchtenberg project occupies a 3 ha site of silty, loess-based soils of variable drainage and pH, under woodland for at least 200 years and located at 325 m asl in an area with average annual precipitation of 900 mm and temperature of 8-9º. Topsoil pH values for the experimental plots fell between 4.0 and 5.5 on 'good' and averaged around 4.0 on 'poor' soils, associated with 'low' and 'very low' availability respectively of the major nutrients nitrogen, phosphorous and potassium (Ehrmann et al., 2014; Schulz et al., 2014). The project has provided the longest run of published experimental slash-and-burn data from Europe, while its reported wheat and barley harvests under this regime are also the best and most consistent achieved to date and far superior to those obtained by the same project on hoed, unburnt plots (Ehrmann et al., 2014, S6). Experimental plots were cleared in winter by felling saplings and slender trees of ash, beech, birch, hornbeam, lime, maple, oak, and willow, the trunks and thicker branches of which were subsequently removed. In autumn or the spring of the following year, dry bundles of the remaining twigs were set alight and dragged across selected cleared plots so as to burn the entire surface, although in practice this required burning twiggy material from a clearance four times larger than the area sown (Ehrmann et al., 2009, 58). A few days later, seeds were dibbled (planted) into the burnt surface without tillage and received no further attention, other than a little weeding, until harvest. Yields from this and other experimental regimes varied considerably between soil types and were worst on those of lowest pH, presumably because acidity reduced the availability to plants of major nutrients. Over 13 years, however, yields in the first year after burning averaged 3.5 tons/ha for traditional and 5.1 tons/ha for modern winter bread wheat. By contrast, the average yield was less than one third as high for the first wheat after clearance on plots that were hoed before sowing (in this case by broadcasting) rather than burned and less than one twelfth as high for the second (hoed) wheat crop (whether the first crop on the same plot followed burning or hoeing). The Forchtenberg team concluded that, without manuring and assuming abundance of land, tillage cannot usually have been a worthwhile alternative to burning, especially on the more acidic forest soils, and that repeated cropping of the same plot will have been even less viable (Ehrmann et al., 2014, S8-9). As has been suggested for other regions of Europe (Sigaut, 1975, 100-1; Steensberg, 1979, 38-45), the beneficial effects of slash and burn were attributed to this counteracting soil acidity and making major nutrients more available to plants.

Estimated pre-harvest labour inputs were almost identical for first-year burnt (710 man-days/ha) and first-year hoed cereals (740 man-days/ha); the latter includes an estimated 630 man-days/ha for tilling the ground with wooden hoes, but this is offset in the burnt regime by the need to fell and trim four times as much woodland for the required twiggy bundles and to sow slowly by dibbling rather than rapidly by broadcasting (Ehrmann, 2009, 70 table 5). Moreover, hoeing was much lighter after the first harvest, as tree roots posed less of an obstacle, so that the additional labour cost of repeated cropping was only 290 man-days/ha. If labour inputs are calculated relative to grain output rather than area sown, however, the advantages of slash and burn seem clear. To produce 400 kg of wheat per year (assuming 200 kg/head and one dependent per worker) after allowance for seedcorn, the burnt regime would have required 84 man-days on good, 127 on medium and 222 on poor soil, while first-year hoeing would have required 189 man-days on good soil; labour requirements would have exceeded availability (i.e. more than 365 man-days) for first-year hoeing on medium or poor soils and for hoed second crops on all soils.

## 3. Clearance for farming in 20th-century Pieria, northern Greece

During the 1930s, clearance of some form of mixed deciduous woodland was quite widespread in the Pieria region of northern Greece, mostly in the context of resettlement of refugees from Turkey and of land redistribution in established village communities. While much of the land distributed was already under the plough, some (including fields that had fallen out of cultivation during late 19th-early 20th century inter-communal unrest) supported or was reverting to woodland exploited to varying degrees for wood pasture, firewood or timber. Informants who had cleared such wooded plots as young adults, or assisted their fathers in so doing as teenagers, were mostly in their eighties or nineties at the time of interview, although a few informants in their seventies or younger had undertaken more piecemeal manual clearance in the 1940s and 1950s. Informants who had participated in, or even observed, clearance were almost exclusively male.

Information is most abundant from the township of Kolindros and neighbouring hamlet of Paliambela (Figure 1), where a dozen men recalled the clearance of lightly wooded land on the east-facing slopes (c. 100-200 m asl) that rise gently to the west of Paliambela. On these slopes, capped by Neogene arenitic marly limestones and conglomerate sandstones (IGME, 1985) that today are significantly lower-yielding than the heavier and more level ground closer to Paliambela, local residents cleared 0.3-ha plots (known locally as *triária*) by hand in the late 1930s and early 1940s. Apart from the odd large deciduous oak that had perhaps survived as a source of shelter, this was open wood pasture with young deciduous oaks (*Quercus* spp.), wild pear (*Pyrus amygdaliformis*), hornbeam (*Carpinus orientalis*), manna ash (*Fraxinus ornus*), Judas tree (*Cercis siliquastrum*), terebinth (*Pistacia terebinthus*), Christ's thorn (*Paliurus spina-christi*) and Cornelian cherry (*Cornus mas*). Eye-witnesses recall the vegetation as being at least as open as that regenerating after recent cutting for firewood on an adjacent northwest-facing slope (Figure 2). Several, geographically more dispersed accounts, again relating to Neogene sandy or marly deposits (IGME, 1986), were also collected of 1930s clearance of similar vegetation by refugees from Turkey in the nearby townships of Aiginio, Kitros and Nea Trapezounta (ca. 50-100 m asl) and of later clearance of the same species on field edges in Aiginio and above Kolindros (ca. 200-300 m asl). Lastly, two informants described piecemeal clearance of light woodland, also including the odd beech (*Fagus sylvatica*) or juniper (*Juniperus communis*), in Ritini and Neo Elatokhori at the foot of the Pieria Mountains (ca. 700-800 m asl) on varied substrates including phyllites, ophiolites, limestones and schists (IGME, 2002). Average annual precipitation of perhaps 600 mm and temperature of 16º in the Pierian lowlands contrast with figures of perhaps 800 mm and 12º at Ritini and Neo Elatokhori (Krahtopoulou, 2010, 14-19). Descriptions of clearance and subsequent cultivation from across Pieria were, for the most part, very similar.

The first step was to fell and trim the trees, other than the occasional oak left to provide shade for later harvesters, and to remove most of the stumps by trenching around their base and cutting the lateral roots. Oaks and wild pears, being more deeply anchored than the other species, were more difficult to grub up and the stumps of larger trees (perhaps those with trunk diameter of more than 50 cm) might be left to rot after severing the laterally spreading roots. Lighter bushes and brambles were likewise cut down or grubbed up, using axe and mattock. Clearance on slopes started at the lower end of the plot, so that earth from digging up roots fell onto bare ground, and as a result proceeded more quickly than on level ground. Of the cleared vegetation, the trunks and thicker branches were removed as firewood for domestic use or sale, while smaller twigs were taken home to heat bread ovens and light fires. The lightest trash, not wanted even as kindling, was disposed of *in situ* by gathering into a heap and burning, sometimes over a remaining stump to speed up death and rotting. Depending on the number, age and type of trees encountered, a plot might be dug over in its entirety or hardly at all in the course of removing roots. One informant, whose father lacked draught animals, had helped dig their 0.3 ha plot superficially by hand and then lightly harrow the surface by manually dragging wild pear branches to cover the first seed that they sowed. Most plots were ploughed at least twice or thrice before sowing for the first time, however, and those with small draught animals sometimes hired a more powerful pair for this particularly demanding task.

Informants' recollections suggest that the time needed to convert such lightly wooded plots into cultivable land ranged between approximately 120 and 200 man-days/ha (Halstead, 2014b, 260-63). The labour expended in clearance depended greatly on the vegetation encountered, with larger trees demanding more time, especially for digging up their deeper and more extensive root systems; grubbing out a *single* mature oak stump might require three man-days of digging, whereas several young trees might be removed in a single man-day. On the other hand, much of the labour invested in felling, chopping and removing wood (but not in grubbing up roots) from these plots would have been expended anyway, to secure fuel for domestic use, and so should not perhaps be counted as a 'cost' of clearance. To place in context the labour expended on clearance, subsequent cultivation of these plots probably required each year something like 6-20 man-days/ha if they were cross-ploughed by a pair of cattle (perhaps rising to 10-40 man-days/ha in the first few years if the ploughman was accompanied by someone with a mattock to remove remaining tree-roots) or 30-100 man-days/ha for the few who worked their land entirely by hand (Halstead, 2014b, 282).

As significant as the amount of labour expended was its timing. This work was undertaken in winter, in the slack period between ploughing and sowing in autumn and their resumption in spring. Moreover, while a few farmers were able to hire day-labourers to complete this task rapidly, others worked single-handed or with a brother or son on days without competing obligations and so might take one, two or even three winters to clear 0.3 ha. In Nea Trapezounta, one refugee from northern Turkey seems to have taken a decade or more to clear 3 ha, after selling the wood to a third party who had felled and removed the trees, leaving just the stumps. For landless villagers lacking the savings to employ labourers, therefore, the clearance of sufficient land to feed a family might not be a rapid solution to their problems.

Land cleared in winter was often first planted in spring with maize, bitter vetch, cotton or – as was usual on the Kolindros-Paliambela *triária* – sesame. The last was sown partly because it produced a saleable cash crop free of weeds (see below) and partly because it was considered to help 'tame' the poorly worked new land. Alternatively, new land might be left bare over summer, for the heat of the sun to help break up clods. In autumn, following summer crop or fallow alike, the new land was sown with wheat for the first time and, in most cases, was sown with wheat for several years without fallowing or rotation (unless alternated with nutrient-demanding maize). For a few years the wheat produced unusually large and weed-free harvests, but many informants insist that the best yields were achieved in the second or even third year after repeated cultivation had reduced the new land to a fine tilth. Both those who had sown the new Kolindros-Paliambela *triária* plots and neighbours passing by with their sheep were impressed by the dense stands, large ears and full grains of early wheat crops. With good spring rainfall, the crop might also be tall enough to be at risk of lodging and so to warrant light preventive grazing by sheep – a precaution usually taken, on established plots, only after heavy treatment with stall manure or use as a pen for livestock. Informants' recollections of the yields of their best early wheat harvests range often between two and three tonnes/ha (Halstead, 2014b, 262-3) and sometimes considerably higher, the variability reflecting differences in steepness of slope, preceding vegetation, and growing season weather, as well as the modest size of some initial clearances. To place these figures in context, and to enhance their analogical value to prehistorians, informants routinely volunteered the view that yields were two or three times higher than what was expected on nearby established fields. Several qualitative observations lend credibility to these recollections of high yields. First, above Kolindros, wheat and maize were sown on newly cleared field edges on slopes where neither crop was otherwise considered worth sowing (less demanding barley and oats being preferred) in the days before artificial fertilisers. Secondly, some Kolindros farmers also owned very fertile land in the newly drained lake basin of Giannitsa where they sowed a variety of wheat ('Mintana') that flourished on their freshly cleared plots but was otherwise unsuitable for the poorer hillsides near home. Thirdly, the newly cleared land was usually sown continuously with wheat for five or even 10-15 years, without fertilizer, before reverting to the biennial rotation or alternate fallow that was normal in the region before industrial fertilisers. Fourthly, some farmers let sheep into luxuriant early crops (as they did on freshly manured land) to retard their growth and so reduce the risk of lodging. Fifthly, woodland on more or less sandy or clayey Neogene deposits at Livadi, just west of the Kolindros-Paliambela *triária*, was cleared (partly by machine) in the 1960s, when tobacco was an important local cash crop, but tobacco needs light land and was not grown on even the poorest new fields for ten years.

High yielding and weed-free wheat crops were usually said to have lasted 4-10 years. Informants attributed the fertility of these plots to the land being 'rested' and to the abundant leaf litter, several centimetres thick, visible on and beneath their surface. Although fires were lit to dispose of woody trash and perhaps kill tree stumps, informants were adamant that they had not attempted (in contrast to practice at Forchtenberg) to burn the surface of cleared plots and several volunteered the observation that this would have destroyed the much valued leafy-litter ‘manure’. Thanks to their fertility, the clearances did not need enriching with animal manure for several years and this in turn helped to keep the plots free of weeds that might otherwise be introduced in dung.

Informants did not measure pH before or after clearance, but the arenitic marly limestones and conglomerate sandstones underlying the new Kolindros-Paliambela *triária* plots are likely to have supported more alkali and more acidic soils, respectively. Similar variability is probable for the rest of lowland Pieria, while soils under recently cleared woodland above the upland villages of Ritini and Neo Elatokhori probably ranged from neutral to acidic (Nakos, 1979). If soil pH was low enough to limit nutrient availability to plants, however, the first cereal crops on new Pierian plots should have grown taller on the spots where trash from clearance had been burnt, making nutrients more available to plants (as, more uniformly, on Forchtenberg plots). This pattern is reported by almost all those who have sown freshly cleared maquis or garrigue in southern Greece (Halstead, 2014b, 270) and by one Pierian informant from upland Ritini, where some soils are known to be acidic. Other Pierian informants did not observe this phenomenon, however, implying that most land cleared in the mid-twentieth century was, at worst, only mild acidic.

Thanks to the Marshall plan for post-war economic reconstruction, industrial fertilisers were progressively adopted in the region from the late 1940s-early 1950s, just as many plots cleared in the 1930s and 1940s were losing the ability to sustain continuous wheat production. To some extent this obscures how long these plots would otherwise have sustained ‘permanent’ cultivation (albeit with crop rotation or regular fallow years) without lengthy abandonment to restorative woodland regeneration. Nonetheless, whereas young woodland is a common sight on abandoned fields above upland Ritini and Neo Elatokhori, where acid-tolerant rye and potatoes were grown rather than wheat or barley, this is relatively unusual in lowland Pieria. Just west of the Kolindros-Paliambela *triária*, some ‘second-category’ land cleared by bulldozer in the 1960s was soon abandoned to rough pasture, despite the availability of industrial fertilisers, but most plots cleared in the 1930s and 1940s are still under cultivation.

## 4. Implications for Neolithic cultivation in Europe?

Before proceeding to consider the implications of Pierian oral history for the costs and benefits of shifting versus permanent cropping of cleared woodland, its implications should be noted for two claimed archaeological proxies of the former regime. First, for Rösch et al. (2014, S129), a striking scarcity of weed seeds in charred grain stores from Late Neolithic Hornstaad-Hörnle 1A in southwest Germany recalls 'the purity of the harvest from the Forchtenberg slash-and-burn fields'. Leaving aside any possible contribution of harvest method and/or crop cleaning (cf. Jacomet et al., 2016, 12) to the scarcity of weed seeds, the Pierian accounts suggest that unusually clean crops should be expected on plots freshly cleared of trees, regardless of whether the cut vegetation was burnt or not, and that weeds might well be rare for a few years thereafter. Scarcity of weed seeds in crop stores burnt eight years after the first houses were built at the site (Styring et al., 2016, 97) is thus compatible with intensive 'permanent' cultivation, as was inferred from the ecological characteristics of the weed seeds (Maier, 1999). Secondly, Schier (2009) has argued that rising frequencies of on- and off-site charcoal (questioned by Jacomet et al., 2016, 9), associated with the later Neolithic of central Europe and contemporary early Neolithic of northern Europe, indicate increased use of fire and thus slash-and-burn farming in the spread of crop husbandry onto agriculturally poorer soils. The Pierian data, however, indicate that burning of cut vegetation is equally characteristic of clearance for long-term crop husbandry involving intensive tillage (as also of clearance for non-agricultural purposes – e.g. Innes et al., 2013; Jacomet et al., 2016).

The oral history of recent mixed-deciduous woodland clearance in the Pierian region of northern Greece makes clear that autumn cereals grown on such land without manure (or chemical fertilizer) can achieve very respectable area-yields for several years. Given the light and more or less degraded nature of the woodland cleared here, reported yields of 2-3 tonnes/ha or even better may significantly underestimate the potential productivity and resilience of early Neolithic plots newly created in mature deciduous woodland, presumably with substantially greater volumes of plant nutrients and associated soil microfauna held in decomposed and decomposing leaf litter. Permanent cultivation of woodland clearings is thus surely viable at least for the Neolithic of the north Mediterranean, but Pierian oral history sheds no direct light on the relative costs and benefits of permanent versus shifting cultivation of cleared land. Short-term slash-and-burn cultivation was quite widespread in mid-twentieth century Greece, especially on infertile substrates with evergreen maquis or garrigue scrub where cereals were often not worth harvesting after the first or second year (Halstead, 2014b, 267; Halstead field notes for 1940s Kythira). It also occurred in mature deciduous woodland in the mountains, where short-term cultivation was again enforced, but by the need to avoid detection of illegal clearance (Loukopoulos, 1983, 131-2). Where mixed deciduous woodland was cleared legally (or infringements were overlooked), however, temporary cultivation may only rarely have been a realistic option given the scarcity of accessible, unclaimed land suitable for crops. The fact that cleared deciduous woodland in Pieria normally remained in long-term cultivation, therefore, need not mean that it offered better returns on labour invested than shifting slash and burn.

Compared with Pierian oral history, the Forchtenberg project provides more precise data gathered under far more controlled conditions, but also has two significant weaknesses. First, in modern agronomic literature, a pH of 6.5 is often treated as ideal for wheat growing and of 5.5 or 5.0 as the threshold below which yields are severely reduced (e.g. Newton et al., 2010, 17; Stodart et al., 2007), whereas reported topsoil pH at Forchtenberg is 4.0-5.5 on the *best* plots. The Forchtenberg experiments, therefore, do not test the relative performance of temporary slash-and-burn versus long-term hoe cultivation of wheat under adequate or favourable growing conditions, but the capacity for burning of freshly cleared surfaces to avert failure of wheat crops on very unfavourable soils. Secondly, the size of the sown plots is small (apparently ca. 1-60 $m^2$ – Ehrmann et al., 2009, 48 fig. 3) and so has probably exaggerated yields, given the tendency for plants on plot edges to out-perform those in the middle facing more competition (e.g. Watson and French, 1971), although this may not have affected the *relative* performance of different regimes. On the other hand, while the Forchtenberg researchers plausibly argue that their strikingly high slash-and-burn yields may be partly attributable to experience accumulated during several years of experimentation (Ehrmann et al., 2014, S6), their total area sown over 13 years probably amounts to less than that cleared and sown by *each* of their Pierian counterparts. The latter, therefore, will have drawn on a vastly broader and longer-term pool of collective knowledge and surely offer a more reliable guide to the practicalities of repeated cultivation of cleared woodland. Several of these Pierian farmers reported that freshly cleared forest soils did not achieve a suitable tilth for successful cereal growing until the second or third year of working, raising the possibility that relatively inexperienced Forchtenberg cultivators, armed with unfamiliar wooden hoes, failed to work the ground intensively enough to make the most of the poor soils, especially given that low pH inhibits crop root growth (e.g. Bian et al., 2013).

In sum, while Pierian oral history documents that permanent cultivation of cleared deciduous woodland on reasonably fertile (perhaps mildy acidic to neutral) soils can deliver good cereal yields, the Forchtenberg experiments confirm the very short-term benefits to cereal yields of burning cleared plots on acidic soil. The fertility of Neolithic soils is not a simple issue, not even of those formed on loess (Catt, 2001), and there is some uncertainty as to how far different tree species may have actively transformed soil properties including pH over the Holocene (Binkley and Fisher, 2013, 191-2; Błonska et al., 2016). Neolithic cultivators were surely capable, however, like their recent counterparts, of identifying underlying soil fertility on the basis of local variation in woodland composition (Coles, 1976; Halstead, 2014b, 264) and so of selectively clearing the land best suited to crop production.

Accordingly, we may attempt to model the relative merits of burning and tillage *in fertile conditions* by combining Pierian and Forchtenberg observations, starting with the Forchtenberg figures for labour inputs, since these are far more precise and detailed and are also inflated by the use of equipment more relevant to the Neolithic than the iron tools of recent Pierian farmers. The pre-harvest labour inputs cited above were almost identical for a single slash-and-burn crop (710 man-days/ha) and for first-year hoed cereals (740 man-days/ha), but the former figure assumes sowing by dibbling, whereas broadcasting in ash followed by harrowing seems to have been more usual for this regime across Europe in recent times (Sigaut, 1975). If both experimental regimes used broadcast sowing, the labour inputs of slash and burn would decline to 580 man-days/ha (Ehrmann et al., 2009, 70 table 5). After the first crop, however, the labour required for manual tillage drops from 630 to 230 man-days/ha, so that the overall input for permanent cultivation with hoeing is only 290 man-days/ha and, including clearance and initial tillage, averages 515, 380 and 335 man-days/ha over two, five and ten years, respectively. In terms of returns on labour, therefore, short-term slash and burn can only compete with long-term tillage by accepting the dramatic decline in yields seen at Forchtenberg under very unfavourable soil conditions. Conversely, the Pierian reports suggest that the returns on long-term tillage, even if optimum yields were not achieved until the third cereal crop, might well outstrip those on slash-and burn within five years. In practice, two further considerations suggest that this may be an unduly pessimistic assessment of permanent cultivation. First, while much of the labour required for clearance of permanent fields might plausibly be 'discounted' on the grounds that the cut tree trunks and branches would be needed for construction and fuel, the same cannot be argued for the clearance of a four times larger area year on year for slash-and-burn farming. Secondly, cattle were evidently yoked for traction from the Middle or Early Neolithic, at least in southern Greece (Isaakidou, 2006), so the inputs of *human* labour to initial and subsequent tillage of permanent plots may have been heavily exaggerated above. With allowance for these two factors, long-term cultivation on moderately fertile soils may have offered better returns on human labour than slash and burn even in the first year of cropping. This conclusion receives anecdotal support from a variety of European historical and ethnographic sources. Most recent European examples of slash-and-burn farming (including several cited by Sigaut [1975] in support of the opposite conclusion) were either enforced by soil poverty or the prohibition of longer-term cultivation or took opportunistic advantage of felling and clearance undertaken principally for the creation of pasture or extraction of wood (e.g. Cornebois, 1881; Montelius, 1953; Rowley-Conwy, 1981; Emanuelsson and Segerström, 2002; Jacomet et al., 2016, 13). Cornebois (1881, 625) was damning in his evaluation of slash and burn farming in the 19th-century Ardennes: it was worthwhile only to someone who accorded no value to his labour because he had no other occupation.

On one final issue, the Pierian and Forchtenberg data broadly agree: woodland clearance for crop growing, whether with burning or hoeing, involves not only considerable investment of human labour, but also a substantial time lapse before this bears reliable fruit. Some Pierian informants opportunistically sowed a spring ‘catch crop’, immediately after winter clearance, but crops sown so late on poorly worked ground are very unreliable (e.g. Halstead, 2014b, 25-26). Their earliest reasonably reliable grain crop was, on tractable soils, that sown in the autumn after clearance and harvested in the following summer or, on heavier soils, that harvested 30 or even 42 months after clearance. At Forchtenberg the first grain crop was harvested roughly 18 months after clearance (with acidic soils obscuring any possible delay in the development of a good tilth), but earlier slash-and-burn experiments in Denmark highlighted the difficulty, given temperate Europe’s wet summers, of burning cut deciduous vegetation that had not been left to dry for two years. Slash-and burn-cultivation in temperate Europe, therefore, even if rain in the months between likely burning and sowing times does not wash away the ash seedbed, might not produce a first harvest until nearly four years after clearance (Rowley-Conwy, 2003, 119).

While Pierian farmers waited 18 (and perhaps 30 or more) months for a reliable grain harvest from freshly cleared woodland, all their new plots were close enough to existing settlements for them to commute from home and so take advantage of stored food, opportunities for paid work, and cooperative labour with kin and neighbours. As farming spread across Neolithic Europe, those clearing land for crops must have faced similar 'start-up' challenges (perhaps with a longer delay to first harvest if they practised slash-and-burn) and, if doing so within daily 'commuting' distance of an existing farming settlement, may again have drawn on the grain stores of kin and neighbours until new plots became productive. Over larger distances (e.g. on Crete or in some of the more isolated loessic basins of central Europe), any participation of acculturated local foragers in the establishment of farming would have facilitated reliance on wild foods for survival to the first successful crop harvest. Where *colonists* introduced farming over distances too great for logistical support from the mother settlement, however, they will have needed to survive for a lengthy period on wild resources (subject to availability and knowhow), transported grain (more feasible with travel by water than overland), or accompanying livestock (if these survived the journey in adequate condition) (cf. Rowley-Conwy, 2011). Accordingly, as recent advances in aDNA retrieval confirm a major role for colonization in the spread of farming, consideration of the delay between clearance and harvest highlights the need to understand the initial subsistence tactics of the first generation of farmers across Europe.

## 5. Conclusions

Oral histories from the Pieria region of northern Greece have significantly enriched the rather sparse pool of available historical, ethnographic and experimental information on the practicalities of forest farming in Europe. Pierian informants' accounts of their first-hand experience of clearing mixed deciduous woodland for cultivation raise questions about two archaeological proxies (scarcity of weed seeds in stored grain samples; off-site abundance of wood charcoal), cited by some scholars in favour of slash-and-burn farming in Neolithic Europe. They also unequivocally demonstrate the capacity of moderately fertile ground cleared of mixed deciduous woodland to support quite high-yielding cereal cultivation over several years in a north Mediterranean environment. Furthermore, such long-term cultivation of cleared land (other than on very unsuitable acidic soils) would arguably have offered better returns on labour inputs also in temperate Neolithic Europe than the slash-and-burn regime tested experimentally at Forchtenberg in southern Germany. The argued 'superiority' of long-term cultivation over short-term slash and burn on cleared woodland of course does not mean that Neolithic farming in Europe necessarily resembled the former regime (also Ehrmann et al., 2009, 71) – that issue must be settled empirically by recourse to archaeological proxies related as directly as possible to methods of crop husbandry. What it does mean is that firm evidence for slash-and-burn farming would imply the shaping of early farming land use by factors other than the costs and benefits of grain production (as suggested by Jacomet et al., 2016). Moreover, whether slash and burn or permanent cultivation prevailed in Neolithic Europe, Pierian oral history poses important questions about how the first generation of farmers survived the time lag between clearance and successful grain production.

Acknowledgements

I owe thanks to: Duska Urem-Kotsou for inviting (and waiting for) this contribution; Amy Bogaard, Peter Rowley-Conwy, Niki Saridaki and Valasia Isaakidou, for supplying some sources cited; Duska and Valasia for commenting on a draft; Nancy Krahtopoulou, Rena Veropoulidou and Valasia Isaakidou for Figure 1; Nasia Makarouna for Figure 2; Yannis Stangidis for introducing me to several of the Pierian informants and landscapes mentioned above; and the pensioners of Pieria for patiently answering my questions. The Pierian interviews were carried out in the course of projects funded by the Institute for Aegean Prehistory, University of Sheffield Faculty of Arts and Humanities, and co-financed European Union (European Social Fund – ESF)/Greek (National Strategic Reference Framework – NSRF) Operational Program 'Education and Lifelong Learning' (Research Funding Program: Thales. Investing in knowledge society through the European Social Fund – project 'Material Culture & Environment**:** Exploitation of Natural Resources during the Neolithic in N. Greece').

References

Antolín, F., Jacomet, S., Buxó, R. 2015. The hard knock life. Archaeobotanical data on farming practices during the Neolithic (5400-2300 cal BC) in the NE of the Iberian Peninsula. Journal of Archaeological Science 61, 91-104.

Arbogast, R.-M., Jeunesse, C. 2013. Early Neolithic pastoral traditions and cultural groups in northern France. In: Colledge, S., Conolly, J., Dobney, K., Manning, K., Shennan, S. (Eds.), The Origins and Spread of Stock-keeping in the Near East and Europe. Left Coast Press, Walnut Creek, pp. 271-282.

Barrett, J.C. 1994. Fragments from Antiquity: an Archaeology of Social life in Britain, 2900-1200 BC. Blackwell, Oxford.

Baum, T., Nendel, C., Jacomet, S., Colobran, M., Ebersbach, R. 2016. 'Slash and burn' or 'weed and manure'? A modelling approach to explore hypotheses of late Neolithic crop cultivation in pre- alpine wetland sites. Vegetation History and Archaeobotany 25, 611-627.

Bian, M., Zhou, M, Sun, D., Li, C. 2013. Molecular approaches unravel the mechanism of acid soil tolerance in plants. The Crop Journal 1, 91-104.

Binkley, D., Fisher, R.F. 2013. Ecology and Management of Forest Soils. Wiley-Blackwell, Chichester.

Błonska, E., Lasota, J., Gruba, P. 2016. Effect of temperate forest tree species on soil dehydrogenase and urease activities in relation to other properties of soil derived from loess and glaciofluvial sand. Ecological Research 31 (5): 655-664.

Bogaard, A. 2002. Questioning the relevance of shifting cultivation to Neolithic farming in the loess belt of Europe: evidence from the Hambach Forest experiment. Vegetation History and Archaeobotany 11, 155-168.

Bogaard, A. 2004. Neolithic Farming in Central Europe: an Archaeobotanical Study of Crop Husbandry Practices. Routledge, London.

Bogaard, A., Fraser, R.A., Heaton, T.H.E., Wallace, M. Vaiglova, P., Charles, M., Jones, G., Evershed, R.P., Styring, A.K., Andersen, N.H., Arbogast, R.-M., Bartosiewicz, L., Gardeisen, A., Kanstrup, M., Maier, U., Marinova, E., Ninov, L., Schäfer, M., Stephan, E. 2013. Crop

manuring and intensive land management by Europe's first farmers. Proceedings of the National Academy of Sciences 110 (31), 12589–12594.
Bogaard, A., Halstead, P. 2015. Subsistence practices and social routine in Neolithic southern Europe. In: Fowler, C., Harding, J., Hofmann, D. (Eds.), The Oxford Handbook of Neolithic Europe. Oxford University Press, Oxford, pp. 385-410.
Bogaard, A., Krause, R., Strien, H.-C. 2011. Towards a social geography of cultivation and plant use in an early farming community: Vaihingen an der Enz, south-west Germany. Antiquity 85, 395-416.
Boserup, E. 1965. The Conditions of Agricultural Growth: the Economics of Agrarian Change Under Population Pressure. Allen and Unwin, London.
Catt, J.A. 2001. The agricultural importance of loess. Earth-Science Reviews 54, 213-229.
Childe, V.G. 1957. The Dawn of European Civilisation. Routledge and Kegan Paul, London.
Clark, J.G.D. 1952. Prehistoric Europe: the Economic Basis. Methuen, London.
Coles, J.M. 1976. Forest farmers: some archaeological, historical and experimental evidence relating to the prehistory of Europe. In: de Laet, S.J. (Ed.), Acculturation and Continuity in Atlantic Europe. De Tempel, Bruges, pp. 59-66.
Cornebois, M. 1881. Notice sur le sartage dans l'arrondissement de Rocroi. Mémoires de la Société Nationale d'Agriculture de la France 126, 601-642.
Ehrmann, O., Biester, H., Bogenrieder, A., Rösch, M. 2014. Fifteen years of the Forchtenberg experiment — results and implications for the understanding of Neolithic land use. Vegetation History and Archaeobotany 23 (Supplement 1): S5-S18.
Ehrmann, O., Rösch, M., Schier, W. 2009. Experimentelle Rekonstruktion eines jungneolithischen Wald-Feldbaus mit Feuereinsatz - ein multidisziplinäres Forschungsprojekt zur Wirtschaftsarchäologie und Landschaftsökologie. Prähistorische Zeitschrift 84 (1), 44-72.
Emanuelsson, M., Segerström, U. 2002. Medieval slash-and-burn cultivation: strategic or adapted land use in the Swedish mining district? Environment and History 8, 173-196.
Fraser, R.A., Bogaard, A., Schäfer, M., Arbogast, R., Heaton, T.H.E. 2013. Integrating botanical, faunal and human stable carbon and nitrogen isotope values to reconstruct land use

and palaeodiet at LBK Vaihingen an der Enz, Baden-Württemberg. World Archaeology 45 (3), 492-517.

Halstead, P. 1981. Counting sheep in neolithic and bronze age Greece. In: Hodder, I., Isaac, G., Hammond, N. (Eds.), Pattern of the Past: Studies in Honour of David Clarke. Cambridge University Press, Cambridge, pp. 307-339.

Halstead, P. 2014a. Archaeological science and the Neolithic: the power and perils of proxy measures. In: Whittle, A., Bickle, P. (Eds.), Early Farmers: the View from Archaeology and Science. Proceedings of the British Academy 198. Oxford University Press for The British Academy, London, pp. 419-433.

Halstead, P. 2014b. Two Oxen Ahead: Pre-Mechanized Farming in the Mediterranean. Wiley-Blackwell, Chichester.

IGME 1985. Geological Map of Greece, 1:50,000: Alexandreia Sheet. Institute of Geology and Mineral Exploration, Athens.

IGME 1986. Geological Map of Greece, 1:50,000: Katerini Sheet. Institute of Geology and Mineral Exploration, Athens.

IGME 2002. Geological Map of Greece, 1:50,000: Kolindros Sheet. Institute of Geology and Mineral Exploration, Athens.

Innes, J.B., Blackford, J.J., Rowley-Conwy, P.A. 2013. Late Mesolithic and early Neolithic forest disturbance: a high resolution palaeoecological test of human impact hypotheses. Quaternary Science Reviews 77: 80-100.

Isaakidou, V. 2006. Ploughing with cows: Knossos and the 'secondary products revolution'. In: D. Serjeantson, D. Field (Eds.), Animals in the Neolithic of Britain and Europe. Oxbow, Oxford, pp. 95-112.

Isaakidou, V. 2011. Gardening with cows: hoe and plough in prehistoric Europe. In: A. Hadjikoumis, E.N. Robinson, S. Viner (Eds.), The Dynamics of Neolithisation in Europe. Oxbow, Oxford, pp. 90-112.

Jacomet, S., Ebersbach, R., Akeret, Ö., Antolín, F., Baum, T., Bogaard, A., Brombacher, C., Bleicher, N.K., Heitz-Weniger, A., Hüster-Plogmann, H., Gross, E., Kühn, M., Rentzel, P., Steiner, B.L., Wick, L., Schibler, J.M. 2016. On-site data cast doubts on the hypothesis of shifting cultivation in the late Neolithic (c. 4300-2400 cal. BC): landscape management as an alternative paradigm. The Holocene 26 (11), 1858-1874.

Kanstrup, M., Holst, M.K., Jensen, P.M., Thomsen, I.K., Christensen, B.T. 2014. Searching for long-term trends in prehistoric manuring practice. δ15N analyses of charred cereal grains from the 4th to the 1st millennium BC. Journal of Archaeological Science 51, 115-125.

Kotsakis, K. 2006. Settlement of discord: Sesklo and the emerging household. In: Tasic, N., Grozdanov, C. (Eds.), Homage to Milutin Garasanin. Serbian Academy of Sciences and Arts, Macedonian Academy of Sciences and Arts, Belgrade, pp. 207-220.

Loukopoulos, D. 1983. Georgika tis Roumelis. Dodoni, Giannina.

Lüning, J., Meurers-Balke, J. 1980. Experimenteller Getreideanbau im Hambacher Forst, Gemeinde Elsdorf, Kreis Bergheim/Rheinland. Bonner Jahrbücher 180, 305-344.

Maier, U. 1999. Agricultural activities and land use in a neolithic village around 3900 BC: Hornstaad Hörnle 1A, Lake Constance, Germany. Vegetation History and Archaeobotany 8, 87-94.

Meurers-Balke, J., Lüning, J. 1990. Experimente zur frühen Landwirtschaft: eine Überblick über den Kölner Versuche in den Jahren 1978-1986. In: Fansa, M. (Ed.), Experimentelle Archäologie in Deutschland. Archäologische Mitteilungen aus Nordwestdeutschland 4. Staatliches Museum für Naturkunde und Vorgeschichte, Oldenburg, pp. 82-92.

Montelius, S. 1953. The burning of forest land for the cultivation of crops. 'Svedjebruk' in central Sweden. Geografiska Annaler 35 (1), 41-54.

Nakos, G. 1979. Forest soils of Greece: physical, chemical and biological properties. Forest Ecology and Management 2, 35-51.

Newton, A. C., Akar, T., Baresel, J.P., Bebeli, P.J., Bettencourt, E., Bladenopoulos, K.V., Czembor, J.H., Fasoula, D.A., Katsiotis, A., Koutis, K., Koutsika-Sotiriou, M., Kovacs, G., Larsson, H., Pinheiro de Carvalho, M.A.A., Rubiales, D., Russell, J., Dos Santos, T.M.M., Vaz Patto, M.C. 2010. Cereal landraces for sustainable agriculture. A review. Agronomy for Sustainable Development 30 (2), 237-269.

Reynolds, P.J. 1977. Slash and burn experiment. Archaeological Journal 134, 307-318.

Robinson, M. 2014. The ecodynamics of clearance in the British Neolithic. Environmental Archaeology 19 (3), 291-297.

Rösch, M., Ehrmann, O., Herrmann, L., Schultz, E., Bogenrieder, A., Goldammer, J.P., Hall, M., Page, H., Schier, W. 2002. An experimental approach to Neolithic shifting cultivation. Vegetation History and Archaeobotany 11, 143-154.

Rösch, M., Ehrmann, O., Herrmann, L., Schultz, E., Bogenrieder, A., Goldammer, J.P., Hall, M., Page, H., Schier, W. 2004. Slash-and-burn experiments to reconstruct Late Neolithic shifting cultivation. International Forest Fire News 30, 70-74.

Rösch, M., Kleinmann, A., Lechterbeck, J., Wick, L. 2014. Botanical off-site and on-site data as indicators of different land use systems: a discussion with examples from Southwest Germany. Vegetation History and Archaeobotany 23 (Supplement 1), S121-S133.

Rowley-Conwy, P. 1981. Slash and burn in the temperate European Neolithic. In: R.J. Mercer (Ed.), Farming Practice in British Prehistory. Edinburgh University Press, Edinburgh, pp. 85-96.

Rowley-Conwy, P. 2003. No fixed abode? Nomadism in the northwest European Neolithic. In: Burenhult, G., Westergaard, S. (Eds.), Stones and Bones. Formal disposal of the dead in Atlantic Europe during the Mesolithic-Neolithic interface 6000-3000 BC. Archaeological Conference in Honour of the Late Professor Michael J. O'Kelly. BAR International Series 1201. British Archaeological Reports, Oxford, pp. 115-144.

Rowley-Conwy, P. 2011. Westward Ho! The spread of agriculture from central Europe to the Atlantic. Current Anthropology 52 (Supplement 4), S431-S451.

Salavert, A.l., Bosquet, D., F. Dambion, F. 2014. Natural woodland composition and vegetation dynamic during the Linearbandkeramik in north-western Europe (central Belgium, 5200-5000 b.c.). Journal of Archaeological Science 51, 84-93.

Saqalli, M., Salavert, A., Bréhard, S., Bendrey, R., Vigne, J.-D., Tresset, A. 2014. Revisiting and modelling the forest farming system of the Early Neolithic Linear Pottery Culture (LBK): 5600-4900 BC. Vegetation History and Archaeobotany 23 (Supplement 1), S37-S50.

Schier, W. 2009. Extensiver Brandfeldbau und die Ausbreitung der neolithischen Wirtschaftsweise in Mitteleuropa und Südskandinavien am Ende des 5. Jahrtausends v.Chr. Prähistorische Zeitschrift 84, 15-43.

Schulz, E., Vannina, U., Hall, M. 2014. The double mosaic-regeneration of vegetation and soil after clearing, burning, and cultivation: lessons from the Forchtenberg experiment. Vegetation History and Archaeobotany 23 (Supplement 1), S19-S36.

Sereni, E. 1981. Terra nuova e buoi rossi e altri saggi per una storia dell'agricoltura europea. Einaudi, Torino.

Sigaut, F. 1975. L'agriculture et le feu: rôle et place du feu dans les techniques de préparation du champ de l'ancienne agriculture européenne. Mouton, Paris.

Steensberg, A. 1979. Draved. An Experiment in Stone Age Agriculture: Burning, Sowing and Harvesting. National Museum of Denmark, Copenhagen.

Steensberg, A. 1980. New Guinea Gardens: a Study of Husbandry with Parallels in Prehistoric Europe. Academic Press, London.

Stodart, B.J., Raman, H., Coombes, N., Mackay, M. 2007. Evaluating landraces of bread wheat Triticum aestivum L. for tolerance to aluminium under low pH conditions. Genetic Resources and Crop Evolution 54 (4), 759-766.

Styring, A., Maier, U., Stephan, E., Schlichtherle, H., Bogaard, A. (2016). Cultivation of choice: new insights into farming practices at Neolithic lakeshore sites. Antiquity 90 (349), 95-110.

Vaiglova, P., Bogaard, A., Collins, M., Cavanagh, W., Mee, C., Renard, J., Lamb, A., Gardeisen, A., Fraser, R. 2014. An integrated stable isotope study of plants and animals from Kouphovouno, southern Greece: a new look at Neolithic farming. Journal of Archaeological Science 42, 201-215.

Watson, D.J., French, S.A.W. 1971. Interference between rows and between plants within rows of a wheat crop, and its effects on growth and yield of differently-spaced rows. Journal of Applied Ecology 8 (2), 421-445.

Figure captions

Figure 1. Map of Pieria, northern Greece, showing modern settlements mentioned in the text 1. Livadi, 2. Paliambela-Kolindrou, 3. Kolindros, 4. Aiginio, 5. Kitros, 6. Nea Trapezounta, 7. Ritini, 8. Neo Elatokhori

Figure 2. Recently cut coppice woodland northwest of the Paliambela-Kolindrou cleared *triaria*, June 2014 (photo: Nasia Makarouna)