Management of Architectural Woods and Variations in Population Density in the Fourth and Third Millennia B.C. (Lakes Chalain and Clairvaux, Jura, France)

PIERRE PÉTREQUIN
C.N.R.S./UMR 9946, Laboratoire de Chrono-Écologie, Besançon, France

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Because the stability of the anaerobic conditions in littoral environments has been favorable to the conservation of wood, vegetal fibers, seeds, and pollen, these locations today provide us with almost unequalled data for the study of the history of relations between agricultural communities and their transformations of the environment through the repercussions of repeated forest clearing. Starting from a specific case study (the littoral Neolithic villages of lakes Chalain and Clairvaux in the Jura), we will try to determine and follow the evolution of materials used for domestic architecture, which was entirely constructed of wood; the question is to determine what is truly intentional human choice and management of the forest and what is due to natural constraints imposed by progressive modification of the forest under the impact of extensive clearance, the temporary bringing of areas under cultivation, and the increase in the abundance of livestock. Finally, beyond this case study, we must ask ourselves what are the more general constraints which can explain the nonlinear evolution of the forest environment, driven by the relative expansion or diminution of the areas covered by cereal agriculture.

1. THE DOCUMENTARY BASE: ARCHITECTURAL WOOD AND LONG-TERM CHRONOLOGY

The small lakes of Chalain and Clairvaux (Figs. 1 and 10) are located on the left bank of the Ain River, exactly at the border of the high, glacial–lacustrine terraces characterized by light soils (favorable today for the cultivation of grain) and a limestone plateau of higher elevation—620–800 m—(today more or less given over to forests and meadows). At 12 km from each other, as the crow flies, these two lakes constitute a coherent archaeological ensemble, in a well-enclosed, small, morphological unit (the Combe d’Ain), where pedological and phytosociological studies (Beaufils 1986; Trivaudeau and Bailly 1991), together with pollen analyses (Richard 1983; Bourgeois 1989; Richard and Géry 1993), allow a possible reconstruction of the potential vegetation during the Neolithic (Fig. 1).

20 years of multidisciplinary research (Pétrequin and Pétrequin 1988; Pétrequin 1986, 1989) have shown that the flattest shores of Lakes Chalain and Clairvaux were occupied, although not with real permanence, by small communities of farmers and stockherders during the 5th–3rd millennia B.C. The decision to establish settlements outside of agricultural areas and on the wet lakeside soils susceptible to flooding may have been motivated by the necessity of defending the communities and their granaries from close neighbors (Pétrequin and Pétrequin 1988). Such a topographic position of permanent settlements also allowed prolongation of the use-life of houses and small storage structures, whose uprights, driven into the lacustrine chalk, could resist deterioration for 10 years or more, while the foundations of this type of construction would not have lasted more than 5–6 years when built on dry land (based on experimental studies 1988–1995).

The choice of a marshy milieu for village location, on continually moist soils suscep-
tible to flooding, necessitated certain architectural adaptations, from covering the soil with bundles of sticks, laying down of bark beds to prevent the humidity from rising, to the building of houses with floors elevated to put them out of the reach of floods. The ensemble of these habitation conditions (wet or floodable soils, bringing in of beds of plant material to stabilize the natural soils lacking mechanical resistance, the covering of archaeological levels by deposits, sometimes rapid, of lacustrine chalk during periods of high water level) has been favorable to the preservation of wood and architectural elements in anaerobic conditions. Without exaggeration, one can state that the architecture of the lakeshore villages is certainly the best known today within the European Neolithic (Pétrequin 1991; Luley 1992).

In addition, these structures, where posts, floors, daub walls (Fig. 2), and superstructures can all be seen, allow very advanced studies, which can take into account the species of wood (Lundstrom-Baudais 1986; Lundstrom-Baudais et al. 1989; Billard et al. n.d.), the conditions of tree growth (Lundstrom-Baudais 1986; Billamboz 1982; Pétrequin 1992), and very precise dating of the principal phases of cutting of oak and ash (Lambert and Lavier 1990, 1993).

It is now possible to follow the evolution of the use of wood for construction over the long term (Fig. 3), roughly between 3600 and 2600 B.C., in a chronologically detailed framework (phases of 25–50 years) and on large samples (nearly 6000 wood fragments analyzed), corresponding to at least 15 different villages.
In parallel, research on the artifacts and techno-cultural assemblages has allowed the definition of the cultural sequence (Pétrequin and Pétrequin 1988; Giligny et al. n.d.): The Combe d’Ain experienced periods of direct colonization, coming alternately from western Switzerland and the Rhone Corridor, and periods of partial to complete abandonment. We will see that these movements, with a partial renewing of the population, are not without effect on the evolution of wooded milieux and the management of species used for construction, in this region of low mountains, which probably served as a zone of welcome for communities coming from rich agricultural zones, who were trying to regulate momentary problems of overpopulation by reproducing the same social organization and technology, as long as new lands were still available.

2. FOREST CUTTING WITH STONE AXES

People have often underestimated the technical importance and the effectiveness of polished stone axes or adzes, which, for almost four millennia, were the tools par excellence of Neolithic cultivators in forested surroundings. It is sufficient to note the estimate that it is necessary to cultivate (and, thus, clear) 1.8 ha to feed a family of five to seven persons (Lüning and Kalis 1993). The question remains whether this consists of permanent fields, which is more or less demonstrable for the early Danubian Neolithic (Lüning and Kalis 1993), or
FIG. 3. Chronology and cultural attribution of the main Neolithic habitation sites on lakes Chalain and Clairvaux during the 4th and 3rd millennia B.C. The dendrochronological dates, from posts or horizontal timbers, are indicated in the central column.

Western Swiss Chronology (1992)

2440
2630 Sauverniére-Cordé récent
3700 Sauverniére-Cordé ancien
3900 Lioscherz
4200

Dendrochronologique Clairvaux et Chalain.

Southern cultural influences
 DIRECT DENDROCHRONOLOGICAL DATE

Eastern cultural influences
 INDIRECT DENDROCHRONOLOGICAL DATE

Cultural attribution
 Approximate chronological position
whether cereal cultivation was moved regularly, following a pattern of shifting agriculture (Carlstein 1982), the old fields being then abandoned after 1 or 2 years of cultivation to the shoots regenerated from old stumps and to recolonization by secondary forest.

At Chalain station 3 at the end of the 4th millennium B.C. (Pêtrequin n.d.), the study of the axe-cut ends, observable on almost 300 structural pieces (Fig. 4), shows that, considering all species of trees together, one can identify two very different techniques of felling. The first technique leaves as its mark short bevels. This technique is found on poles of less than 15 cm diameter, from young trees, dominated by light-loving species, which are rapid colonizers, or by species which regenerate well from stumps. The second technique presents long bevels from cutting, on trees of greater than 20 cm diameter, among which oak, ash, and linden 70 years old and older often are found, coming from a primary forest, or old secondary forest, judging from the study of tree-rings (Lundstrom-Baudais 1986; Lambert and Lavier 1990).

One can thus demonstrate the opening of new parcels of land in the direction of old forest, as well as the return to cultivation of earlier cleared parcels. It remains to be seen if these two techniques are successive in time or whether they were utilized together.

3. DETERMINATION OF WOOD SPECIES AND INTERPRETIVE MODELS

Looking at the lists of species determinations for architectural wood found in archaeological context at Chalain and Clairvaux, one realizes quickly that the percentages of different species can vary rapidly in space and in time.

Spatial variations among neighboring and contemporary houses can be accounted for in terms of human choice and property rights with respect to the forest. Around 3450 B.C. one house at Clairvaux station II was set on foundations of ash, while its neighbor was built on posts of oak (Lundstrom-Baudais et al. 1989); dendrochrono-

![Diagram](https://example.com/Fig.4.png)

**Fig. 4.** Felling with stone axe: The relationship between the length of the longest cutting bevel and the diameter of the tree allows the demonstration of two different origins of architectural wood: small diameter limbs from fallow fields or forest edges, and trees of greater diameter taken from a primary forest or an older secondary forest.
logical studies also show that, in this village, the oak posts of two contiguous houses were cut in different environments (Lambert and Lavie cited in Pétrequin 1989). This spatial variation suggests, therefore, that in this period, the zones of felling (and from this the areas brought under cultivation) could be different from one basic social group (household) to another.

But these spatial variations are minor compared to the chronological variations that are exhibited by most of the worked woods utilized successively over the course of a millennium. Billamboz (1982) and Lundstrom-Baudais (1986) have demonstrated, by two different approaches, that these chronological variations, relating to the wood species, to their manners of growth, and to the norms of preparation by splitting, might suggest an evolution of the forest communities, in particular through the effects of human clearances.

To interpret the evolution of woods used for construction in the Neolithic, it is suitable therefore to build up the following interpretive models:

● The phytosociological models of natural equilibrium (Fig. 5, upper panel), and Fig. 1), with the zonation of the vegetation being a function of the types of soil and the distance from the lake, are the most classic, but do not take into account very well the effects of repeated clearances;

● The models of human exploitation (Fig. 5, lower panel), based on the observation of present-day forest communities that are subjected regularly to clearances, suggest that certain species which colonize rapidly or regenerate well from their stumps can be favored by repetitive clearance for agricultural and/or pastoral purposes;

● Present-day ethnographic models (Carlstein 1982; Pétrequin and Pétrequin 1992, 1993) suggest rhythms of exploitation (permanent or shifting cultivation), forms of management of space and daily time, or modes of exploitation (equilibria with population densities, social organizations, and techniques) that are worth testing and demonstrating in the past;

● Models of experimental architecture (Pétrequin 1991), finally, allow the definition of certain functional necessities for the architectural wood found in excavation and the verification of the plausibility of hypothetical reconstructions of structures.

Only those hypotheses that involve all of these interpretive models have some chance of approaching the realities of the past.

4. HOUSE POSTS: HUMAN CHOICE AND THE EVOLUTION OF THE FOREST ENVIRONMENT

Among all the possibilities for choice that the forests offered during the final Neolithic, the people of Clairvaux and Chalain largely utilized oak, and to a lesser degree ash, for the foundations of their houses and granaries, often with raised floors. The evidence indicates that this situation is the result of a selection of the most resistant species with long fibers that split well (Fig. 6).

But, in detail, one can contrast certain periods during which these two species are accompanied by maple, beech, elm, hazel, and willow (Fig. 6: 3600, 3100, and 2700 B.C.) and moments when oak and ash constituted by far most (virtually all) of the main posts of the houses (Fig. 6: 3450 and 3000 B.C.).

This first schematic opposition can be complemented by the study of the diameter of the cut trees (young trees as opposed to old trees) and by the forms of preparation of the trunks (direct utilization of circular trunks or splitting them into large timbers), such as those which we have seen in Section 2, above (Fig. 4). When the supply of timber comprises diverse species (3600 and 3100 B.C.), the posts are taken from long trunks of small diameter, used without modification (Fig. 7). On the contrary, when the posts are almost exclusively of oak and ash, we see posts of subtriangular cross-
section, taken from large logs divided by splitting. Finally, around 3700 B.C., circular and split trunks are used together (Fig. 7, upper panel), during a period when the species utilized are very diverse.

The models laid out above allow us to suggest an interpretation of these phenomena which goes first in the direction of a shifting agriculture in a forested environment (fields abandoned in the forest, then...
Evolution of the arboreal species utilized for the main posts of constructions during the 4th and 3rd millennia B.C. at lakes Chalain and Clairvaux. The evidence indicates that choice falls on the hardwoods (oak and ash) for seating durable foundations. But the forest environments impacted by clearance vary through time. One can thus contrast moments when all environments are affected (3600, 3100, and 2700 B.C.) with other periods when cutting for the most part fell on oak groves little modified by man (3450 and 3000 B.C.). We interpret these different representations as variations in the density of population: stable or declining communities within a large agricultural area where the young forest is in full development vs a growing population expanding in the direction of the limits of agricultural land and toward the primary forest.
brought back into cultivation), then cycles of expansion-retreat of the lands impacted by woodcutting (and by agricultural clearing), and finally a progressive degradation of the forest. Figure 7 summarizes these interpretations:

- 3600 B.C. Clearances for agriculture touch young growths, probably according to the rhythms of shifting cultivation. All forested environments close to the lake are affected, including the shores and the softwood forests. The primary forest of hard-
woods is not reached by the woodcutting. Dendrochronological datings are difficult on these young poles from a regularly cleared environment.

- 3450 B.C. Woodcutting is now carried out on a primary forest of hardwoods, beyond the former territorial limits. The logs of old trees are split, and it is easy to date them dendrochronologically because they were cut in a forest of slow, natural growth.

- 3100 B.C. After a period of abandonment of the lake shores, new cuttings relate uniquely to young trees, as at 3600 B.C., within the preceding territories, where the populations of ash (a light-loving species) were favored with respect to groups of oaks. This is a period of recession in the area covered by cereal agriculture.

- 3030 B.C. The area affected by woodcutting expands once more and is more distant from the villages, as the increase in oak and ash suggests, of which certain ones can be dated by dendrochronology.

- 3000–2900 B.C. The woods utilized for posts are almost exclusively large, split oaks, easily placed within a dendrochronology. The extent of land covered by cultivated grain is now at its maximum.

- 2800–2600 B.C. After a new period of abandonment of the lake shore, woodcutting relates to both young saplings and trunks of large diameter but which developed as shoots from stumps (Lundstrom-Baudais 1986), corresponding to a secondary forest and thus are difficult to date by dendrochronology. Fields of grain are in recession in comparison to the preceding period and never again find the extension demonstrated during the 30th century B.C. (Pétrequin 1992).

This evolution of clearances can be traced also through the means of transport of wood for construction. One can distinguish:

- Long, thin poles taken from the secondary forest (Fig. 8:1, 2—Chalain, station 3, level VIII), cut retaining their terminal branchings, then cut to length in the village, even if that means removing the natural forks if the wood is not utilized as a load-bearing post.

- Long, large diameter trunks (Fig. 8:3—Chalain, station 5), destined to be split and pulled probably by cattle, as suggested by notches arranged for the tying of a cord around one end of the log (Pétrequin et al. 1991).

5. POLES AND PLANKS OF THE SUPERSTRUCTURES

The criteria of choice for the poles for superstructures (joists, high stringers, and frame) are different. Indeed, for these pieces of wood, one has to be much more demanding in terms of the criteria of form (great length of the poles, regularity of small diameters) than in terms of the durability of these elements of the frame, directly sheltered by the bark covering (Pétrequin 1991). It is not really surprising, therefore, that, in general, ash was especially favored, which, in conditions of strongly competitive growth, provides trunks of great regularity (Fig. 9). Yet, the variety of species utilized for the superstructures is still clearly greater than for the posts.

The chronological variations in the species utilized for the frame show that the well-developed forest diminishes little by little (Fig. 9, oak and linden in particular), which is the normal evolution at the end of the Atlantic, but here, this transformation may have been accelerated by clearances. Certain species like ash and maple which reproduce well and sprout rapidly from stumps were, on the contrary, favored (Fig. 9, around 3190 B.C.). Finally, around 3040 B.C., when the clearances begin to gain on the primary forest and the lands covered by cereal agriculture expand, all types of forest environments are affected by woodcutting.

The logs split for floors pose a more particular problem. Only trees with long fibers and without knots, of regular growth (and, thus, coming from the primary forest) can
be split to obtain floor planks with the techniques of the time (axe with stone blade, cleaver of antler, and, later, splitting wedges of beech): Around 3200 B.C., people chose ash, linden, poplar, and, to a lesser degree, oak. With the retreat of the primary forest, they then turned, first, to the oaks, more and more frequently utilizing splitting wedges (Pétréquin and Pétréquin 1988). When trees with regular trunks began to be scarce, people turned to the high elevation forest, far from the cleared...
HIGH ELEVATION FOREST
c. 2700 B.C.

OPEN FOREST AND DEVELOPED FOREST
maximum c. 3190 B.C.

WETLAND ENVIRONMENT
OPEN FOREST
AND DEVELOPED FOREST
maximum c. 3040 B.C.

DEVELOPED FOREST

c. 2700 B.C.

c. 3600 B.C.
fields, to seek trunks of fir (Lundstrom-Baudais 1986), perhaps even up to an altitude of 800 m (Fig. 9, right panel, 2700 B.C.).

Everything suggests that around 2700 B.C., all of the high terraces of the Ain had been cleared at least once and that primary forest no longer existed.

6. POLLEN DIAGRAMS AND EVOLUTION OF WOODED LANDSCAPES

From a methodological point of view, it is interesting to compare the above results, taken from a single study of the woods used in architecture to the evolution of forest cover recorded in a pollen diagram from Chalain 2 AC, over the period from 3100 to 2600 B.C. (Bourgeois 1989).

The site of Chalain 2 AC has three habitation layers, dated respectively to around 3000, 2800, and 2600 B.C. Note, first, the fact that the pollen profiles are strongly affected by these habitation levels; the percentage of arboreal species diminishes drastically with the construction of the villages, to rebound rapidly as soon as the villages are abandoned; and the natural deposition of lacustrine chalk, coincident with the high water levels of the lake, begins again. The synchrony between human occupation and decline in arboreal pollen cannot possibly be interpreted here as a direct effect of forest clearance on pollen frequencies. In fact, it is simply the bringing of beds of vegetal material into the villages and the local threshing of grain harvests which can account for the sometimes extremely high percentages of cereal pollen and pollen of ruderal plants that come to mask the effects of the natural pollen rain (Richard 1985, 1992). The same is true for Allium cf. Ursinum, a plant whose leaves and flower stems were consumed in great quantity; Hedera, Viscum, and Tilia were also used for the feeding of stock, as has been possible to demonstrate by the identification to species of the sticks at Chalain 3 and 4 (Billard et al. in preparation). This effect of anthropogenic “pollution” on the pollen diagram is exacerbated by the speed of sedimentation, which is vastly more rapid during the phases of occupation of the site and the artificial accumulation of beds of vegetal material than during the epidoses of abandonment of the villages and the beginning again of natural sedimentation (Pétrequin and Pétrequin 1984; Richard 1985).

The occupation site of Chalain 2 AC shows itself to be, therefore, a poorly chosen point at which to evaluate the direct effects of clearances on the forest cover; to do this, it would have been necessary to find a sedimentary sequence more distant than the habitation sites, which is not possible in our case, because all of the shores of the lake have been profoundly modified by man since at least the 5th millennium. And in this domain of the selection of woods for woodworking, pollen analyses are less effective than the direct study of architectural pieces, since it is virtually impossible to determine in the samples the exact role of pollen brought in by man and that deposited naturally by local or regional pollen rains.

Fig. 9. Change in the representation of the different arboreal species utilized for the superstructures of houses (excluding posts). The change in species representation suggests a progressive evolution of the forest environments between 3600 and 2700 B.C. The myth of the restraint observed by Neolithic people in forest clearance and of the low efficiency of Neolithic forest clearing must be abandoned. The diminution of species characteristic of the Atlantic forest is noticeable from 3600 B.C., while species that thrive on repeated clearances increase. The transformations of the forest are accentuated towards 3040 B.C. when all environments are affected, including lake shores and rivers. Finally, regular trees from which to take planks must be sought at high altitudes around 2700 B.C., because the linden, ash, and oak of regular growth no longer exist in the valley of the Ain.
FIG. 10. The progressive distancing of the fronts of clearance around Lake Chalain can be demonstrated from the preceding studies. In the 32nd century, the clearances fell within a young secondary forest where softwoods were still present (see also Fig. 1). During the second half of the 31st century, the oaks and ash of the primary forest begin to be affected, including the very slow growth ash, whose distribution is probably limited to the limestone plateau. In the 30th century, it is likely that the primary forest was cleared at least as far as Montigny, 5 km away as the crow flies, as suggested by an oak dated by dendrochronology (Lambert and Lavier 1993). Finally, the trunks of fir exploited for planks in the 27th century came from a high forest, perhaps even above 800 m.
On the contrary, if one compares the layers not “polluted” by the construction and occupation of the villages, contemporary with the recurrence of natural sedimentation in shallow water, two periods can be contrasted:

- Around 3100 B.C., a period of regular rhythms of limited clearance, where beech is particularly affected while hazel, oak, and ash are relatively spared. We interpret these as rhythms of clearance followed by abandonment of fields to regeneration from stumps and the return of the forest—the effect of fallowing and of shifting cultivation.

- After 3000 B.C., the impact of man on the forest cover intensifies, and, between 2800 and 2600 B.C., it stabilizes, while the length of occupation of the villages tends clearly to increase. We suppose that the agro-pastoral system has then become more stable, in connection with much larger cleared areas.

Through the bias of palynology (and of four pollen columns at Chalain and Clairvaux), one finds again, to a certain degree, the opposition demonstrated by the study of construction wood, first with exploitation by shifting agriculture and a management of the young, secondary forest, followed by an extension of clearances, which then affect, in first place, primary forests or old secondary forests.

Finally, at Chalain 2 AC, the increase in the percentage of pollen of Plantago major/media (associated with moist and trodden areas), while the representation of pollen of Plantago lanceolata (associated with temporary pastures) decreases, would be completely in accord with such an increased stability of agro-pastoral systems (Richard and Géry 1993).

7. EXPANSION AND RETREAT OF THE CLEARANCES: RELATIONS WITH POPULATION DENSITY

Taking into account the types of soils on which the arboreal species for architecture likely grew (Fig. 5), we now can propose a general chronology of the expansion of clearances around Chalain (Fig. 10). This proceeds from the softwood forests on the moist shores of the lake on the west to the high terraces of the Ain with primary forest (end of the 31st century), the edges of the limestone plateau with slow-growing ash (end of the 31st century), and toward the north, as far as Montigny-sur-Ain, from which comes an oak cut during the 30th century, exactly at the moment of the maximal expansion of the far edges of clearance (Lambert and Lavier 1993). This extreme limit of the area of cultivated land would be located roughly at 5 km, as the crow flies, from the villages of Chalain and thus at barely an hour’s walk. After the 30th century, the zones exploited would have covered a more restricted area, in secondary forest, where both old and young trees were exploited. For this period, pollen analyses (Richard and Géry 1993) indicate that the very noticeable rise in Plantago major/media, which comes to dominate Plantago lanceolata, could coincide with the rise in herding (Arbogast and Pétrequin 1993), leading to a veritable sterilization of the overgrazed and trodden wetlands. The same phenomenon was recognized around the lake of Clairvaux (Richard 1983), at the moment when cattle begin to represent more than 50% of the faunal remains found in the dumps.

Between the 36th and 30th centuries B.C., the increase in clearances was very important. One can get an idea of this increase by thinking that in the 36th century there was probably only a single village of about a dozen houses on the lake shore; six centuries later, the number of contemporary villages was six at the minimum, or close to 60 houses. Taking a figure of 1.8 ha of cereal cultivation each year for a household (Lüning and Kalis 1993), people could make do with around 20 hectares cultivated for grain in the 36th century, while in the 30th century, the area of cereal cultivation would
have had to be, at the minimum, on the order of 100 hectares, which probably required certain forms of sedentary agriculture, because the available areas on the high terraces of the Ain within an hour’s walk were not sufficient to allow cycles of shifting agriculture with wooded fallowing (Carlstein 1982). It is not surprising therefore that the cultivation of legumes (*Pisum sativum*) develops exactly during this period of stabilization of cultivation and of long permanence of habitations, certain villages being occupied without interruption for more than three generations (Lambert and Lavier 1993; Pétrequin n.d.).

The coincidence between demographic growth (Fig. 11A, number of contemporaneous villages) and the evolution of woods utilized for architecture is strikingly demonstrated. But one should not imagine a regular and irreversible growth. Everything indicates on the contrary that variations in population, estimated from the number of contemporary villages, responded to cycles where demographic growth—for the 31st century following upon the arrival of communities of the Ferrières Culture from the edges of the limestone plateaus bordering the Cévennes (Fig. 11D, cultural sequence)—is followed by periods of recession, even complete abandonment of villages and agricultural lands.

The climatic variations demonstrated by Magny (1991, 1993a) from sedimentological studies of lakes Chalain and Clairvaux and illustrated by a related phenomenon, the variations in the $^{14}$C content of the atmosphere (Fig. 11B; Damon et al. 1989), tend to make us think that the economy of these Neolithic communities was fragile—several years unfavorable to cereal cultivation and then the whole economic system collapsed, with, as a consequence, the abandonment of villages and probably the whole Combe d’Ain. Or, a succession of rainy and cool years and of poor harvests could lead people to abandon fields already extensively exploited over a period on the order of a century and to go search elsewhere for equivalent land, where the state of the forest permitted the identical reproduction of their social and technical systems.

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