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Leaf-foddering of Livestock in the Neolithic: Archaeobotanical Evidence from Weier, Switzerland

by PETER RASMUSSEN

INTRODUCTION

The question of feeding leaves and branches to livestock in the Neolithic has been discussed on the basis of palynological evidence for over 40 years. Numerous pollen analysts and archaeologists have claimed and discussed the occurrence of leaf-foddering in the Neolithic over the greater part of Europe. In this debate one thing has consistently been absent: Firm archaeological evidence.

The theory of leaf-foddering was originally formulated by Rolf Nordhagen, but first put into print by Knut Fægri (1940, 1944). Fægri proposed that the elm decline, which today has been demonstrated across a large part of Europe and has been dated to the centuries around 3000 b.c.,[1] was the result of neolithic farmers lopping branches and leaves from trees for use as fodder. In this way the potential of elm trees to flower and produce pollen would have been greatly reduced. The leaf-foddering theory, along with Firbas' work from 1937 and Johs. Iversen's from 1941, is one of the first examples of a palynologically-demonstrated vegetational change being interpreted as a consequence of cultural activity. Troels-Smith (1953, 1955, 1960) through his research in Denmark and Switzerland was able to expand and develop the leaf-foddering theory. In particular, the palynological investigations associated with waterlogged Swiss settlements suggested that this practice took place. One locality central to Troels-Smith's work is the neolithic settlement Weier, which lies in N.E. Switzerland in Cantone Schaffhausen. During the archaeological excavation of the site two heaps of leaf-bearing twigs were found. These comprised twigs of elm (*Ulmus*), birch (*Betula*), oak (*Quercus*), lime (*Tilia*), maple (*Acer*) and ash (*Fraxinus*) (Guyan 1955). In addition, in some of the buildings thick layers containing animal dung were found. The latter shows that livestock had been kept confined in the settlement and the heaps of twigs suggest that they were fed on leaf fodder. The result of the palynological and archaeological investigations at Weier form, without doubt, the strongest evidence we have to date for leaf-foddering in the Neolithic.

One of the events which plays a crucial role in Troels-Smith's arguments concerning leaf-foddering is the neolithic elm decline. In the concluding remarks in his thesis (1955) he writes:

"It is reasonable to suppose that the animals were foddered in the byre and in primitive systems this is characterized by leaf-foddering, particularly with elm, but also with ash, lime, poplar etc. Consistent with this interpretation is the very marked decline in elm, the tree which since time immemorial has been the most prized for animal fodder" (translated from Danish).

Since Troels-Smith's investigations a vigorous debate has developed concerning the cause or causes of the elm decline. In addition to leaf-foddering, other factors proposed, either singly or collectively, include climatic change, soil deterioration and an elm-specific disease (Iversen 1960, 1973; Smith 1961; Watts 1961; Heybroek 1963; Tauber 1965; Rackham 1980; Groenman-van Waateringe 1983; Huntley and Birks 1983; Göransson 1984; Aaby 1986 *inter alia*).

Discussions concerning possible leaf-foddering in the Neolithic and the cause of the elm decline are thus closely linked. With time however, the associated cultural phenomena, pollarding and leaf-foddering, have also been incorporated into explanations of other vegetational changes demonstrated in pollen diagrams from the Neolithic (Andersen 1978; Aaby 1986; Behre and Kučan 1986; Kalis 1988 *inter alia*). Some pollen analysts have, furthermore, interpreted palynologically-demonstrated vegetational changes in terms of a particular form of tree management (i.e. shredding – see later) (Aaby 1983; Andersen 1985). In the archaeological world, pollarding of trees and leaf-foddering have also been incorporated into descriptions of the prehistoric economy as a more or less accepted fact (Clark 1952; Lüning 1982; Madsen 1982; Poulsen 1983; Kristiansen 1988 *inter alia*).

Ever since Johs. Iversen first demonstrated in 1941 that the neolithic population was capable of changing its environment, it has been difficult to integrate palynolo-

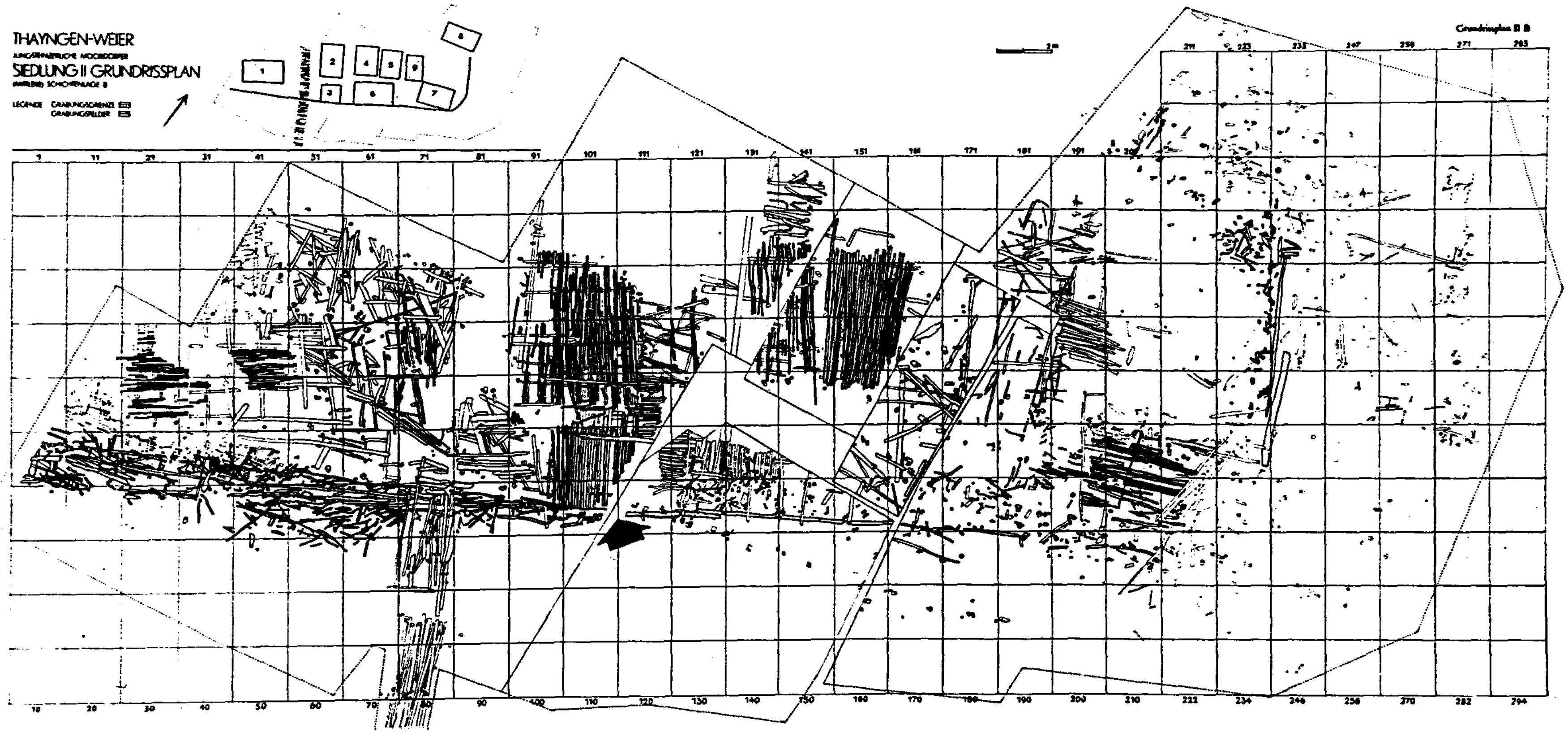

Fig. 1. Excavation plan of the Weier settlement (Weier II) (after Guyan 1967).
Building 1: House with hearth; at the western end of the house there was an extension which contained a thick layer of goat/sheep faeces.
Building 2: House with hearth.
Building 3: Byre containing dung layers which were identified via their content of thousands of house fly puparia (*Musca domestica* L).
Building 4: No hearth; building's function unknown.
Building 5: No hearth; two heaps of leaf-bearing twigs (elm, birch, oak, maple and ash) were found in this building.
Building 6: House with hearth.
Building 7: No hearth; fly puparia present.
Building 8: No hearth; fly puparia were present in the western end of this building.
Building 9: No hearth; building's function unknown.
A wooden trackway runs between building 1 and buildings 2 and 3.

gically-based cultural-historical interpretations with the archaeological evidence. This also applies to a great extent to the leaf-foddering theory, which is built up almost completely around palynological evidence. Firm archaeological evidence for leaf-foddering is rare and there is no doubt that demonstrating this phenomenon by palynological evidence alone is exceedingly difficult, if not impossible. The more one is able to involve and compare both the palynological and archaeological evidence, the better the possibilities for evaluating the theory. In this article the first clear example of leaf-foddering of livestock in the European Neolithic is presented. The results of these analyses and the perspectives which they open up are of relevance not just at Weier but everywhere that leaf-foddering and the character of neolithic agriculture are discussed.

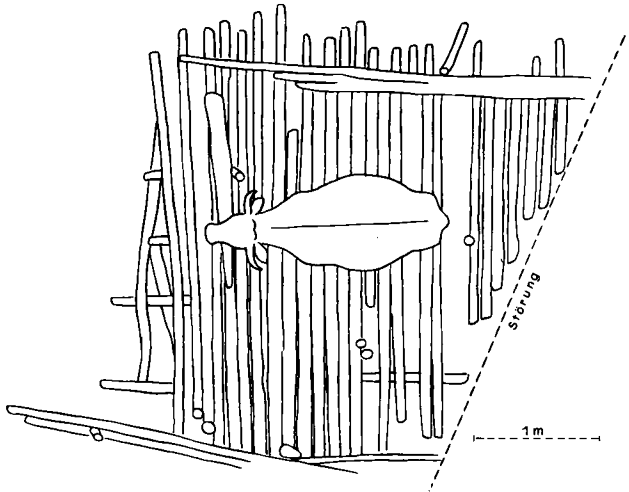

Fig. 2. Above: Excavation photograph of the byre, which is marked with an arrow on figure 1 (building 3). The building's wooden floor can be seen to the left of the picture together with the remains of a presumed wall. To the right is the wooden trackway which runs parallel to the byre.
Below: Drawing of the byre (after Guyan 1967).

THE WEIER SITE

As mentioned earlier the results of the palynological and archaeological investigations at Weier comprise the strongest evidence to date for leaf-foddering in the European Neolithic. The site also lends itself to a closer archaeobotanical examination of the leaf-foddering theory in two particular ways:

1. There is palynological evidence suggestive of leaf-foddering, in addition to archaeological evidence in the form of the remains of harvested leaves and twigs.
2. There are well-preserved byre layers containing dung of domesticated animals.

The latter are something very rarely found in sites of neolithic age and they represent a very special opportunity to investigate the question of leaf-foddering; by analysing the dung layers it is possible to say, with a great deal of certainty, what the animals were fed on.

Earlier archaeological, botanical and zoological investigations at Weier have been dealt with in a long series of publications. For this reason only a brief description will be entered into here: The site was constructed around 3100 b.c. on a small dried-out gyttja island in a shallow lake on the Weier valley floor. The lake measured c. 100 x 500 metres and the site was surrounded by water and marshland. In its three phases the site covered in total between 6000 and 9000 m^2 and it was enclosed by a wooden fence or palisade (fig. 1). Three settlement phases can be recognized at the site (Weier I–III) all of which belong to the Pfyner Culture (Guyan 1967; Winiger 1971). The oldest phase, Weier I, originally comprised 8–10 buildings, Weier II comprised 10–15 buildings and Weier III c. 30 buildings (Guyan 1967). The three phases are dated to 3106 b.c. (Weier I), 3026 b.c. (Weier II) and 2810 b.c. (Weier III) respectively (Troels-Smith 1981). The site is one of the classical archaeological localities in Switzerland which earlier went by the name of "Pile Dwellings". Cultivation at the site involved first and foremost wheat, barley, flax and opium poppy (Troels-

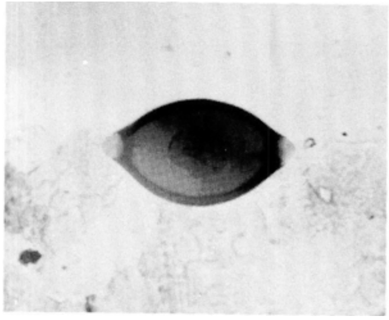

Fig. 3. Ovum (egg) of the parasite whipworm (*Trichuris spp.*) found in dung from the byre at Weier. The egg measures 52 x 24 µm. (Photo: P. Nansen).

Fig. 4. Ovum (egg) of the parasite liver fluke (*Fasciola hepatica* L.) found in dung from the byre at Weier. The egg measures 155 x 70 µm. (Photo: P. Nansen).

Fig. 5. House fly puparia (*Musca domestica* L.) found in dung from the byre at Weier; seven puparia can be seen on the picture. (Magnification approximately x 4.5). (Photo: L. Larsen, National Museum).

Smith 1955, 1981, 1984; Jørgensen 1975; Fredskild 1978; Robinson and Rasmussen 1989). Livestock at the site was dominated by cattle, with pig, goat and sheep being of lesser importance (Soergel 1969).

The Dung Layers

The finding of compact layers containing animal dung shows that, at certain times of the year at least, livestock were kept confined within the settlement. One of the areas where the animals stood is that referred to by the excavator, W. U. Guyan, as "*Rinderstall*" or "*Rinderstandplatz*" (fig. 2). The fact that the structure was used by animals is confirmed by the presence of ova of the internal parasites whipworm (*Trichuris spp.*) and liver fluke (*Fasciola hepatica L.*) (figs. 3 and 4). Two samples from the dung layers, each 50 g in weight, were subjected to flotation and sedimentation. One sample (Wh 87) yielded 25 *Trichuris* ova, the other (Wh 84) yielded 25 *Trichuris* ova and 7 *Fasciola hepatica* ova (Nansen 1984, 1987). These ova are shed in faeces and show therefore that the layers in the building are, to some extent, composed of dung. The identification of fossil ova of whipworm to species is difficult and accordingly the identity of the host animal cannot be determined with certainty. The *Trichuris* genus has a broad host spectrum which includes cattle, sheep, goat, pig, dog, cat and man, all of which, with the exception of cat, could have been present at Weier. On the other hand, the liver fluke, as a consequence of its life cycle, is specific to ruminants. The presence of liver fluke ova shows therefore that the layers contain ruminant dung. The layers can hardly consist entirely of dung however, rather a mixture of dung from the byre floor and other material brought, intentionally or by accident, into the byre as a result of human and animal activity. The size of the dung component is difficult to estimate. The concentration of parasite ova is low, but this does not necessarily mean that only a small amount of dung is present. We do not know the extent of the parasite burden which the animals carried neither do we know to what extent these parasite ova survive in such ancient material.

In the byre layers there are also large numbers of house fly puparia (*Musca domestica* L.) (fig. 5) which together with the parasite ova serve to confirm the material's faecal origins. Dung heaps or middens are the most important breeding grounds for this species (Blædel/Troels-Smith 1956; Guyan 1981; Overgaard Nielsen 1989; Troels-Smith 1984).

As only 3 goat/sheep faeces were found in the dung layers and given liver fluke's host specificity, it seems fairly safe to conclude that the dung present in the layers is primarily from cattle.

The composition of the dung layers

Figure 6 shows part of a section through the byre and the dung layers. Three floor layers are present in the byre, each constructed of whole and split tree trunks. Between each of the floors was up to 30 cm of dung and other organic material. The dung layers must have been thicker in the past, perhaps double so thick, but due to compaction over the millennia, their thickness has been much reduced. They contain a wide range of macrofossils of which twig and leaf fragments are the most abundant (figs. 7 and 8). The volume of twigs contained in the layers is given in table 1. As can be seen from the table, the quantities of twigs are large. If the quantities of leaf fragments are also considered then it is clear that large quantities of leaf-bearing twigs must have been brought in to the animals. On the basis of the samples which were analysed it can be estimated that the dung layers in the byre all in all contain in the region of 53000 twig fragments. These vary in size from under 1 mm up to pieces over 7 cm in length and 1.3 cm in diameter. The majority of

Layer no	Twigs %
g	25.0
h	≤12.5
i	12.5
k	50.0
l	50.0
m	25.0
n	≤12.5

Table 1. The estimated volume occupied by twigs in the dung layers. (det. by J. Troels-Smith and Svend Jørgensen in 1956).

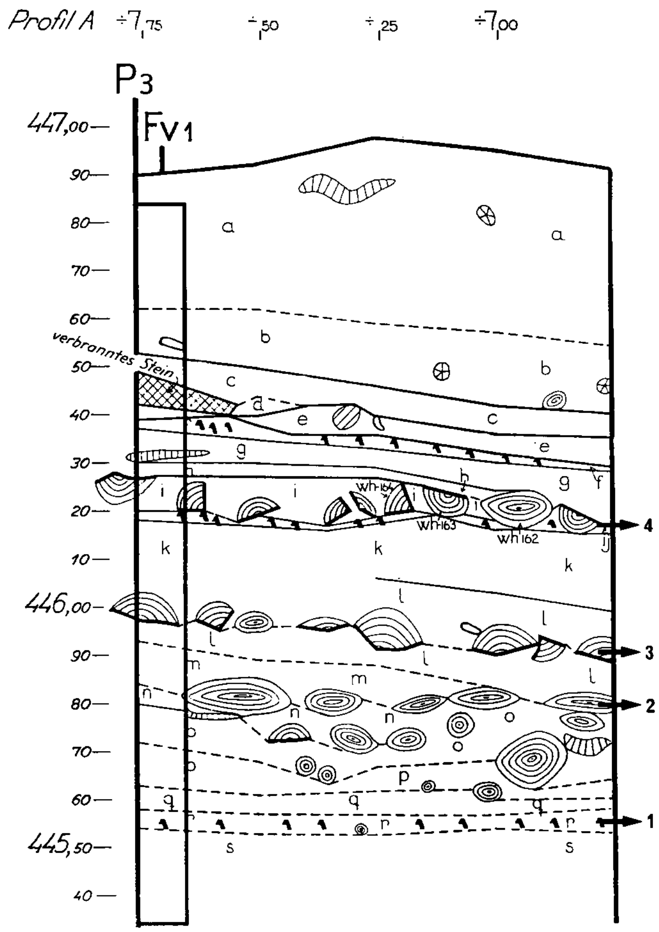

Fig. 6. Part of the section through the byre and dung layers. Three floor levels can be seen in the section, each made of whole and split tree trunks (arrows 4, 3 and 2) (cf. fig. 2). Arrow 1 marks the position of a charcoal-rich layer, which is the oldest archaeological layer in this section. The four layers have been radiocarbon dated as follows:

4: 2760 ± 60 b.c. (K-4928) Mean: 2805 b.c.
2850 ± 65 b.c. (K-4929)
3: 2920 ± 65 b.c. (K-4930) Mean: 2940 b.c.
2960 ± 65 b.c. (K-4931)
2: 2870 ± 135 b.c. (Ua-1009) Mean: 2870 b.c.
2870 ± 135 b.c. (Ua-1010)
1: 2820 ± 135 b.c. (Ua-1011) Mean: 2820 b.c.

The narrow range of the dates shows that the floor levels in the byre were established over a relatively short period of time. On the basis of archaeological/stratigraphical evidence, one of the layers is assigned by the excavator to phase II at the Weier site. Unfortunately the identity of the floor level is not specified (Guyan 1967). The new radiocarbon dates are consistent with the interpretation that all three floor levels belong to the Weier II phase. The section was measured and drawn by J. Troels-Smith and S. Jørgensen in 1956.

The dung samples which were analysed were taken from layers g-n in the column marked Fv1.

Fig. 7. The larger twig fragments (a total of 77) in sample of 200 cm³ from the dung layers. They include fragments of the following species: Ash (48), willow (19), oak (4), hazel (3), ivy (1), alder (1), birch/alder (1). (Photo: L. Larsen, National Museum).

Fig. 8. The leaf fragments in a sample of 200 cm³ from the dung layers. (Photo: L. Larsen, National Museum).

these fragments have not been through the animals digestive systems but was left behind after the leaves and smaller twigs had been eaten. It is the thousands of small wood fragments (2–3 mm or less) and the many small leaf fragments which have passed through the animals. The partially-digested and undigested material was thoroughly mixed together and the formation of the dung layers can perhaps best be illustrated by way of a series of photographs taken of a modern experiment involving feeding leaf hay to cattle (figs. 9–11). The experiments were carried out under the auspices of the Historical-Archaeological Experimental Centre at Lejre.

Tree species used for fodder

22 samples, each of 200 cm³, were analysed from the dung layers. These samples yielded 1610 twig fragments. 11 woody species were represented (table 2). The figures given in the table should be treated with a certain measure of caution as it is not certain here (and in all analyses of this nature) how representative the analysed samples are of the material as a whole. One thing is clear however and that is that leaves and branches from a wide range of tree species were gathered and brought in as livestock fodder. If we compare the species present here with those exploited in historical times, there is a great measure of similarity, both in Switzerland and other countries where leaf-foddering was practised (Brockmann-Jerosch 1918, 1936). Austad (1985) writing about Norway, where leaf-foddering is still practised today, states that: "All accessible deciduous trees were exploited for fodder but various districts had differing views as to the value of each species of tree" (translated from Norwegian). So, despite the fact that all available trees were exploited for fodder, there were some species which were considered to be better than others. In Brockmann-Jerosch's (1918, 1936) ac-

		Weight (g)	%	Number	%
Ash	(Fraxinus)	114.3	27	339	21
Lime	(Tilia)	81.5	19	285	18
Willow	(Salix)	71.8	17	308	19
Alder	(Alnus)	40.1	9	217	13
Ivy	(Hedera)	28.7	7	186	12
Clematis	(Clematis)	28.6	7	69	4
Hazel	(Corylus)	27.5	6	64	4
Oak	(Quercus)	15.1	4	68	4
Elm	(Ulmus)	14.5	3	45	3
Misteltoe	(Viscum)	0.3	0.07	5	0.3
Honeysuckle/Privet	(Lonicera/Ligustrum)	0.16	0.04	3	0.2
Birch/Alder	(Betula/Alnus)	1.0	0.2	18	1
Poplar/Willow	(Populus/Salix)	0.4	0.09	3	0.2
Σ		423.96		1610	

Table 2. All the twig fragments identified from the dung layers arranged according to species. The percentages for the various species are calculated on the basis of the total weight and the total number of twigs.

counts of leaf-foddering in Switzerland in historical times it was generally ash which was considered to be the best deciduous tree for animal fodder. If we consider the collective picture from Weier, over 25% of the material is ash, showing that it must have been one of the preferred species. Lime is the next most abundant with 19% and as lime grows on drier soils it must have been gathered at some distance from the site. Willow, alder, hazel and oak also make up a significant proportion of the material. They too have been used for fodder during historical times although without their being attributed particular significance. On the contrary elm, which in the past has been considered a particularly valuable fodder tree (Troels-Smith 1960), makes up only a very modest proportion (3%) of the material present. Ivy and clematis, conversely, are present in surprisingly large quantities – 7% in each case. In a number of countries, including Switzerland, ivy has a history of being used as fodder for cattle, sheep and goats. It is an evergreen and was often collected in winter when it could be a problem collecting other kinds of fodder (Brockmann-Jerosch 1936; Troels-Smith 1960; Rackham 1980). Clematis on the contrary is not particularly known as animal fodder in historical times. As both ivy and clematis are creepers, growing up trunks and out along branches, it is possible that they were brought in unintentionally along with branches and twigs of other species. The quantities of both species present in the dung tend however, to suggest that this was not the case. With regard to ivy, it should also be mentioned that pollen analyses from the culture-layers at several neolithic settlement sites in Switzerland and Germany show unusually high values of ivy pollen, which is also consistent with the intentional collection of this plant (Troels-Smith 1960; Welten 1967; Schütrumpf 1968; Leroi-Gourhan and Girard 1971; Heitz-Weniger 1978; Liese-Kleiber 1985). Indisputable evidence for the selective gathering of ivy was found at the Pfyner settlement of Feldmeilen-Vorderfeld (on Lake Zürich in Cantone Zürich), where 18% of the twig fragments examined were of ivy (Bräker 1979). Furthermore at the Egolzwil 3 settlement in Wauwilermoos, Cantone Luzern (Egolzwiler Culture) 3% of the twigs in samples containing goat faeces were ivy (Rasmussen in prep.).

Mistletoe, which is present very occasionally in the

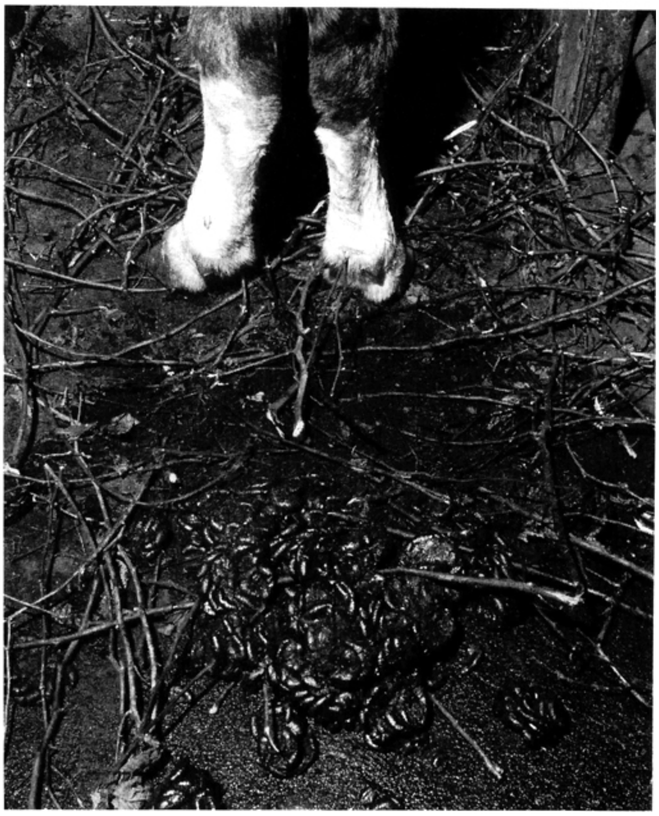

Fig. 9 (above). A modern leaf-foddering experiment: The cow is fed with dried ash leaves and twigs. It pulls the twigs through the bars and eats the leaves and the smaller twigs. (Photo: H. Rasmussen, Historical-Archaeological Experimental Centre, Lejre).

Fig. 10 (above, right). The larger twigs are not eaten by the cow and together with some leaves which are wasted they accumulate at the rear of the cow where they become mixed with dung. If the dung is allowed to lie for any length of time the cow tramples the twigs into small pieces and twigs, leaves and dung are mixed together producing something very similar to that found in the dung layers from Weier. The leaf-foddering experiment revealed that the quantities of larger twigs eaten depends on how hungry the animals are. Analysis of the modern dung also showed that leaves and twigs are not completely digested by the animals. Identifiable twig fragments up to 2.5 cm in length and with a diameter of 0.3 cm, and leaf fragments measuring 1.1 x 1.0 cm passed through the animals digestive systems. (Photo: H. Rasmussen, Historical-Archaeological Experimental Centre, Lejre).

Fig. 11 (below, right). Cow fed on elm leaves – cf. caption to figure 10. (Photo: H. Rasmussen, Historical-Archaeological Experimental Centre, Lejre).

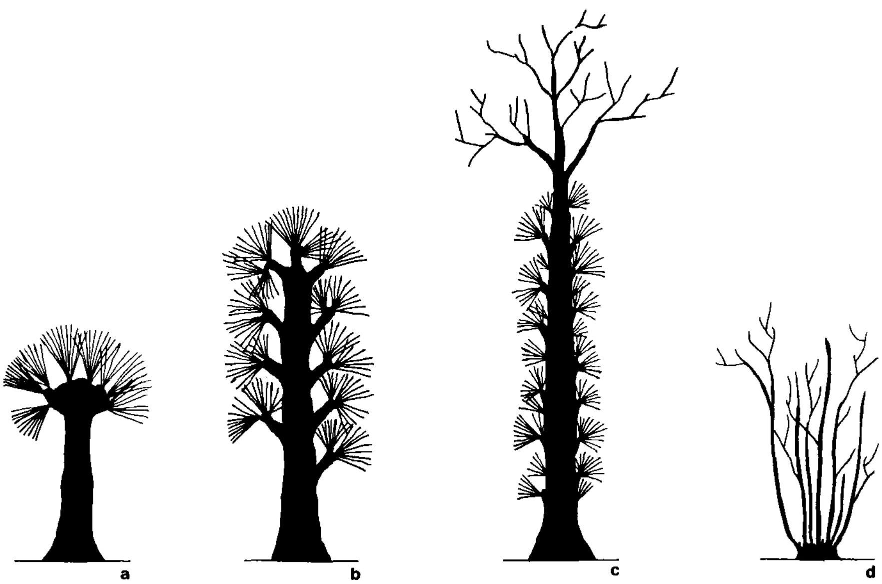

Fig. 12. Schematic representation of methods of tree management known from Europe during historical times. (Peter Rasmussen del.).
a: Pollarding b: "Pollarding" with the trunk intact c: Shredding d: Coppicing

Weier dung layers, has been used as a fodder plant in historical times in Central Europe in time of shortage, for example by farmers in the Vosges (Brockmann-Jerosch 1936). It grows parasitically on various tree species (primarily lime) and as there were so few fragments in the dung layers it seems likely that it was brought in unintentionally in association with branches of other tree species. The possibility cannot be excluded however, that it was gathered intentionally. A convincing example of the selective gathering of mistletoe is known from the late-neolithic settlement of Auvernier La Saunerie (on Lake Neuenburg, Cantone Neuenburg) where mistletoe makes up 3.6% (59 fragments) of the 1596 twig fragments which were examined (Schweingruber 1976). In Denmark recent palynological studies strongly suggest that both mistletoe and ivy were collected by the earliest farmers at the transition between the Atlantic and Sub-Boreal Periods (Andersen 1984; cf. Troels-Smith 1960). A sound basis for the interpretation of the Danish pollen diagrams is thus to be found in the archaeological evidence from the Swiss sites which shows unequivocally that neolithic farmers gathered both of these species.

THE MANAGEMENT OF TREES TO PRODUCE LEAF FODDER

Leaf-foddering in historical times was closely associated with particular methods of harvesting and lopping trees. According to Rackham (1976, 1980), this management can be divided into two main types: Pollarding and shredding. Pollarding consists of cutting off the top of the tree at a height of between 1.5 and 5 metres and harvesting the shoots which arise from the cut surface (fig. 12a). In a variation on this, not mentioned by Rackham, the trunk is left intact and the branches are cut at some distance from the trunk. The shoots which arise from the cut branches are then harvested (fig. 12b). In shredding the trunk and crown are left intact and the side branches are removed. The new shoots which are formed along the trunk are then harvested (fig. 12c). These management practices serve at least 3 main purposes:

1. They increase the production of leaf fodder.
2. They make the practical work of harvesting the leaf fodder easier.
3. The leaves are rendered inaccessible to freely-grazing animals.

From historical times and up into the recent past, various methods are known by which the fodder was harvested from the trees. In Norway for example, there are distinctions between "*rising*", "*risping*" and "*lauving*" (Austad *et al.* 1985). "*Ris*" means branches without leaves, which were collected in the winter and early spring and used particularly as cattle fodder. "*Risping*" entails ripping off the leaves from the branches either for use im-

Age of twigs in years	Willow (Salix)	Elm (Ulmus)	Ash (Fraxinus)	Oak (Quercus)	Hazel (Corylus)	Alder (Alnus)	Lime (Tilia)
	% (W)	% (W)	% (W)	% (W)	% (W)	% (W)	% (W)
1	50		6	4	8	6	0.2
2	8	5	14	33	8	16	4
3	16	46	23	36	12	30	16
4	13		23	4	2	13	14
5	4	7	9	7	5	5	11
6	4	0.3	16		20	13	15
7	3	6	2	11	35	12	15
8	2	9	2		8	5	9
9		18	0.4	5	1		3
10		3	1				5
11			1				
12		0.6	0.1		0.4		0.3
13			1				1
14							1
15			0.6				2
16							
17		3					0.7
18		2					0.3
19							2
Σ	73.75	14.36	113.01	15.04	25.31	38.16	76.46

Table 3. The age distribution of twigs found in the dung layers, arranged after species. The percentages are calculated on the basis of the total weight (g) of each individual tree species.

mediately in fresh state, or dried for later use. By far the most important of fodder-gathering activities in all areas was "*lauving*". Branches were harvested in a leafy state in July/August and after drying were stored for use as winter fodder. In "*lauving*" individual trees are harvested at 2–4 year intervals, although this varies to some extent depending on local conditions; in some areas the tree was harvested every year, in others up to 7 years could elapse between the harvesting of each individual tree.

Apart from pollarding and shredding there is a third important form of tree management, that of coppicing. This involves cutting through the tree trunk close to the ground, something which promotes the formation of a vigorous growth of shoots from the remaining stump (fig. 12d). With a few exceptions (see Petrovič 1936) coppicing has rarely been used to produce animal fodder in historical times. The primary aim was always to produce long straight rods or poles for use for example in fencing, house construction and for fuel (Worsøe 1979; Rackham 1980). A consequence of this is that the trees were not cut as often as they were with pollarding and shredding. The normal coppicing interval lay somewhere between 10

Age of twigs in years	Number	%
1		
2	18	64
3	3	11
4	3	11
5	2	7
6	1	4
7	1	4

Table 4. Frequency and age distribution of cut twigs from two ash branches which were lopped at 2-year intervals between 1964 and 1968. Lötschental, Switzerland.

and 20 years, although woods are known from Eastern England with a coppicing interval in the Middle Ages as short as 4–8 years (Rackham 1980).

So far it has been difficult to determine to what extent the gathering of leaf fodder at the Weier site was linked to any of the above activities. Counting the annual rings of the twigs from the dung layers and determining their age distribution at harvest can give a certain amount of information (table 3). However before the age distribution of the twigs can be evaluated in terms of a possible organized harvesting, it is important to know the expected age distribution of twigs that have been harvested on a formal basis i.e. via a system of pollarding or shredding. The analyses of two branches from two modern pollarded trees from Lötschental, Switzerland are helpful in this respect. The branches were collected in 1968 (by J. Troels-Smith), at which time the trees were still being pollarded by local farmers with the aim of producing leaf fodder. A dendrological analysis of the branches (Bartholin 1970), shows that one ash branch was lopped three times, in 1968, 1966 and 1964, and that the cut twigs had the following age distribution:

1968:	5	2-year old twigs
	1	4-year old twig
	1	7-year old twig
1966:	5	2-year old twigs
1964:	2	3-year old twigs

The second ash branch had been lopped 5 times, in 1968, 1966, 1964, 1958 and 1956, and the twigs cut in these years had the following age distribution:

1968:	7	2-year old twigs
1966:	1	4-year old twig
	1	5-year old twig
1964:	1	6-year old twig
1958:	1	4-year old twig
	1	5-year old twig
1956:	1	2-year old twig
	1	3-year old twig

The investigations shows that since 1964 the two branches had been lopped at 2-yearly intervals, but this does not mean that all the twigs harvested were 2-years old. Not all the twigs were removed at each harvest, some of them remained to be cut at a later harvest hence the distribution seen above. 2-year old twigs are however very much in the majority (table 4).

This modern example illustrates the difficulties in trying to link the age distribution of twigs with a particular management practice carried out on a particular tree. It does however show that it is possible to demonstrate a connection between the dominant age category of twigs and the time interval at which the tree has been harvested. On the basis of this it is possible to evaluate the fossil twig material from the dung layers. There are however some factors regarding the dung material which make comparison difficult. For example, the proportion of the branches which the animals have eaten, how fragmented the twigs are and, not least, the extent to which the analysed material is representative are all unknown. If a comparison is attempted despite these reservations then the following is found to be the case: With regard to elm and willow there is good agreement with the modern material in that one age category is dominant. In the case of willow it is the 1-year old twigs (comprising 50% of the material), with elm it is the 3-year old twigs (comprising 46% of the material (table 3). With regard to the other tree species the picture is rather more diffuse, although there is a tendency for age categories comprising two consequtive years to dominate. In ash it is the 3- and 4-year old twigs, making up almost 50% of the material. Amongst oak twigs, it is the 2-and 3-year old twigs which are the most abundant, comprising almost 70% of the material. In hazel, 6- and 7-year old twigs are the most abundant, forming over 50% of the total and in alder it

Age in years	Number	Weight g	%	%
1	266	49.1	14	
2	197	38.4	11	
3	218	76.2	21	
4	177	52.9	15	
5	106	27.1	8	
				69
6	88	42.8	12	
7	59	32.6	9	
8	32	15.7	4	
9	20	6.5	2	
10	15	5.1	1	
				28
11	2	1.3	0.4	
12	5	0.5	0.1	
13	3	2.0	0.6	
14	4	0.7	0.2	
15	4	2.0	0.6	
				1.9
16	-	-	-	
17	2	1.0	0.3	
18	2	0.5	0.1	
19	1	1.7	0.5	
				0.9
Σ	1201	356.1		

Table 5. Age distribution of all the twigs examined from the dung layers. The percentages for the various age groups are calculated on the basis of the total weight of twigs. (In the case of 409 twigs it was not possible to determine the age).

is the 2-and 3-year old twigs which together make up 46% of the total. Lime deviates from this pattern in that there is an even distribution across the age categories.

On the basis of the age categories alone, it is not possible to determine to what extent the leaf fodder was harvested from formally-lopped trees. Much suggests however, that the different tree species were treated in different ways. The problem of demonstrating tree management in the Neolithic has also been approached by way of tree-ring analysis. The results of this research are described in detail in Rasmussen (1990).

On the whole the twigs from the dung layer were harvested at an early age: 69% fall in the 1–5 year old category and 97% are under 10 years old (table 5). This distribution is very suggestive of selective harvesting with the aims of:

a: obtaining the highest possible amount of leafy material combined with the lowest possible amount of woody material.

b: producing woody material which the animals were able to chew.

Measurements of twig diameter suggests that the latter consideration played an important role in determining which branches were harvested. All the older twigs (i.e. those in the range 10–19 years old) have a diameter approximately equal to or less than those in the 1–10-year age category (table 6). Normally twig diameter is directly proportional to age but this is not the case in the dung layers. It would appear therefore that older twigs are included in the fodder because their thickness is such that the animals were able to chew them.

LEAF FODDER AND ANIMAL HUSBANDRY

The housing of livestock in the settlement, either in byres or other enclosures, is not something unique to the Weier site. Several of the Swiss settlement sites have been found to contain either byres containing great concentrations of fly puparia: Egolzwil 4 (Cortaillod Culture) (Vogt 1969) or concentrations of goat and/or sheep faeces which can form layers up to several tens of centimetres thick: Egolzwil 3, (Egolzwiler Culture) (Vogt 1951), Egolzwil 2 (Cortaillod Culture) (Heierli and Scherer 1924), Robenhausen (Pfyner Culture) (Heer 1865), Thayngen-Weier (Pfyner Culture) (Guyan 1955), Niederwil (Pfyner Culture) (Clason 1966), Feldmeilen-Vorderfeld (Pfyner Culture) (Winiger and Joos 1976), Horgen "Dampfschiffsteg" (Pfyner Culture), Horgen Scheller (Horgen Culture), Zürich "Mozartstrasse" (Horgen Culture) and Saint Blaise (Lüscherz Culture).[2] Together,

Age in years	Number	Max. dia. cm	Min. dia. cm	Average dia. cm
1	266	1.15	0.10	0.34
2	197	0.9	0.15	0.35
3	218	1.0	0.15	0.45
4	177	0.95	0.10	0.42
5	106	0.77	0.15	0.40
6	88	1.07	0.17	0.51
7	59	1.35	0.17	0.51
8	32	1.05	0.2	0.47
9	20	0.67	0.25	0.45
10	15	0.72	0.35	0.50
11	2	0.55	0.5	0.52
12	5	0.65	0.27	0.40
13	3	0.65	0.27	0.50
14	4	0.52	0.3	0.38
15	4	0.75	0.4	0.53
16	-	-	-	-
17	2	0.62	0.47	0.55
18	2	0.62	0.45	0.53
19	1	0.7	0.7	0.7
Σ	1201			

Table 6. Diameter of the various age categories of twigs from the dung layers, given in the order: maximum, minimum and mean diameter.

these sites cover a period stretching from the oldest early Neolithic until the Corded Ware Culture; i.e. from 3400 b.c. until 1900 b.c. These are the sites where there is positive evidence for livestock being contained within the settlement. There are certain to be a large number of settlements where faeces and house fly puparia have been present without their being recognized as their detection demands of very special awareness during excavation. In the light of this one can assume that the practice of keeping livestock within the settlement was widespread. In contrast, questions as to why and at which time of year this occurred remain unanswered. Several possibilities exist, but the most likely of these is that livestock were kept confined for at least the duration of the winter; a time when food in the surrounding landscape was scarce and there was a need or desire to protect them from snow and frost, and perhaps, most importantly, to collect their dung for use as manure.

Winter and early spring has always been a difficult period in primitive agricultural societies due to the lack of food for both people and animals. In the book "*Vår Gamle Bonde-Kultur*" ("Our old farming culture") Visted and Stigum (1951) give a vivid description of conditions in Norway at the turn of the century. This description seems also in many ways appropriate to a prehistoric agricultural society:

"In this country livestock had to be foddered indoors for the greater part of the year. In some places in the coastal district sheep and goats could probably manage outside the whole year round; further inland this was not possible. Cows were able to find fodder outside for four months of the year, but in some places the grazing season was shorter. In others, such as on Sørlandet, it was slightly longer. In spring it was generally the sheep which were turned out before the cattle and they could also manage outside longer in the autumn... In the autumn it was necessary to decide how many animals it was possible to keep alive through the winter. It was desirable to have as many as possible and there was a tendency to keep too many animals relative to the amount of fodder available. This system is now often called the starvation feeding principle. This does not mean that livestock starved everywhere, although we can take it that the general level of winter fodder was lower than that which today would be considered either productive or defensible. There have been all possible variations in this relationship, and there are many accounts of suffering and hunger in the byre. In difficult years the cows starved to death in their stalls, and it was not unusual that they had to be helped outside in the spring. There are also accounts of bad years which affected the human population, neither was it unusual for people to die of deficiency diseases or directly of starvation" (translated from Norwegian).

It is difficult to determine with certainty the time of year at which the livestock in the Swiss Neolithic were confined in the settlement but there are indications from several localities which suggest that is was during the winter months (see also Rasmussen in prep.). As mentioned earlier, pollen analyses from culture-layers at several neolithic sites have revealed very high values of ivy pollen (table 7). As ivy flowers in the period October/Novem-

Culture	Locality	Hedera %	Author
Cortaillod	Kleiner Hafner 1	12.9	Heitz-Weniger 1978
Cortaillod	Kleiner Hafner 3	14.3	Heitz-Weniger 1978
Cortaillod	Burgäschisee-Süd	46.0	Welten 1955, 1967
Cortaillod	Baulmes "abri de la Cure"	22.0	Leroi-Gourhan & Girard 1971
Pfyner	Hornstaad-Hörnle I	12.6	Liese-Kleiber 1985
Michelsberg	Ehrenstein	33.0	Schütrumpf 1968
Horgen	Kleiner Hafner	9.0	Heitz-Weniger 1978

Table 7. Examples of neolithic settlements in Switzerland and southern Germany with high pollen percentages of ivy (*Hedera*).

ber, this must indicate that flowering branches were brought into the sites at this time i.e. at the start of the winter. If this evidence is seen in the light of the investigations at Weier which show that ivy was brought in specifically as animal fodder and where one pollen sample from the dung layers contained no less than 43% ivy pollen (Rasmussen 1988), then it seems likely that the high ivy pollen percentages at the other sites also reflect the collection of ivy for fodder. It is reasonable to conclude therefore that the livestock was kept confined in the settlement during the winter months, this does not however exclude the possibility that the animals were also foddered inside during the summer – this is just harder to prove or disprove.

THE LEAF-FODDERING THEORY AND THE ELM DECLINE

At Weier several pollen diagrams show a marked elm decline which is contemporary with the settlement's oldest phase.[3] The elm decline in the Weier valley has played an important role in shaping the theory that the fall in the elm-pollen curve is a result of the selective harvesting of elm by neolithic farmers for use as animal fodder (Troels-Smith 1955, 1960). We now have a valuable opportunity at the Weier site to re-evaluate the relationship between leaf-foddering and the elm decline. We now know to some extent which trees were harvested to produce fodder and we know in some detail the extent of the exploitation of the surrounding woodland which accompanied the construction of the village.

Together the Weier settlement's three phases covered an area of between 6000 and 9000 m^2 and large quantities of timber went into the construction of houses, roads, fences and other structures. In addition it has been shown that there were arable plots in the valley which were contemporary with the settlement (Troels-Smith 1981, 1984). The establishment of these must have involved the clearance of a substantial area of woodland.

Topographically the Weier valley is small and elongated. It is surrounded on all sides by hills which, with the exception of a narrow opening toward the Fulach valley to the west, reach a height of between 40 and 80 m. The valley's longitudinal axis is orientated almost east-west and is just under 2 km in length. The distance across the valley, from hill-top to hill-top is approximately 800 metres. During the Atlantic and Sub-Boreal Periods there was a shallow lake *c.* 100 x 500 metres on the valley floor. The lake had an outlet to the Fulach river but no inlet. Given this relatively limited and isolated topography it is possible to compare what is known about the effect of the neolithic farmers on the woodland in the Weier valley with a pollen diagram from the Weier basin. The main question is whether the influence of the neolithic folk in the form of timber extraction, clearance for agriculture, leaf fodder harvesting etc. is reflected in the pollen diagram?

Table 8 is a summary of all the published wood identifications from the Weier settlement's three phases. It includes *c.* 4600 identifications ranging from small pieces of charcoal up to complete tree trunks.[4] This summary does not, of course, give a complete picture of how the woodland was exploited, but given the quantity of material analysed it is likely to give a reasonably representative picture of the relative quantities in which the various species were used. It is evident from the table that the timber

	Settlement		Field		Gyttja		Σ		Dung			
	n	%	n	%	n	%	n	%	W(g)	%	n	%
Quercus	896	37	102	25	66	47	1064	35	15.1	4	68	4
Fraxinus	628	26	62	15	19	13	709	24	114.3	27	339	21
Alnus	299	12	113	27	1	0.7	413	14	40.1	9	217	13
Salix & Populus	162	7	72	17	6	4	240	8	72.2	17	311	19
Betula	55	2	2	0.5			57	2				
Acer	37	1	15	4	9	6	61	2				
Tilia	120	5	23	5	14	10	157	5	81.5	19	285	18
Corylus	212	9	12	3	14	10	238	8	27.5	6	64	4
Sorbus	2	0.08	11	3	3	2	16	0.5				
Fagus	4	0.2	3	0.7	9	6	16	0.5				
Carpinus	7	0.3					7	0.2				
Malus	3	0.1					3	0.1				
Taxus	3	0.1					3	0.1				
Abies	3	0.1					3	0.1				
Prunus	2	0.08					2	0.07				
Cornus	2	0.08					2	0.07				
Rosaceae	1	0.04					1	0.03				
Ulmus	1	0.04			1	0.7	2	0.07	14.5	3	45	3
Hedera									28.7	7	186	12
Clematis									28.6	7	69	4
Viscum									0.3	0.07	5	0.3
Lonicera/Ligustrum									0.16	0.04	3	0.2
Betula/Alnus									1.0	0.2	18	1
Summa	2437		415		142		2994		423.96		1610	

Table 8. Summary of all wood identifications carried out in connection with the Weier settlement's three phases and comprising wood from the settlement, an arable field, a gyttja layer and dung layers from the settlement. (See note 4).

used in the construction of houses, fences, etc. is, in the main, oak (*Quercus*), ash (*Fraxinus*), alder (*Alnus*) and willow/poplar (*Salix/Populus*).[5] It is also largely these species which were cleared in connection with the establishment of the arable plots (cf. Troels-Smith 1981). The leaf fodder remains from the byre dung layers show a slightly different spectrum. Here there are relatively small quantities of oak (*Quercus*) but a great deal of lime (*Tilia*) and willow (*Salix*). In addition there are relatively large quantities of ivy (*Hedera*) and clematis (*Clematis*).

As mentioned above, table 8 gives an average picture of how the woodland around the Weier site was exploited by the neolithic farmers over a period of about 300 years, from 3100 b.c. to 2800 b.c. If this information is compa-

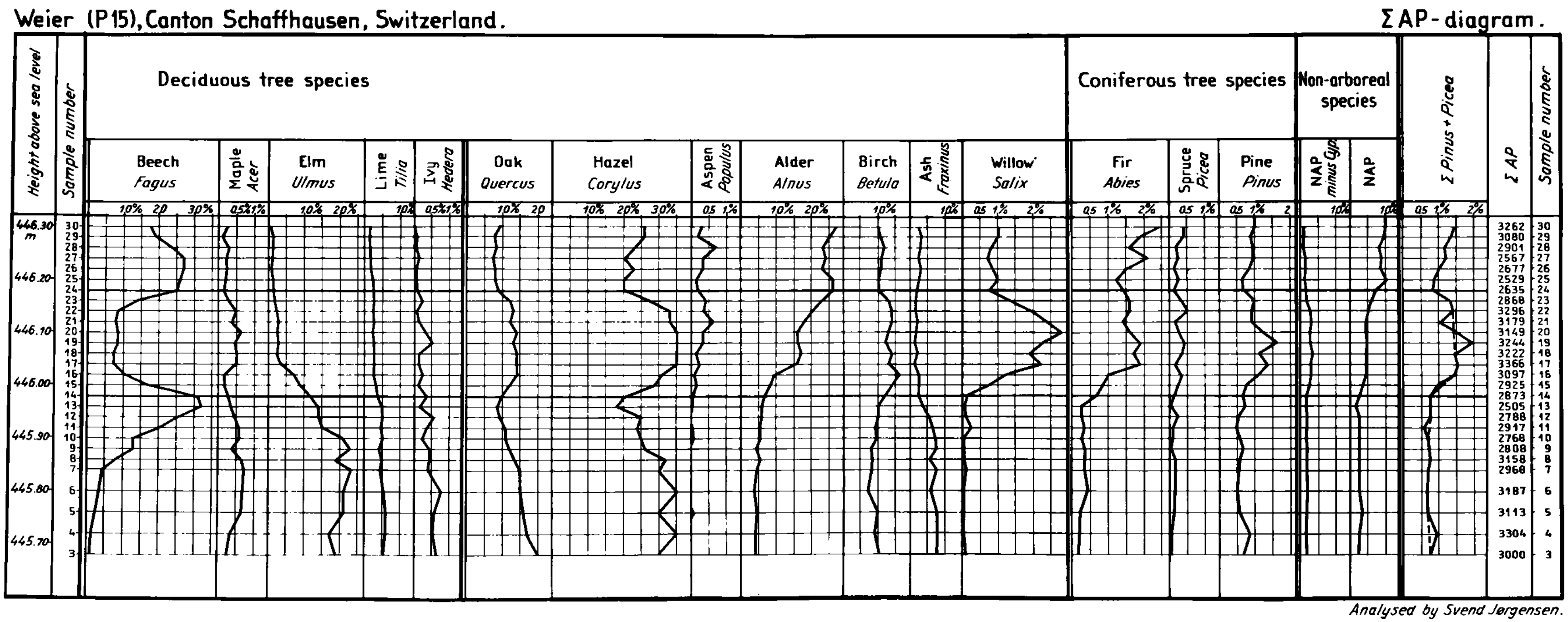

Fig. 13. Pollen diagram from the Weier basin (after Tauber 1965). The diagram is calculated on the basis of a pollen sum consisting of all arboreal species including hazel (Σ AP). Curves for less significant species (e.g. yew, rowan, elder, apple) are not shown. Σ NAP comprises Gramineae and Cyperaceae (Tauber 1965). The pollen samples were taken from an open section in gyttja, 12 metres from the Weier settlement. The investigation of the composition and stratigraphy of the profile and the collection of the pollen samples was carried out by J. Troels-Smith and Svend Jørgensen in 1958.

red with the pollen diagram (fig. 13) which covers the same period (from sample 14 to 24), it is clear that there are a number of events which cannot be explained on the premise that a fall in the pollen curve for a particular species is a result of felling or lopping that species. In this paper only the events relevant to the elm curve will be examined in detail (the situation with regard to beech (*Fagus*) has already been examined in detail by Troels-Smith (1981)).

Table 8 shows that on the whole elm was not used for house building and other construction work. One piece of elm was found in the oldest phase of the settlement (Weier I) and the species is also modestly represented in the dung layers (3% of the total). On this basis we can therefore conclude that only very limited use was made of elm in the settlement. If we then consider the theory that the elm decline was caused by human activity it is clear that the evidence from the wood identified from the settlement contrasts sharply with the evidence from the pollen diagram. In the latter the elm curve shows a marked decline which increases around 3100 b.c. (sample 14) the time at which the first farmers came to the Weier valley. From then onwards, throughout the 300 year existence of the settlement, there is a continued decline in the elm pollen curve. There is nothing in the wood identifications from Weier which suggests that the elm decline is the result of timber extraction. Similarly the analyses of the byre dung layers show that the lopping of elm for animal fodder can also be excluded as the main cause of the elm decline. These layers are dated to about 150–200 years later than the beginning of the elm decline and we do not know to what extent elm leaf fodder was gathered during that period. However the theory linking leaf-foddering and the elm decline states that after an initial marked fall, the elm curve maintains consistent low levels due to the persistent harvesting of leaf fodder which in turn prevented the elm trees from flowering (cf. Troels-Smith 1960 p. 24). For this to be the case, substantial quantities of elm twigs would be expected to be found in the byre layers even as long as 200 years after the initial decline; this is not the case.

The problem can also be approached from another angle. In so far as the elm decline is a result of leaf fodder collection then the elm trees must have been harvested selectively. This in turn means that large quantities of elm leaf fodder must have been brought in to the site. Historical accounts of leaf-foddering and modern leaf-foddering experiments both show that a herd of 10 cows (not an unrealistic figure for the Weier settlement) need 40 kg of fodder per day (4 kg per cow/day) (Rasmussen in press). If we assume that the animals were fed over a period of six months, this means that the requirement is a total of 7.2 tonnes of leaf fodder. If we also assume that a 10-cow herd was fed with elm leaf fodder over 50 winters, this would require 360 tonnes of elm leaf fodder. Even though we do not know with certainty how representative the wood identifications in table 8 are, it is clear that elm would have been much better represented had 360 tonnes of elm leaf fodder been brought into the settlement. On the basis of this evidence and the considerations presented here, the only conclusion possible is that no link can be found between the elm decline and the neolithic farmers exploitation of elm trees. Accordingly, the theory that the elm decline at Weier was caused by human activity can be dismissed.

What did cause the elm decline? The debate has been running for decades and in recent years several workers have argued the case strongly for the involvement of an elm-specific disease, similar to, or identical with, the present-day Dutch Elm Disease. The problem with this explanation is however, that it is particularly difficult to prove or disprove. At West Heath Spa, Hampstead Heath, London, fossil remains (two wingcases) of the elm bark beetle (*Scolytus scolytus* F.) were found in deposits approximately contemporary with the beginning of the elm decline (Girling and Greig 1985; Girling 1988). A piece of elm wood of approximately the same age was found in Åmosen, Denmark with galleries identified as being those of the elm bark beetle (*Scolytus Laevis* Chap.) (Stockmarr 1966; Fredskild 1968; Kolstrup 1988).The elm bark beetle is the main vector of the fungus *Ceratocystis ulmi*, which today causes Dutch Elm Disease. The beetle is however only responsible for transporting the fungal spores which cause the disease and its presence says nothing about the extent to which the fungus was present. In the few investigations which have been carried out into fungal spores in prehistoric deposits to date, it has not been possible to demonstrate the presence of *Ceratocystis ulmi* (van Geel 1978; van Geel, Dee and Bohncke 1981). The situation at present is therefore, that the presence of the elm disease vector at the time of the elm decline can be demonstrated, but that of the disease itself can not.

Despite the fact that there is no evidence for the elm decline at Weier being caused by elm disease, it is worth noting that there is evidence from the settlement for the presence of the disease vector; an elm trunk was found at the site which exhibited beetle galleries characteristic of the elm bark beetle (*Scolytus scolytus*) (Guyan 1955).

CONCLUSION

Discussions of neolithic leaf-foddering with their roots in the elm decline have almost become stereotyped. As the investigations at Weier show, the elm decline in pollen diagrams is misleading when it comes to evaluating the extent to which neolithic farmers fed their livestock with leaf fodder. The analyses of the dung layers from the Weier settlement show that we are dealing with a much more complex situation than has previously been appreciated. There is clear evidence for the use of a broad spectrum of tree species for fodder – something which has close parallels in more recent societies which practised leaf-foddering. The two species which dominate in the byre layers at Weier are ash and lime. Together they make up almost 50% of the material present. In addition to these two species, there are nine other species represented: willow, alder, ivy, clematis, hazel, oak, elm, mistletoe and honeysuckle/privet. Of these, ivy is remarkably abundant and several important facts are linked with its presence. At the transition from the Atlantic to the Sub-Boreal Periods many European pollen diagrams show a fall in the ivy pollen-curve. It has long been debated whether this decline is climatic or anthropogenic in origin. The analyses of the dung layers from Weier together with evidence from several other Swiss sites, provide incontrovertible evidence for the fact that neolithic farmers gathered ivy. The high pollen values for ivy in the dung layers show in addition that the ivy branches must have been collected during ivy's flowering period i.e. October/November, and this in turn means that the animals must have been fed during the winter. It cannot be determined with certainty whether the twigs from the dung layers were harvested from managed (pollarded/shredded) trees or not. Further analysis of twigs and branches from a number of sites, together with tree-ring analyses of tree trunks and branches are needed before further light can be shed on this problem.

As mentioned in the introduction it is particularly difficult to demonstrate leaf-foddering on the basis of palynological evidence alone. It is unknown to what extent, and in what way, leaf harvesting is reflected in a pollen diagram. It is often possible to see the effects of human influence in a pollen diagram, but to determine whether this influence is the result of leaf fodder harvesting appears to be almost impossible. An agricultural activity such as leaf fodder harvesting can not be demonstrated on the basis of fluctuations in pollen curves alone, it is particularly vital to also have firm archaeological evidence.

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NOTES

1. All datings are expressed in conventional C-14 years before Christ (b.c.).
2. Jürg Elmer, Landesmuseum in Zürich, kindly drew my attention to the unpublished find of goat/sheep faeces from the settlement site Horgen "Dampfschiffsteg". Together with Martin Dick, Botanical Institute, University of Basel, I have identified a small number of goat/sheep faeces from the site Zürich "Mozartstrasse". Goat/sheep faeces were identified by the author at the site of Horgen Scheller during an excavation in December 1989. Philippe Hadorn, Botanical Institute, University of Bern, has found goat/sheep faeces at the site of Saint Blaise (P. Hadorn personal communication).
3. Heitz-Weniger (1976) maintains that the elm decline is not contemporary with the Weier settlement, because the elm decline in a section from the site lies deeper than the culture-layer. This conclusion is based on a misconception as it is not certain that the culture-layer in this particular section belongs to the settlement's oldest phase (Weier I). If it belongs to the middle or youngest phase (Weier II and III) then the elm decline will be found at a lower level. Radiocarbon dating of the oldest phase of the settlement and the elm decline shows that the former are contemporary with the beginning of the latter.
4. The table is compiled from the results of the following investigations:

a. *Settlement*

Neuweiler 1925, p. 514, Table 1 (710 identifications; apart from the species identification, no other information is given about the nature of the sample, its location in the settlement etc.).

Neuweiler 1946, p. 122–136 (83 identifications; the samples consists of waterlogged wood. No further information about the samples is given).

Huber and Jazewitsch 1958, p. 448, Table 2 (260 identifications; waterlogged wood; the samples come exclusively from posts).

Huber; in Guyan 1967, p. 11 (1384 identifications; waterlogged wood; samples are partly from horizontally-orientated beams and boards and partly from vertical posts).

b. *Field*

Tellerup 1958; in Troels-Smith 1981, p. 102, Abb. 7 (303 identifications; apart from 108 uncarbonized twigs, the samples consist of charcoal).

Rasmussen 1984, Unpublished report, Natural Sciences Department of the Danish National Museum, NM VIII A3922 (92 identifications; all samples consist of charcoal).

Hauschild 1986, Unpublished report, Natural Sciences Department of the Danish National Museum, NM VIII A3922 (54 identifications; all samples consist of charcoal).

c. *Gyltja*

Tellerup 1958; in Troels-Smith 1981, p. 102, Abb. 7 (142 identifications; apart from one uncarbonized twig, all the samples consist of charcoal).

d. *Dung*

Present article.

5. It is normally possible to separate willow and poplar on the basis of wood anatomy, but as this was not done in the earlier analysis which are incorporated into table 8, records of these two species have been combined.

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