INTERDISCIPLINARIA ARCHAEOLOGICA

NATURAL SCIENCES IN ARCHAEOLOGY

Abies alba and *Homo sapiens* in the Schwarzwald – a Difficult Story

Manfred Rösch[a]*

[a]Laboratory of Archaeobotany, Regional Heritage Institute Baden- Württemberg, Fischersteig 9, 78343 Gaienhofen-Hemmenhofen, Germany

ARTICLE INFO

ABSTRACT

High-resolution pollen profiles from the centres of all the cirque lakes of the northern Schwarzwald give new evidence on the forest and landscape history of the Schwarzwald National Park and its vicinity during the last six millennia. In the early 4th millennium, *Abies alba* became the most frequent tree of the mountain forest; it had invaded the region several centuries earlier together with *Fagus sylvatica*. The trees replaced were *Quercus*, *Ulmus*, *Tilia*, *Fraxinus*, and *Corylus*. The first human impact occurred towards the end of the 4th millennium: small-scale deforestation, followed by reforestation – starting with *Betula*. As a consequence, *Fagus* increased and became more frequent than *Abies*. In spite of heavy human impact and clearances, especially during the pre-Roman Iron Age and the High Medieval period, *Fagus* and *Abies* remained the main trees of the mountain forest. Due to human promotion, *Quercus petraea*, which before had nearly disappeared, became the third-most important tree during the Late Medieval period. In the early Modern period, the forest became systematically over-exploited and to a greater part destroyed, and *Quercus* and later *Abies* became seldom or even disappeared. According to the pollen record, *Picea abies* was not present in the area before the Medieval period, but took advantage of the forest devastation of the early Modern period, and was planted preferentially as a forest tree from the 19th century. But it remains unclear whether, in the Schwarzwald National Park without any human impact in the future, the natural forest of *Abies* and *Fagus* will come back, because there are still disturbances such as hurricanes and bark-beetle, and overstocking of red deer.

1. Introduction

The northern Schwarzwald (northern Black Forest) is today one of the most densely-forested landscapes in central Europe. In some parts, particularly in the higher-altitude Grindenschwarzwald, forest cover is more than 90% (Fischer 1967; Huttenlocher, Dongus 1967). The mountains have a north-south extension of less than 60 km and a west-east extension of about 40 km, with an altitude up to 1163 m asl (Hornisgrinde). If one ignores the deep and narrow valleys of Enz, Nagold, Murg and some smaller rivers, mean elevation increases from more than 600 m asl in the east to more than 1000 m in the west. The bedrock is mostly Triassic sandstone, but also granite, resulting in rather poor and acidic soils. The climate is sub-oceanic, with decreasing temperatures and increasing precipitation as altitude increases. The Hornisgrinde (1163 m), for example,

has an annual mean temperature below 5°C and an annual precipitation of 2000 mm.

The Schwarzwald National Park, since 1st January 2014, is situated in the southwestern part of Nordschwarzwald`, with elevations over 1000 m. A major aim of the park`s management policy is to re-establish a natural forest cover. After an initial phase during which active – though restricted – forest management is allowed, this re-establishment of the natural forest should happen without any human interference. Finally, the potential natural vegetation should cover the entire park (Tüxen 1956; Dierschke 1994). In the actual present-day vegetation, *Picea abies*, introduced and planted since the 19th century, is the most frequent tree with a coverage of more than 60%. *Abies alba* and *Fagus sylvatica*, which are regarded as the main trees of the natural mountain forest in Schwarzwald, are much rarer and cover about the same area as *Pinus sylvestris*. Other trees, such as *Acer pseudoplatanus*, *Quercus petraea*, *Alnus glutinosa* and *incana*, *Fraxinus excelsior*, *Tilia platyphyllos*, *Sorbus aria*, *Salix caprea*, *Populus tremula*, as well as the introduced

*Corresponding author. E-mail: manfred.roesch@rps.bwl.de

Figure 1. The Schwarzwald National Park and the cirque lakes of Nordschwarzwald. Glaswaldsee is 6 km to the south of Ellbachsee.

Table 1. The cirque lakes of Nordschwarzwald.

No.	Lake	Near	Koordinates		Elev.	Length	Width	Depth	Water expense	Pollen samples	¹⁴C Datings
			N	E	m.a.s.l.	m	m	m	ha		
1	Herrenwieser See	4 km w Forbach	48°40'10"	8°17'48"	830	200	80	9,5	1,2	369	37
2	Glaswaldsee	4 km e Bad Peterstal	48°25'36"	8°15'45"	839	200	200	11	2,9	153	16
3	Mummelsee	4 km ne Seebach	48°35'56"	8°12'07"	1028	250	170	17	3,3	193	12
4	Schurmsee	4 km wnw Schönmünzach	48°36'50"	8°19'12"	795	175	105	13	1,6	244	19
5	Wilder See am Ruhestein	4 km e Seebach	48°34'15"	8°14'24"	910	170	150	11,5	2,1	259	16
6	Huzenbacher See	3 km sw Huzenbach	48°34'33"	8°20'58"	747	250	155	7,5	2,5	364	22
7	Buhlbachsee	10 km w Baiersbronn	48°30'06"	8°14'43"	790	200	170	4,5	2,2	318	18
8	Ellbachsee	4 km wsw Baiersbronn	48°29'03"	8°18'20"	770	110	90	2	2,9	85	

species *Larix decidua* and *Pseudotsuga menziesii,* are rare and of no economic importance.

The big question now is whether *Abies* will come back as the main component of the area's natural forest – as the forest ecologists hope – or if the system is already too disturbed for a natural resilience.

During the last ice age, the northern Schwarzwald was partly glaciated. The glaciers left behind kettle holes, which, filled with water, became lakes. During the Holocene, most of these so-called cirque lakes developed into mires; only the six largest and deepest, Herrenwieser See, Schurmsee, Mummelsee, Huzenbacher See, Wilder See, and Glaswaldsee, survived as lakes (Table 1, Figure 1). Buhlbachsee and Ellbachsee also have open water surfaces, but artificially caused by dams in early Modern times; their purpose was to flush wood into the valley. All the lakes are rather small, with water surfaces between 1.3 and 3.7 ha.

All lakes are situated at distances of more than two km from lowlands lower than 700 m asl and are either inside or close to the national park. Thus a pollen analysis of their sediments should be the optimal instrument for getting to know the vegetation history of the national park: a precondition for a prognosis and comprehension of the park's future development. The relationships between the main components of the mountain forest, *Abies*, *Fagus*, and *Picea*, is thereby of particular interest.

Until recent years, the Schwarzwald was believed to have been colonized rather late, more precisely not before the High Medieval period (Hausrath 1938; Brückner 1981; Ottnad 1981; Schaab 2003; Wilmanns 2001; 2009). After the formulation of some doubts, based on palynological and archaeological evidence (Frenzel 1982; Radke 1973; Jensen 1986), mining-archaeological research of the last decade has supported the idea of a much earlier colonization of at least parts of the region (Gassmann *et al.* 2006). But archaeological evidence is still rare, especially for prehistory. The reasons for this are: the lack of salvage excavations, because there is neither agriculture nor extended building activity; the difficulty of archaeological prospecting due to the topography; and also due to the fact that in the acid soil neither bones nor pottery are preserved.

To get a better understanding of the land-use history of this region, differentiated in space and time, the Laboratory for Archaeobotany of the Regional Heritage Institute Baden-Württemberg, with financial support of the DFG, initiated a fresh vegetation historical project, dealing first with peat profiles from the mires Bruckmisse and Wildseemoor, and later with lake sediments from the centres of the above-mentioned cirque lakes (Rösch 2009a; 2009b; 2009/10; 2012; Rösch *et al.* 2005; 2009, Rösch, Tserendorj 2011a; 2011b). This paper deals with the results of this project. It tries to answer the questions: how was the vegetation and particularly the forest in this region composed, before human impact changed the situation? Can this early natural state be regarded as a model for the potential natural vegetation? And can this natural state be attained, without management, under the given general setup?

2. Material and methods

Pollen analysis is the most used and approved method in vegetation history (Berglund 1986). Its direct results are the relative or absolute contents of pollen types in sediments – and these are proxy data for forest cover and composition.

To come from pollen percentages to vegetation, these proxy data must be calibrated. Calibration methods have been developed, for example, by Andersen (1970) and by Sugita (2007a; 2007b). They consider the differences in pollen production and dispersion of different species. But these methods cannot answer the question about the point of origin of a single pollen grain. This also influences the question of where does the pollen deposited in a lake or mire come from (Tauber 1965). As a general rule we can assume that with increasing distance between the point of origin and the point of deposition the amount of pollen decreases exponentially. The correlation between vegetation and pollen spectra is not constant, but must be evaluated for every region specifically. Unfortunately a transfer into the past is in principal impossible, but there is agreement that small lakes generally reflect the vegetation in a radius of 1–2 km (Sugita 1994; 2007b).

Most of a plant's pollen remains with the plant and in its direct vicinity. Some pollen, especially of wind-pollinated plants, can reach the upper atmosphere with the help of updrafts. The speed of fall in air of pollen is low compared to typical wind velocities; hence some pollen can be transported rather far. Close to the ground, tall vegetation, and particularly forest, filters much of the pollen from the air, before it can be deposited on the surface of a lake or mire. Therefore a small lake or mire whose surroundings are densely forested has less influx of far-distance pollen than a large basin in an open landscape. We can assume that most of the pollen deposited in the small, forest-surrounded, Schwarzwald lakes originated from distances of perhaps 1–2 km. The pollen component transported from further away should not exceed 10% (see below). In a flat or hilly landscape, a pollen input from several km would not be problematic, because in such landscapes the same vegetation units cover huge areas and vegetation gradients are shallow. In mountains, a horizontal distance of a few km can involve a vertical gradient of several hundreds of meters and therefore sharp changes in vegetation. The horizontal component of the transported pollen flux may be the same as in the flat landscape area, but it is not possible to resolve from which altitudinal belt the pollen has originated. The fact that not all pollen types behave in the same way does not make the problem any easier. We can assume that the pollen of wind-pollinated trees, as for example *Pinus,* is capable of being transported rather far, but pollen of wind-pollinated NAP (Non-arboreal pollen), for example Poaceae, only in those cases when they grow in open vegetation. Pollen of forest grasses has only a very slight chance of escaping the forest and travelling very far. Even such grasses of forest-recovery stages as *Festuca*, *Deschampsia*, *Calamagrostis*, *Agrostis* and others, which are components of the natural forest, are

hardly reflected in the pollen spectrum outside of the forest: because their pollen has hardly a chance of leaving the small clearings and reaching the atmosphere (Tauber 1965). In the natural forest, after the early Holocene reforestation, the NAP percentages in lake sediments are therefore in most cases clearly below 5%. Zoogamous plants have a much lower pollen production than wind-pollinated plants. There transport distance depends on the cruising radius of the animal in question. Hexapods, for example the honey bee, can cover several meters up to a few kilometres. Birds can carry pollen in their intestines or in there plumages much farther.

Another problem, already discussed by Firbas (1949), is how to interpret pollen percentages below 1. Generally, vegetation history can prove the presence of a species, but not its absence (recently Ammann *et al.* 2013). The practical approach is the assumption that a species which is neither documented by pollen nor by other evidence, most probably did not occur. If an anemophilous tree with a rather high pollen production such as *Picea* should have less than 1%, then the pragmatic point of view would explain these few pollen grains as being transported long-distance, and conclude that *Picea* is not present in the immediate area. A plausible conclusion maybe, but one that can only be verified by studies comparing actual vegetation and pollen precipitation (*cf.* Pidek *et. al.* 2013). But we can assume, with very high certainty, that the species was at least very rare. This discussion is important because we want to know if the pollen influx into the high-altitude Schwarzwald lakes reflect local events, or events, that took place at some distance away and at much lower elevations.

To estimate the amount of long-distance transported pollen in the recent pollen spectrum, the registered pollen and spore types were classified into four classes "local AP", "local NAP", "long-distance AP", and "long-distance NAP" (Table 2, Figure 2). The criteria for the classification were our own vegetation observations and the upper-altitude limits for plant species in the Schwarzwald in Oberdorfer (1970).

All cirque lakes were sampled using a modified Livingstone sampler with a tube length of 1 m and a tube diameter of 5 cm (Merkt, Streif 1970). The cores were taken in the centres of lakes at maximum water depth, using a platform. All sediments from the water/sediment-limit down to the Late Weichselian clay were taken. Each profile was dated with about 20 radiocarbon dates to enable reliable time models and the construction of time-linear pollen diagrams. A test to compare the ages of bulk and plant macrofossil data yielded no significant differences, because limestone is lacking in the region. Therefore we could use bulk data.

All profiles were investigated with sampling intervals between 5 and 10 cm below the first occurrence of *Abies* and *Fagus*, and above to the top of the core in 1 cm-intervals without gaps. The pollen sum in each sample was at least 1000 arboreal pollen. Loss-on-ignition was determined using the same sampling concept.

To evaluate the actual pollen spectra at each lake, samples from mosses from their shores were used. The aim was to evaluate the relation between recent vegetation and pollen spectra, to detect long-distance transported pollen, and to have a time control for the upper ends of cores. All data were processed using the programs Tilia and Taxus. For
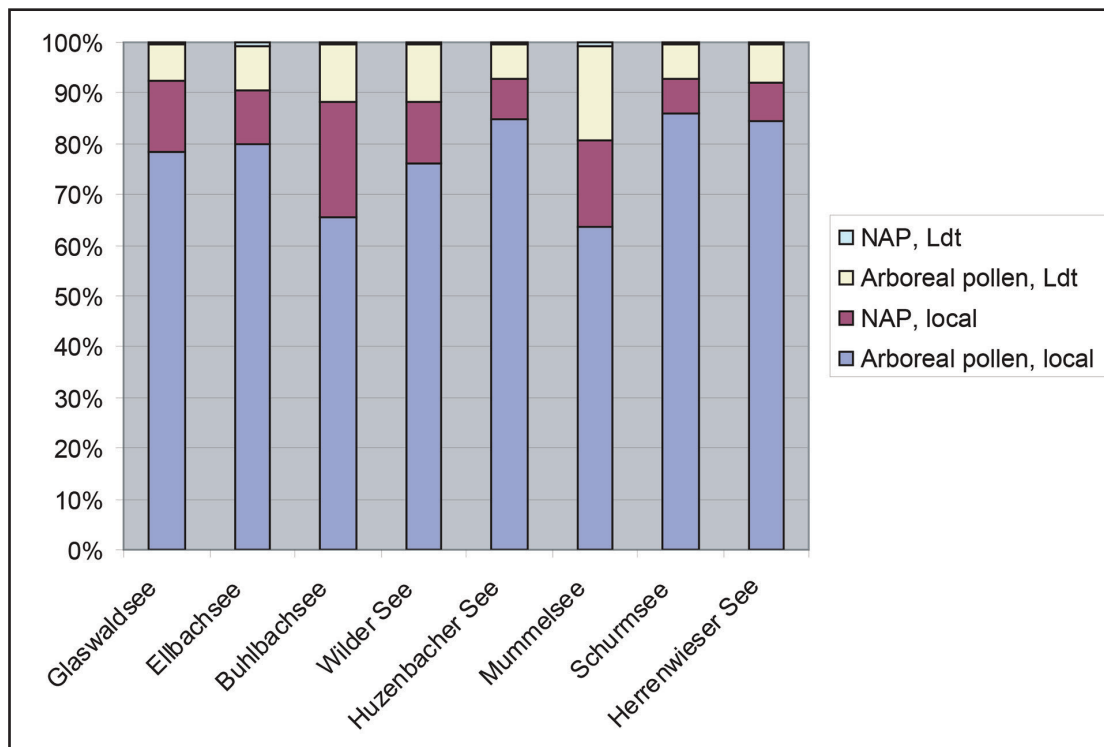

Figure 2. Composition of the recent pollen spectra at Nordschwarzwald lakes, classified into local and long-distance transported arboreal and non-arboral pollen; NAP = Non-arboreal pollen, Ltd = Long-distance transported.

Table 2. Constancies and percentages of pollen types from surfaces samples (mosses) from the shores of the Nordschwarzwald cirque lakes. Evaluation (column 2): 1 local arboreals 2 extralocal arboreals 3 local non-arboreals 4 extralocal non-arboreals 5 water and mire plants 6 spores; arrangement in groups 1–4 according to upper limit in Schwarzwald after Oberdorfer (2001).

Highest occurrence Schwarzwald m a.s.l.	Group		Constancy		Frequency	
			n	%	n	%
1480	1	Abies alba	24	100	1448	4,707
1450	1	Acer	18	75	48	0,156
	3	Achillea T	2	8	2	0,007
1100/1350	3	Aconitum T	1	4	1	0,003
	2	Aesculus hippocastanum	1	4	1	0,003
	3	Alchemilla G	1	4	1	0,003
1370	3	Allium ursinum T	2	8	2	0,007
1000/1100	1	Alnus glutinosa T	24	100	1153	3,748
1190	3	Anthriscus sylvestris	2	8	3	0,010
	3	Apiaceae undiff.	4	17	5	0,016
1020	3	Artemisia	20	83	43	0,140
1350	1	Aruncus T	1	4	1	0,003
1000	3	Astragalus T	1	4	1	0,003
1450	3	Athyrium	14	58	78	0,254
	4	Avena T	4	17	5	0,016
1400/1280	1	Betula	24	100	2253	7,324
1350	3	Blechnum spicant	3	13	3	0,010
	3	Brassicaeae	22	92	80	0,260
	6	Bryideae	3	13	3	0,010
	2	Buxus sempervirens	1	4	1	0,003
1025	5	Callitriche	1	4	1	0,003
1490	3	Calluna vulgaris	17	71	131	0,426
1450	3	Caltha T	1	4	1	0,003
970	2	Carpinus betulus	24	100	415	1,349
1445	3	Carum carvi	3	13	28	0,091
1000	2	Castanea sativa	22	92	204	0,663
1400	3	Centaurea jacea T	3	13	3	0,010
1000	3	Centaurium pulchellum T	2	8	2	0,007
1280	3	Cerastium fontanum T	3	13	3	0,010
	4	Cerealia T	7	29	8	0,026
1420	3	Chaerophyllum hirsutum T	1	4	1	0,003
	3	Chenopodiaceae	17	71	37	0,120
	3	Cichoriaceae	11	46	23	0,075
750	2	Cornus sanguinea	1	4	1	0,003
1350	2	Corylus avellana	24	100	796	2,588
	2	Cotynus coggyria	1	4	1	0,003
1020	3	Cuscuta europaea T	1	4	1	0,003
	5	Cyperaceae undiff	23	96	732	2,380
1400	1	Daphne	2	8	2	0,007
950	3	Daucus carota	8	33	16	0,052
1450	3	Diphasium alpinum T	3	13	5	0,016
1380	5	Drosera	3	13	6	0,020
1400	3	Dryopteris dilatata	12	50	75	0,244
1400	3	Dryopteris T	9	38	10	0,033
1170	3	Echium	1	4	1	0,003
600	4	Eryngium	1	4	1	0,003
	3	Eupatorium cannabinum T	6	25	6	0,020
	3	Euphorbia	1	4	1	0,003
1470	1	Fagus sylvatica	24	100	1730	5,624
1050	3	Fallopia	2	8	2	0,007

Table 2. Constancies and percentages of pollen types from surfaces samples (mosses) from the shores of the Nordschwarzwald cirque lakes. Evaluation (column 2): 1 local arboreals 2 extralocal arboreals 3 local non-arboreals 4 extralocal non-arboreals 5 water and mire plants 6 spores; arrangement in groups 1–4 according to upper limit in Schwarzwald after Oberdorfer (2001). (Continuation).

Highest occurrence Schwarzwald m a.s.l.	Group		Constancy		Frequency	
			n	%	n	%
1420	3	Filipendula	18	75	61	0,198
1000	1	Frangula alnus	1	4	1	0,003
1230	1	Fraxinus excelsior	24	100	274	0,891
	3	Geum T	3	13	4	0,013
1350	3	Heracleum sphondyleum	2	8	3	0,010
595	2	Hippophaë rhamnoides	2	8	2	0,007
	4	Hordeum T	13	54	22	0,072
730	2	Humulus/Cannabis	11	46	21	0,068
1425	3	Huperzia selago	1	4	1	0,003
1300	3	Hypericum perforatum T	2	8	2	0,007
1100	1	Ilex aquifolium	2	8	2	0,007
1300	3	Impatiens	1	4	1	0,003
	6	indiff	24	100	255	0,829
720	2	Juglans regia	22	92	70	0,228
1240	1	Juniperus communis	4	17	5	0,016
	1	Larix decidua T	22	92	68	0,221
1490	3	Lotus	1	4	1	0,003
1370	3	Lycopodium clavatum T	3	13	11	0,036
1350	3	Lysimachia vulgaris T	2	8	2	0,007
1470	3	Melampyrum	5	21	7	0,023
1100	5	Menyanthes trifoliata	6	25	6	0,020
600	4	Mercurialis annua	4	17	5	0,016
1200	3	Mercurialis perennis T	3	13	3	0,010
675	4	Myriophyllum spicatum	1	4	1	0,003
	2	Olea europaea	5	21	6	0,020
720	4	Orlaya grandiflora	1	4	1	0,003
1400	3	Oxalis acetosella	3	13	5	0,016
1350	3	Pedicularis palustris T	1	4	1	0,003
	3	Peucedanum palustre T	1	4	1	0,003
1480	1	Picea abies	24	100	6396	20,793
1300	3	Pimpinella major T	3	13	3	0,010
1150	1	Pinus sylvestris T	24	100	7884	25,630
1320	3	Plantago lanceolata	23	96	183	0,595
1450	3	Plantago maior	4	17	6	0,020
1040	3	Plantago media	4	17	5	0,016
	2	Platanus orientalis	11	46	26	0,085
	3	Poaceae undiff	24	100	2189	7,116
1300	3	Polygonum aviculare T	1	4	1	0,003
1400	3	Polygonum bistorta	1	4	1	0,003
1100	3	Polygonum persicaria T	1	4	1	0,003
	6	Polypodiaceae undiff	22	92	1160	3,771
1300	3	Polypodium vulgare	1	4	1	0,003
1340	1	Populus	8	33	17	0,055
	3	Potentilla T	10	42	14	0,046
1200	1	Prunus T	5	21	5	0,016
1280	3	Pteridium aquilinum	5	21	12	0,039
1120	2	Quercus	24	100	1235	4,015
	3	Ranunculaceae undiff.	7	29	11	0,036
	3	Ranunculus acris T	18	75	62	0,202
	2	Rhus G	1	4	1	0,003

Table 2. Constancies and percentages of pollen types from surfaces samples (mosses) from the shores of the Nordschwarzwald cirque lakes. Evaluation (column 2): 1 local arboreals 2 extralocal arboreals 3 local non-arboreals 4 extralocal non-arboreals 5 water and mire plants 6 spores; arrangement in groups 1–4 according to upper limit in Schwarzwald after Oberdorfer (2001). (Continuation).

Highest occurrence Schwarzwald m a.s.l.	Group		Constancy		Frequency	
			n	%	n	%
	2	Rosa	1	4	1	0,003
1090	3	Rosaceae undiff.	12	50	15	0,049
	3	Rubiaceae	13	54	23	0,075
1400	1	Rubus	12	50	13	0,042
1050	3	Rumex aquaticus type	2	8	2	0,007
1310	3	Rumex obtusifolius T	1	4	2	0,007
1200	3	Rumex undiff.	23	96	140	0,455
1450	1	Salix	24	100	157	0,510
1200	1	Sambucus nigra/racemosa	22	92	55	0,179
1400	3	Sanguisorba officinalis	1	4	1	0,003
1350	5	Scheuchzeria palustris	3	13	13	0,042
	4	Secale cereale	16	67	37	0,120
	3	Senecio T	8	33	10	0,033
	3	Silene T	2	8	2	0,007
720	4	Solanum dulcamara	4	17	4	0,013
1390	1	Sorbus T	12	50	22	0,072
960	5	Sparganium T	2	8	6	0,020
1493	5	Sphagnum	14	58	443	1,440
980	2	Taxus baccata	6	25	13	0,042
950	1	Tilia	15	63	26	0,085
1130	3	Trientalis europaea	1	4	1	0,003
1490	3	Trifolium repens T	1	4	1	0,003
	3	Trifolium undiff.	1	4	1	0,003
	4	Triticum T	14	58	23	0,075
970	5	Typha latifolia T	4	17	4	0,013
1380	1	Ulmus	16	67	31	0,101
1300	3	Urtica/Parietaria	16	67	86	0,280
555	4	Utricularia	1	4	2	0,007
1490	3	Vaccinium T	18	75	139	0,452
1060	3	Valeriana officinalis T	1	4	1	0,003
	3	Varia	10	42	15	0,049
	3	Veronica	1	4	2	0,007
1000	1	Viburnum lantana	1	4	1	0,003
850	1	Viburnum opulus	4	17	4	0,013
	3	Vicia T	1	4	3	0,010
	2	Vitis	9	38	11	0,036
	4	Xanthium spinosum T	11	46	17	0,055
	4	Zea mays	4	17	4	0,013

the calculation of percentages, water plants, spores and Cyperaceae were excluded from the pollen sum. All ages mentioned in this paper are calibrated.

3. Results and discussion

3.1 General outline of the Holocene vegetation history of northern Schwarzwald

The studies of Glaswaldsee, Wilder See, Huzenbacher See, and Herrenwieser See are published (Rösch 2009a; 2009b; 2009/2010; 2012; Rösch, Tserendorj 2011a; 2011b; Rösch *et al.* 2009). Mummelsee, Schurmsee und Buhlbachsee are the topic of a PhD thesis at Göttingen University by Gegeensuvd Tserendorj. The evaluation of the Ellbachsee profile is in preparation.

All profiles depict the history of vegetation and landscape from the Late Weichselian to Modern times without gaps, and for the Subboreal and Subatlantic with very high time-resolution. Before the increase of *Abies alba*, the development in all profiles is very uniform in time and space. (Figure 3). Afterwards there are still similarities between the
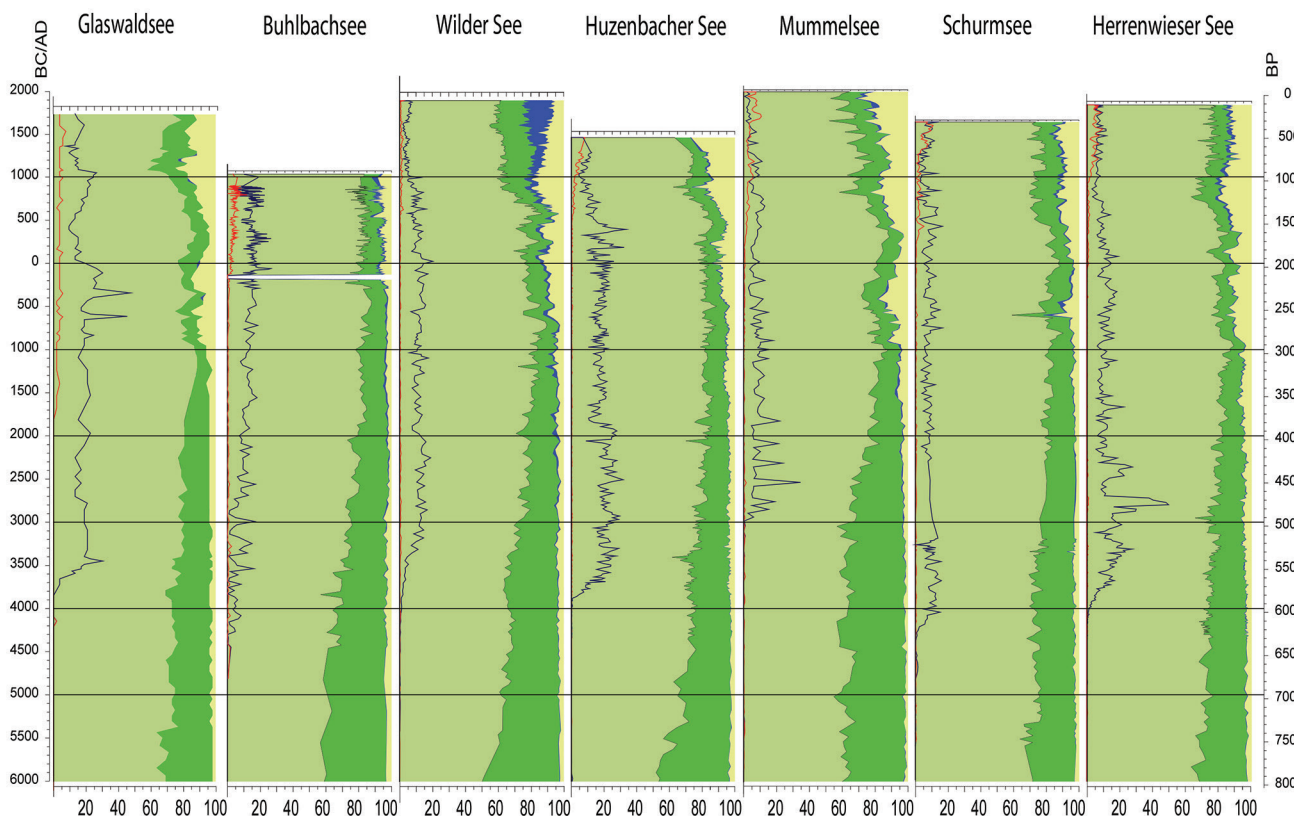
Figure 3. The pollen profiles of the cirque lakes of Nordschwarzwald. Main diagrams: percentages of trees (light green), shrubs (green), dwarf shrubs (blue), and terrestrial NAP (yellow)), adding up to 100%, and the curves of *Abies alba* (blue line) and *Picea abies* (red line), linear time axis.

pollen profiles, but differences in detail, concerning timing of events, forest cover and forest composition. Very significant are the differences during prehistory, whereas during the Medieval and Modern Ages the vegetation history is again rather uniform. From these differences we can conclude that the lakes reflect the situation of their surroundings, up to a distance of most probably not more than 1–2 km, without any major input from longer distances; if there had been pollen input originating from the Rhein valley, reflecting human impact in the lowlands, then all the lakes would have shown an identical picture. We can also conclude that the development of the cultural landscape during the Bronze and Iron Age happened at a local scale.

According to the increase of terrestrial NAP (yellow areas in Figure 3) the onset of strong deforestation in the local environs of the lakes had already occurred in the Bronze and pre-Roman Iron Age. This first strong deforestation phase is separated from the Medieval deforestation by a reforestation phase of the Migration and Early Medieval period. The extent and age of these early deforestation phases are different, as well as the percentages of *Abies alba* (blue lines in Figure 3). These differences between the lakes are evidence for the events being local. As already pointed out, the archaeological evidence is weak, but there is proof for extensive mining activities in the North Schwarzwald during the pre-Roman Iron Age (Gassmann *et al.* 2006). In the profiles, Buhlbachsee, Wilder See and

Mummelsee, situated near the steep western slopes, as well as at Schurmsee, *Abies alba* was less frequent. Most frequent was *Abies alba* at Glaswaldsee in the south, at Huzenbacher See, situated farthest to the east, and at Herrenwieser See, the northernmost lake. But at all lakes, it is, together with *Fagus sylvatica*, the most frequent tree of the mountain forest, from its first increase until the Late Medieval period. During this time – about five millennia – the pollen curves of *Picea abies* remain low, hardly exceeding 1% (red lines in Figure 3).

We can in summary say that the natural forest in northern Schwarzwald was a forest without *Picea abies* but dominated by *Abies alba*. However, this natural state had already ceased about 3000 BC due to increasing human impact. Afterwards, *Fagus sylvatica* became as or even more frequent as *Abies alba*, but *Picea abies* was still absent.

3.2 Vegetation changes of the last five millennia according to the pollen record of Herrenwieser See

The main trends are visible in all profiles, but Herrenwieser See is a representative pollen profile for Nordschwarzwald, because out of all the lakes it has the longest lithostratigraphy and therefore the best time resolution (Figure 4; Rösch 2012).

Abies alba appears at Herrenwieser See shortly after 5000 BC, shortly after *Picea abies* and at the same time as *Fagus sylvatica* (start of continuous pollen curves). Until 4000 BC, the percentages of all 3 taxa remain below 1%. From 4000 BC, together with the mid-Holocene *Ulmus*

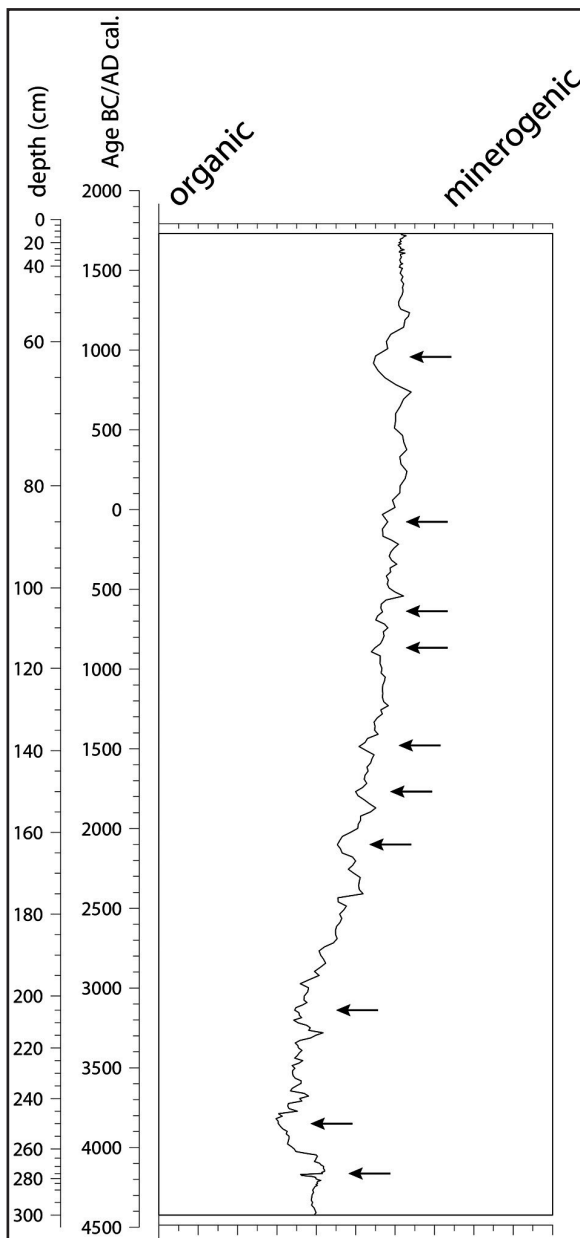**Figure 4.** Pollen diagram of Herrenwieser See, linear time axis.

Figure 5. Loss-on-ignition (LOI) curve of Herrenwieser See, linear time axis; arrows indicate erosion phases.

decline (Peglar, Birks 1993), *Abies* increases and reaches around 3300 BC 27.5%. After a decline to minimal 5.5%, accompanied by a *Betula* peak, *Abies* increases again and obtains around 2800 BC its maximum value of almost 50%. Only 100 years later, *Abies* decreases again to less than 9%. At the same time *Betula, Quercus* and *Fagus sylvatica* increase. Afterwards, *Abies* recovers and obtains, about 2400 BC, once again 28%. These fluctuations of the *Abies* curve are no spurious effect of calculation, because the total pollen influx is more or less constant during the period considered. Therefore a decrease of the *Abies* curve from 27 to 9% indicates a real decline in the *Abies* pollen influx.

The following fluctuations of the *Abies* curve are slightly less. Until 700 BC it has between 10 and 15% and afterwards until 300 BC between 15 and 20%; afterwards, until the Late

Medieval, it has about 12%. During the Late Medieval and Modern Ages the values of *Abies* are mostly considerably below 10%.

The prehistoric declines of *Abies* are accompanied by single cereal grains (particularly around 2700 and 2300 BC), by an increase of apophytes like *Plantago lanceolata* (particularly 2600–2300 BC), and of charred particles (Figure 4, around 2700 and 2400 BC) and followed by *Betula* peaks. There is also a decrease of LOI (Figure 5) caused by minerogenic material from eroded topsoils in the catchment area. In general the LOI of Herrenwieser See gradually increases between 4500 BC and the 18th century AD from 40 to 60%, a consequence of mire development and raw humus accumulation (Rydberg *et al.*, in print). Sudden and short decreases of LOI against this general trend at 3200, 2300–2000, 1800, 1400, 800, 600 and 200 BC, and after 800 AD indicate soil erosion.

The decreases of *Abies* are short-term events, taking place over a few decades. Natural causes like forest fires or windstorms are rather improbable. The recovery phases take somewhat longer – over one or two centuries; they may indicate a natural forest succession after the disturbance has ceased. However, other reasons cannot be totally ruled out – neither can human impact.

The four decreases of *Abies* date to 3500 BC, 3000 BC, 2500 BC and 2200 BC and correspond to land-use phases described by Rösch (2012). In contrast to the Bronze Age or younger land use, Neolithic land use is not correlated with a clear increase of NAP, because the Neolithic land-use systems did not result in permanent open vegetation with a lot of wind-pollinated grasses and herbs (Kuneš *et al.* 2015; Kalis *et al.* 2003; Rösch 1987).

The first *Abies* decline dates towards the end of the Younger Neolithic (Michelsberg culture), the second and third into the Final Neolithic (Corded ware culture), the last into the Earliest Bronze Age – more precisely into the time of the Bell Beaker culture (Lüning 1996). So an important forest change from *Abies* to *Fagus*, in some phases to pioneer or coppiced forest or even *Quercus*, happened not in the Medieval period, and not in the pre-Roman Iron Age, but already in the final two millennia of the Neolithic. It should also be mentioned here: the increase of the *Pinus* curve during the first *Abies* decline, most probably indicating occupation of the lake shores by *Pinus*; the decrease of *Isoetes lacustris* and *I. echinospora*, starting together with the *Abies* expansion; and the increase of *Sphagnum* and *Calluna vulgaris*, indicating paludification and a shift of the lakes' status from oligotrophic to dystrophic. There is no evidence of soil acidification to hamper the growth of *Abies*. All decreases of *Abies*, the prehistoric as well as the later ones, are also phases of LOI decrease, therefore phases of soil erosion (Figure 5). Why *Abies* became so frequent before *Fagus*, why it decreased afterwards and lost its leading role to *Fagus*, and how it could still remain frequent till modern ages, needs further discussion. And, as already pointed out, clear archaeological evidence for pre-Iron age human occupation of the Schwarzwald is very scarce (*cf.* Valde-Novak, Kienlin 2002). From the Bronze Age onwards, human impact is
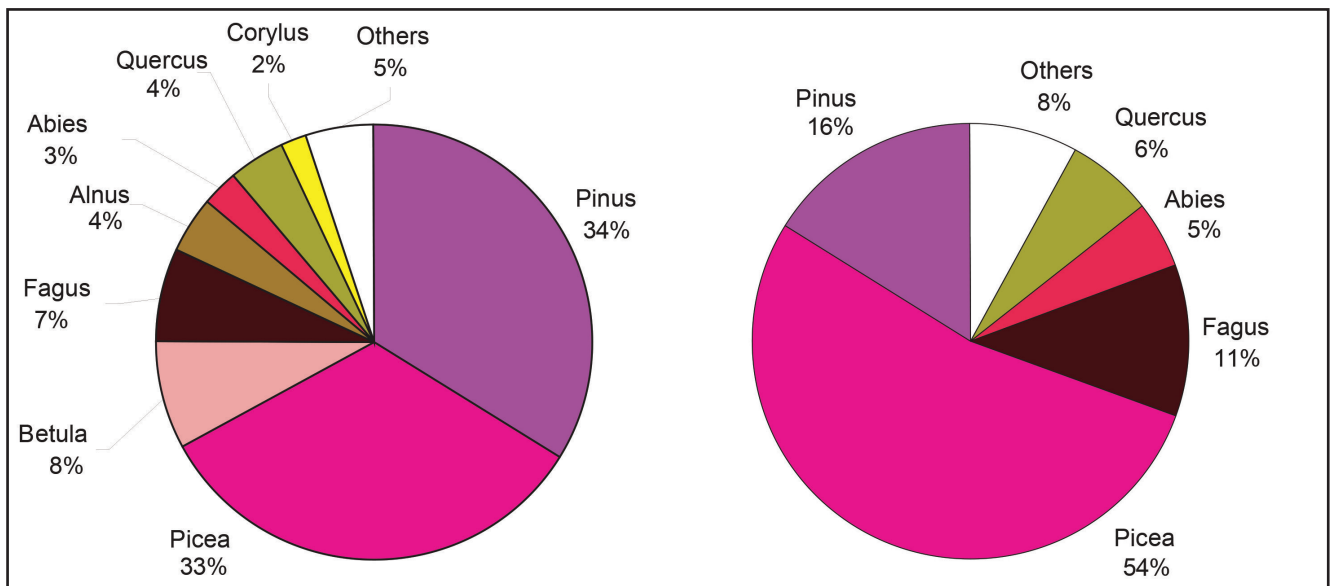
Figure 6. Pollen spectra of mosses from the shore of Herrenwieser See. a) Percentages of arboreal pollen; b) Percentages of arboreal pollen, arboreals from the lake shores excluded.

more clearly visible in the pollen record by an increase of non-arboreals, indicating different forms of land use with permanent open land (Kalis *et al.* 2013; Rösch *et al.* 2014).

In comparison with *Abies*, *Fagus* increases very slowly. Not until 3000 BC, during the first *Abies* decline, does *Fagus* exceed 10%. After the third *Abies* decline at 2200 BC, *Fagus* became the most common tree for a long time. During the pre-Roman Iron Age, *Abies* again became more frequent than *Fagus*. But not always increasing *Fagus* is correlated with decreasing *Abies,* and *vice versa*. Other trees, *Betula*, *Pinus*, *Alnus*, are also components of the forest ecosystem and influence, with changing pollen input, the curves of the

other trees. These trees can grow within the forest as well as at the lake shore.

During the period being considered, *Picea abies* has always less than 1%. It does not achieve 1% until the Roman period. Not until the last decades of the Late Medieval period does its curve slowly exceed 1%. It climbs to 5% in the early Modern period, at Glaswaldsee, Buhlbachsee and Huzenbacher See somewhat earlier. In the topmost sediments of the long core of Herrenwieser See, dating to the late 17th or early 18th century AD. it always remains below 10%. At the top of the two short cores of Herrenwieser See, dating into the 19th century AD, *Picea* increases to 20% (Rösch 2012).

Figure 7. Actual forest composition around Herrenwieser See. Data of Forsteinrichtung, Landesforstverwaltung Baden-Württemberg.
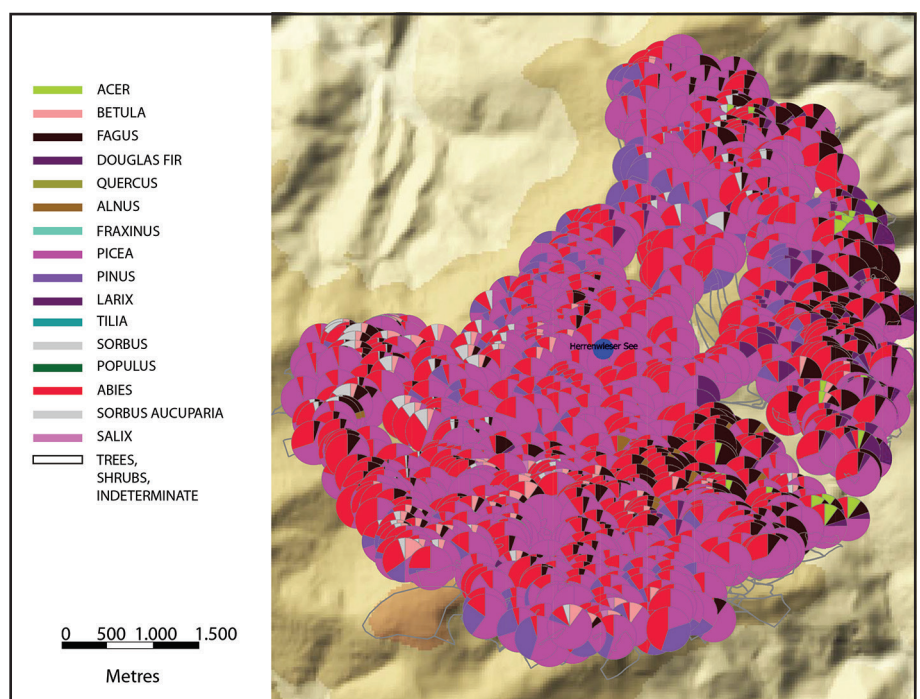
In the actual pollen spectra, preserved in mosses from the shore of Herrenwieser See, *Picea* has 33%, about as much as *Pinus*, *Fagus* 7%, and *Abies* only 3% (Figure 6a). With *Betula*, *Corylus*, *Alnus* and two thirds of the *Pinus* as local components of the lake shores excluded from the pollen sum, *Picea* has 54%, *Pinus* 16%, *Fagus* 11%, *Abies* 5%, *Quercus* 6% and other trees 8% (Figure 6b). This is in good agreement with the recent forest cover of 60% *Picea*, 15% *Abies*, 10% *Pinus*, 5% *Fagus* and 10% other trees, especially when we keep in mind that this comparison was done without considering the differences in pollen production and distribution (Figure 7). Even in the short core from Herrenwieser See, *Picea* remains below 20%, indicating a gap of at least the last several decades. The situation at the other lakes is very similar: The present dominance of *Picea* is well reflected in the pollen rain.

3.3. The ecological conditions triggering the forest composition

In the third millennium BC the expansion of *Abies* in Schwarzwald was complete. *Abies* was now the most frequent tree with 40% or more in the pollen spectrum and most probably an even stronger participation in the forest composition. Compared with *Fagus* and *Picea*, and even more so compared with *Pinus* and *Betula*, *Abies* is badly represented in the pollen spectrum (Andersen 1970).

This phase of the vegetation history in Schwarzwald was appropriately called "Tannenzeit" (Lang 1955). It represents the final stage of the natural forest development of the Holocene, triggered only by natural causes – climate, soil, plant migration, competition. All later changes took place under human influence. These changes can therefore be regarded, at least partly, as man-made degradation of the forest. Other trees took advantage of the anthropogenic disturbance, at first *Fagus*. It has similar ecological features and competitive power as *Abies*. The outstanding competitiveness of *Abies* in Schwarzwald is based on its maximal size and age, but mainly on its dark shading of other trees and its ability to tolerate shade in its youth (Ellenberg 1996).

As is well known, *Picea* did not have any significance in Nordschwarzwald until the Modern Ages (Lang 2005). Why *Picea*, which was present at high elevations in Südschwarzwald at least since the Subboreal, did not occur in the Nordschwarzwald in larger quantities before the Late Medieval period, is unclear. Ludemann (2014) discusses the early natural occurrence of *Picea* in Nordschwarzwald, but our data do not confirm this opinion and remove any doubt whether *Picea* did occur in the region during prehistory.

At least its occurrence in the forest on medium or good soils before the Medieval period can be excluded. Single azonal stands at mires, very steep slopes, or at the base of rock fans, protected from the competition of *Abies* and *Fagus*, may have been possible.

In the southern and central Schwarzwald, the situation for *Picea* was perhaps a little more favourable. Here it did occur at elevations above 1000 m asl, at the habitats mentioned above, already during prehistory (Lang 2005; Rösch 2000).

The somewhat higher and earlier increasing percentages of *Picea* at Glaswaldsee (Figure 3) confirm that the history of *Picea* in Schwarzwald must be discussed at the local scale. At medium-elevation habitats, *Picea* could not take advantage of its earlier immigration, but was later replaced by *Abies* (Sudhaus 2005).

We can conclude that the natural forest of Nordschwarzwald would be a forest without *Picea*, dominated by *Abies* and *Fagus*. For the Schwarzwald National Park the question then arises: Will such a natural forest without *Picea* come back by itself, and how much time will this take?

Quercus, today in Schwarzwald very rare, must also be discussed. Before the increase of *Abies*, the Schwarzwald forest consisted of *Quercus petraea*, together with *Corylus avellana*, *Fraxinus excelsior*, *Ulmus*, *Tilia* and *Acer* (Figure 4). During the period of dominating *Abies* and *Fagus*, *Quercus* has been represented for more than three millennia rather constantly at 10%. Assuming 5% *Quercus* pollen as being transported long-distance (Figure 5), that still leaves 5% of local occurrence. Most probably *Quercus* never did disappear totally from Schwarzwald. In contrast, during the Late Medieval period, *Quercus* became the most frequent pollen type with more than 20% (Figure 6 in Rösch 2012), a consequence of the medieval forest management which supported *Quercus*. From the 16th century onwards, *Quercus* has decreased to her present level of 5%. The reason is not "the Little Ice Age", but again forest management: During the period Mercantilism held sway in Europe (17th–18th century), the timber stock of Nordschwarzwald was sold to the Netherlands for ship construction (Scheifele 1996). The Duke of Württemberg and the Margrave of Baden needed the sale revenue to finance their budgets. Initially mostly *Quercus* was exploited, because sailing ships were constructed with more than 90% oak (*Quercus)*. However, due to its high density, oak could only be rafted in combination with coniferous wood. There is historical evidence from written sources of the occurrence of *Quercus* up to the highest elevations of Nordschwarzwald (Scheifele, 1996). The time of the "Holländertannen" (Dutch firs) came later, mainly during the 18th century.

When the absolutist sovereigns had finally achieved what many generations of farmers, charcoal burners and miners since the Iron Age had not been able to do – to nearly totally deforest the Nordschwarzwald – *Picea* came as an emergency measure for the forest administrators. Before the start of large-scale reforestation in the 19th century, *Picea* was already present in the region from the 16th century; it had already invaded disturbed forests (von Hornstein 1951). Concerning the occurrence of *Picea* in the Modern Ages, vegetation history and forest history are in good accord (Hausburg 1968).

3.5. General framework for the future forest development in Schwarzwald National Park

Under natural conditions, *Abies* is the strongest competitor among the trees of the mountain forest, at least in Schwarzwald with a suboceanic, wet, and not-too-cold climate. Under

Figure 8. Young *Abies alba* damaged by game animals, Nationalpark Schwarzwald.

different climatic and soil conditions, the story may be different. On the other hand, it is very sensitive against forest disturbance, especially most forms of human impact. It cannot recover from rootstock, is sensitive against fire, and cannot start as a first colonizer of clearings. Red deer and roe deer feed on young *Abies* saplings by preference and thus give other species such as *Picea* or *Juniperus* an advantage. Just how much damage caused through the browsing of game animals can influence today the future of the forest demonstrates a viewpoint on mixed forests of *Abies* and *Picea* that is held within the National Park (Figure 8). *Picea* seedlings can grow undisturbed, whereas *Abies* seedlings suffer strong or even lethal damage by game animal browsing.

Of the three most important mountain trees, *Picea* suffers least from browsing. Furthermore, it can act as a pioneer species in clearings. Thus game animals play a crucial role in the future of the forest (Senn, Suter 2003). Not only in Schwarzwald, but in many other forests in Germany, an attempt at reforestation with deciduous trees or *Abies* is only possible by fencing off sensitive areas.

Throughout the entire Holocene red deer were present in Schwarzwald, and since the Bronze Age or even earlier there has also been browsing by domestic animals. Nevertheless, *Abies* remained together with *Fagus* the main tree in Schwarzwald until the High Medieval period. It was able to cope with this and other human impacts, perhaps even taking advantage from certain ways of forest management that did not include large clearings. Without the competition of *Picea*, the browsing had no lasting effect. Obviously, the damage on *Abies* seedlings made by domestic animals was less than that caused by game animals (Málek 1971; 1981). On abandoned clearings, a pioneer forest of *Betula* gave *Abies* the chance to come back; perhaps the farmers kept the wild game density low to protect their fields. This situation changed when hunting became a privilege of the

nobility and rich. Getting trophies was now more important than preventing the fields from being damaged. The density of wild game was artificially increased substantially to guarantee the hunters more success and more pleasure.

Abies was able to deal with this situation too. But when in the 19th century huge clearings were reforested with *Picea*, its battle was finally lost. *Abies* could not be used to reforest the clearings because it is not a pioneer tree growing in open spaces.

Inside the national park there will be no artificially-created clearings in the future, but there will be clearings made by hurricanes and extensive damage by bark beetle. Therefore, there will always be some open land where the forest must start again. It is an open question as to whether, despite the overstocking of red dear, *Abies* will be able to successfully compete against *Picea* in this situation. Perhaps this will be the case when the reforestation, as in the past, will be initiated by *Betula* instead of *Picea* (Figure 4). To give *Abies* a better chance, the populations of red and roe deer should be reduced drastically. Because of the national park's small size and its present contact to the surrounding landscape this will be difficult.

The history of *Abies* in Schwarzwald is not singular. There are, for example, similarities with that of the Bohemian Forest (Svobodova *et al.* 2001; 2002). In the Southern Alps, *Abies* had increased and become the most common tree already in the 7th millennium BC, but then nearly disappeared in the 4th and early 3rd millennium BC (Finsinger, Tinner 2006; Gobet *et al.* 2000; Tinner *et al.* 1999; van der Knaap *et al.* 2005). Climatic change, forest fires, and human impact are given as reasons for this change (Wick, Möhl 2006; Rösch *et al.* 2012). In eastern central Europe, *Abies* arrived later (Kozáková *et al.* 2011); here it reached its maximum during the Bronze and Iron Age. It then declined in the pollen record during the High Medieval.

There are still open questions. The existence of different *Abies* races, each with different eco-physiological characteristics, must also be taken into account (Burga, Hussendörfer 2001). Populations in regions with a warmer climate have perhaps lower shade requirements and higher drought resistance. Within a regional population, the range of eco-physiological behaviour and potential can be wide, allowing the species as a whole to deal with the changing environmental conditions. This would explain why *Abies* has expanded in the past in regions which are thought by geobotanists and forest scientists to be too warm and dry, for example, into the Hoch- and Oberrhein valley, and why the Late Medieval reforestation in lowland areas by the seeding of conifers, initiated by Peter Stromer in Nürnberg, was not only able to use *Pinus sylvestris* and *Picea abies*, but *Abies alba* as well (Lechner 2005; Wick, oral announcement; Hasel, Schwartz 2002).

4. Conclusions

High-resolution and radiocarbon-dated pollen profiles from the central cores of small lakes in Nordschwarzwald have been able to reflect the history of landscape, vegetation and human impact during the last 11 millennia. This paper focuses on the history of the mountain forest and its main tree components and on possible reasons for the changes. The reasons for the shift from mixed oak forest to dominating *Abies* in the 4th millennium BC are not clear, but at the same time there occurred a change in the lake ecology and chemistry, indicated by a decrease of *Isoetes* and by an increase of mercury (Rydberg *et al.*, in press). An acidification of the surrounding soil can be deduced by the increase of *Calluna* and Ericaceae. In the third millennium BC *Abies* decreased and *Fagus* became more frequent. This is accompanied by *Betula* peaks and some human impact indicators, of which, with good reason, we think, that they are local. From the third millennium BC to the first millennium AD the relation between *Abies* and *Fagus* remained rather unchanged. A point to mention is the strong role played by *Quercus*, having an occurrence even at higher altitudes. *Picea* was present only during the last millennium and became the most frequent tree when the vastly destroyed forest was reforested preferentially with *Picea*. Foresters, ecologists and botanists expect, or at least hope, that inside the Schwarzwald National Park, without any future human impact, *Abies* will regain its dominating role and will replace *Picea*. The vegetation history, at least of the last millennium, and the continuation of disturbances like windstorms, bark beetle, and the overstocking of game (deer), put some doubt on this expectation.

Acknowledgements

References

AMMANN, B., VAN DER KNAAP, W. O., LANG, G., GAILLARD, M.-J., KALTENRIEDER, P., RÖSCH, M., FINSINGER, W., WRIGHT H. E., TINNER, W. 2014: The potential of stomata analysis in conifers to estimate presence of conifer trees: examples from the Alps. *Vegetation History and Archaeobotany* 23, 249–264.

ANDERSEN, S. T. 1970: *The relative pollen productivity and pollen representation of North European trees, and correction factors for tree pollen spectra.* Geological Survey of Denmark 2/96, Copenhagen.

BERGLUND, B. E. 1986: *Handbook of Holocene Palaeoecology and Palaeohydrology.* Chichester.

BRÜCKNER, H. 1981: Die Entwicklung der Wälder des Schwarzwaldes durch die Nutzung vergangener Jahrhunderte und ihre heutige Bedeutung. In: Liehl, E., Sick, W. D. (Eds.): *Der Schwarzwald – Beiträge zur Landeskunde.* Veröff. Des Alemannischen Instituts Freiburg 47 (Bühl), 155–180.

BURGA, C. A., HUSSENDÖRFER, E. 2001: Vegetation history of *Abies alba* Mill. (silver fir) in Switzerland – pollen analytical and genetic surveys related to aspects of vegetation history of *Picea abies* (L.) H. Karsten (Norway spruce). *Vegetation History and Archaeobotany* 10, 151–159.

DIERSCHKE H. 1994: *Pflanzensoziologie. Grundlagen und Methoden.* Ulmer, Stuttgart.

ELLENBERG, H. 1996: *Vegetation Mitteleuropas mit den Alpen.* Ulmer, Stuttgart.

FEZER, F. 1957: *Eiszeitliche Erscheinungen im nördlichen Schwarzwald.* Forsch. Deutsch. Landeskde. 87, Bad Godesberg.

FINSINGER, W., TINNER, W. 2006: Holocene vegetation and land-use changes in response to climatic changes in the forelands of the southwestern Alps, Italy. *Journal of Quaternary Science* 21, 243–258.

FIRBAS, F. 1949: *Spät- und nacheiszeitliche Waldgeschichte Mitteleuropas nördlich der Alpen.* Bd.1, Fischer, Jena.

FISCHER, H. 1967: *Die naturräumlichen Einheiten auf Blatt 169 Rastatt.* Geographische Landesaufnahme 1:200 000, Naturräumliche Gliederung Deutschlands, Bad Godesberg.

FRENZEL, B. 1982: Über eine vormittelalterliche Besiedlung in einigen Teilen des nördlichen Schwarzwaldes. In: Winkel, H. (Ed.): *Festschrift für Günther Franz zum 80. Geburtstag, (Thorbecke, Sigmaringen).* 239–263.

GASSMANN, G., WIELAND, G., RÖSCH, M. 2006: Das Neuenbürger Erzrevier im Nordschwarzwald als Wirtschaftsraum während der Späthallstatt- und Frühlatènezeit. *Germania* 84/2, 273–306.

GOBET, E., TINNER, W., HUBSCHMID, P., JANSEN, I., WEHRLI, M., AMMANN, B., WICK, L. 2000: Influence of human impact and bedrock differences on the vegetational history of the Insubrian Southern Alps. *Vegetation History and Archaeobotany* 9, 175–187.

HASEL, K., SCHWARTZ, E. 2002: *Forstgeschichte. Ein Grundriss für Studium und Praxis.* Kessel, Remagen.

HAUSBURG, H. 1967: Die Ausbreitung der Fichte im Hornisgrinde-Kniebis-Murggebiet des Nordschwarzwaldes bis etwa 1800. Mitt. Ver. Forstliche Standortskde. *Forstpflanzenzücht* 17, 3–22.

HAUSRATH, H. 1938: *Aus der Waldgeschichte des Schwarzwaldes.* Freiburger Universitätsreden 26, Freiburg.

V. HORNSTEIN, F. 1951: *Wald und Mensch. Waldgeschichte des Alpenvorlandes Deutschlands, Österreichs und der Schweiz.* Maier, Ravensburg.

HUTTENLOCHER, F., DONGUS, H. 1967: *Die naturräumlichen Einheiten auf Blatt 170 Stuttgart.* Geographische Landesaufnahme 1:200 000, Naturräumliche Gliederung Deutschlands, Bad Godesberg.

KALIS, AJ., MERKT, J., WUNDERLICH, J. 2003: Environmental changes during the Holocene climatic optimum in central Europe – human impact

and natural causes. *Quaternary Science Reviews* 22, 33–79.

KOZÁKOVÁ, R., ŠAMONIL, P., KUNEŠ, P., NOVÁK, J., KOČÁR, KOČÁROVÁ, R. 2011: Contrasting local and regional Holocene histories of *Abies alba* in the Czech Republic in relation to human impact. Evidence from forestry, pollen and anthracological data. *The Holocene* 21, 431–444.

KUNEŠ, P., SVOBODOVÁ-SVITAVSKÁ, H., KOLAR, J., HAJALOVÁ, M., ABRAHAM, V., MACEK, M., TKÁČ, P., SZABO, P. 2015: The origin of grasslands in the temperate forest zone of east-central Europe: long-term legacy of climate and human impact. *Quaternary Science Reviews* 116, 15–27.

JENSEN, I. 1986: *Der Schlossberg von Neuenbürg. Eine Siedlung der Frühlatènezeit im Nordschwarzwald*. Materialhefte z. Vor- u. Frühgesch. Bad.-Württ. 8, Theiss, Stuttgart.

LANG, G. 1955: Neue Untersuchungen über die spät- und nacheiszeitliche Vegetationsgeschichte des Schwarzwaldes. II. Das absolute Alter der Tannenzeit im Südschwarzwald. *Beitr. naturk. Forsch. Südwestdeutschl.* 14, 24–31.

LANG, G. 2005: *Seen und Moore des Schwarzwaldes als Zeugen spätglazialen und holozänen Vegetationswandels.* Andrias 16, Staatliches Museum für Naturkunde, Karlsruhe.

LECHNER, A. 2005: *Paläoökologische Beiträge zur Rekonstruktion der holozänen Vegetations-, Moor- und Flussauenentwicklung im Oberrheintiefland.* Dissertation zur Erlangung Universität Freiburg, Freiburg.

LUDEMANN, T. 2014: Die Wälder des Nordschwarzwaldes. *Standort Wald* 48, 41–62.

LÜNING, J. 1996: Erneute Gedanken zur Benennung der neolithischen Perioden. *Germania* 74, 233–237.

MÁLEK, J. 1971: Vliv pastvy dobytka na přeživáni semenáčků a přirozenou obnuvu jedle (The influence of livestock grazing on the survival of silver fir seedlings and on the natural regeneration of the silver fir). *Lesnická práce* 50, 543–546.

MÁLEK, J. 1981: Problematik der Ökologie der Tanne (*Abies alba* Mill.) und ihres Sterbens in der ČSSR. *Forstwiss. Central Bl.* 100, 170–174.

MERKT, J., STREIF, H. J. 1970: Stechrohr-Bohrgeräte für limnische und marine Lockersedimente. *Geologisches Jahrbuch* 88, 137–148.

OBERDORFER, E. 1970: *Pflanzensoziologische Exkursionsflora für Süddeutschland.* Ulmer, Stuttgart.

OTTNAD, B. 1981: Zur Territorialgeschichte des Schwarzwalds. In: Liehl, E., Sick, W. D. (Eds.): Der Schwarzwald – Beiträge zur Landeskunde, *Veröff. des Alemannischen Instituts Freiburg* 47, 181–204.

PEGLAR, S. M., BIRKS, H. J. B. 1993: The mid-Holocene Ulmus fall at Diss Mere, South-East England – disease and human impact? *Vegetation History and Archaeobotany* 2, 61–68.

PIDEK, I. A., SVITAVSKÁ-SVOBODOVÁ, H., VAN DER KNAAP, W. O., MAGYARI, E. 2013: Pollen percentage thresholds of *Abies alba* based on 13-year annual records of pollen deposition in modified Tauber traps: perspectives of application to fossil situations. *Review of Palaeobotany and Palynology* 195, 26–36.

RADKE, J. 1973: Landschaftsgeschichte und -ökologie des Nordschwarzwaldes. *Hohenheimer Arbeiten* 68, Stuttgart.

RÖSCH, M. 1987: Zur Umwelt und Wirtschaft des Neolithikums am Bodensee – Botanische Untersuchungen in Bodman-Blissenhalde. *Archäol. Nachr. a. Baden* 38/39, 42–53.

RÖSCH, M. 2000: Long-term human impact as registered in an upland pollen profile from the southern Schwarzwald, south-western Germany. *Vegetation History and Archaeobotany* 9, 205–218.

RÖSCH, M. 2009a: Zur vorgeschichtlichen Besiedlung und Landnutzung im nördlichen Schwarzwald aufgrund vegetationsgeschichtlicher Untersuchungen in zwei Karseen. *Mitt. Ver. Forstl. Standortskunde u. Forstpflanzenzüchtung* 46, 69–82.

RÖSCH, M. 2009b: Botanical evidence for prehistoric and medieval land use in the Schwarzwald. In: *Medieval Rural Settlement in Marginal Landscapes.* Ruralia VII, Turnhout (Belgium), 335–343.

RÖSCH, M. 2009/2010: Der Nordschwarzwald – das Ruhrgebiet der Kelten? Neue Ergebnisse zur Landnutzung seit über 3000 Jahren. *Alemannisches Jahrbuch 2009/2010*, 155–169.

RÖSCH, M. 2012: Vegetation und Waldnutzung im Nordschwarzwald während sechs Jahrtausenden anhand von Profundalkernen aus dem Herrenwieser See. Standort. Wald, *Mitteilungen des Vereins für forstliche Standortskunde und Forstpflanzenzüchtung* 47, 43–64.

RÖSCH, M., VOLK, H., WIELAND, G. 2005: Frühe Waldnutzung und das Alter des Naturwaldes im Schwarzwald. *AFZ Der Wald* 12, 636–638.

RÖSCH, M., GASSMANN, G., WIELAND, G. 2009: Keltische Montanindustrie im Schwarzwald – eine Spurensuche. In: *Kelten am Rhein.* Proceedings of the Thirteenth International Congress of Celtic Studies, erster Teil, Archäologie, Ethnizität und Romanisierung, Beihefte Bonner Jahrbücher 58,1, 263–278.

RÖSCH, M., TSERENDORJ, G. 2011a: Florengeschichtliche Beobachtungen im Nordschwarzwald (Südwestdeutschland). *Hercynia N. F.* 44, 53–71.

RÖSCH, M., TSERENDORJ, G. 2011b: Der Nordschwarzwald – früher besiedelt als gedacht? Pollenprofile belegen ausgedehnte vorgeschichtliche Besiedlung und Landnutzung. *Denkmalpflege in Baden-Württemberg* 40, 2, 66–73.

RÖSCH, M., FISCHER, E., LECHTERBECK, J., WICK, L. 2012: Pollenanalysen an drei Bohrkernen aus dem Profundal des Ortasees (Piemont, Italien). In: Stobbe, A., Tegtmeier, U. (Eds.): *Verzweigungen, eine Würdigung für A. J. Kalis und J. Meurers-Balke.* Frankfurter Archäologische Schriften 18, 225–247.

RYDBERG J., RÖSCH, M., HEINZ E., BIESTER H. (in print): The influence of catchment vegetation on mercury accumulation in lake sediments from a long-term perspective. *Science of the Total Environment.*

SCHAAB, M. 2003: *Beiträge zur Siedlungs- und Wirtschaftsgeschichte des Schwarzwaldes.* Veröff. Komm. Geschichtl. Landeskde. Bad.-Württ., Reihe B, Forschungen, 156, Kohlhammer, Stuttgart.

SCHEIFELE, M. 1996: *Als die Wälder auf Reisen gingen. Wald – Holz – Flößerei in der Wirtschaftsgeschichte des Enz-Nagold-Gebietes.* Braun, Karlsruhe. Company: Braun.

SENN, J., SUTER, W. 2003: Ungulate browsing on silver fir (*Abies alba*) in the Swiss Alps. Beliefs in search of supporting data. *Forest Ecology and Management* 181, 151–164.

SUDHAUS, D. 2005: *Paläoökologische Untersuchungen zur spätglazialen und holozänen Landschaftsgeschichte des Ostschwarzwaldes im Vergleich mit den Buntsandsteinvogesen.* Freiburger Geographische Hefte 64, Freiburg.

SUGITA, S. 1994: Pollen Representation of Vegetation in Quaternary Sediments: Theory and Method in Patchy Vegetation. *Ecology* 82 (4), 881–897.

SUGITA, S. 2007a: Theory of quantitative reconstruction of vegetation. I. Pollen from large sites REVEALS regional vegetation. *The Holocene* 17, 229–241.

SUGITA, S. 2007b: Theory of quantitative reconstruction of vegetation. II. All You Need Is LOVE. *The Holocene* 17, 243–257.

SVOBODOVÁ, H., REILLE, M., GOEURY C. 2001: Past vegetation dynamics of Vltavský luh, upper Vltava river valley in the Šumava mountains, Czech Republic. *Vegetation History and Archaeobotany* 10/4, 185–199.

SVOBODOVÁ, H., SOUKUPOVÁ, L., REILLE, M. 2002: Diversified development of mountain mires, Bohemian Forest, Central Europe, in the last 13,000 years. *Quaternary International* 91, 123–135.

TAUBER, H. 1965: Differential pollen deposition and the interpretation of pollen diagrams. *Danmarks Geologiske Undersøgelse* II/89, 1–69.

TINNER, W., HUBSCHMID, P., WEHRLI, M., AMMANN, B., CONEDERA, M. 1999: Long-term forest fire ecology and dynamics in Southern Switzerland. *Journal of Ecology* 87, 273–289.

TÜXEN, R. 1956: Die heutige potentielle natürliche Vegetation als Gegenstand der Vegetationskartierung. *Angew. Pflanzensoz.* 13, 5–42.

VALDE-NOWAK P., KIENLIN, T. L. 2002: Neolithische Transhumanz in den Mittelgebirgen: Ein Survey im westlichen Schwarzwald. *Prähistorische Zeitschrift* 77, 29–75.

VAN DER KNAAP, W. O., VAN LEEUWEN, J. F. N., FINSINGER, W., GOBET, E., PINI, R., SCHWEIZER, A., VALSECCHI, V., AMMANN, B. 2005: Migration and population expansion of *Abies, Fagus*, *Picea* and *Quercus* since 15000 years in and across the Alps, based on pollen-percentage threshold values. *Quaternary Science Reviews* 24, 645–680.

WICK L., MÖHL, A. 2006: The mid-Holocene extinction of silver fir (*Abies alba*) in the Southern Alps: a consequence of forest fires? Palaeobotanical records and forest simulations. *Vegetation History and Archaeobotany* 15, 435–444.

WILMANNS, O. 2001: *Exkursionsführer Schwarzwald. Eine Einführung in Landschaft und Vegetation.* Ulmer, Stuttgart.

WILMANNS, O. 2009: Zur Landschaftsökologie des Mittleren Schwarzwaldes – Von der Römerzeit zum Frühmittelalter. In: Kleiber, W. (Ed.): *Tarodunum/Zarten – Brigobannis/Hüfingen. Kelten, Galloromanen und frühe Alemannen im Schwarzwald in interdisziplinärer Sicht.* Abhandlungen der Geistes- und Sozialwissenschaftlichen Klasse 2009/4, Mainz/Stuttgart, 77–102.