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Supplementary Information: This Supplementary Information has not been peer reviewed.

Title: Bridging forest history and forest ecology – why it is important to understand the history of forests and what are the main sources and methods

Supplementary Information on main sources and methods

Field surveys – investigating the woods

Detailed field surveys of forests is a powerful tool in forest history. The combination of a detailed spatial analysis of the trees in a forest, and with the addition of temporal analysis of tree ages, denseness of the forest, recruitment of trees, growth patterns and signs of disturbance (cf. Lorimer 1985), provide very useful information for a broader analysis of the history of a forest or a forest landscape. The methods range from detailed surveys of all trees within a smaller plot (Hellberg et al. 2003), to surveys of randomly or systematically placed plots placed within a forest (Abrams and Orwig 1996; Piovesan 2005). In a study by Andersson et al. (2008), two methods, i.e., circular plots vs strip surveys, were tested to determine the best way to find specific unique trees (culturally modified trees) in a forest. Their results indicated that circular plots were more cost-effective for estimating abundance frequences, but smaller subpopulations of scarce CMT types, the strip-surveying method was superior.

The analysis of the living trees can be combined with a recording of logging stumps, logging roads, paths and archaeological remains (such as earthworks, boundaries or other types of artefacts) and other traces of human land-use within the plots (Orwig and Abrams 1999; Josefsson et al. 2010) and fire-scars (Van Horne & Fulé 2006; Huffman & Rother 2017), which add the dimension of human land use and natural disturbances. Moreover, systematic collection and archiving of samples through national forest surveys can also be used to cover regions (Andersson and Östlund 2004) or even countries (Basset et al. 2026). Surveys of forest is labour intensive in the field and subsequently in the lab when samples and data are analysed, and thus generally not suited for larger forests (but see Josefsson et al. 2010). Another problem is sometimes a too detailed focus on a particular forest and its history, rather than asking broader forest history questions, leading to less comparison and generality.

Especially old-growth forests have potential for unravelling forest history in a longer time perspective. In forests with long continuity, ancient live and dead trees provide unique opportunities to study the relationship between people and forests (Foster et al. 1996; Jönsson et al. 2009; Cagliero et al. 2022; Hauenschild et al. 2023). Interestingly and while there is often an assumption that old-growth forests are stable system, such studies often reveal a complex interaction between natural and low intense human disturbance as factor behind their current appearance (Foster et al 1996).

The strength of this method is that the spatial and temporal data can verify and complement data obtained from, for example, historical maps and aerial photos (Foster 1992). The field surveys provide an independent dataset, with a high spatial and temporal resolution. Field surveys also provide a unique arena for interdisciplinary collaboration in forest history. Forest ecologists and archaeologists both have the practice and experience of surveying sites, forests and landscapes in common. On the border between these two fields novel interdisciplinary studies of human action and ecosystem change can be achieved (Briggs et al. 2006; Scharf 2014). Furthermore, interesting discussions on forest history are, in our experience, more likely to happen outdoors in the field rather than indoors in offices or meeting rooms.

Figure 1 SI1: Field survey on culturally modified trees (CMTs) in western Patagonia, Chile (photo: Lars Östlund, SLU).

Figure 2 SI1: Establishing a rectangular inventory plot (50x50 m) to investigate tree-ages and spatial forest structure in the old-growth Tjeggelvas forest reserve (photo: Lars Östlund, SLU).

Figure 3 SI1: Measuring tree diameter at breast height (BHD) is a standard method to assess the forest structure (photo: Simon Speich, WSL/LFI).

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Tree rings – dendrochronology and dendroecology

Trees, in contrast to most other organisms, produce an annual record of growth. These tree rings can be analysed in a variety of ways, but in general they provide a spatially precise account for tree growth and forest stand dynamics (Schweingruber 2012). By coring trees with an increment borer (Figure SI2), extracting a sample, measuring the width of the tree rings, constructing a series of measurement from one or many trees, and then cross-dating the tree-rings (Larsson and Larsson 2022), the history of a tree or a forest can be analysed in detail. Since many trees are long-lived, tree-ring records can cover centuries and even millennia. In particular old-growth forests give opportunities to create long-term studies of forest history (Foster et al. 1996). In addition, dead trees on the ground, in mires or submerged in lakes can be included in a tree-ring chronology and extend it more than ten-thousands of years back in time (Friedrich et al. 2004). Dendrochronology also has the potential to bridge the gap between historical ecology and forest archaeology since both disciplines use this as a tool (Trouet et al. 2017).

Tree rings furthermore register environmental changes, such as nutrient availability (Bassett et al. 2026), pollution (Bindler et al. 2004) and water availability (Treydte et al. 2024). Another important historical application is that scars and marks on live or dead trees (usually named culturally modified trees or CMT's) can be dated with dendrochronological methods (Greenwood et al. 2025, Östlund et al. 2002). Typical examples are trail-blazes, border-marks and bark-peeling scars, inscriptions or marks on sacred trees (Östlund et al. 2002; Turner et al. 2009; Larson et al. 2019; Deur et al. 2020; O'Connor 2025). CMT's have been reported from many different forest ecosystems and have received attention both from forest historians, historical ecologists and archaeologists dure to their inherent value of giving a spatially precise of peoples relations to forests and trees (e.g., Östlund et al. 2002).

Fire, both natural and anthropogenic, is one of the most important disturbance agents in forest ecosystems during the entire Holocene (Klaminder et al 2024). Fire often leaves scars on the lower part of the tree, and these fire-scars give the possibility to date fires to year and sometimes season (Labrecque-Foy et al. 2025; Niklasson and Granström 2000). Blazes, marks and bark-peeling scars on trees can similarly be dated, and they provide important information of peoples use and movement in forests (Östlund et al. 2002).

Tree rings have the advantage that they records events which are rarely recorded in such detail in other records. For example, logging events, forest fires, bark harvest and grazing by domestic animals can be recorded far back in time and in a spatially precise manner. Also, the growth and decline of forests can be analysed very precisely and in relation to climate and human interventions (Dinca et al. 2025).

While tree rings and dendrochronology have many benefits, there are also limitations. Not all tree species produce clear annual rings, and some are difficult to analyse. A sufficient number of trees must be available for the specific aim of the study, and this might depend on the previous human intervention, fuelwood collection, logging etc, in the forest. There is a general problem of decreasing sample depth further back in time due to tree longevity and decomposition of woody material in forests (Kipfmueller and Swetnam 2001), but also methods have been developed to analyse and

overcome this problem (Šamonil et al. 2015). Each sample also provide data of one specific tree (i.e. place) within a forest and to understand the history and dynamics of a forest, many samples must usually be taken to give a representation of the entire forest. The technique is therefore labour-intensive and hands-on analysis of each sample is necessary in the lab, although scanning techniques have facilitated the analysis (Larsson and Larsson 2020). In conclusion, the spatial scale of tree-ring analysis can be somewhat limited. Furthermore, trees die, get stem rot and have been harvested selectively by people in the past. Therefore, gaps in the tree-ring record are common. To overcome this problem, and to include also hollow trees and trees with stem rot, several methods have been tested to date and estimate age of forests and trees (Baudet 2020).

Figure 1. SI2: F Coring tree in ancient Sámi forest North Sweden (photo: Anna-Maria Rautio, SLU).

Figure 2 SI2: Ponderosa pine (Pinus ponderosa) with charred fire-scar on the left-hand side and bark-peeling scar on the right-hand side, Fales Flats, Montana, USA (photo: Lars Östlund, SLU)

Figure 3 SI2: Fire scar on an ancient Scots pine tree dated to early Holocene (9500-9900 yrs BP), northern Sweden (photo: Lars Östlund, SLU).

Figure 4 SI2: Cross-section of a Scots pine showing dated fire-event. The tree started growing in 1379 and the fire event spanned 1477 and 1769. Sample from the province of Dalarna, northern Sweden (photo: Lars Östlund, SLU).

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Palaeoecological evidence – pollen and macrofossil analysis

Analysis of pollen and macro-fossils in peat of sediment stratigraphy's provide a powerful tool to analyse long term forest change at different spatial scales (Godwin 1934; Sanchez Goñi 2022). Pollen is then counted in the layers as they have been accumulated in the peat and sediment (Fig 1 SI3), and layers are dated by using ^{14}C-methods to provide a chronology. A special case are varved lake sediments which provide layers which can be interpreted as calendar years, recording annual changes in surrounding forests or forest landscapes. Often pollen-analysis is used to give a broad landscape view of forest cover spanning centuries or millennia (Rey et al. 2026), but also methods have been developed to study forests at a smaller scale. The method is rather time consuming since each sample core and each layer needs to be prepared and analysed (Fig 2 SI3) and the pollen from many different species or taxa must be counted individually (Fig 3 SI3). A challenge is also that not all tree species (or plants) produce pollen in a way that they can be analysed in a sample. Human impact in forests, such as clearing, changes of species, livestock grazing can be inferred directly through changes in the pollen assemblages or indirectly by analysis of indicator species (Franks 1957, Deza-Araujo et al. 2020). Macrofossils such as seeds, and pieces of plants have an advantage since they are preserved in situ and generally do not travel far by air (in contrast to pollen in general). Also, forest fire can be detected through charcoal layers in the peat or sediment core, either as macro-fossils (Stähli et al. 2006) or as airborne micro-particles (Hörnberg and Liedgren 2012). Furthermore, charcoal layers in sediments can be combined with analysis of fire-scars on trees and with analysis spores of pyrophilous fungal species to verify the accuracy of past fire-event reconstructions (Stivrins 2019).

Pollen analysis provides unique possibilities to lengthen the time perspective provided by other methods and to contextualize evidence from historical records or dendrochronology. Analysis of pollen and macro-fossils in peat of sediment stratigraphy's provide a powerful tool to analyse long term forest change at different spatial scales. This method has been used since the early 1900s to understand and document the history of vegetation for a variety of purposes and disciplines (Godwin 1934; Sanchez Goñi 2022). By combining pollen studies across larger regions, a broad spatial and temporal analysis of forest change, including deforestation and reforestation can be attained (Roberts et al 2018). This also provide a better understanding of the matrix of past forest landscapes ranging from nearly pristine to intensively altered by people, and how these landscapes have changed over very long time-periods. Such information is important for present and future forest conservation and management (Whitlock et al 2018).

This process allows for unique insight into the vegetation composition and shifts from the past, such as tracking species, disturbance events and tree refugia (Nieto-Lugilde et al. 2015). Using this technique, researchers can answer questions on broad timescales, as one study used pollen analysis to find vegetation shifts during the beginning of the Holocene, or approximately 11,700 years ago (Gordon et al. 2024). Further, this method can be utilized to reconstruct long-term fire and vegetation change histories for specific regions (Krikunova et al. 2024). Regarding accuracy, Nieto-Lugilde et al. (2015) found pollen estimates of vegetation turnover to be reliable when comparing fossil pollen data to long-term monitoring vegetation data in eastern USA. Human impact in forests, such as clearing,

changes of species, livestock grazing can be inferred directly though changes in the pollen assemblages or indirectly by analysis of indicator species (Behre, 1986). Forest fire can also be detected through charcoal layers in the peat or sediment core, either as macro-fossils (Greisman and Gaillard 2009,) or as airborne micro-particles (Malmgren and Franzén 2012). Pollen analysis is useful for its ability to provide a long record of events that can be cross-referenced using other methods. However, many studies discuss the challenge of resolution regarding pollen analysis and the need for calibration studies (Senn et al. 2022). One important facet is that of scale, particularly regarding where samples are taken. According to Overballe-Petersen et al. (2011), samples taken from a lake or bog will be at a regional scale, while samples for analyses at the local or stand scale need to be taken from a hollow or smaller source. Mitchell (1988) compared both and found the scale of the Killarney Oakwoods was too small to use a sample from a lake when compared to pollen data from a hollow. Additionally, the pollen composition found in analyses does not completely reflect the actual vegetation composition at the time as there is variability in preservation, dispersal and production across species. This requires calibration studies to investigate the relationship between the pollen present and the surrounding vegetation at the site of sampling and ensure conclusions from pollen data are drawn with limited influence by variability factors (Senn et al. 2022). Also, this method is rather time consuming since each sample core and each layer needs to be analysed and the pollen from many different species or taxa must be counted individually. However, there are some recent methodological advances, by using guided deep learning and automated pollen classification, which saves time in the analysis (Barnes et al. 2023). Another challenge is also that not all tree species (or plants) produce pollen in a way that they can be analysed in a sample.

In conjunction with other forest history methods, pollen analysis can serve as the main method of study or a supplementary means to provide context about what was occurring ecologically at a local, regional (Foster et al 2002) or global scale. Pollen analysis can answer questions that go back further than historical records, as Mitchell (1988) examined the extent of the Killarney Oakwoods in Ireland where there were only general descriptions going back to the 1600s, but no documented area encompassed by the Killarney Oakwoods. When paired with charcoal analyses, vegetation shifts can be explained with disturbance events, as Bradshaw and Zackrisson (1990) who found instances where birch declines in the pollen data corresponded with evidence of fire events in the charcoal analyses. In Poland, dendrochronological analysis was conducted on trees fossilised in a peat bog, and pollen analysis was then used to provide information regarding decreased annual tree ring growth and forest die off due to bad ecological conditions (Krąpiec et al. 2016). In conclusion, pollen analysis is a way forest historians can establish a historical record of ecological events at varying spatial scales that can be weaved alongside other methods to expand our understanding of the past. The analysis of sedimentary ancient DNA (sedaDNA) (e.g., Dommain et al. 2020) opens new possibilities to also reconstruction of local to regional vegetation changes. It remains to be seen, to what degree it will supplement, or even replace pollen analysis.

Figure 1 SI3: Sediment cores, up to 13 meters long, were taken from the Hüttwilersee, Canton of Thurgau, Switzerland, in November 2019 (photo from Heiri et al. 2024, reproduced with permission of the Thurgauische Naturforschende Gesellschaft TNG).

Figure 2 SI3: Before being analysed for e.g., pollen and macrorests, a sediment core taken from the Hüttwilersee, Canton of Thurgau, Switerzland is prepared and cleaned (photo from Heiri et al. 2024, reproduced with permission of the Thurgauische Naturforschende Gesellschaft TNG).

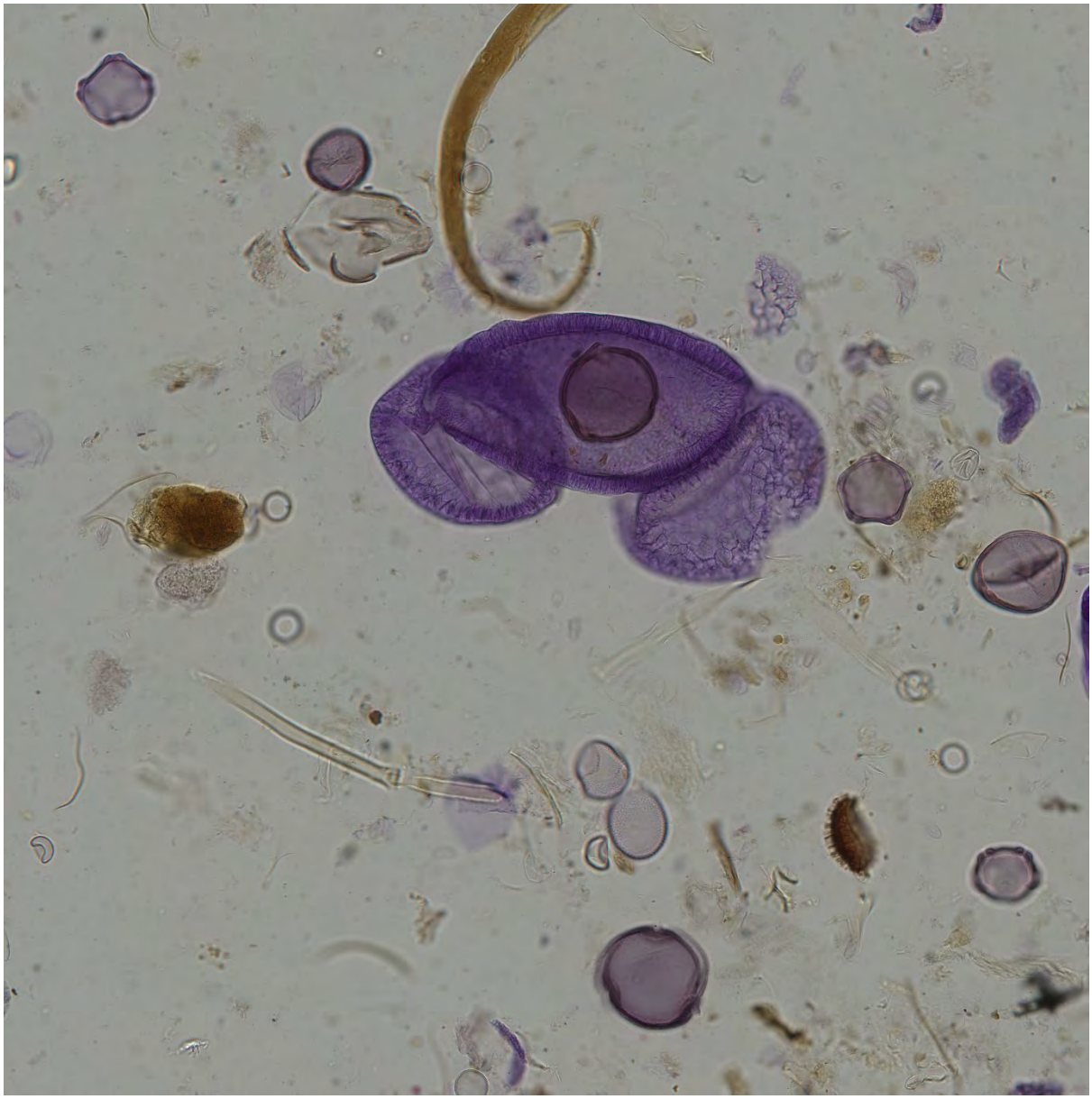

Figure 3 SI3: Pollen sample from the sediments of Burgäschisee, Switzerland (Rey et al. 2026), prepared for microscope analysis (400x magnification) (photo: Oliver Heiri).

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Documentary evidence – written records and maps

Forests are important features in everyday life of, especially rural, populations or of outsiders visiting a forested area. Both types of perspectives, i.e., the emic perspectives of insiders, and the etic perspectives from outsiders are expressed in various types of published and unpublished documents, including local histories, journal articles, letters, forest history diaries (Östlund & Sandberg 2005) etc. To be used in scientific projects, they must be interpreted using a source critical approach following the standards of historical research e.g., considering the historical context in which the document has been compiled and the writer's purpose and background (Edmonds 2001; Müllerová et al. 2012).

Important examples of early etic perspectives are traveler's reports, often compiled with an ethnographic approach and a focus on people in relation to forest ecosystem. Although not formally labelled as an ethnographer, Carl Linneaus did document forest-people relationships in his travels in Sweden in the early 18th century (Linné [1732] 1913). His way of studying nature (including forests) and people was rather influential and many early researchers followed his path in the 18th and 19th centuries. Some early ethnographers who were interested forests include James Teit. He worked primarily in western North America and his research and detailed accounts on several First Nations provide invaluable information on the use of forests, the state of the forest in the early 20th century and colonial perspectives of forest exploitation (see for example Teit 1898; Teit 1912).

Other types of documents, which tend to be of great use for forest history, include court records, or historical records of forest use, such as timber volume harvested, amount of litter collected, or other statistical records related to forest management. Where available, survey records, often consisting of descriptions and maps or at least topographical sketches, show forest conditions from an early settlement phase (Whitney and DeCant 2001), but are due to limited spatial resolution foremost useful for larger-scale studies.

The same holds true for topographic maps, as a differentiation between forested and non-forested areas allows for assessing continuity of ruptures in forest cover, but does not provide a more detailed assessment of changes in forest structure or forest type. Nevertheless, given the ecological importance of intact forest ecosystem (Watson et al. 2018) and habitat continuity, time series of high-quality topographic maps revealing changes in size and shape of forests can serve as a base to determine ancient forest species (e.g., Hermy et al. 1999) and provide input for forest preservation planning (Cillis et al 2021).

A different set of documents becomes important for analysing the dynamics of secondary forests, as their development is influenced by the type of intermediate land use practices, involving ploughing, pasturing, fertilizing and potentially resulting in different degrees of erosion. Here, information about land use taken from historical records is especially relevant, as e.g., in the classic study on history of land use in the Harvard Forest (Raup and Carlson 1941).

In sum, the type of records used largely depends on source availability (to state the obvious), but also long-term trajectory of the forest under study and if the focus of the study conducted is on reconstructing changes in forest structure, forest use or meaning of the forest for local population or society at large. Comparing different types of written records, e.g., contrasting emic and etic perspectives can be especially revealing and allows to better consider the writer's positionality and

bias. Not all stakeholder's perspectives had the same probability to be expressed in texts and consequently, a bias regarding education, gender, social power and status cannot be avoided but certainly must be considered and reflected in interpreting written records.

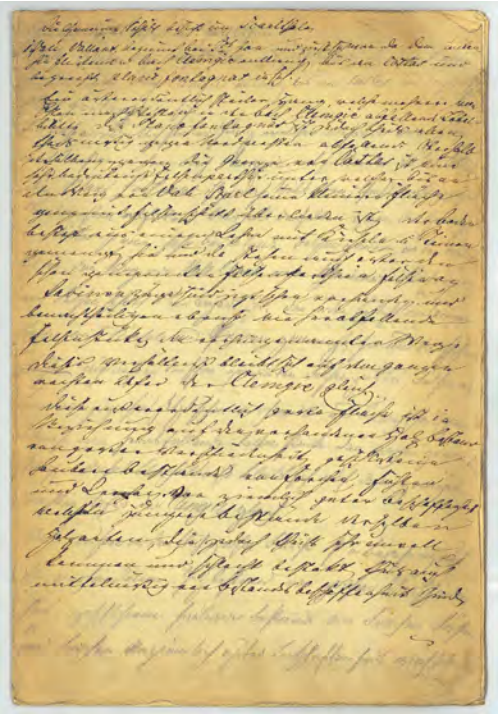

Figure 1 SI4: Excerpt of a forester's report on a forest in the upper Val S'charl, Lower Engadine, Switzerland ("Schuls Arven in Tamangur. Tabellen und Beschreibung". Archive of the Amt für Wald und Naturgefahren, Chur).

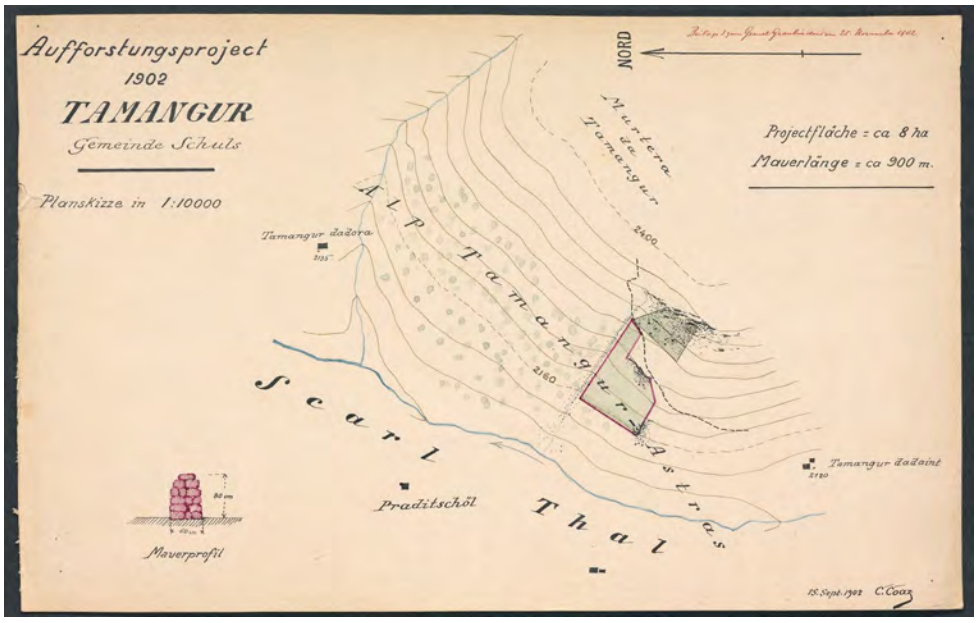

Figure 2 SI4: Map as part of a project dossier on a high-altitude afforestation with protective stone wall against grazing cattle in the upper Val S'charl, Lower Engadine, Switzerland (Schweizerisches Bundesarchiv, Bern. Signatur BAR E3270A#1967/30#1557*. Projekt 179: Tamangur-Astras, Gemeinde Schuls (1902-1923))

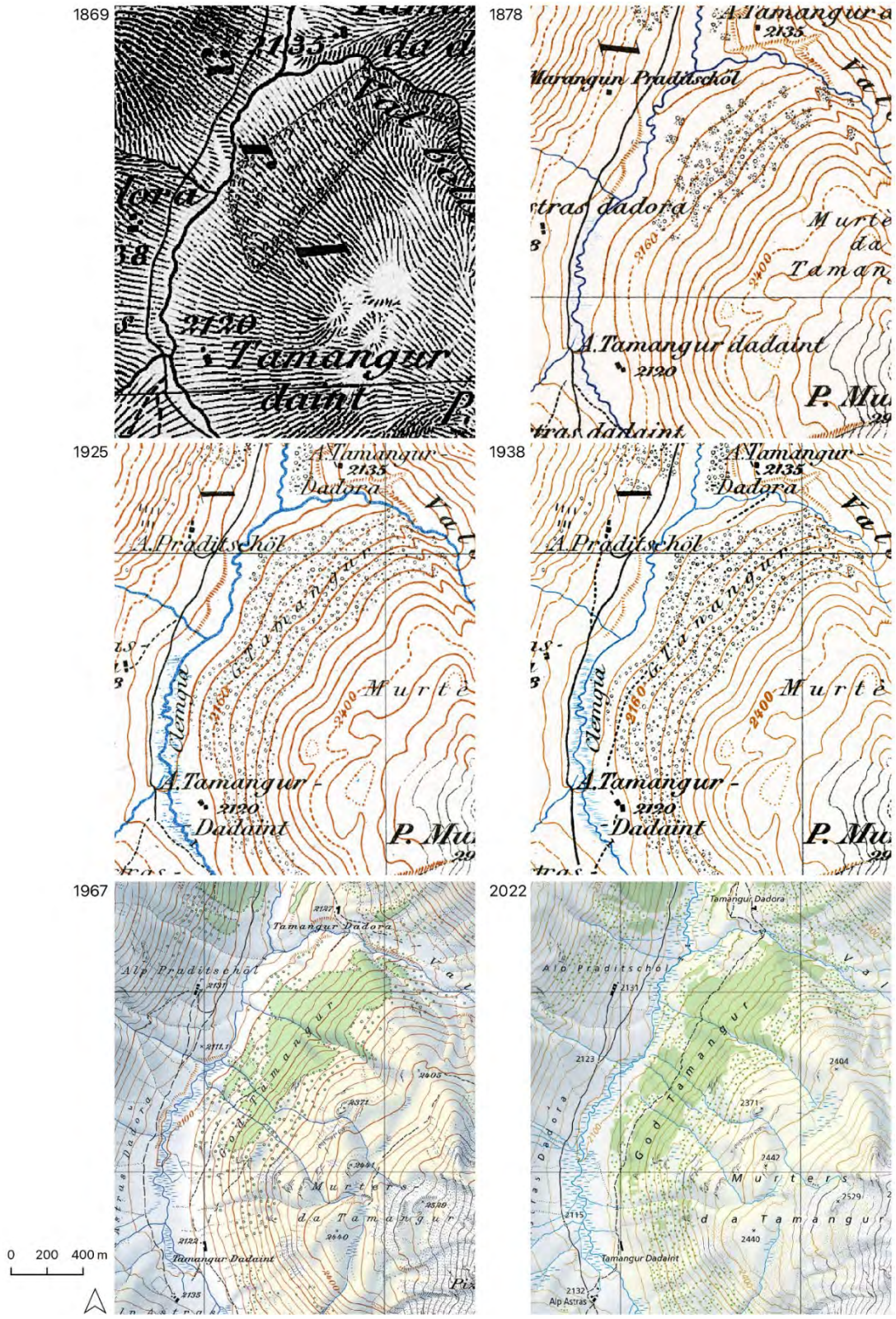

Figure 3 SI4: This series of excerpts from topomaps for the years 1869, 1878, 1925, 1938, 1967, and 2022 shows how forest “God da Tamangur”, located in the Lower Engadin, Switzerland, and its surroundings have been depicted on maps over time. © swisstopo/WSL (Bürgi and Lock 2025).

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Forest management plans – the forester's perspective

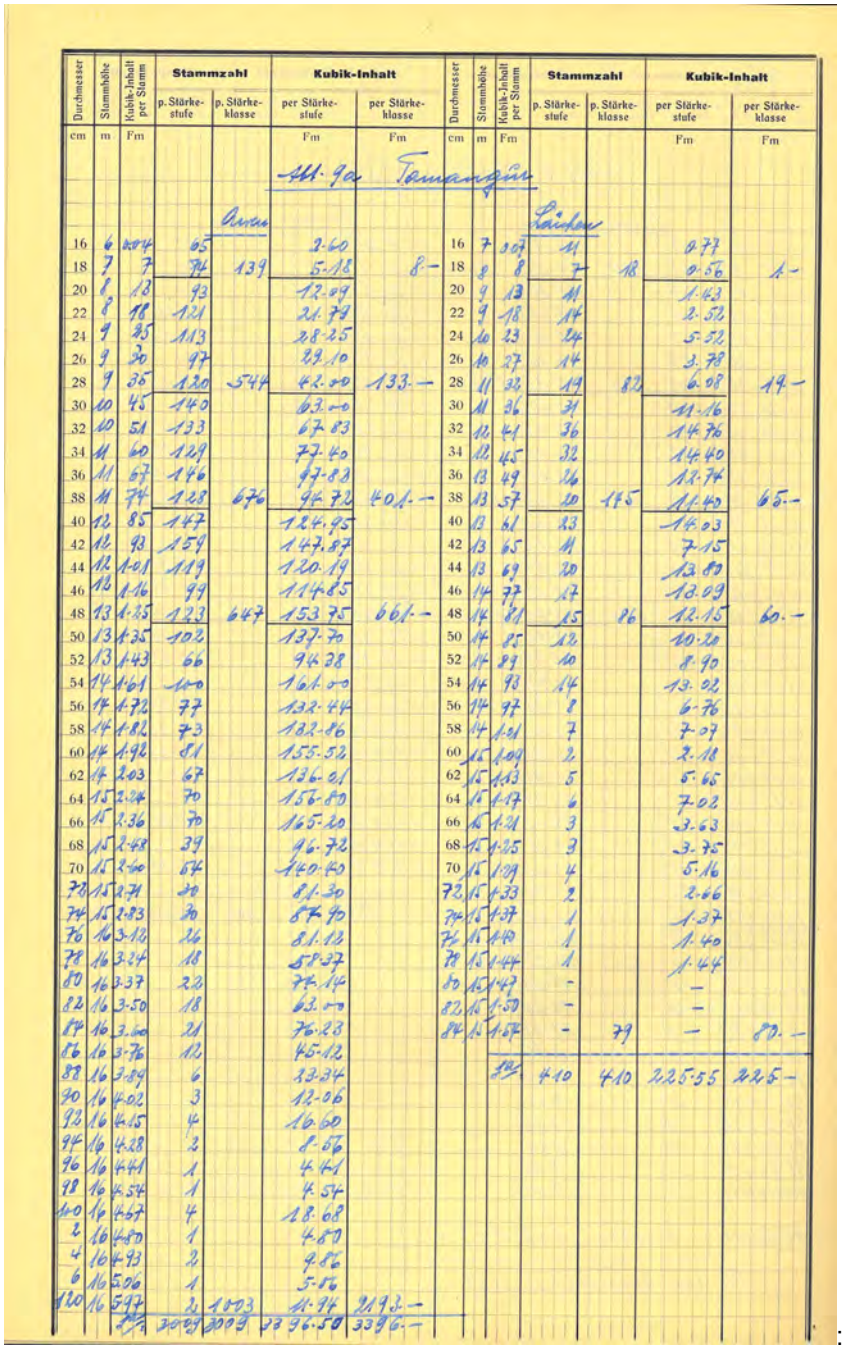
Forest management plans are a special type of documentary evidence which – if available – shows to be especially useful for forest history. Forest use and utilization of forests managed by administrative units, such as the state (forest service), concessioned logging companies, or private forest owners, is planned and controlled in standardized processes and documented in forest management plans. Such management plans were first developed in Germany in the 18th and early 19th centuries (Cotta 1817), a practice spreading quickly from there. These working documents typically contain a description of the environmental characteristics and potentially former use of the forest area, an assessment or inventory of the resources available, the description of foreseen management activities, and eventually records of e.g., the amount of timber harvested, are also updated as appendix to the plan. Additionally, often a detailed map of the forest compartments described is included (Figure SI5). Forest management plans, therefore, contain both quantitative and qualitative information. The structure and quality of these planning documents differ from place to place and changed over time. Early examples in Europe stem and contain foremost visual assessments and descriptions of forest use and forest structure. Since about 1920, standing timber inventories by full calipering have been increasingly part of these plans. Such inventories provide precise information on the growing stock, number of stems and dominant tree species in every stand and forest (Figure 2 SI5).

As they are revised and updated regularly (e.g., ten to twenty years), they allow for detailed reconstruction of stand development (timber volume, number of stems, tree species composition), special events (e.g., forest fires), management activities and intentions, etc. on the level of management units (Axelsson and Östlund 2001).

A source critical approach to forest management plans requires to consider the fact that these are planning documents used within forest administration. For the descriptive part and current forest use this means that for example illegal forest use practices, or activities which are not in line with official management regulations or rules, might not be reported in adequate ways. For the quantitative part, changes in methods applied for measuring trees and conducting forest inventories have to be considered. This includes changes from visual assessments to full inventories or later on potentially again inventories based on sampling plots. Increasingly, automated assessments using remote sensing techniques are being used, further limiting the comparability of the data over time. An additional complication arises from the fact that most data is collected and reported per management unit, whereby the division of a forest into these management units can change over time and the methods of assessing, such as minimum diameter of trees measured, often also experienced some changes. Furthermore, forest management plans must be analyzed with source critical methods established in the historical profession (Östlund et al. 1997; Ernst 2000). These include verification and assessing the origin and the real purpose of the forest management plan and contrasting these sources to other available sources.

Provided that an adequate way of dealing with these limitations can be found, forest management plans are extremely valuable sources for reconstructing the spatial and temporal development of forest stands. Examples from Switzerland (Bürgi 1999), Sweden (Axelsson et al. 2002), Slovenia

(Boncia et al. 2003), Hungary (Tanács et al. 2007), France (Rochel 2016) and Canada (Danneyrolles et al. 2025) show the diversity of applications and relevance of this source for assessing forest dynamics.



Durchmesser	Stammhöhe	Kubik-Inhalt per Stamm	Stammzahl p. Stärkestufe	Stammzahl p. Stärkeklasse	Kubik-Inhalt per Stärkestufe	Kubik-Inhalt per Stärkeklasse	Durchmesser	Stammhöhe	Kubik-Inhalt per Stamm	Stammzahl p. Stärkestufe	Stammzahl p. Stärkeklasse	Kubik-Inhalt per Stärkestufe	Kubik-Inhalt per Stärkeklasse
cm	m	Fm			Fm	Fm	cm	m	Fm			Fm	Fm
					111.90 Tamangür								
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16	6	0.84	65		2.60		16	7	0.97	11		0.77	
18	7	7	74	139	5.18	8.–	18	8	8	7	18	9.56	1.–
20	8	13	93		12.09		20	9	13	11		1.63	
22	8	18	121		21.78		22	9	18	14		2.52	
24	9	25	113		28.25		24	10	23	24		5.52	
26	9	30	97		29.10		26	10	27	14		3.78	
28	9	36	120	544	42.00	133.–	28	11	33	19	82	6.98	19.–
30	10	45	140		63.00		30	11	36	31		11.16	
32	10	51	133		67.83		32	12	41	36		14.76	
34	11	60	129		77.40		34	12	45	32		14.40	
36	11	67	146		97.83		36	13	49	26		12.74	
38	11	74	128	676	94.72	401.–	38	13	57	20	125	11.40	65.–
40	12	85	147		124.95		40	13	61	23		14.03	
42	12	93	154		143.87		42	13	65	11		7.15	
44	12	1.01	119		120.19		44	13	69	20		13.80	
46	13	1.16	99		114.85		46	14	77	17		13.09	
48	13	1.25	123	647	153.75	661.–	48	14	81	15	86	12.15	60.–
50	13	1.35	102		137.70		50	14	85	12		10.20	
52	13	1.43	66		94.38		52	14	89	10		8.90	
54	14	1.61	100		161.00		54	14	93	14		13.02	
56	14	1.72	77		132.44		56	14	97	8		6.76	
58	14	1.82	73		133.86		58	14	1.01	7		7.07	
60	14	1.92	81		155.52		60	15	1.09	2		2.18	
62	14	2.03	67		136.01		62	15	1.13	5		5.65	
64	15	2.24	70		156.80		64	15	1.17	6		7.02	
66	15	2.36	70		165.20		66	15	1.21	3		3.63	
68	15	2.48	39		96.72		68	15	1.25	3		3.75	
70	15	2.60	54		140.40		70	15	1.29	4		5.16	
72	15	2.71	30		81.30		72	15	1.33	2		2.66	
74	15	2.83	30		84.90		74	15	1.37	1		1.37	
76	16	3.12	26		81.12		76	15	1.40	1		1.40	
78	16	3.24	18		58.32		78	15	1.44	1		1.44	
80	16	3.37	23		77.14		80	15	1.47	-		–	
82	16	3.50	18		63.00		82	15	1.50	-		–	
84	16	3.62	21		76.23		84	15	1.54	-	79	–	80.–
86	16	3.76	12		45.12								
88	16	3.89	6		23.34					410	410	225.55	225.–
90	16	4.02	3		12.06								
92	16	4.15	4		16.60								
94	16	4.28	2		8.56								
96	16	4.41	1		4.41								
98	16	4.54	1		4.54								
100	16	4.67	4		18.68								
2	16	4.80	1		4.80								
4	16	4.93	2		9.86								
6	16	5.06	1		5.06								
120	16	5.97	2	1003	11.94	2193.–							
			3003	3003	9396.50	3396.–							

Figure 1 SI5: Tabulated inventory of all trees above a diameter of 16 cm in the section 9a of the forest of “Tamangur”, in the upper Val S’charl, Lower Engadine, Switzerland. Due to the great number of high-diameter trees, the forester had to extend the table to include trees of diameters up to 120cm (Archiv Amt für Wald und Natur Graubünden, Wirtschaftsplan über die Waldungen der S-charler Alpen der Gemeinde Scuol pro 1934/35).

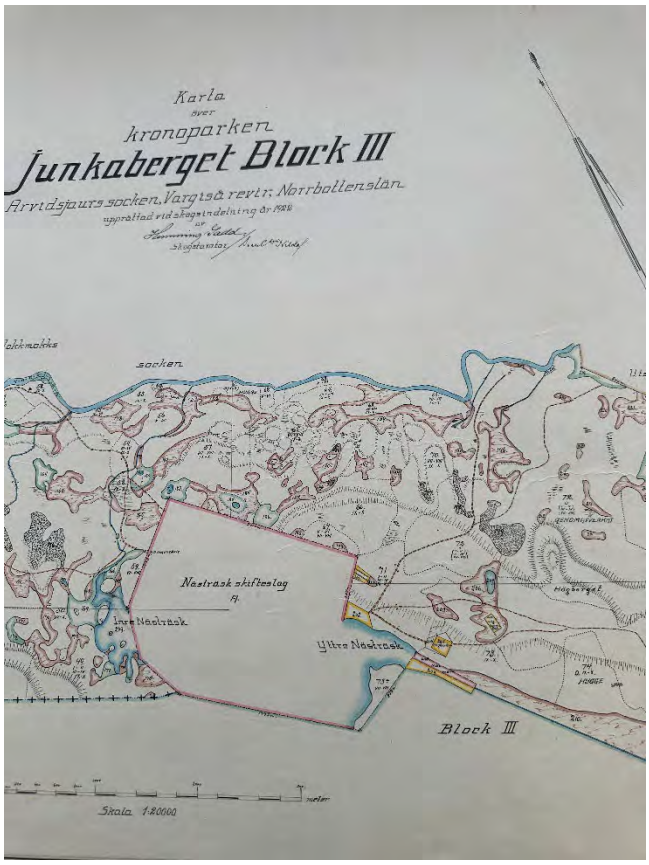

Figure 2 SI5: The fact that forest management plans often come with a detailed stand map, makes this source type especially valuable for stand level forest histories (Forest inventory map Junkaberget North Sweden early 20th century. Domänverket (the National Forest) archive at the National Archive, Sweden).

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Remote sensing – history of forests in a larger perspective

Many types of evidence pertain to specific and spatially limited forests and/or are restricted to the forest per se, excluding the larger landscape and elements which are enclosed in or surround the forest. There is therefore often beneficial to use remote sensing to analyse the history of forest landscapes. The area of interest of a historical remote sensing analysis can be variable, and a particular forest can be studied in a larger context. A further benefit is that remote sensing data often provides a possibility to visualize, by sequences of maps, trajectories of change of forest landscapes over time. The downside of remote sensing in forest history is the somewhat limited time-range. Data-series are most often covering decades, rather than centuries. Another problem is varying accuracy between different datasets and the degree of detail visible in the data, which limits interpretation. Furthermore, verification can be difficult.

One of the first usable remote sensing data sources are aerial photography from the early 1900's. The image quality became successively better in the 1940's and after that it is often possible to acquire images of high-quality in a sequence until present time (Piemattei et al. 2026). In these photos individual trees can be discerned and even the approximate height of trees can be measured if stereo image data is available (Næsset 2002). Extent of forest in a landscape (Fensham and Fairfax 2002), species composition (or at least separation of deciduous and conifer trees), impact of forestry operations such as selective logging and clear-cutting (Lundmark et al. 2021), and denseness of forests in relation to fire disturbance (Lydersen and Collins 2018), can be followed over time by analysing successive aerial photographs. A few interesting forest history studies exist where aerial photos are combined with other methods. One such example has been done to validate aerial photos with dendrochronology in wetland forest stands, which give a possibility to increase the precision in the analysis (Linderholm and Leine 2004). Another example is a novel combination of dendrochronological analysis and Bayesian inference analysis to overcome the problem of how to compare low-quality older aerial photos with high-quality recent aerial photos (Kulha et al. 2018).

Satellite-imagery became more readily available for the forest research communities in the 1980's (Holmgren and Turesson 1998). The use of satellite data received a boost with the opening of the USGS Landsat Archive in 2008 and the launch of the European Copernicus Program in 2015. Also, in this case image quality and availability has improved dramatically over the years. One of the main uses of satellite imagery has been to track deforestation rates in different forest landscapes (Green and Sussman 1990; Goebel et al. 2025). Also, satellite images can be combined with aerial photos to construct longer time-series of forest change in larger landscapes (for example analysing deforestation rate and scale) (Scales 2011).

LIDAR (Light Detection and Ranging) is a more recent remote sensing method which has been applied to forest landscapes during the last ca 20 years. As opposed to the other remote sensing methods, LIDAR provides a high-resolution 3D-model of the forest and where the 3D point resolution can vary depending on the intensity of the laser pulses sent out. Individual trees as well as a 3D model of the terrain can be analysed and presented. While this method has been used only during a rather short period of time, and therefore has a shorter temporal span, it provides other important opportunities. LIDAR can be used to detect cultural objects or ditch and drainage networks in forest

ecosystems and give a spatial understanding of past land use. For example, such diverse objects as hunting pits (Lidberg et al. 2024; Rimpi 2025), charcoal kilns (Žižlavská and Herber 2025), and large ancient monuments hidden under tree canopies (Vinci and Bernardini 2017), can be detected and (subsequently protected from forest operations). LIDAR furthermore open possibilities to merge analysis of important cultural objects hidden in forests, such as charcoal kilns, with analysis of associated forest structures (Garbarino et al. 2022).

Figure 1 SI6: PhD-student Elle Eriksson flying a drone to investigate the historical pattern in reindeer herding landscape pattern in Varjisån Ecopark northern Sweden. The current drone images are compared with historical forest management maps (photo: Lars Östlund, SLU).

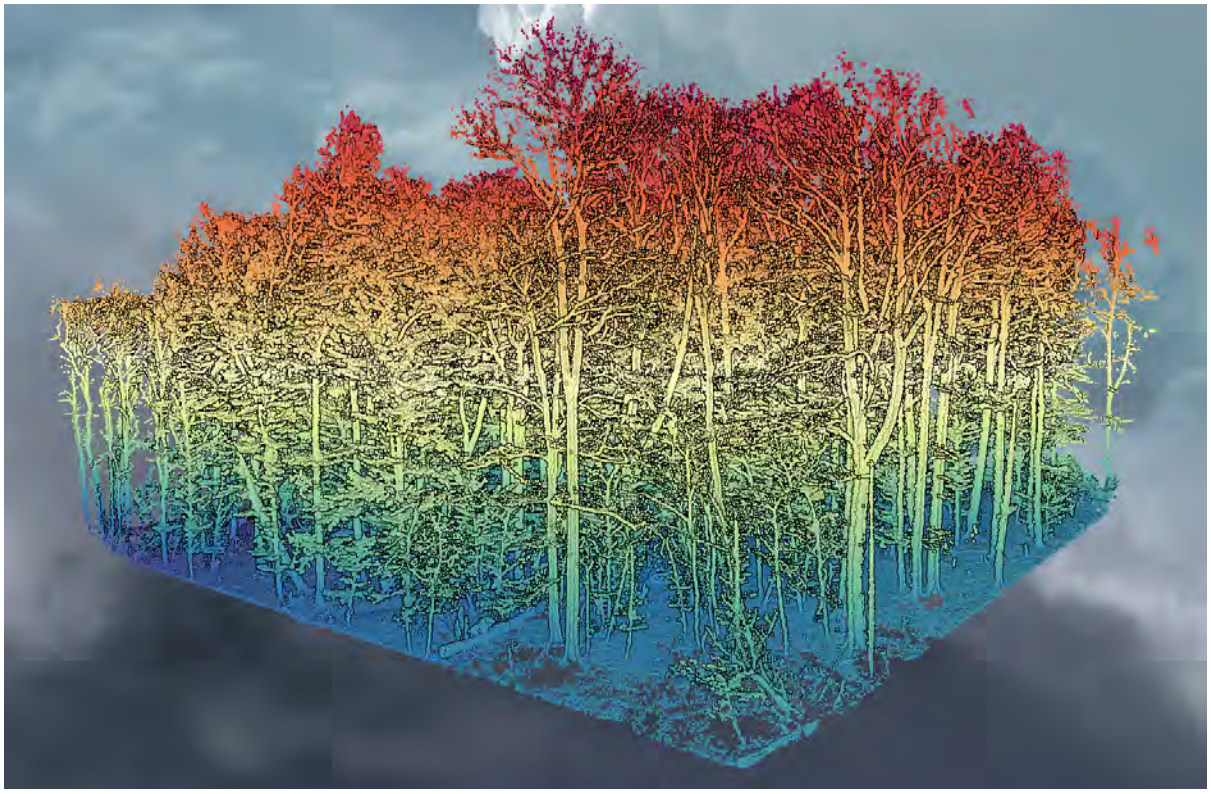

Figure 2 SI6: High resolution 3D point cloud of a forest stand, acquired with a combination of terrestrial and drone laserscanning (Christian Ginzler, WSL).

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Pictorial sources – looking at the forest

Apart from aerial photographs, forest history draws on a variety of other pictorial sources. Artwork and historical paintings have been used to explore historical forest use and forest structure (e.g. Camilli et al. 2026), despite they are not primarily intended to depict historical forest conditions accurately. Instead, they offer artistic interpretations, which limits their value as sources for reconstructing forest development. From the mid-19th century onwards, historical terrestrial photographs, become increasingly available, showing the structure of forests from a human perspective. Two main types can be distinguished: In mountainous areas, they often show the forest structure from the opposite slope perspective, thus extending the aerial image time series further into the first decades of the 20th century (e.g., Rhemtulla et al. 2002). Terrestrial photographs taken from within the forest provide detailed information on tree composition and structure but also ground vegetation and regeneration. Despite (historical) photography provides a much more accurate representation of the forest structure compared to historical paintings, the information in both types of pictorial sources is heavily shaped by the perspective the painter or photographer decides to show. Unless if used in combination with other source types, there is no way of assessing the representativity of the view shared by the producer.

One way of enhancing the documentary value of historical photographs is by conducting repeat photography (Webb et al. 2010, Figure SI7), which includes visual and descriptive approaches as well as more quantitative and automated assessments of the visible changes. The Forest Service of USDA used repeat photography extensively to systematically monitor for example management on rangeland development (Prevedel et al. 2005), management of a ponderosa pine forest (Smith and Stevens 1999) or landscape development of wilderness areas (Skovlin et al. 2001).

However, due to lacking documentation, re-finding the same location, especially if taken within a forest stand, can be tedious. Sometimes, emblematic trees and perspectives which include some view on objects in the distance, such as mountain ranges, facilitate the task.

Despite limited by availability of historical photographs, lacking documentation on location and year and challenges for conducting repetitions, repeat photography offers ground-based insights into forest dynamics and – being attractive to a larger public - proves especially valuable for outreach activities and participatory processes (Bürgi et al. 2026). Furthermore, historical photos or artwork provide an opportunity to complement data with a visual image of a specific forest at a certain time and thus facilitating a better understanding of the forest history.

Figure 1 SI7: Repeat photography available provides (yet anecdotal) insights into persistence and dynamics of forest stands. On rare occasions, especially for emblematic and well-known forest stands, they can even be available from more than two time points, providing a more detailed picture of the dynamics. Example from the forest “God da Tamangur”, lower Engadin, Switzerland (Bürgi and Lock 2025) (photo top: “Oberste Arve im Wald Tamangur”, E. Muret, 1902 (published in Coaz and Schröter 1905). middle: Ruedi Zuber, Chur, 1987. bottom: Susan Lock, WSL, 2023).

Figure 2 SI7: Pre-industrial Scots pine forest, northern Sweden. An open multi-storied fire-regenerated forest typical for northernmost Sweden and before forest exploitation and modern forest management (photo archive at the Forest library at the Swedish University of Agriculture).

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Oral history interviews and forest ethnography – stakeholders' memories

"Forest ethnography" has recently been promoted for the study of the dynamics in structure and functions of urban forests, conceptualized as socio-ecological phaenomena (Ogden et al. 2019), but also applied in a study on a National Park (Nebasifu et al. 2025). Ethnographic research provides a culturally sensitive, in-depth understanding of the relationship between communities and their forests. It is however usually very time consuming and the findings, due to its inherent subjectivity and place-specificity, hard to generalize – which, depending on the objective pursued, does not have to be an aim of forest historical studies anyway.

An important element of forest ethnographies are interviews with time witnesses, i.e., Oral History Interviews (OHI). OHIs were traditionally part of anthropological methods, before in the 1940s, American historians began using them to fill information gaps due to incomplete official documentation in federal archives (Wierling 2003). Over the last 30 years, OHIs have increasingly been used in various interdisciplinary approaches such as studies on land use and landscape change (e.g., Riley and Harvey 2007). A prominent application of OHIs in the forest history context, is the Forest History Society's oral history collection, including more than 250 OHIs collected since the 1940s with "individuals involved with the management and use of forests and their related resources" (https://foresthistory.org/research-explore/oral-history-interview-collection/). This reflects the core strengths of OHIs, i.e., providing firsthand information from people on topics such as specific land use practices, perceived changes in forest structure or historical events, such as fires, windthrow or other types of disturbances, their effect of the forests and management measures taken.

We distinguish between expert interviews, which focus on specific aspects of land use, and narrative interviews, which are more exploratory (Wierling 2003). Finding interview partners is greatly facilitated by local knowledge, existing contacts and cooperation with study partners or institutions, such as local history societies, professional associations and city councils. Depending on the target group requirements, additional interviewees can be found using snowball sampling thereafter. Basic knowledge of social science approaches is strongly recommended if oral history information is collected (Moon and Blackmann 2014) Preparing, documenting and postprocessing OHIs has to be considered early on in the project, as well as in which setting the interview will be conducted (e.g., outside as proposed by Riley and Harvey 2007), and extra care has to be given to privacy and data protection issues.

The temporal depth for which information can be obtained by OHIs, is limited by the age of the interviewees available and their ability to remember – be it first-hand experiences, or (with some caution) their knowledge of the experiences of the former generation. It is a rather time-consuming technique, which is also limited by the fact that memory is resulting from individual perception and remembering interacting with societal discourses.

A key strength of oral history interviews (OHIs) is that they provide a bottom-up perspective complementing other historical sources, which only depict what was considered important by the issuing authority. This is particularly important in terms of social justice, as it enables the voices of those who have been marginalised to be recognised and considered. Additionally, OHIs are especially valuable where no other historical sources are available (Mohr et al..2023). Furthermore, most

documentary evidence of forests has been collected by men, giving a gender skewed picture of past forest use. By OHIs, a better balance can be obtained (Östlund et al. 2020).

Figure 1 SI8: Young woman working as cook in a logging cabin in the early 20th century, northern Sweden (photo archive at the Forest library at the Swedish University of Agriculture).

Figure 2 SI8: Two young women working in a logging camp in northern Sweden in the early 20th century (photo archive at the Forest library at the Swedish University of Agriculture).

Figure 3 SI8: Gertrud Lundmark (Älvsbyn, northern Sweden) who worked for several years as a cook in a logging camp in her youth. Interviewed about her experiences for a research project (Östlund et al 2020) (photo: Gerd Aurell).

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