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Availability and Consumption of Wooden Resource for the Construction of Late Medieval Roof Structures in Finland

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Availability and Consumption of Wooden Resource for the Construction of Late Medieval Roof Structures in Finland

FRANZISKA DALHEIMER & TUOMAS AAKALA

Introduction¹

Cultural interest in Finland's medieval stone churches arose in the early 1870s,² and several individual art-historical studies were published regarding the dating and the regional types of these structures during the following decades.³ Emerging archaeological fieldwork beginning in the 1920s contributed to the research on medieval architectural history through findings of preceding wooden church buildings and theories on construction sequences.⁴ During the following decades, Markus Hiekkanen's extensive scientific work in particular shaped the understanding of Finnish stone churches that we now possess. Additionally, new methods such as dendrochronological dating were introduced in the 1980s and the medieval timber roof structures of stone churches contributed to the establishment of a Finnish dendrochronological database for Scots pine (*Pinus sylvestris*).

The last two decades have witnessed an intensified investigation into the timber roof structures in late medieval stone churches in Finland, first in connection with restoration projects, followed by detailed multidisciplinary field research.⁵ At least 20 remaining original large-scale wooden roof structures have survived the past 550 years, and they represent the last still standing medieval structural timber in Finland's built environment. This allows a shift in the attention from church interior and facades to the marvels of medieval wood construction in the attics. The latest research results on structural principles, especially those of the roof structures of the medieval stone churches of

¹ We would like to express our gratitude to Ilari Aalto (University of Turku) for complementing and cross-referencing the structural members' length through total station survey.

² Anssi Mäkinen and Kimmo Taskinen, *Kivokirkot: Matka keskiajan katoliseen Suomeen*, Kustannusosakeyhtiö Tammi: Helsinki 2019, 24.

³ Emil Nervander, *Sommarresor i Finland: På Åland och i Åbo-trakten*, Frenckell: Helsinki 1872, 43; Eliel Aspelin, *Suomalaisen taiteen historia pääpiirteissään*, Suomalaisen Kirjallisuuden Seura: Helsinki 1891, 7–8; Karl Konrad Meinander, *Konsten – Finlands kulturhistoria: Medeltiden*, M.G. Schybergson and P. Nordmann: Helsinki 1908, 146–7.

⁴ Iikka Kronqvist, 'Die mittelalterliche Kirchenarchitektur in Finnland – I. Die Anfänge', *Jälkeenjääneitä tutkielmia* XLVIII (1948), 7–30, at 13.

⁵ Panu Savolainen, Laura Laine and Ilari Aalto, 'Keskiaikaisten kattoristikoiden salat avautuvat', *SKAS* 1 (2020), 54–63, at 57.

Pernaja and Hammarland,⁶ are helping to bring Finnish research abreast of the decades of systematic research work already done in other Nordic countries. It even makes a broader international research comparison on Gothic rafter foot roof trusses and Romanesque roof trusses possible, for example with England, Germany, France, and Romania. Furthermore, detailed case studies have been published on the origin of the building master of Pernaja church⁷ and the interpretation of the church account books of the Old Church of Keminmaa was connected with other archaeological evidence, such as timber carvings.⁸ Those contributed not only to new insights into structures and construction methods, but also to the perception of medieval communities in Finland.

Two other notable examples of such medieval timber structures are found in the St. Olaf's church in Ulvila and St. Henry's church in Pyhtää. This article provides a new analysis approach to examining this wooden built heritage, combining previous research on both stone churches' settlement history, as well as the dendrochronological dating of the timber and regional vegetation history with a field work study including surveyed measurements of the nave's structural timber members, their physical appearance and a microscopic identification of 66 wood species samples. This approach brings together the church surroundings, its naves, their members and their microscopic analysis. As a result, this research aims to reveal new insights into the local resource availability and consumption of wooden material for major medieval construction projects in Finland. The purpose is to strengthen the still-emerging field of medieval wooden building archaeology in Finland through a multidisciplinary research approach. The present-day significance of this research is gaining a deeper comprehension of the exceptional manual labor of Finnish late medieval communities as well as shedding new light on long-lasting structural building solutions. The research scope has been narrowed to the structural church naves timber in the case studies, due to the on-site accessibility and the difference in felling dates of the timber. Additionally, temporary holders, roof covering, and possible scaffolding were excluded from the scope.

St. Olaf's church in Ulvila & St. Henry's church in Pyhtää

The stone churches of Ulvila and Pyhtää were built under the auspices of the Diocese of Turku, which stretched from central western Finland to southern Finland. Both churches are located in the south of present-day Finland, Ulvila with access to the Baltic Sea and Pyhtää close to the Gulf of Finland (Figure 1). The construction of permanent stone churches emphasizes the consolidation of the Catholic faith and increased building duration due to fire safety in equal measure, compared to the previous tradition of wooden churches. Although the initiators of the construction projects were likely representatives of the church and members of the nobility, the local peasant community usually provided the labor and cost-intensive basis.⁹ Two examples of church building projects that

⁶ Panu Savolainen, Liisa Seppänen, Laura Laine, Marko Huttunen and Tuomas Aakala, 'Revealing the innovations in late medieval roof structures of Finland', *International Journal of Wood Culture* 3 (2023), 65–85, at 80.

⁷ Panu Savolainen, Tuomas Aakala, Marko Huttunen, Laura Laine, Mia Puranen and Pauliina Saarinen, 'Itä-Uudenmaan keskiaikaisten kivikirkkojen kronologia ja rakennusvaiheet: Erityistarkastelussa Pernajan Kirkko', *SKAS* 2 (2020), 21–36, at 21.

⁸ Panu Savolainen, Laura Laine, Elina Wirkkala, Lauri Saarinen and Marko Huttunen, 'Historiallisen arkeologian näkökulma uuden ajan alun kivikirkkoon: Tapaustutkimus Keminmaan Vanhasta Kirkosta', *SKAS* 2 (2018), 40–64, at 57.

⁹ Markus Hiekkänen, *Suomen kivikirkot keskiajalla*, Otava: Helsinki 2003, 29.

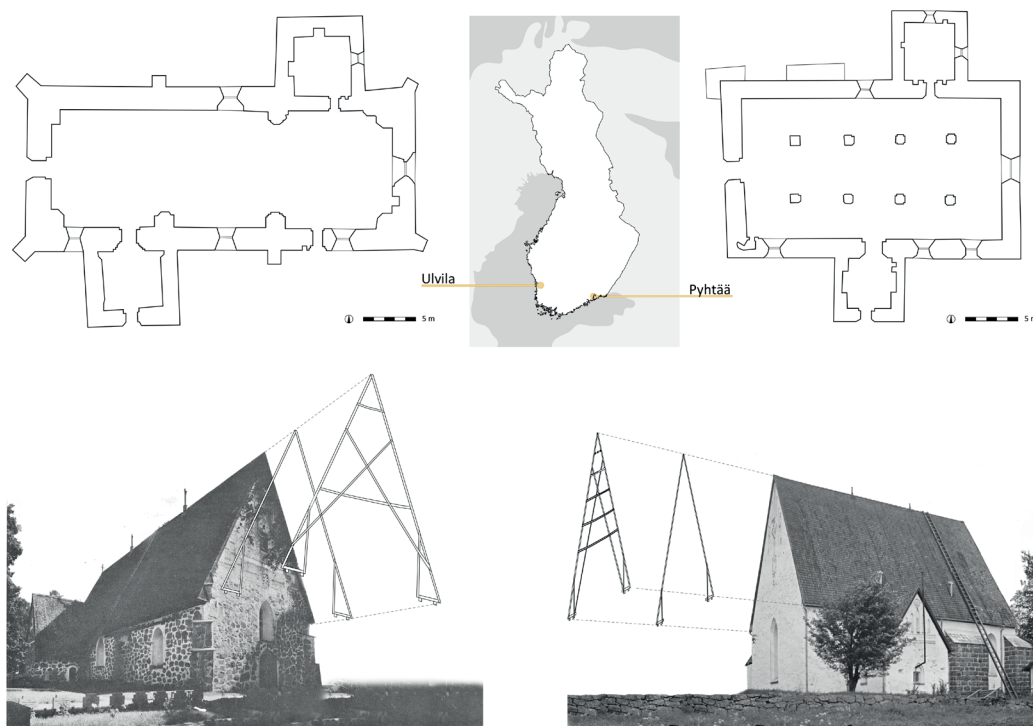


Figure 1. Ulvila church (left) and Pyhtää church (right) location in current-day Finland with their floor plans and roof truss scheme. Map: Franziska Dalheimer. Floor plans: Franziska Dalheimer, based on Hiekkänen 2007, 266, 464. Photograph of Ulvila church: Sven Raita, 1955, Satakunta Museum's collections. Photograph of Pyhtää Church: unknown author, 1926, Finnish Heritage Agency. Both photographs modified by Franziska Dalheimer.

have been carried out this way are the town of Ulvila with its marketplace and the parish of Pyhtää with its numerous distant villages.

There are several similarities in the churches, location-wise and regarding the layout, size, age, and roof typology. The orientation in the landscape is typical for late medieval Finnish stone churches with the gables facing West and East and the sacristy oriented to the North.¹⁰ The dendrochronological dating of both nave roof structures date the churches back to the Finnish Late Middle Ages with the trees felled between 1500–1501¹¹ in Ulvila and 1461–1462¹² in Pyhtää. Both nave structures belong to a type of rafter foot roof (Gothic) without a tie beam.¹³ The external stone wall dimension of Ulvila is 36.9*14.9 m, which is around 10 m longer than Pyhtää church outside wall measurements with 27.8*16.5 m.¹⁴ The difference in length is also reflected in the number of

¹⁰ Markus Hiekkänen, 'Near but far: Finnish and Estonian church architecture in the Middle Ages', *Suomen museo* 98 (1991), 15–41, at 25.

¹¹ Pentti Zetterberg, *Uvilan Pyhän Olavin kivi­kir­kon puurakenteiden sekä puisen nostolaitteen ja kuoripenkin iänmäärittäminen*, Joensuun yliopisto: Joensuu 2003, 1.

¹² Pentti Zetterberg, *Pyhtään kirkon keskiaikaisten puurakenteiden dendrokronologisten ajoitusten seloste*, Joensuun yliopisto: Joensuu 1991, 1.

¹³ Savolainen et al. 2023, 71.

¹⁴ Markus Hiekkänen, *Suomen keskiajan kivi­kir­kot*, SKS: Helsinki 2007, 267 and 465.

trusses. There are altogether 34 nave trusses in Ulvila church, including four trusses without scissor beams and collar beams in the gable walls (Figure 1). Pyhtää church has 22 nave roof trusses, including two of them in the gable wall. Both churches had at least one wooden predecessor at the same location.¹⁵ The similarities between the two churches provide an incentive for a comparison of their wooden resource consumption and availability during the building process. Despite their similarities, differences in the settlement history of the town of Ulvila and the parish of Pyhtää may suggest varying demands for wooden building materials.

Consumption of wooden resources

The original medieval roof structures provide information on the resource consumption during the construction phase. This section begins with a reconstruction of the volume and weight of the whole nave structure by surveying each structural member, grouped in member types (Figure 2), and subsequently scaling the weight and volume up to one whole roof truss. The weight can only be determined through the identification of the used wood species, which can be used to infer the preferences of the builders or the availability of certain wood species. Lastly, the physical appearance of the timber members reveal insights into its manufacturing process and can be used to reconstruct the original dimensions of the used trees.

The weight of the nave's roof structure of both churches can be estimated based on the identified wood species, their densities and surveyed measurements. The most typical building materials for late medieval roof structures were Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*),¹⁶

¹⁵ Markus Hiekkänen, 'Ulvilan kirkko ikä', *Sarka: Satakunnan Museon Vuosikirja* (2000), 20–39, at 22–4; Hiekkänen 2007, 464.

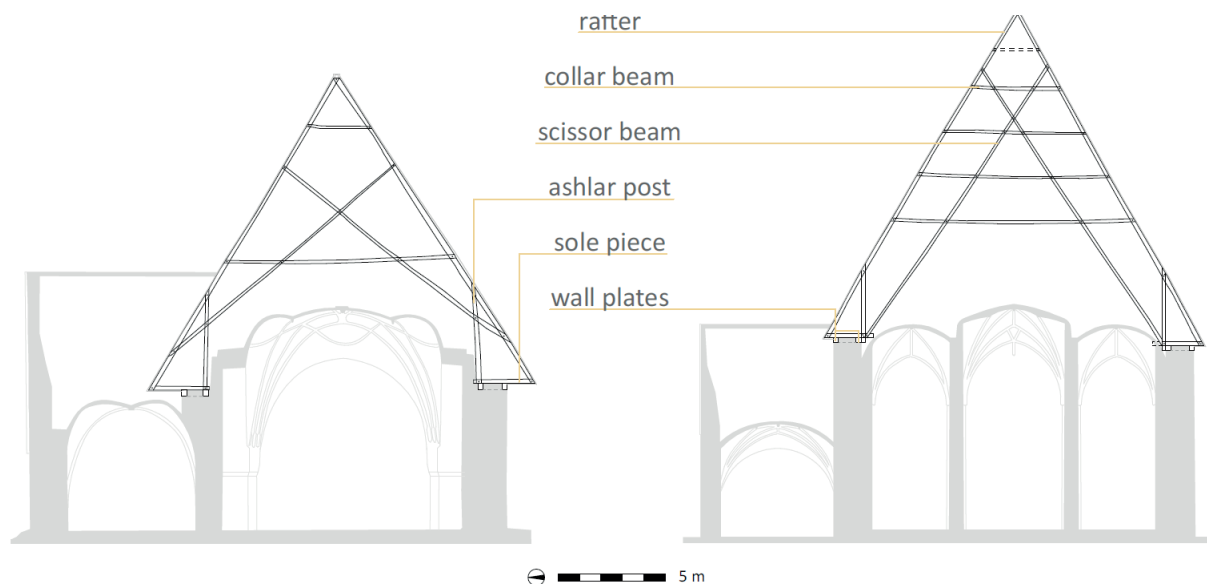


Figure 2. Nave roof structures of Ulvila church (left) and Pyhtää church (right). Drawings: Franziska Dalheimer & Ilari Aalto, church rooms based on Otto Iivari Meurman and Mildred Grönholm, 1913, museovirasto arkisto & Carolus Lindberg (?), 1915/16, Aalto University Archives.

¹⁶ Savolainen et al. 2023, 70.

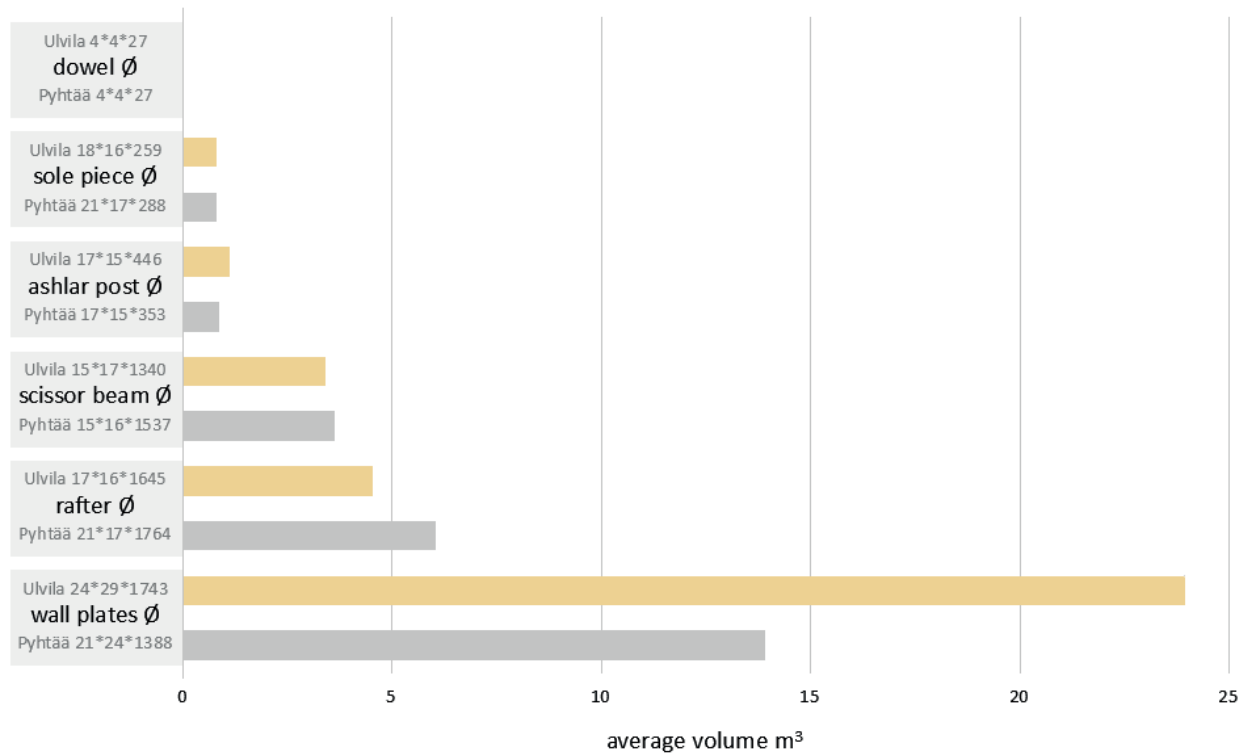


Figure 3. The average volume [m³] and average dimension [cm - height*width*length] of comparable nave roof structures of Ulvila church (yellow) and Pyhtää church (brown). Measured on a height closest to the church stone walls, excluding wall plates connections and collar beams. Graph: Franziska Dalheimer.

which were both identified in the naves of Ulvila and Pyhtää. Using wood density estimates for air-dried wood with around 20% moisture content from the literature, pine has an average density of 490 kg/m³ and spruce 430 kg/m³.¹⁷ It is noteworthy that the weight based on these values are likely to be underestimates. This is because conifer wood density is dependent, among other things, on growth rates so that slow-growing trees tend to have a higher density. Although the growth rates in the construction timbers in these churches are unknown, trees that grew before the onset of the modern forest management that aims to achieve high volume growth tend to have lower average growth rates and likely a higher average wood density relative to the (modern) density values used in the computations here.

The total weight of Ulvila church nave's roof structure is more than 362,300 kg and the total weight of Pyhtää church nave's roof structures is higher than 316,600 kg. The results seem misleading, since Ulvila has 12 trusses more than Pyhtää. The average weight of one truss can be compared better instead, even though Pyhtää church nave has three collar beams more. One truss in Ulvila weighs more than 9,600 kg (5,500 kg for each truss in the gable wall) and the weight of one truss in Pyhtää is higher than 12,900 kg (7,850 kg for each truss in the gable wall). The trusses in the church walls have no scissor beams or collar beams (Figure 1) and are thus lighter. Their weight is estimated based on the dimensions of the other trusses, since they are integrated into the stone

¹⁷ Robert Jandl, Lars Vesterdal, Mats Olsson, Oliver Bens, Franz Badeck and Joachim Rock, 'Carbon sequestration and forest management', *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 2 no. 017 (2007), 1–16, at 5, Tabel 2.



Figure 4. The rafter extension in the nave roof structures of Ulvila church. Photo: Laura Laine, edited by Franziska Dalheimer.

gables and cannot be accessed. The weight breaks down into the calculation of the volume of the different structural member types and wood species as follows. Figure 3 shows a simplification of the average volume [m³] of all comparable structural members, all measured at their points closest to the church walls, where the dimensions have a higher diameter, since the truss members tend to get thinner towards the top at Pyhtää church. This is not the case for all the beams in Ulvila church. The circumference of some rafters is smallest at the height close to the highest collar beam. Many rafters show a doveled connection at this position to lengthen an apparently short rafter with an extension beam (Figure 4).

Each structural member of each type is comparable in their dimensions with respect to height, width, and length in both churches. It can be assumed that these were purposely chosen dimensions by the master builder. Two of the member types were excluded from Figure 3. The first ones missing are the approximately 1 m long beams, which connect the wall plates, since they were not accessible in Ulvila church. The second ones missing are the collar beams since their length and numbers are not comparable (Figure 1). We chose to compare the volume and not the weight in this case since the weight is influenced by the wood species. The largest proportion have the wall plates (Figure 3) with a higher amount of used timber in Ulvila, which is influenced by the 10 meter

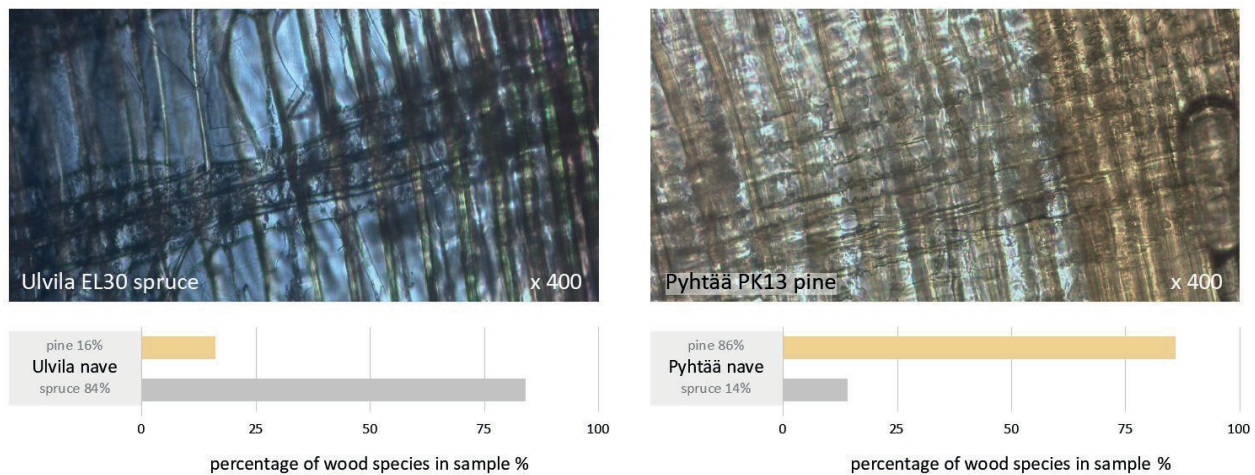


Figure 5. The identification of the wood species in the nave roof structures of Ulvila church (left) and Pyhtää church (right). Graph and photos: Franziska Dalheimer.

longer church nave. However, the wall plates' overall share of the roof structures' total volume is relatively low, since there are only eight wall plate elements per church, but for example 60 of the rafters in Ulvila or 40 in Pyhtää's nave roof structure.

Figure 5 shows the proportion of identified wood species in both church naves. All structural member types were sampled in an equal number, except for the collar beams in Pyhtää church due to accessibility. There were ten samples in total taken of all rafters, ten of all scissor beams, ten of all sole pieces and ten of all dowels, twelve of all wall plates and two samples of the collar beams from Ulvila church. Additionally, two horizontal beams which were resting in the gable church walls without being connected to the structural beams were sampled in Pyhtää church but were absent in Ulvila church.

The 32 samples of the Ulvila church nave roof structure were microscopically identified as 84% spruce and 16% pine, of which all the wall plate timber was pine. The dowels were equally pine and spruce, but no other species were found. The 34 samples of the Pyhtää church nave roof structure were 86% pine and 14% spruce. The share of spruce was not concentrated in a certain member type, but was identified in a sole piece, an ashlar post, a scissor beam and in a rafter. The analyzed dowels and wall plates in Pyhtää were all made of pine.

The material preference for pine wood for both churches' wall plates seems to be deliberately made and the dowels of both church roof structures are made of the same wood as the remaining timber members and no other tree species was found within the samples. However, the material choices clearly differ, with a high proportion of spruce in Ulvila church and pine in Pyhtää.

The physical appearance of the structural members can provide additional information. The shape of the timber tells us about the possible size of the original tree and from which part of the tree the timber originates. Cleaving was a common technique for preparing wooden building material during the medieval times especially for churches in Sweden,¹⁸ but this is not the case for the structural members of the Ulvila and Pyhtää church naves. The profiles of the timber (Figure 6) and of the heartwood, which is not visible on the surface, show that whole and uncleaved timber was

¹⁸ Bengt Bygdén and Karl-Magnus Melin, 'Kluset virke', in *Forskningsprojektet Södra Råda timmerkyrka: Att forska i hantverk*, Hantverkslaboratoriet: Mariestad 2022, 19–21, at 20.

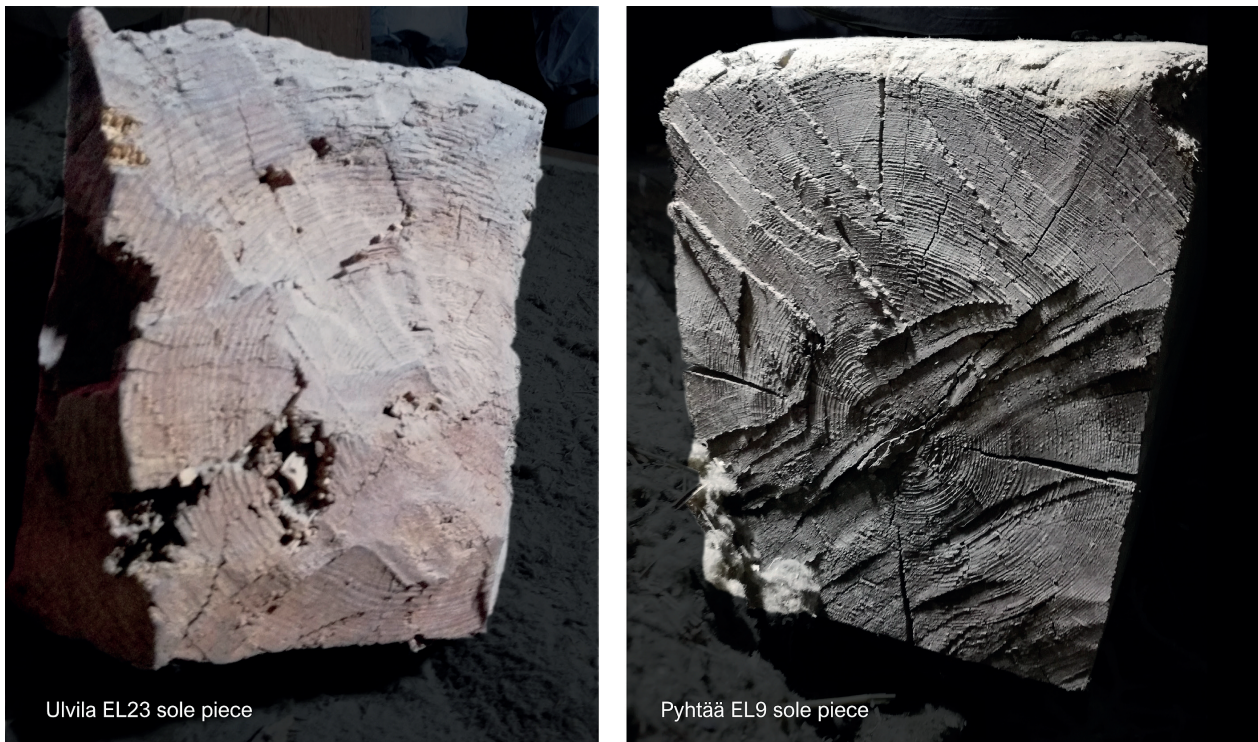


Figure 6. The profiles of sole piece (EL23) at Ulvila church nave (left), sole piece (EL9) at Pyhtää church nave (right). Both members are rectangular hewn and not cleaved timber. Photos: Franziska Dalheimer.

used. Many of Ulvila's scissor beams, rafter and collar beams were not completely rectangularly hewn but still have at least one or two round corners. The ashlar posts even have up to three or four round corners. The dimensions in Figure 3 show that the ashlar posts in Ulvila church's nave are comparable in width and height to the ashlar posts in Pyhtää, which means that younger, smaller diameter trees were chosen, as long as they were of certain dimensions. On a few members in Ulvila church traces of bark can even be found on the round corners or show galleries of phloem-feeding insects, located immediately under the tree bark (Figure 7). These insects invade weakened or recently dead wood but remain in the wood only until the phloem is either consumed or dried out. In this case, the presence of these galleries indicates that the trees were not debarked before use and were prone to insects while left to dry short-term before manufacturing.

This is opposed to the physical appearance of the roof structures of the Pyhtää church nave. Only a very few members can be found with one or more round edges and although there still might be bark left in those cases, galleries of phloem-feeding insects are absent. This suggests that the timber was equally not or only poorly debarked before processing, but not invaded by insects. The absence of the waney edge in the timber in Pyhtää suggests that the trees were larger compared to Ulvila, with enough material to craft the timber from.

Availability of wooden resources

The church building projects cannot be viewed in isolation from their surroundings. On the one hand, the natural environment provides renewable resources, and on the other hand, these resources are consumed by humans in their built environment.

A closer look at the development of the settlements around the church in combination with

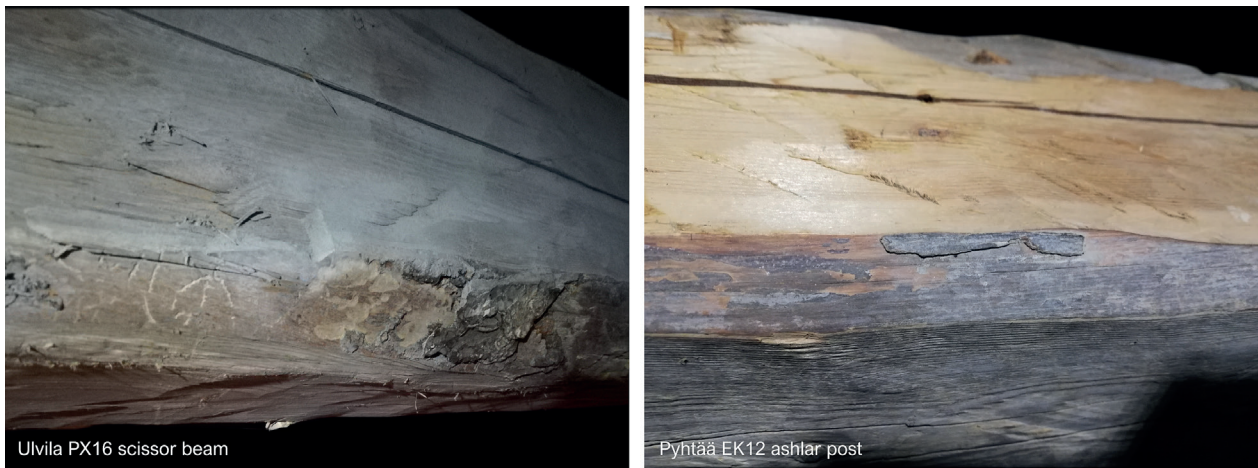


Figure 7. A scissor beam (PX16) with bark and insect galleries at Ulvila church nave (left), ashlar post (EK12) with remaining bark at Pyhtää church nave (right). Both members are not rectangularly hewn but have round edges. Photos: Franziska Dalheimer.

a cautious interpretation of the pollen diagrams can help to reconstruct the availability of wood resources. In this case study, pollen diagrams are used to reflect on the vegetation history and general changes in the landscape rather than to provide a reconstruction of the exact local distribution, quantities, and composition of the local forest stand.

There are currently no pollen data sets available for the surroundings of Pyhtää church. Likewise, the availability of the original medieval sources of Pyhtää church that have been handed down is scarce. This is comparable to the situation of medieval written sources throughout Finland, as the documents are generally absent or were not preserved. The earliest mention of Pyhtää was from 1347,¹⁹ developed presumably from a farming settlement of Swedish settlers in the second half of the 13th century.²⁰ Pyhtää was since at least 1380 an independent parish and had in 1543²¹ around 36 villages with 236 farmsteads within up to about 15 km distance. Not much is known about the size or number of settlements around 1461–1462²² when the church was built, except that the current stone church had at least one wooden predecessor church at the same location.²³ The lack of historical sources and a local pollen diagram makes the reconstruction of the availability of wooden resources quite speculative. However, in 1695, Strömfors Iron Works were established a mere 5 km from the church location. As ample forest resources are cited as an important factor in choosing the locality for the iron works, it seems likely that at least regionally, the wood availability was good.²⁴

A different picture emerged when looking at the secondary literature on the settlement's history as well as the two pollen diagrams available in the area of Ulvila. Those are Siikasuo (19 km south

¹⁹ Eeva-Liisa Oksanen, *Vanha Pyhtää: Pyhtään ja Ruotsinpyhtään historia vuoteen 1743*, Pyhtään kunta: Pyhtää 1991, 41.

²⁰ Hiekkanen 2007, 464.

²¹ Oksanen 1991, 227.

²² Zetterberg 1991, 1.

²³ Hiekkanen 2007, 464.

²⁴ Olle Sirén and Åke Palmén, *Strömfors: Tehdas ja tehdasyhdyskunta 1695–1970*, Suomalaisen Kirjallisuuden Kirjapaino Oy: Helsinki 1971, 5.



Figure 8. Historical maps of the surroundings of Pyhtää church, unknown author, 17th century. Photograph © Jyväskylä University Digital Repository, Jyväskylä. <http://urn.fi/URN:NBN:fi:jyu-201009162591>

of Ulvila church) and Tullerinsuo (12 km south of Ulvila church).²⁵

Ulvila was granted town privileges in 1365²⁶ in order to centralize the trading, based on an earlier establishment of a marketplace with settlements in the 1340s.²⁷ The town grew especially after its founding and particularly during the 15th century.²⁸ Around a hundred years later, at the end of the Finnish Middle Ages, Ulvila used to be the second biggest town after the episcopal town of Turku,²⁹ with a population of around 580 inhabitants in 1548 according to latest reinterpretation of the tithe list.³⁰ Around that time Ulvila had twelve farmsteads.³¹ In 1550 the town privileges were withdrawn, because of the siltation of the river in combination with land uplift, which made the

²⁵ Irmeli Vuorela, 'Lounais-suomen varhaismetallikautinen asutus ja viljely siitepölyanalyysin valossa', *Karhunhammas* 13 (1991), 2–23, at 8–11.

²⁶ Seppo Suvanto, *Satakunnan historia III: keskiaika*, Satakunnan maakuntaliitto: Pori 1973, 334.

²⁷ Aki Pihlman, 'Ulvila: myöhäiskeskiaikainen taajama Kokemäenjoen varrella: asuinpaikan kronologisista vaiheista saviastia-aineiston perusteella', *Historiallista arkeologiaa* 78 (1982), 99–113, at 113; Sari Viertiö, 'Keskiaika maassa ja maisemassa', in *Ulvila maisemassa*, Ulvilan kaupunki: Ulvila 2000, 9–16, at 12.

²⁸ Aki Pihlman, 'Utgrävningarna vid den medeltida staden i Ulfsby', *Historisk Tidskrift för Finland* 4 (1977), 434–46, at 438.

²⁹ Markus Hiekkanen, 'Die mittelalterlichen Stadtkirchen in Finnland', in Robert Schweitzer and Waltraud Bastman-Bühner ed., *Die Stadt im europäischen Nordosten. Kulturbeziehungen von der Ausbreitung des lübischen Rechts bis zur Aufklärung*, Aue Stiftung: Lübeck 2001, 453–69, at 464.

³⁰ Tapio Salminen, 'Suomen "pienet" kaupungit keskiajalla? – Keskiajan kaupunkien tutkimuksesta Suomessa sekä Ulvilan ja Rauman keskiajan erityispiirteistä ja mahdollisuuksista', in Jorma Ahvenainen ed., *Kauppa ja kaupungit Satakunnassa: Porin Raatihuoneella 5. huhtikuuta 2008 pidetyt seminaarin esitelmät*, Satakunta kotiseutututkimuksia: Harjavalta 2011, 8–63, at 11.

³¹ Sari Viertiö, 'Rakennettu maisema', in *Ulvila maisemassa*, Ulvilan kaupunki: Ulvila 2000, 77–120, at 79.



Figure 9. Section of a historical map of the surroundings of Ulvila church (Ulfsby kyrka) with the city of Pori (Biörnborg) at ca. 6.5 km distance, mid-17th century, Hans Hansson. Photograph © Jyväskylä University Digital Repository, Jyväskylä. <http://urn.fi/URN:NBN:fi:juu-200910284280>

navigation of seaworthy ships and thus trading impossible.³² The burghers were ordered by King Gustav I of Sweden to move to the newly founded city of Helsinki in 1555.³³ Considering the time-span of the town privileges of Ulvila from 1365 to 1550, the current stone church with its sacristy and porch was constructed in the later stage of the town development between 1495 and 1510.³⁴ It remains undistinguishable as to how many previous church buildings there were in Ulvila and of its 1.5 km upstream situated neighboring church in Liikistö, since historical sources mention that a wooden church was built in the second half of the 13th century at either both or only one of the locations. However, the church in Liikistö fell out of use when Bishop Hemming consecrated

³² Hermann Beyer-Thoma, 'Deutsche in Finnland während des Mittelalters', in Robert Schweitzer and Waltraud Bastman-Bühner ed., *Der Finnische Meerbusen als Brennpunkt: Wandern und Wirken deutschsprachiger Menschen im europäischen Nordosten*, Stiftung zur Förderung deutscher Kultur: Helsinki 1998, 43–87, at 51; Hiekkänen 2001, 458.

³³ Viertiö 2000, 11.

³⁴ Zetterberg 2003, 1.

the predecessor of the current stone church in Ulvila in 1347.³⁵ There is evidence that this wooden church was destroyed in a church fire around 1429 which indicated that there were at least two wooden churches preceding the current stone church.³⁶

The sacristy is the oldest part of the stone church constructed most likely in 1495,³⁷ since it was a common habit in Finland to first build the stone walled sacristy. Only later on the main nave (1500–1501) and porch (1509–1510) were built to the south of the sacristy (Figure 1) most commonly replacing a wooden predecessor church.³⁸

It is likely that the long-term settlement development including dwellings and farmsteads with outhouses and several large-scale wooden building projects, and the need for fuelwood had influenced the availability of wooden resources during the construction phase of Ulvila church. The pine tree population might be especially influenced by previous building activities, as it was the preferred building material of log-frame dwellings.³⁹

The pollen diagrams (Figure 10) show several changes in the soil's pollen concentration around the radiocarbon years BP 500, when the current stone church in Ulvila was built.⁴⁰ The up to 150 years before that are equally considerable, when Ulvila appeared first in medieval sources and oldest archaeological findings also point to this time.⁴¹ The data of the pollen analysis should be considered with caution in many regards. High values in pine or spruce are often caused by the characteristics of wind pollinated species and are not evidence of the presence of large pine forests. This also means that insect and self-pollinated species are underrepresented in these sediments. Lastly, the exact years of pollen accumulation are not accurate. Sediment dates may vary from decades to centuries depending on the accuracy of the radiocarbon dates, the pollen accumulation rate, and the thickness of the sediment sub-sample analyzed.⁴²

The first category (Figure 10) of *Picea* (spruce) and *Pinus* (pine) can be considered the most informative, since it equally provides insights into agricultural and building activity. A decrease around the time when a marketplace with settlements were established in the 1340s in Ulvila could indicate that the surrounding forest was cleared and cultivated, using slash-and-burn methods, with the felled trees used for construction. The most common dwelling type at this time was a log-frame smoke cottage made of pine logs. Since Ulvila is located close to the Baltic Sea, long and straight pine timber might have also been used for ship building.⁴³

The second category shows *Poaceae* (grasses). The increasing grass concentration can be an indicator of opening forests, most likely in connection with human land use such as clearing fields. It was handed down that there were rye fields in Ulvila until the 1900's when the cultivation was

³⁵ Hiekkänen 2000, 22–24 and 2001, 458–9; Erkki Lehtinen, 'Keskiajalta 1860-luvulle', in *Suur-Ulvilan historia I*, Porin maalaiskunta: Pori 1967, 3–78, at 25.

³⁶ Hiekkänen 2000, 22–4.

³⁷ Hiekkänen 2007, 269.

³⁸ Zetterberg 2003, 1; Hiekkänen 1991, 25.

³⁹ Risto Vuolle-Apiala, *Hirsitalo*, RAK: Jyväskylä 1996, 35.

⁴⁰ Vuorela 1991, 8–11.

⁴¹ Pihlman 1982, 113.

⁴² Irka Hajdas, 'Radiocarbon dating and its applications in Quaternary studies', *Quaternary Science Journal* 57 (2008), 2–24, at 14.

⁴³ Tapani Tasanen, *Läksi puut ylenemähän: metsien hoidon historia Suomessa keskiajalta metsäteollisuuden läpimurtoon 1870-luvulla*, Metsäntutkimuslaitos: Helsinki 2004, 93–4.

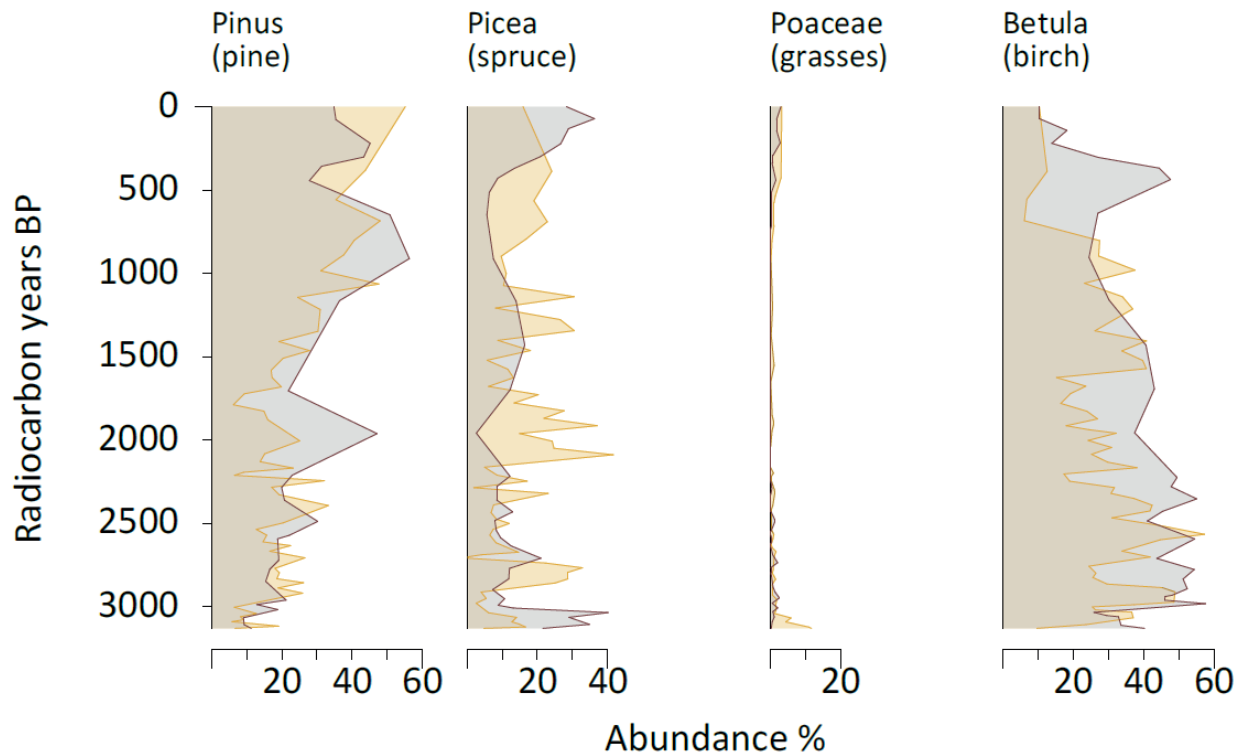


Figure 10. Selection of pollen concentrations of Siikasuo (gray) and Tullerinsuo (yellow). Graph: Franziska Dalheimer based on Irmeli Vuorela, "Lounais-Suomen varhaismetallikautinen asutus ja viljely siitepölyanalyysin valossa", *Karhunhammas* 13, (1991): 8–11.

changed to wheat and barley.⁴⁴ The family of Poaceae includes not only grains used for human food production, but also grasses grown as food for domesticated animals.

The last category shows *Betula* (birch). This wood species is not directly linked to the building material of pine and spruce of the roof structures. However, in the Siikasuo sample it shows an initial increase in the pollen concentration, which could have been caused by birch regeneration on formerly used land, in logged areas, or after forest fires that tend to increase with human presence. In addition, birch was a common choice for firewood, which might explain the decrease in the birch pollen concentration close to settlements, even if not necessarily used directly as building material.

In the end, there are many inaccuracies in basing a conclusion only on pollen diagrams. The values only show a change in the landscape around Ulvila, but this is most likely caused by human activity.

Conclusion

Prior to this research there were many similarities known between the late medieval stone churches in Ulvila and Pyhtää and at first glance they are comparable in many regards: location-wise and in layout, size, age, and roof typology. That could give reason to assume that the resource consumption and availability would also be comparable in both cases.

Considering the scarcity of surviving medieval sources and even fewer surviving medieval building structures, it was still possible to shed new light on the Finnish cultural heritage and gain

⁴⁴ Janne Lampolahti, 'Ulvilan kirkonseudun kasvillisuus selvitys', *Ulvila maisemassa*, Ulvilan kaupunki: Ulvila 2000, 53–60, at 58.

insights into a bygone world. This paper showed additional similarities of the churches, especially in their resource consumption, indicated by the dimensions and thus their weight and volume. However, there was only one common material choice in both church nave roof structures. Pine was used in both cases for the wall plate timber, with significantly higher dimensions of height, width and length compared to all other timber. This gives reason to assume that the material as well as the dimensions were purposely chosen.

The most noticeable findings were the differences in resource consumption, especially regarding the material choice. The used building material of the church nave roof structure in Ulvila was spruce and in Pyhtää pine. The results in wood species identification of 66 samples in total might indicate a difference in the availability of wooden resources. The analysis of the history of the surrounding settlements shows several factors indicating that the differences might be caused by the preference for using pine for other building activities, such as dwellings, previous churches or even ship building. Ulvila developed into a town already around 150 years before the current stone church was built whereas Pyhtää church was the central parish of around 36 farming villages within a 15 km distance. The higher the human activity and denser their presence, the less likely it might be to find right sized pine trees. This could have been the case in Ulvila, where spruce was chosen for the roof structure timber, which is still comparable to pine in terms of its structural properties. But even here, the appearance of the timber shows that the trees might not have a large enough diameter to be completely hewn rectangularly and an attempt was made to get as large as possible dimensions out of the felled trees. This is also the case for the aimed length of the rafter beams in Ulvila church, since many rafters were lengthened with an extension beam. None of the structural timber members were cleaved, which additionally shows that there might not have been large sized trees available. Nevertheless, the absence of the right sized wooden material and the unavailability of a certain tree species at Ulvila did not influence the implementation of a around 10 meters longer (12 more trusses) nave, which is still structurally stable in the present day. This research shows that the structures in both case studies are closely linked to their environs, more specifically in terms of the potential scarcity and general availability of natural resources required. They show how the construction was carried out considering the occurrence of possible resource shortages. In these cases, the requisite expertise and expenditure of manual labor for these large-scale construction projects, which have survived for 550 years, have also been highlighted.

The research also leaves still unanswered questions and provides an opportunity to widen the scope of the research, which could lead to further research. This could include a more detailed study of the age and wood species of the sacristy and porch roof structures or a continuation of wood species identification of other late medieval roof structures in Finnish stone churches.