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POTARCH INDUSTRIES AND ENVIRONMENTAL IMPACT FROM THE MIDDLE AGES TO THE EARLY MODERN PERIOD

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ABSTRACT

The environmental influence of the PoTaRCH industry in the Middle Ages – both within Europe and beyond – has received only limited scholarly attention. To address this gap, this study evaluates the ecological consequences of producing and using non-timber forest products during the medieval period and assesses their broader significance in the preindustrial era. We conducted a comprehensive review of the secondary literature and, when available, contemporary written sources. Our methodological approach integrates comparative historical analysis with regional case studies to examine production technologies, terminology, trade networks, and strategies for exploiting forest resources. We also employ multidisciplinary and interdisciplinary perspectives to clarify the economic and social roles of these materials across several regions. As this paper shows, inconsistent terminology and uneven research coverage across topics and regions complicate comparative work and highlight the need for more detailed, systematic investigations. Given the substantial regional variation in medieval developments, the period examined here extends from the Great Migrations following the collapse of the western Roman Empire to the Early Modern period in the late sixteenth century. Where necessary, later evidence is also used. Our findings indicate that charcoal production exerted significant ecological effects during the medieval period, particularly in relation to mining and metallurgy. By contrast, potash production had a more pronounced impact in the Early Modern period. Although research on pitch and tar remains comparatively sparse, available evidence suggests that their production contributed to localized forms of forest degradation.

Keywords: charcoal, potash, pitch, tar, resin, environment, medieval

INTRODUCTION

The study of forest-derived natural raw materials and their importance in daily life, material culture, and symbolic systems of the medieval world continues to expand. In addition to timber, valued chiefly for construction and fuel, non-timber products – including potash, tar, resin, and charcoal (PoTaRCh) – were important resources from prehistory onward and remain relevant today. Throughout the medieval period and into later centuries, these materials were obtained from trees and forest vegetation, making their production a fundamental component of forest-based industries. Yet the manufacture of these non-timber goods often exerted significant environmental pressures, notably through heightened wood consumption and degrading soil and water quality. This study evaluates these impacts by advancing our understanding of current research on their medieval production and use and, where necessary, refining the relevant terminology.

MATERIAL AND METHODS

The primary material used in this study consists of scientific literature addressing human impacts on the environment through the production and use of potash, tar, resin, and charcoal. Our methodological approach combines analysis of available information, comparative assessment, and synthesis. The corpus of sources includes diverse written and material evidence, findings from multiple regions, and studies on the use and traditional production of potash, tar, resin, and charcoal. Literature was selected based on its relevance to the production, use, and environmental effects of PoTaRCH products during the medieval and Early Modern periods. This approach enabled us to determine the extent of their environmental impact and to clarify their significance in everyday life as well as in various industries and crafts. Comparative analysis also allowed us to identify parallels in the effects across regions and materials. This was particularly useful for charcoal production, which played a central role in medieval metallurgy. However, relatively few detailed studies address these products specifically within the medieval period. With the exception of charcoal – of particular interest in archaeology and paleoecology – most information is dispersed across work focused on other subjects. Accordingly, we incorporated several country-level case studies concerning the medieval and Early Modern periods, with particular attention to those addressing the production of resin, pitch, and tar. The principal methodological limitations include uneven availability and preservation of sources across regions and time periods, and an overall scarcity of dedicated research. Inconsistent terminology in historical documents, especially for resin, pitch, and tar, also hindered comparative analysis. These limitations were taken into account through the careful interpretation and comparison of findings across multiple disciplines.

RESULTS

The evidence examined in this study, together with current knowledge of relevant industrial developments, indicated that the four materials produced distinct environmental impacts. Charcoal production imposed the most substantial pressures during the Middle Ages, surpassing the effects associated with other materials in this period. In subsequent centuries, the expansion of potash – driven by the growing demand of industries such as glassmaking and gunpowder manufacturing – became a principal contributor to increased wood consumption beyond the medieval era. Although resin extraction was not initially included in our assessment, closer analysis of traditional collection methods and the quantities required for various products showed that this practice also affected certain tree species and their local environments. Even so, its overall impact remained limited when compared with the greater environmental consequences of pitch or tar.

Charcoal

Written sources and accompanying drawings (Biringuccio, 1540), together with later descriptions of traditional charcoal production (Glavonjić, 2008; Glavonjić et al., 2011; Nedelkovski, 1994), indicate two principal methods of manufacture. The first employed pit kilns that produced small quantities of charcoal within a short period (8–10 hours), suitable for local needs and crafts such as forging (Pleiner, 2000, p. 119). Circular and rectangular remains of such kilns have been identified at a limited number of medieval sites (Deforce et al., 2018; Klemm et al., 2005). The second method involved stacking wood into free-standing piles that smoldered for several days – possibly about a week – releasing thick, acrid smoke (Katić, 2009, pp. 201–202; Pleiner, 2000, p. 119; Simić, 1988, pp. 80–83). This technique yielded the larger quantities required for ore smelting. Field research at Virovo, near Demir Hisar in present-day North Macedonia, suggests that later charcoal-making practices differed little from those used when the craft first developed.

High-quality charcoal required careful carbonization. Production began by digging a pit and constructing the "upper" and "lower" sides of the furnace. Chopped wood was stacked inside, then covered with leaves and a layer of earth before being ignited through an opening on the lower side. Once the fire caught, the opening was sealed with leaves and earth, and smoke was vented through two chimneys on the at the top of the furnace. Rather than burning, the wood smoldered for 10–15 days before the charcoal was removed (Nedelkovski, 1994). Charcoal offered clear advantages: its carbon content could reach 90%, it had high calorific value, and it was easily transportable in bulk. It is estimated that about 1 m^3 of dry wood (about 600 kg) yielded roughly 55% charcoal by volume, or 16–20% by weight (Hrubý, 2024; Pleiner, 2000). Pleiner (2000) cites an experiment in which 570 kg of pine wood produced 100 kg of charcoal in free-standing piles with flat bases. At Kutná Hora – one of Europe's major medieval mining centers – annual production of charcoal in the second half of the sixteenth century ranged between 6,000 and 11,000 tons (Matoušek and Woitsch, 2020; Rohlíček, 1973).

Analyses of charcoal and wooden artefacts from medieval European sites typically focus on reconstructing forest composition and resource-use strategies. Interdisciplinary studies combining archeology, bioarcheology, anthracology, dendrochronology, and sediment analysis now permit increasingly detailed reconstructions of past woodland cover (Haag et al., 2023; Hrubý, 2024; Knapp et al., 2015; Ludemann, 2010; Rybníček et al., 2022; Tolksdorf et al., 2015; Vranić, 2021). Yet landscapes in historical mining regions were shaped by multiple human activities – including agriculture, grazing, and warfare – and available data are often insufficient to reconstruct production intensity with precision (Deforce et al., 2018; Iles, 2016, p. 1260).

Archaeological evidence indicates that charcoal production depended heavily on local resources, particularly the availability of suitable tree species and nearby watercourses. Beech and oak were especially valued for producing high-quality charcoal (Deforce et al., 2018; Hrubý, 2024; Tolksdorf et al., 2015). In medieval Hungarian ironworks, pedunculate and sessile oak (*Quercus robur* and *Q. petraea*) predominated (Gömöri, 2000; Török, 2011). Growing demand for fuel altered forest composition: by the late fourteenth century, nearly every available tree species was exploited in the Czech-Moravian mining regions (Hrubý, 2024). As mining expanded and environmental pressures intensified – particularly through the increased use of wood – production sites were established farther from the mines and economic centers (Husa, 1957, p. 12). By the sixteenth century, large areas of the Giant Mountains (Krkonoše) in the Czech Republic had been deforested to supply charcoal for the silver mines of Kuttenberg (Kutná Hora) (Rohlíček, 1973, pp. 149–156; Speranza et al., 2000a; 2000b; Woitsch, 2009, pp. 92–93). In the Middle Ages and later, several meters of sediment accumulated in the Elbe River (Labe) Valley in central Bohemia, eroded from the deforested foothills of the Giant Mountains. This deposition irreversibly transformed the valley's geomorphology and vegetation. Much of this deforestation was driven by settlement expansion and agricultural land clearance, although the specific contribution of forest crafts remains insufficiently studied (Dreslerová et al., 2004; Pokorný, 2011, pp. 187–197).

Historical sources provide mainly indirect evidence, particularly through mining legislation referring to charcoal burners, trade, and production (Fostikov, 2019; 2025; Husa, 1957; Katić, 2009; Magyar, 1983). Some of these laws reveal an awareness of environmental risks associated with charcoal burning. For example, King Christopher's Law of the Realm (1442) in Sweden prescribed liability and compensation for forest fires caused by activities such as slash-and-burn agriculture or charcoal making, reflecting efforts to regulate forest use and protect private and communal property (Kuningas Kristoferin maanlaki 1442, 1978; Tasanen, 2004). Similar concerns appeared in medieval Serbia: Article 123 of Dušan's Code (mid-fourteenth century) granted miners access to forest resources for mining and settlement, after which the land was to be left for regeneration (Fostikov, in press; Šarkić, 2014). Blazovich (1985) argued that in south-east Hungary, increased wood use in the sixteenth century was partly driven by charcoal making carried out by shepherds who had fled the advancing Ottoman armies. In Portugal, mid-sixteenth century royal legislation sought to preserve cork oak needed for charcoal production, notably the Cork Oak Law of 1546, which prohibited tree topping and root cutting for charcoal and ash production along the left bank of the Tagus River between Lisbon and Abrantes, and 10 *léguas* inland (Leão, Nunes de. Leis Extravagantes (Lisbon: 1565), P. IV, Titulo 17, Lei XI). A similar ban was issued in 1564 for the Sado River region between Alcácer do Sal and Setúbal, extending to a radius of 10 *léguas* (Neves, 1993). Comparable forest management policies appear elsewhere: in the northern Pyrenees, evidence suggests efforts to maintain sustainable wood and charcoal supplies (Fouédjeu et al., 2022), while in France's Massif Central, regulated production between the eleventh and fifteenth centuries contributed to the preservation of beech forests (Paradis-Grenouillet et al., 2015).

Potash

Potash production involved four stages: burning wood or other terrestrial plants to obtain ash; leaching the ash with water; evaporating the leachate by boiling it in iron cauldrons; and finally calcining or annealing the raw potash in dedicated furnaces. The result was a product composed predominantly of potassium carbonate (K_2CO_3) together with other compounds. Prior to the Industrial Revolution of the late eighteenth and early nineteenth centuries, potash and soda ash (see below) were the only alkaline chemicals produced in Europe. Potash was indispensable for processing textiles and leather, and various other materials, but most of it was consumed by glassworks, where it acted as a flux (catalyst) for melting silica sand (Cílová and Woitsch, 2012; Wedepohl, 2003).

Written sources suggest that potash, as a deliberately refined product, was not manufactured in the Middle Ages. The complex technological process required for its production appears to have become widespread in Europe only in the sixteenth century. Throughout Central, Eastern, Western, and Northern Europe, ash from terrestrial plants ("forest ash") was used as a source of alkali for the crafts mentioned above, while in the Mediterranean region, seaweed and plants from salinas and brackish waters served the same purpose (Adlington et al., 2019; Laibl, 1996; Wedepohl et al., 2011). On this basis, we initially assumed that medieval potash production was not directly relevant to our study because potash was not produced in Europe at the time. However, the historical situation proves considerably more complex.

The basic principles of ash production and leaching were already known in ancient Egypt, Greece, and Rome; Pliny the Elder, for example, recommended tree ash for glassmaking (Freestone, 2008). This knowledge persisted in Arab scientific tradition, and it is likely – though not certain – that it entered medieval Europe through Spain. Independent technological developments are also possible. Arab and Persian authors were the first to articulate the chemical distinctions between products derived from different kinds of plant ash (e.g., soda ash vs. potash). Continental European glassmaking, nevertheless, depended for centuries on imported soda ash. The shift toward using forest ash was gradual at first and later accelerated by the political and economic upheavals following the collapse of the Roman Empire. The production of forest ash peaked between the eleventh and fifteenth centuries (Beckmann, 1799; Bezborodov, 1975; Fester, 1923; Theobald, 1935; Turner, 1956).

Deciduous woods were the preferred raw material for burning ash. Beech produced the highest-quality ash with the greatest alkali content, although birch, maple, alder, elm, and other deciduous species also appear in contemporary recipes. Fir was the only conifer used to any notable extent. Certain herbaceous plants also contained far higher proportions of alkali (sometimes up to 10 times higher), but also produced undesirable impurities for glassmaking. Fern, thistle, wormwood, swallowwort, aubergine, and various cultivated crops are occasionally mentioned, and inferior products such as "fern glass" indirectly attest to their use. Nevertheless, tree ash was clearly predominant (Cílová and Woitsch, 2012; Jackson and Smedley, 2004; Stern and Gerber, 2009). The environmental effects of using trees as a source of ash were significant, though highly variable geographically and chronologically, and impossible to reconstruct precisely for the medieval period. Forest stands were likely altered through the selective harvesting of preferred species and, in some areas, through complete deforestation, especially around glassworks.

Mythology from the early fifteenth century credits Angelo Barovier with refining sea ash into *sal di cristallo* (soda ash) (Hohlbaum, 1910; Verità, 1985). Alchemical writings of the eleventh and twelfth centuries mention the possibility of producing potash from wood ash, and Paracelsus later experimented with it. Although potash technology appears to have been spreading during the sixteenth century, Georgius Agricola was the first to provide a comprehensive description of it in 1556. This century is generally regarded as the period when potash production began in Europe. Subsequent authors, including Neri in 1612, describe glassmaking processes in which potash was already widely used. Wood ash, nevertheless, remained in use in some regions until the nineteenth century (Agricola, 1556; Kunckel, 1743; Laibl, 1996; Leng, 1835).

Recent compositional analyses of historic glass have significantly revised earlier assumptions about the chronology of potash production (Cílová and Woitsch, 2012; Jackson and Smedley, 2004; Kunicki-Goldfinger, 2020; Mecking, 2013; Pactat and Munier, 2020; Stern and Gerber, 2004; Wedepohl 1997; Wedepohl, 2000; Wedepohl and Simon, 2010). These studies reveal that, from the fourteenth century onwards in Central and Western Europe, both potash and wood ash were used in glassmaking. This strongly suggests that written sources underestimate the antiquity of potash production and that its origins may lie earlier than previously believed, although further research is required. Purely potash-based glass, however, does not appear to have been produced during the medieval period.

The transition from the Middle Ages to the Early Modern era brought major political and socio-economic changes, accompanied by notable technological developments, which in turn, altered the environmental impact of forest-based crafts. Whereas charcoal production was the dominant driver of forest exploitation in the the medieval period, potash production became the most significant factor in the Early Modern period[1]. To illustrate the scale of resource consumption, a "medieval" kilogram of ash required the burning of roughly 150 kg of beech wood, while producing a "modern" kilogram of potash required approximately three metric tons – a difference with substantial environmental implications.

[1] In practice, these patterns cannot be generalized. In some areas of the Czech Republic, such as the Brdy Forest, charcoal production remained considerably more important than potash production during the Early Modern period. In other regions, determining whether potash production associated with glassworks or charcoal production associated with mining was the more significant driver of economic change would be highly speculative; detailed historical and palaeoecological research would be required to resolve this. In the Ore Mountains, however, this situation was reversed. Glassworks had been established there since the thirteenth century, but in the late Middle Ages and Early Modern period, they were displaced by greater demand for wood and charcoal for mining and smelting (cf. Černá, 2016, p. 208). As Tolksdorf et al. (2015, p. 70) note, "Local deforestation and soil erosion has been associated mainly with this later phase of charcoal production and may indicate that the human impact of glass production is sometimes overestimated."

Tar, Resin, and Pitch

Compared with charcoal and potash – both of which have been studied extensively due to their roles in pre-industrial industries – resin, pitch, and tar remain far less investigated, particularly in relation to the medieval period. In many countries, systematic research on the history of these substances has scarcely begun. A further obstacle is the frequent confusion and interchangeability of the terms resin, pitch, and tar in both historical sources and modern scholarship (Regert et al., 2019). Terminological overlap in many languages, common in medieval primary sources and often perpetuated in modern translations, makes it difficult to determine which specific product is being referenced. These terms appear inconsistently even in specialist literature, and historical documents and ethnographic works from the nineteenth and early twentieth centuries often feature ambiguous labels such as "white tar," "black tar," "yellow pitch," or "black pitch" (Duchoslav, 1925, pp. 217–219). Similar inconsistencies appear in kiln terminology (e.g., "tar kilns," "pitch kilns"; see Orengo et al., 2013). Ottoman documents from the early sixteenth century likewise employ multiple terms – *katran* (tar), *zift* (pitch), *kara sakız* (black resin), and *ak sakız* (white resin) – whose exact meaning and chemical distinctions remain unclear (Dursun, 2007). These terminological problems make reliable interpretation for the medieval period extremely difficult and indicate the need for dedicated future research. In some regions, however, such as Hungary, these products were recorded in place names, some of which date back to the Middle Ages (Csánki, 1890).

The production of these substances can be classified in several ways, including by method of extraction. Resin can be collected naturally from tree scars or extracted from resin-rich wood. Pitch and tar are produced by heating resin or resinous wood, often in kilns that operated using different extraction systems. According to modern studies, distinctions between pitch and tar depend primarily on distillation temperature (Abraham, 1920; Beglinger, 1958) or chemical composition (Woitsch, 2012). Terminology and translation also vary by region and by the period in which production began. With these difficulties in mind, we provide here a concise overview of how resin, pitch, and tar were produced and used, in order to assess their potential environmental impacts. Given the historical and geographical variation in terminology, we present material through local and regional case studies and retain the terminology used by the original authors.

The use of pine resin in Greece and Byzantium (Moullou and Mantanis, 2025) can be traced back to antiquity, as documented by Theophrastus (*Historia Plantarum*, Book 9), Dioscorides (*De Materia Medica*, Book I, 40), and Pliny the Elder (*Naturalis Historia*, 16.22). Theophrastus provides detailed accounts of resin extraction, as well as the production of charcoal and pine pitch, describing incisions made into tree trunks to stimulate resin flow and the controlled heating of wood to produce charcoal and pitch (Theophr., *Hist.Plant.* 9.2). Pliny elaborates on pine pitch production for waterproofing and construction (Plin, *HN* 14.25; 16.22), noting that wood was placed in a furnace heated externally. Theophrastus also describes a Macedonian method in which pitch was obtained by heating pine logs in earth-covered piles on sloping ground, allowing resin to flow into a channel. These ancient methods continued into the Byzantine period for shipbuilding, trade, and industry. Byzantine medical writers – including Oribasius, Aetius of Amida, and Paul of Aegina – preserved and expanded this knowledge, documenting resin's use in treating wounds, inflammation, dental problems, and for surgical applications (Anagnostakis, 2013; Germanidou, 2019; Kühn, 1829; Merousis, 2010; Olivieri, 1935; Raeder, 1928–1933). Pine resin also served as a coating for vessels (*Geoponica*, 6.4) and, following long-standing practices, was used to preserve and flavor wine – most notably in resinated wine, the predecessor of modern *retsina*. Likewise, it was used as fuel for torches in lighting and religious ceremonies (Doorninck, 2002; Grünbart, 2007). In the arts, resin functioned as a binder and varnish in encaustic icon painting, as confirmed by analyses of Byzantine artworks (Katsibiri and Howe, 2010; Valianou et al., 2011; Vieillescazes et al., 2005).

In shipbuilding, resin and pitch remained essential throughout the Middle Ages for waterproofing hulls, sealing joints, and preventing decay, following techniques inherited from Greek and Roman traditions. The Byzantines relied on resin-based caulking to maintain warships such as the *dromon*, and ropes and sails were sometimes treated for enhanced durability (Kocabaş, 2015). Pitch was traded and regulated, as evidenced in the *Book of the Eparch* (Koder, 1991). Pitch residues derived from burning Pinaceae woods were identified on large ceramic jars from the port of Piombino, which were likely used to prepare or store pitch for waterproofing vessels (Pecci, 2006; Pecci and Salvini, 2007; Salvini et al., 2008). Resin also had military applications: it was a key component of Greek Fire, a powerful incendiary weapon composed of resin, naphtha, and quicklime that was used during sieges and naval battles. Resin, often combined with pitch, was likewise employed in hand grenades and other incendiary devices (Korres, 1989; Triantafyllidis, 2016). During the siege of Dyrrhachium in the early twelfth century, Byzantine forces gathered pine resin for defensive countermeasures (Partington, 1960; Reinsch and Kambylis, 2001).

In the Nordic regions, tar production was particularly widespread. Modern laser scanning has identified over 16,000 tar kilns across Finland, revealing the immense scale of production, especially in the northeast. In the 1620s, Sweden invited foreign specialists to introduce improved tar-burning techniques. Historical records document significant environmental effects, including increased wood consumption and altered forest composition, though long-term ecological impacts remain understudied (Anttiroiko et al., 2023; Hallberg, 1959; Maanmittauslaitos, 2020). From the late sixteenth century, European naval and commercial expansion drove demand for pine tar ever higher, especially after Central Europe's primary tar-producing forests were exhausted. In 1648, a state-backed tar company received a regional monopoly – primarily over Finnish production – to centralize and maximize exports. By the seventeenth century, tar had become Sweden's leading export, with Finland's extensive woodlands as its main source (Tikka, 2020; Turpeinen, 2010).

Scandinavian wood tar was traditionally produced in kilns in which wood was piled and covered with turf, moss, or charcoal to limit oxygen once ignited (Fig. 1, left). Heat caused resin to drip into an outlet pipe, a feature likely in the late Middle Ages (Hennius, 2018). Because early distillates were produced at lower temperatures, different tar fractions with distinct properties could be collected separately, and medieval producers appear to have recognized their

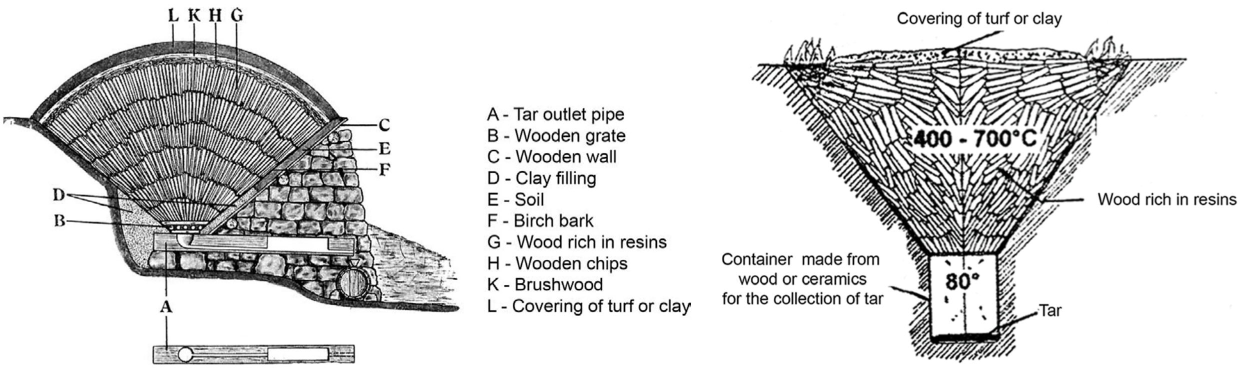

Fig. 1. Schematic section of an Early Modern tar kiln used in Scandinavia with a tar outlet pipe at the bottom (left) and funnel-shaped tar kilns used in the Roman Iron Age (Hennius, 2018) (right)
Ryc. 1. Schemat przekroju wczesnonowożytnego pieca do wytopu dziegciu używanego w Skandynawii z rurą odpływową na dnie (po lewej) oraz lejkowate piece do wytopu dziegciu z okresu rzymskiej epoki żelaza (Hennius, 2018) (po prawej)

varied uses (Egenberg et al., 2002). Earlier structures from the late Roman Iron Age and early Middle Ages were simpler and produced single-batch outputs of around 15 liters (Fig. 2 right). The upper parts of these kilns had to be removed to access the lower chamber, where the extracted tar was collected in batches of roughly the same volume. These were excavated at settlements around Uppsala, Sweden. Later excavations in more remote forests uncovered much larger tar production sites capable of producing 200–300 liters per batch, dated to 680–900 CE. These sites reflect a substantial reorganization of production and included practices such as advanced forest management, wood processing, fire monitoring, and tar storage in wooden barrels.

Small-scale production sufficed for construction and household needs until the Late Iron Age (550–1050 CE), but other factors, such as maritime expansion and evolving shipbuilding during the Viking Age, likely increased demand (Hennius, 2018). Ravn and Manley (2016) estimate that constructing a large Viking personnel-carrier ship required roughly 500 liters of tar, 18 m^3 of wood, and 1,600 work hours. Tar was also used to seal woolen sails, which were highly permeable; sealing mixtures combined tar with fats, grease, and resins. Given the size of Viking sails, substantial volumes of tar were required (Hennius, 2018). Notably, no historical records exist for large-scale resin tapping in Sweden, possibly due to harsh climatic conditions that already placed considerable stress on trees. From the sixteenth century, forest use was increasingly regulated to prevent depletion and to direct use toward activities benefiting the Swedish Crown. The first realm-wide forest law was issued in 1647 (Starlander, 2023; Tasanen, 2004).

Archaeological evidence from the eastern Pyrenees (Andorra) indicates the presence of tar-production structures that appeared after the fall of the Roman Empire and remained in use for long periods. One example was active from the fourth to the seventh century CE. It had a circular plan nearly 2 m in diameter, with baked-clay walls and a paved stone floor ending in an orifice connected to an evacuation hole (Fig. 2, left). Carbonized pine logs bearing resin residues were found in this channel, indicating the tar production feedstock was *Pinus mugo ssp. uncinata* (Orengo et al., 2013). These installations were located in high-altitude, remote areas rich in forest resources and accessible only between April and October, suggesting seasonal large-scale production. Pollen evidence indicates that pitch production had detectable environmental effects, although forest regeneration followed the cessation of activity (Orengo et al., 2013).

Similar kilns discovered in the Montseny Massif in Spain were constructed in much the same way as those in the French Pyrenees but had thicker walls and were significantly taller, reaching heights of about 2 m

Fig. 2. Kilns in the eastern Pyrenees (left, ©J.M. Palet) and Montseny Massif, Spain (right, ©H.A. Orengo) (Orengo et al., 2013)

Ryc. 2. Piece wschodnich Pirenejów (po lewej, ©J.M. Palet) oraz masywu Montseny w Hiszpanii (po prawej, ©H.A. Orengo) (Orengo i in., 2013)

(Fig. 2, right). Their precise date of construction, however, remains debated.[2]

In the Czech Republic, several tar-production sites with pits dated between the eleventh and thirteenth centuries have been identified[3]. The excavated pits were circular in plan and funnel-shaped in section. Ceramic vessels were placed at their bases to collect liquids produced during the thermal decomposition of the wood and/or bark. The batch material was placed above the vessel within the pit (Snášil, 1982; Snítilý and Válek, 2011, p. 33; for Slovakia: Bialeková, 1962).

The types of devices used for tar production during the thirteenth and fourteenth centuries remain uncertain. Apart from the tar pits noted above, finds from this period originate mostly from surface surveys, and excavated sites were often poorly preserved or insufficiently documented. The most common device may have been the tar pile (tar dale), which resembled a charcoal pile. Its base was not, or only minimally, excavated, making it far less likely to survive archaeologically than pits or kiln structures. The principles of thermal decomposition were similar to those used in charcoal production. The base of the tar pile was prepared to collect the liquid products of decomposition – typically with an impermeable layer of clay, a stone construction, or a single stone – and equipped with a drain leading from the bottom of the pile to an external collection area (Duffek et al., 2023; Woitsch, 2012, pp. 85–86).

From the fifteenth century until at least the nineteenth or twentieth century, double-walled kilns were used in this region (Nováček and Vařeka, 1997; Pleiner, 1970; Woitsch, 2012). One such kiln, built in the nineteenth century and located in the Bolevec forest in Pilsen, West Bohemia, survives almost at its original height (Anderle et al., 1998). Alongside these kilns, tar piles – with or without a stone base (*pechstein*) – continued to be used, and several such stones or bases survive today. Written records indicate that both double-mantle kilns and tar piles remained in operation into the late nineteenth and early twentieth centuries (Belisová, 2004; Fröhlich, 1996; Woitsch, 2012).

In contrast to tar piles, double-mantle (double-walled) kilns heated the batch indirectly. The kiln consisted of two chambers – one inner and one outer – separated by a thin wall. The batch was placed in the inner chamber, while a fire burned in the surrounding outer chamber. The heat acted on the batch, and the

[2] There is some debate regarding the date of these kilns. The Inventory of the Archaeological and Paleontological Heritage of Catalonia identifies them as Roman (https://invarque.cultura.gencat.cat/card/10293), whereas the Inventory of the Architectural Heritage of Catalonia dates them to the ninth–tenth centuries CE (https://invarquit.cultura.gencat.cat/card/29337).

[3] Pitch and tar were produced in this area from prehistoric times onward; however, no production installations have yet been documented, and only resin or pitch/tar itself has been recovered (e.g., Pavlů, Zápotocká 2013, 72).

liquid products of the distillation flowed out through a drain at the bottom into the outer area of the kiln and then into a collection vessel (Pleiner, 1970; Woitsch, 2012).

Additional evidence comes from the Placy forest southwest of Prague, where systematic fieldwalking identified sixteen tar-production sites comprising more than forty kilns across an area of 25 km^2. Eight sites date to the fifteenth century, while others remain undated. Excavations at one site uncovered a fifteenth-century kiln and refining furnace, along with indirect evidence for thirteenth-century production. The concentration of kilns and their similar dimensions suggest that tar extraction was organized as a specialized craft and that production exceeded local demand. The tar kilns were double-walled, with firing taking place in the space between the walls. The estimated diameter of the complete kiln was around 4.5 m, with a core about 2.2 m across. Associated finds include a refining furnace, charcoal heaps, and pottery sherds presumed to have been used primarily for tar storage and processing (Nováček and Vařeka, 1997).

At the opposite side of the continent, tar production in Portugal started much later, in the 1790s, owing to a misconception that maritime pine was unsuitable for tar production (Pereira da Silva and Batalha, 1843). As a result, terminology referring to pitch and related combustion processes is more varied. Resin-based products in Portugal are attested as early as 1475 (Arala-Pinto, 1938), when the two main derivatives were *pez* (raw pitch) and *pixe* (cooked pitch). The raw material, known as *acha resinosa*, consisted of resin-rich roots, trunks, or branches of pine trees. Resin could accumulate naturally or be artificially induced through a method called *rechega*, which involved striking pine trunks longitudinally and forcefully until the inner wood was reached (Pereira da Silva and Batalha, 1843; Radich, 1995). *Pez*, a thick, black liquid, was produced by rapidly combusting resinous wood in a specialized furnace for no more than 18 hours. It was then heated further to produce *pixe*, which thickened and homogenized into a material that could be shaped into blocks and mixed with sand if required (Anastácio and Carvalho, 2008). In the 1790s, a tar master from Ragusa (modern Dubrovnik) was hired to initiate tar production in the Marinha Grande region. As with pitch, tar was made from *acha resinosa* through a slower combustion process lasting four to six days, depending on furnace type. The resulting thick, dark liquid separated into two layers as it cooled: a viscous solid (tar), known as *alcatrão*, which sank, and a darker liquid, *água-ruça*, which rose to the top (Radich, 1995; Arala-Pinto, 1938, 1939).

Fig. 3. Location of ovens for pitch production. Map of the pinewoods of His Majesty, and of the Municipality of Leiria and the University of Coimbra with the nearby places and towns, made by Maximiano José da Serra under the orders of Lieutenant Colonel Guillherme Elsden, July 1st 1769

Ryc. 3. Lokalizacja pieców do produkcji smoły. Mapa lasów sosnowych Jego Królewskiej Mości oraz gminy Leiria i Uniwersytetu w Coimbrze wraz z okolicznymi miejscowościami, wykonana przez Maximiano José da Serra na polecenie podpułkownika Guillherme Elsdena, 1 lipca 1769 r.

The environmental impact of the resin, pitch, and tar industries

The environmental impact of resin, pitch, and tar production during the medieval and Early Modern periods has not yet been systematically examined. Orengo et al. (2013) indicate that pitch production had detectable effects, but studies of resin harvesting – such as an 1880s instigation conducted in Portugal – suggest that resin extraction caused only limited ecological damage (Branco, 2005). In the Portuguese case, a commission of experts, including Joaquim Ferreira Lapa and Jayme Batalha Reis (Lapa et al., 1881), used microscopic and chemical analyses to compare resinous and non-resinous wood. They found that resin tapping reduced tree mass but did not significantly alter wood chemistry. The commission recommended continued resin tapping but stressed the importance of selecting appropriate trees to minimize negative impacts. It also advised that extraction techniques follow the system introduced by Bernardino José Gomes in the Leiria pine forest in the nineteenth century, which involved making V-shaped incisions in the bark to channel resin into collection vessels. Portuguese resin tapping methods were later compared with the more advanced French system, which used shallower cuts and clay pots to collect resin, thereby reducing tree damage and promoting faster healing (Radich, 1995).

Although the precise ecological consequences of medieval resinous-wood industries remain unclear, their cumulative effects were likely considerable. Resin, pitch, and especially tar were essential for both industrial and domestic uses, and were indispensable in naval and mercantile shipbuilding. Even if these effects were often local and short-term compared with settlement expansion, mining, charcoal, or glassmaking, the volumes were nonetheless large. As noted above, building a single large Viking ship required approximately 500 liters of tar, which alone demanded around 18 m^3 of wood for the initial batch and additional quantities for ongoing repairs. When the needs of the Byzantine fleet and other maritime powers were considered, the total volume of resinous wood processed must have been substantial.

Maintaining forests capable of supporting tar production also proved difficult. As noted earlier, Finland's forests became central to tar production once suitable Central European woodlands had become depleted. Comparable pressures are recorded in the Ottoman Empire: sources report that *katrancıs* (tar makers) exhausted the resinous trees on Kaz Mountain in the Biga Sancak's region, forcing them to relocate or migrate when adequate timber could no longer be obtained. Tar production, therefore, shaped not only local economics but also land use and community organization. Because these forests were essential long-term resources, the Ottoman state imposed strict regulations and closely monitored production, revealing a concern both to maximize output and to safeguard woodland resources (Sarı and Gürcan, 2025).

Despite these examples, we found only one study – Orengo et al. (2013) – that directly assesses the environmental impact of tar production. Overall, the topic remains largely understudied, and existing evidence is insufficient to determine the scale or character of its ecological effects. This gap is particularly apparent when contrasted with the extensive research on regions where metal mining and smelting, with their associated deforestation, logging, and charcoal production, are recognized as major drivers of environmental change (cf. Derner et al. 2024). One relevant case is fifteenth-century tar production in the Placy forest in the Příbram region of Central Bohemia. Archeological evidence suggests intensive forest exploration, and the enormous number of tar production sites implies that their impact may have been significant, potentially altering vegetation composition and contaminating local water sources. However, no paleoenvironmental studies have yet been conducted to corroborate these findings.

In the Early Modern period, dispersed tar production appears either to have had only minor effects on vegetation or to have left signals obscured by more intensive activities, including timber harvesting and charcoal production. In Bohemian Switzerland – an area with abundant paleoecological records and numerous tar and pitch production sites dating from the fifteenth to the nineteenth century (Lissek, 2004, 2005) – major vegetation changes have instead being linked to charcoal production, timber extraction, and shifts in forest management in the eighteenth and nineteenth centuries, especially the widespread introduction of Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) to secure timber supplies (Abraham and Pokorný, 2008, pp. 465–466).

DISCUSSION

Assessing the findings presented here is inherently complex because the environmental impact of PoTaRCH industries in the medieval and Early Modern periods has not been examined in a consistent or systematic manner. Regional and chronological variation in product use – shaped by local economic and social traditions – remains insufficiently documented, and both medieval and modern terminology create further interpretive challenges. Although non-timber products were crucial to specialized industries such as mining, glassmaking, shipbuilding, and military production, their effects on natural resources remain poorly understood. These issues are compounded by uneven source quality, fragmentary or only partially studied material evidence, and production processes that often must be reconstructed through experimental archeology or later written accounts. The broad chronological and regional scope of our investigation, therefore, reveals significant gaps in previous scholarship and underscores the need for a more detailed, structured analysis of these products.

As a result, this paper can offer only a preliminary introduction to the broader investigation of the environmental impacts associated with non-timber products and their production. Further research into the specific effects of these practices is essential for understanding how forests – and the ecosystems they supported – were altered, including changes to their structure and composition. Future studies should therefore examine the production of these materials within individual regions and historical periods, together with the environmental consequences that accompanied their use. The findings presented here thus represent only an initial step toward addressing this larger and more complex set of questions. The scope of inquiry must also be expanded to include additional non-timber forest products – such as oak bark, which played a significant role in the tanning industry, or sap, which is chemically distinct from resin despite occasional terminological overlap in medieval sources. As demonstrated, further work is needed on the terminology associated with PoTaRCh products in various local languages and the translation challenges they pose. Imprecise renderings of terms found in original documents – often perpetuated in later scholarship – highlight the need for greater linguistic accuracy and contextual understanding. In addition, archeological investigations combined with new analytical techniques should be applied more systematically.

Addressing these challenges requires a stronger emphasis on critical engagement with original texts in their source languages and the adoption of interdisciplinary methods integrating historical linguistics, archaeology, ethnography, wood science, and environmental science. Only through such approaches can we begin to reconstruct the full scope of medieval production and use of resin, pitch, and tar, and assess their environmental impact in relation to better-documented materials such as charcoal and potash. Several important issues remain insufficiently explored, including:

- trade networks and the regulation of resin and wood-resinous production;
- legislation produced by local or central authorities concerning the production, consumption, supply, and environmental impact of PoTaRCh products – including fuller documentation of conflicts between competing uses of wood resources and the role of these products in forest management and protection from the medieval period to the eighteenth century;
- the provenance, supply chains, and environmental consequences of charcoal use in industrial and urban contexts;
- the use and production of resinous materials from the medieval period to the present.

Taken together, the evidence surveyed here – necessarily discussed at different levels of detail due to the breadth of the topic – underscores the need for sustained and focused research. A full understanding of the use and environmental impact of these products can only be achieved through careful, multidisciplinary examination of each of these interrelated issues.

CONCLUSIONS

The findings presented here demonstrate that the multilayered relationship between humans and forest ecosystems in medieval and Early Modern Europe – particularly the exploitation of PoTaRCh products – remains a substantial and understudied field of inquiry. Whereas traditional approaches have focused primarily on timber and firewood, this study shows that non-timber products played an equally significant – and in some cases enduring – role in shaping and transforming the environment.

Charcoal, with its central function in mining and metallurgy, produced some of the most immediate and visible effects in the Middle Ages, as confirmed through extensive archeological evidence and contemporary legislation. Potash production, by contrast, required far larger quantities of wood and exerted a marked ecological impact during the Early Modern period, when its use expanded in tandem with the growth of glassmaking and military industries. Tar and pitch – often marginalized in scholarship – were vital to maritime trade, preservation techniques, military logistics, and technical knowledge, and their production left long-term consequences for local ecosystems. This study also shows that, even in the Middle Ages, forest resources were intermittently regulated and PoTaRCh products were subject to varying degrees of control.

Methodologically, several challenges emerged: fragmentary archeological and written sources; inconsistent or ambiguous terminology; regional variation in historical practices and the extent of existing research; and limited possibilities for estimating production volumes. The coexistence of multiple languages and the use of overlapping terms – such as resin, tar, and pitch – in both medieval sources and modern studies without clear chemical or functional distinctions further complicate comparison and interpretation. These difficulties highlight the need for a dedicated terminology database and corpus to support more precise linguistic and historical analysis.

In light of these issues, future research should prioritize regional studies that combine historical sources with archeological findings and scientific methods – such as dendrochronology and pollen analysis – that can illuminate changes in forest composition and resource availability. Greater attention should also be given to interpreting legal regulations and technical terminology in their original linguistic and cultural contexts, and to reconstructing production technologies with appropriate methodological rigor. Taken together, such approaches would offer a far more detailed understanding not only of PoTaRCh products but also of their environmental impacts in the preindustrial world. Finally, because this study was unable to examine all PoTaRCh resources in equal depth – notably oak bark, for which almost no research exists on its medieval or Early Modern use or ecological effects – these materials warrant careful and systematic investigation in the future.

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BRANŻE POTARCH I WPŁYW NA ŚRODOWISKO OD ŚREDNIOWIECZA DO POCZĄTKÓW ERY NOWOŻYTNEJ

ABSTRAKT

Wpływ przemysłu związanego z produktami PoTaRCH na środowisko w okresie średniowiecza – zarówno w kontekście europejskim, jak i poza nim – został dotychczas zbadany jedynie częściowo. Celem niniejszego opracowania była zatem ocena konsekwencji ekologicznych produkcji i wykorzystania niedrzewnych produktów leśnych w średniowieczu oraz określenie ich znaczenia w okresie przedindustrialnym na podstawie obszernego przeglądu literatury i – tam, gdzie było to możliwe – dostępnych źródeł pisanych. Zastosowana metodologia obejmuje analizy historyczno-porównawcze oraz studia przypadków regionalnych, służące zrozumieniu technologii produkcji, poznaniu terminologii, strategii handlu i eksploatacji zasobów leśnych. Wykorzystano podejścia multidyscyplinarne i interdyscyplinarne, aby rozpoznać znaczenie tych materiałów w gospodarkach i społeczeństwach różnych regionów w badanym okresie. Autorzy wskazują, że złożone kwestie terminologiczne oraz niespójności między studiami dotyczącymi różnych obszarów i zagadnień utrudniają badania porównawcze i wskazują na potrzebę bardziej szczegółowych analiz. Uwzględniając zróżnicowanie doświadczeń średniowiecznych w poszczególnych regionach, okres badawczy obejmuje czas od wielkich wędrówek ludów po upadku Cesarstwa Zachodniorzymskiego do wczesnej nowożytności w drugiej połowie XVI wieku, przy czym w uzasadnionych przypadkach wykorzystano również informacje z późniejszych epok. Stwierdzono, że wytwarzanie węgla drzewnego miało znaczący wpływ ekologiczny w średniowieczu, zwłaszcza w związku z górnictwem i hutnictwem, podczas gdy produkcja potażu wywierała znacznie większe oddziaływanie w epoce nowożytnej. W przypadku smoły drzewnej badania są mniej liczne, lecz istnieją dowody na to, że jej wytwarzanie również przyczyniało się do lokalnej degradacji lasów.

Słowa kluczowe: węgiel drzewny, potaż, smoła, dziegieć, żywica, środowisko, średniowiecze