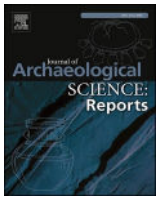
Journal of Archaeological Science: Reports 60 (2024) 104836

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep



Woodland exploitation by early modern military camps and their impact on the forest environment. Anthracological analysis from Ninove-Doorn Noord (1692–1693, 1745, Belgium)

Hello-Laprérie Germain [a,b,*], Deforce Koen [b], Verbrugge Arne [c], Callou Cécile [a], Salavert Aurélie [a]

[a] UMR 7209 (CNRS-MNHN), AASPE, Muséum National d'Histoire Naturelle, CP 56 -57 rue Cuvier 75005, Paris, France
[b] Ghent University, Department of Archaeology, Sint-Pietersnieuwstraat 35, UFO, 9000, Ghent, Belgium
[c] SOLVA Dienst Archeologie, Gentsesteenweg 1B 9520, Sint-Lievens-Houtem, Belgium

ARTICLE INFO

Keywords:
Anthracology
Conflict archaeology
Military encampments
Woodland
Pioneer species

ABSTRACT

Few anthracological studies exist for the modern period (CE 1400–1900) in Europe, particularly for military camps. Nevertheless, wood was a principle strategical resource in the daily life of armies during conflicts. This paper focuses on the anthracological analyses of fire pits from a set of military camps located in Ninove-Doorn Noord (northern Belgium), dating from 1692, 1693 (Nine Years' War) and 1745 (War of the Austrian Succession). The goals were to observe the dynamic of the landscape between the two periods of occupation and to improve our understanding of the firewood supplies of modern armies at a local scale.

This study focuses on the taxonomic identification of more than 8,000 charcoal fragments. In total, 116 samples from 72 structures were analyzed. The results revealed that the troops mainly gathered firewood in riparian formations dominated by alder, Salicaceae and ash. The charcoal assemblages of the earliest camp (1692–93) present a higher taxonomic diversity than those of the following camp (1745) – 16 and 14 taxa, respectively. Furthermore, the increase of Salicaceae charcoals in the 1745 assemblage suggests a degradation of the environment, probably due to anthropogenic pressure (forestry, agriculture, conflicts). These results highlight the potential of anthracology to improve our knowledge of the impact of warfare on woodland history.

1. Introduction

While historical sources such as testimonies and chronicles give valuable information on the damage caused by military campaigns, conflict archaeology potentially provides direct evidence of the environmental impact of war (Kreike, 2021; Scott & McFeaters, 2011; Desfossés et al., 2014). Soldiers depended on the exploitation of local resources for their everyday livelihoods, which influenced troop movement and encampment locations (Cénat, 2010).

Wood, essential for shipbuilding, siege infrastructures and fuel, was a key military resource until the Industrial Revolution (Brosse, 2000). However, the first significant anthracological studies of early modern military contexts (CE 1500–1900) were only carried out about ten years ago. Such studies provide information on firewood management practices and the diversity of fuel resources exploited by the armies. Furthermore, charcoal analysis complements archival research, providing a comprehensive understanding of historical firewood usage (Hello, 2013; Salavert et al., 2016).

Belgium's dense network of waterways and abundant agricultural resources made it a strategic location for military engagements (Childs, 1991; Cénat, 2017). The city of Ninove, situated to the west of Brussels, was occupied by several camps during early modern conflicts. Three of these camps were partially excavated at Doorn Noord. The first two encampments dating from 1692 and 1693 were occupied by allied armies during the Nine Years' War (1688–1697) and the third camp by the French army in 1745 during the War of the Austrian Succession (1740–1748). The excavated archaeological remains mainly consist of structures, organized in several lines according to the battlefield order. This paper aims to compare the soldiers' firewood management practices during these two phases, characterize the woodland diversity exploited by the armies, and assess the impact of conflict on the woody vegetation using charcoal identification and statistical analyses.

* Corresponding author.
E-mail addresses: germain.hello-laprerie@mnhn.fr (H.-L. Germain), Koen.Deforce@UGent.be (D. Koen), arne.verbrugge@so-lva.be (V. Arne), cecile.callou@mnhn.fr (C. Cécile), aurelie.salavert@mnhn.fr (S. Aurélie).

https://doi.org/10.1016/j.jasrep.2024.104836
Received 24 June 2024; Received in revised form 11 October 2024; Accepted 16 October 2024
Available online 30 October 2024

1.1. Geographical situation

The Doorn Noord site is located in the north-eastern part of Ninove (50.83°N 4°E, 14 m above sea level) situated along the alluvial plain of the river Dender (Fig. 1). The dominant soil type is sandy loam. The region is characterized by an Atlantic climate with a mean annual precipitation of 817 mm. The mean maximum and minimum temperatures for January are 7 °C and 2 °C respectively, and for August 24 °C and 13 °C (meteoblue.com, s. d.). Local natural woodland vegetation includes 58 species of shrubs and trees, belonging to several phytosociological groups, such as alluvial forest with black alder and European ash (Alno-Padion) on moderately wet alluvial soil, and oak-hornbeam forest (Carpinion betuli) on drier soils (Noirfalise, 1984).

1.2. Historical background

The first two encampments were constructed during the Nine Years' War (1688–1697). The French army of Louis XIV (1638–1715), King of France, fought against the allied armies of Leopold I (1640–1705), Emperor of the Holy Roman Empire, and William III of Orange-Nassau (1650–1702), Stadtholder and King of England. From 1690 to 1697, Spanish Flanders became a key battleground (Childs, 1991; Lynn, 1999). The archaeological features discovered at Ninove relate to the encampments of the allied armies, which were occupied from 20th to 25th August 1692, and from 20th September to 16th October 1693. Each camp housed approximately 60,000 soldiers and 40,000 horses (Wauters & Verbrugge, 2022). Historical maps show that both camps were at the exact same location, with similar layouts. This makes it difficult to attribute the archaeological features to one particular camp; therefore, we merged the charcoal data from features belonging to both (1692–1693) (see materials and methods).

The third encampment was constructed during the War of the Austrian Succession (1740–1748). In 1744, Louis XV (1710–1774), King of France, declared war on Maria-Theresa of Habsburg (1717–1780), heiress to the Habsburg possessions, and George II (1683–1760), King of the United Kingdom. From 1744 to 1748, the conflict resulted in battles in the Austrian Netherlands (Anderson, 1995; El Hage, 2017). In autumn 1745, the French army, led by Louis XV and Marshal de Saxe, camped between Aalst (Alost) and Ninove from 8th September to 14th October. Some of the excavated archaeological features correspond to the southern part of this camp which housed c. 6,000 soldiers, including elite cavalry troops of the King's household (Wauters & Verbrugge, 2022).

1.3. Site and features

From 2018 to 2020, a rescue excavation was carried out by SOLVA Dienst Archeologie on the Doorn Noord site. Twenty-two acres were excavated (Fig. 1-b, area 1). During these excavations, structures dating from the Neolithic to the contemporary period were found, in addition of the three early modern encampments. Recently, an additional small excavation was carried out by SOLVA, situated next to the Doorn Noord site (Fig. 1-b, area 2), named 19-NIN-DN (Verbrugge et al., 2022). The military structures found on the 19-NIN-DN-site are also included in this study.

1.3.1. The allied encampments (1692–1693)

According to preliminary results of the material finds and historical maps, between 330 and 360 of the excavated military structures can be attributed to the 1692–1693 encampments. Two types of structures were identified. Type 1 corresponds to small circular or rectangular pits (10 to 15 cm deep) which are believed to represent the remains of open-air fireplaces. Type 2 corresponds to larger rectangular pits with a fireplace, representing shelters. Both types are related to cooking and heating activities and likely linked to the shelters of soldiers, officers and/or traders. One structure was identified as a hearth related to metallurgical activities and labelled 'N/A'.

The features found during the excavation can be grouped in seven clusters and are organized along two parallel lines (A-D to the north; E-G to the south), spaced 370 m apart and oriented south-west/north-east, similar to the battlefield order (Fig. 2). Each cluster is attributed to a battalion or a squadron. Fifty-five structures could not be attributed to a cluster. One sample comes from the 19-NIN-DN-site.

1.3.2. The French encampment (1745)

Between 110 and 140 of the excavated structures can be attributed to the encampment of 1745 (Fig. 3). Four types of structures were identified. Type 3, the most common, consists of small shelters for soldiers organized in parallel bands. Type 4 comprises large underground roofed structures, with a chimney, seats, stairs and other features, likely shelters for officers or heated huts for the soldiers. Type 5 includes circular pits with a central hearth, which are interpreted as kitchens. Type 6 are large rectangular pits with a central recesses or tables and a fireplace. Types 3 and 4 often contain several hearths (Verbrugge et al., 2022).

The camp of 1745 is organized into three distinct clusters (A, B and C), arranged in north-west/south-east oriented parallel bands, each measuring 150 to 200 m length and spaced 30 m apart (Fig. 4). The

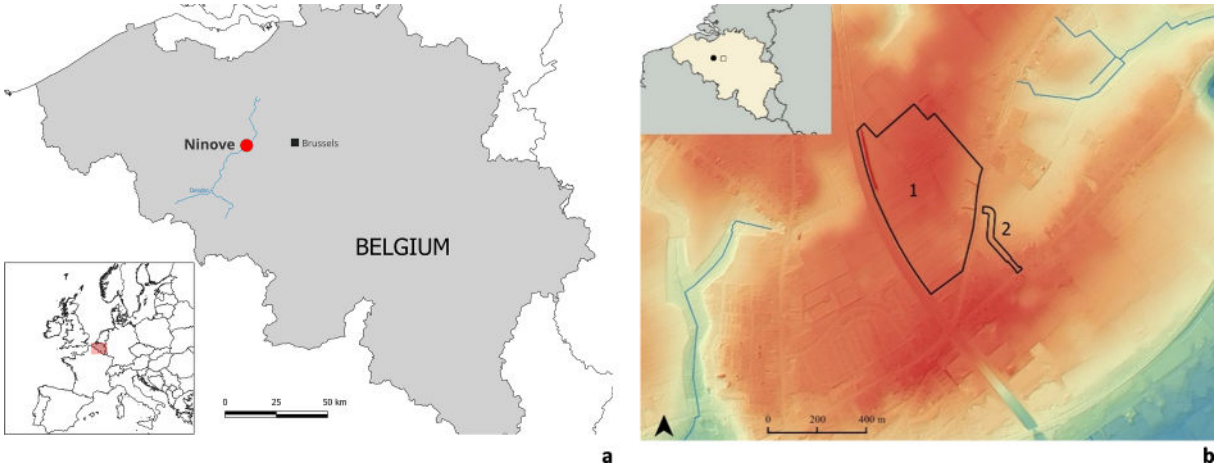


Fig. 1. Location of Ninove (a) and digital terrain map of the Ninove region with the excavated areas in black (@SOLVA Dienst Archeologie) (b).

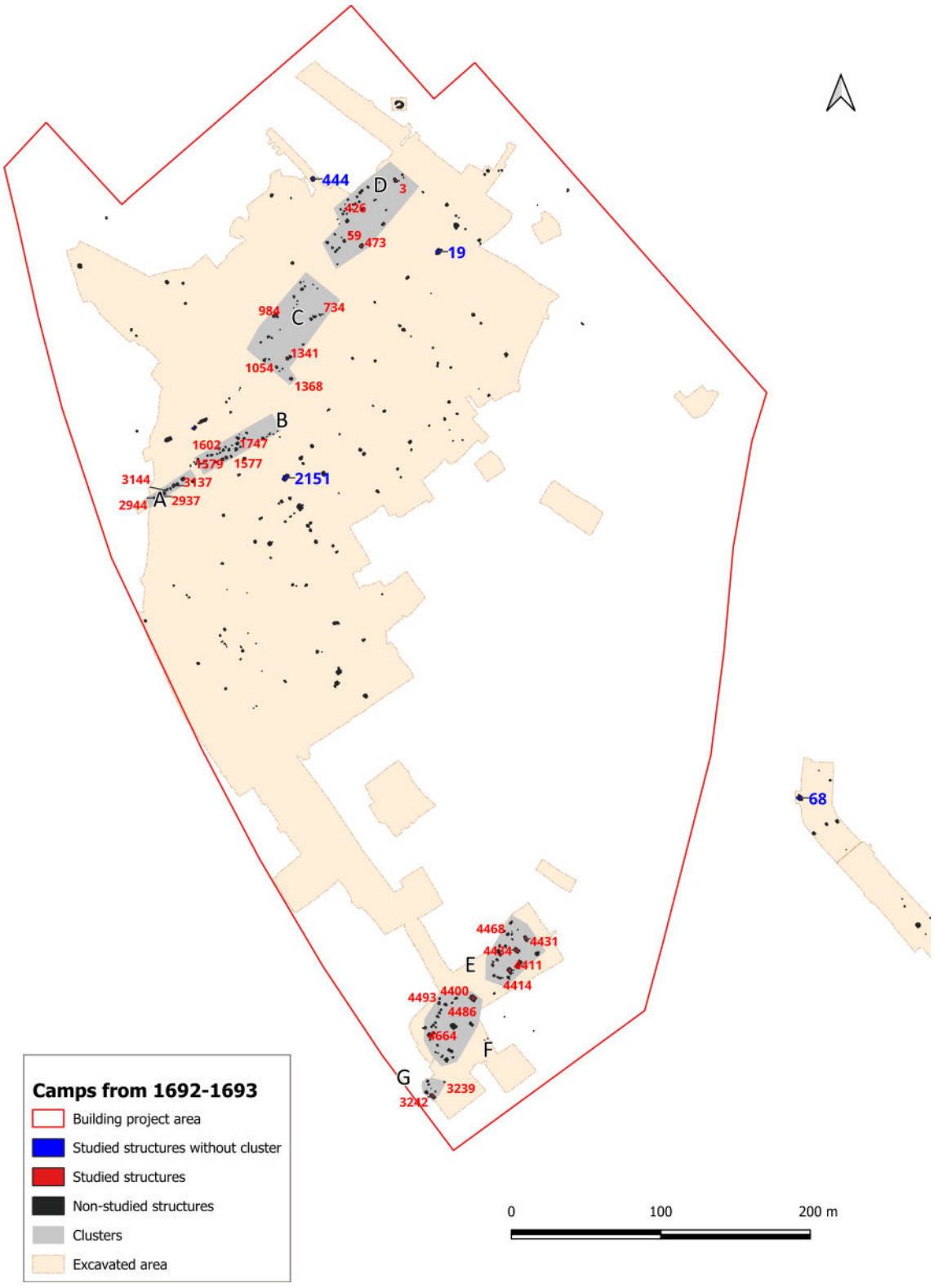


Fig. 2. Ninove Doorn Noord – Organization of military structures in the 1692–1693 encampments.

soldiers' tents were probably installed between these rows of structures. Three structures are not attributed to a cluster (Verbrugge et al., 2022).

For both phases of occupation (1692–1693; 1745), the structures were probably emptied regularly throughout the occupation; therefore, the excavated charcoal fragments likely result from the final fires.

2. Materials and methods

2.1. Sample treatment and selection

A total of 10 m^3 of sediment was sampled during the excavation. These samples were wet sieved using a 2 mm mesh. Among the 471

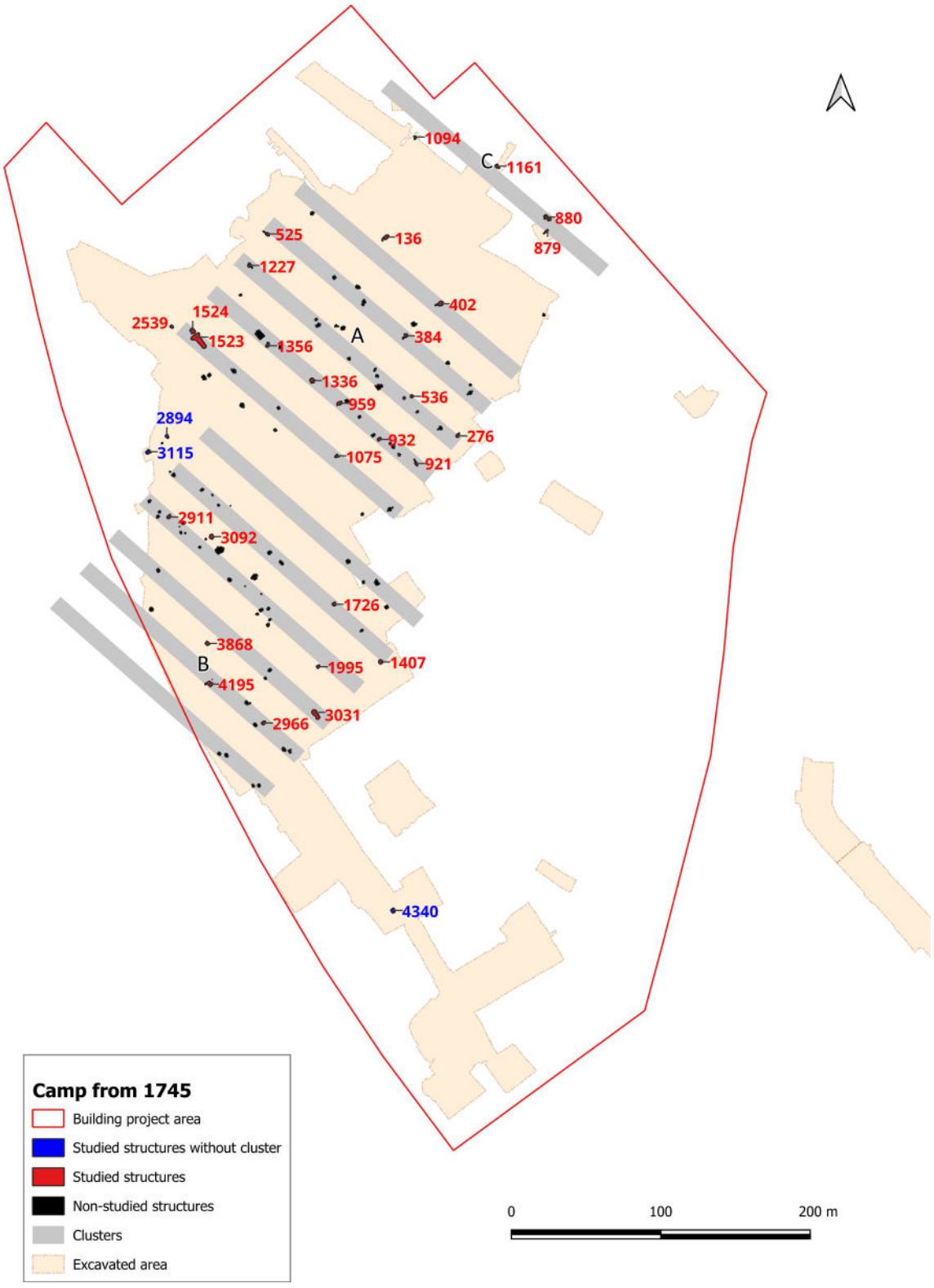


Fig. 3. Ninove Doorn Noord – Organization of military structures in the 1745 encampment.

military structures excavated, 116 samples were selected for anthracological analysis. Some of these samples are from different areas within the same structure. The selection chosen for this study aimed to maximize feature diversity, ensuring that each cluster and type of structure from both phases of occupation (1692–1693 and 1745) was well represented (Table 1).

2.2. Anthracological analysis

A minimum of 50 charcoal fragments per sample were studied. For each newly identified taxon, 50 additional charcoal fragments were examined. Each charcoal fragment was randomly selected. The three anatomical sections of each fragment were observed with a reflected-

light microscope (x50 – x1000). An identification key (Schweingruber, 1990) and a reference collection of modern charred wood samples (UMR AASPE, CNRS-MNHN) were used for the taxonomical identification of charcoal fragments. Some fragments, such as bark, could not be identified and were listed as undetermined.

Two calculation methods were applied to evaluate the hierarchy of taxa. Firstly, all identified charcoal fragments were counted for each sample and for each identified taxon. Then, the percentage of each taxon was calculated. The occurrence was also calculated, representing the number of structures in which a taxon was identified. The occurrence was represented as a curve (Fig. 4). Taxa were ranked, from the most to the least frequent. A taxon was considered dominant when its percentage was greater than 10 %, secondary when its percentage was between 1 % and 10 %, minor when its percentage was less than 1 %.

In addition, the evaluation of firewood quality used during both periods of occupation was conducted to provide insights into the evolution of woodlands using the method described by Deforce (2017). This method assumes that firewood quality primarily depends on the caloric value and thus the density of the wood species used, given that all taxa have a similar moisture content (Deforce, 2017). This results in the following formula:

$$FWQI_i = \sum_{j=1}^{n} (a_j \times \rho_j)$$

with $FWQI_i$ the firewood quality index for the period of occupation i; n the number of taxa for each period of occupation i; a_j the percentage of taxon j for the period i; ρ_j the density (kg/m^3) of the j taxon at 12 % of moisture (BS EN 350-2, 1994; FEM, 2012).

2.2.1. Statistics

To identify potential correlations between specific areas within the camp or hearth types and the corresponding charcoal assemblages, a non-metric multidimensional scaling (nMDS) was done using the metaMDS function from the vegan package, with plots created using the ggplot2 package (Oksanen et al., 2012; Wickham et al., 2024). Ward's hierarchical clustering was also performed to distinguish groups without predefined clustering criteria, using the color_branches function from the dendextend package (Galili, 2015). Analyses were performed with R 4.3.2 (R Core Team, 2020).

A Pearson's chi-squared test was performed to compare the proportions of taxa between the two occupation phases and determine if the assemblages were different, with a significance level of 5 %, using R 4.3.2 (R Core Team, 2020).

3. Results

In total, 8,817 charcoal fragments were studied, resulting in the identification of 18 different taxa (Fig. 4). An average of five taxa per sample were identified for the first period of occupation (1692–1693), and four taxa per sample for the second period of occupation (1745). The dominant taxa are alder (*Alnus glutinosa*); Salicaceae, the family including poplar (*Populus* sp.) and willow (*Salix* sp.); ash (*Fraxinus excelsior*); and deciduous oak (*Quercus* sp.), which together make up 88 % to 91 % of the assemblage, for the first and the second period of

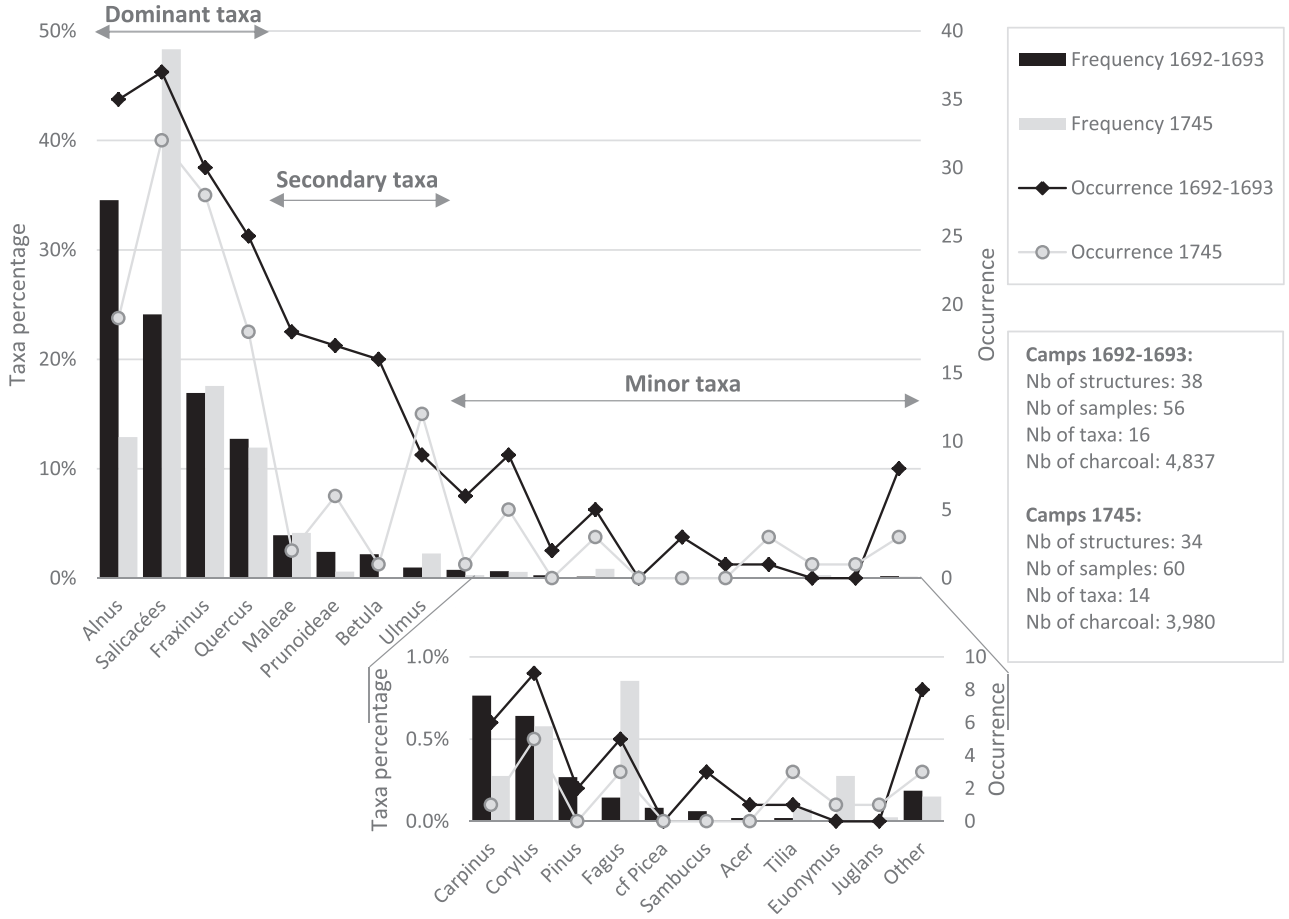


Fig. 4. Ninove Doorn Noord – Anhtracological results from the two periods of occupation and the occurrence of each taxon.

Table 1
Comparison of the number of excavated military structures and samples, according to clusters and types of structures for each camp phase.

Camp phase	1692–1693	1745	
Clusters of military structures	8	3	
Types of military structures	3	4	**Total**
Nb of military structures studied	38	34	**72**
Including not attributed structures	4	3	**7**
Nb of samples studied	56	60	**116**

occupation, respectively.

The secondary taxa of the first period are Maleae (formerly Maloideae), the tribe including apple (*Malus* sp.), pear (*Pyrus* sp.), hawthorn (*Crataegus* sp.) and medlar (*Mespilus* sp.); Prunoideae, the subfamily including cherry, plum and related species (*Prunus* sp.); and birch (*Betula* sp.). The secondary taxa account for 9 % of the total assemblage for the first period. The secondary taxa of the second period are less diverse and include Maleae and elm (*Ulmus* sp.), which together make up 6 % of the assemblage.

Minor taxa of the first period include elm, hornbeam (*Carpinus betulus*), hazel (*Corylus avellana*), pine (*Pinus* sp.), beech (*Fagus sylvatica*), spruce (cf *Picea abies*), elder (*Sambucus* sp.), maple (*Acer* sp.) and lime (*Tilia* sp.), which together make up 3 % of the assemblage. Minor taxa of the second period include beech, Prunoideae, hazel, hornbeam, spindle tree (*Euonymus europaeus*), lime, birch and walnut (*Juglans regia*), which together make up 3 % of the assemblage.

The group titled 'Other' consists of unidentified charcoal fragments and fragments with uncertain identification, i.e., those identified with the prefix 'cf'. For the first period, this group include six taxa, cf Maleae, cf Prunoideae, cf *Quercus* sp., cf *Sambucus* sp., cf Salicaceae and cf *Ulmus* sp. For the second period, this group include three taxa, cf *Alnus glutinosa*, cf Prunoideae and cf *Tilia* sp.

The occurrence curves are generally consistent with taxa percentages. This indicates that no taphonomical bias affects the taxa hierarchy for the two phases. The only significant difference in both calculation modes concerns elm in the second phase. The use of elm by the 1745 troops is enhanced by taking into account the number of occurrences – while the percentage of elm is low, it is identified in over 10 % of the studied structures.

3.1. First period of occupation: 1692–1693

The four dominant taxa account for at least 80 % of the total assemblage in each cluster (Fig. 5). The 19-NIN-DN cluster (Fig. 2, no. 68) is characterized by the absence of ash and the abundance of birch (13 %). Birch and minor taxa are more frequent in the southern clusters (E: 13 %; F: 7 % and G: 18 %) than in the northern clusters (A: 2 %; B: 1 %; C: 3 % and D: 3 %).

For types 1 and 2, the assemblages of the structures are similar (Fig. 6). The taxonomic composition of the undefined structure (N/A) is dominated by ash (56 %) and shows low taxonomic diversity (5 taxa), possibly related to metallurgical activity. In conclusion, it appears that there are no significant differences between clusters or types of military structures.

To verify this observation, based on charcoal percentages and occurrences, statistical analyses were performed. The nMDS results show

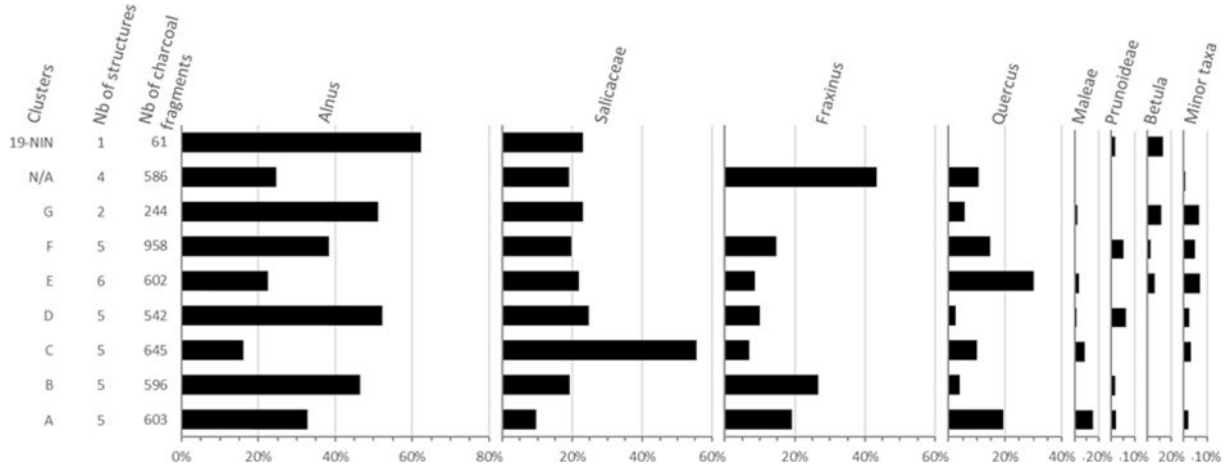


Fig. 5. Ninove Doorn Noord – Anthracological results for each cluster of the 1692–1693 encampments.

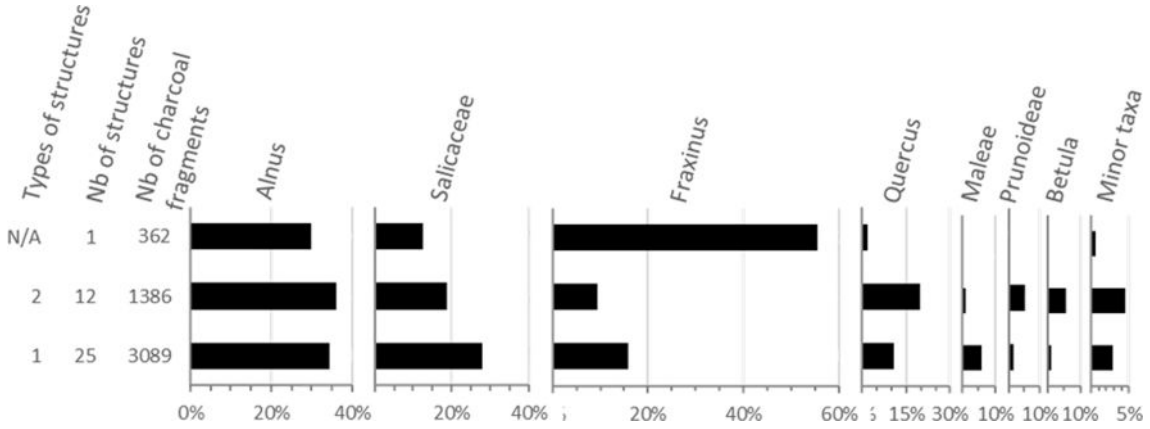


Fig. 6. Ninove Doorn Noord – Anthracological results for each structure type of the 1692–1693 encampments.

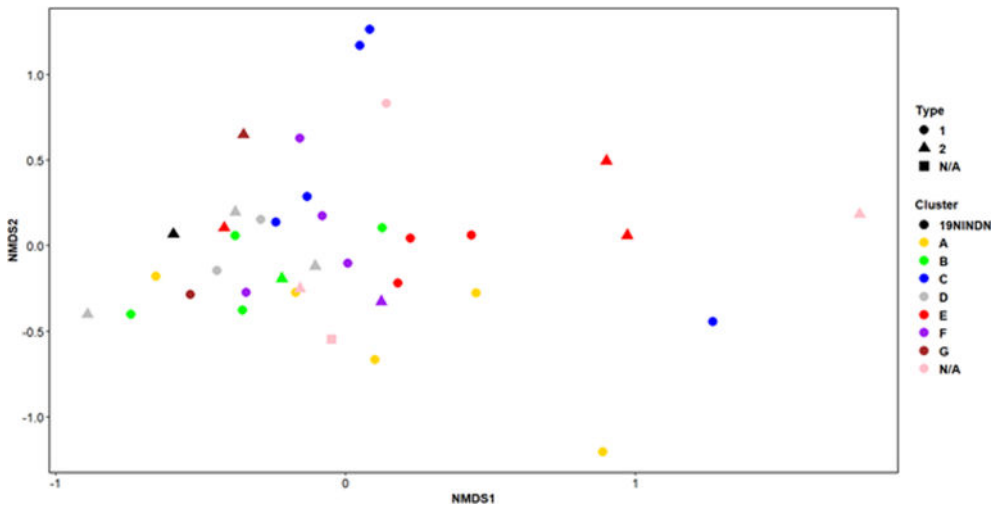


Fig. 7. Ninove Doorn Noord – Non-metric multidimensional scaling (nMDS) of the charcoal assemblages from the 1692–1693 encampments.

that clusters of structures cannot be differentiated, as the charcoal assemblages exhibit greater variation within clusters than between clusters (Fig. 7). The same observation can be made regarding the type of structure. In conclusion, clusters and structure type are not effective variables for explaining differences between structures. The clustering identified three classes (Fig. 8): the first group is characterized by a high proportion of oak and includes seven structures, except for number 3144, which exhibits a high proportion of Maleae; the second group is dominated by a high proportion of alder and contains nine structures; the third group is heterogenous. The proximity of assemblages associated with the spatial distribution of the structures suggests that the observed variability is not due to different firewood management practices based on clusters or types of structures.

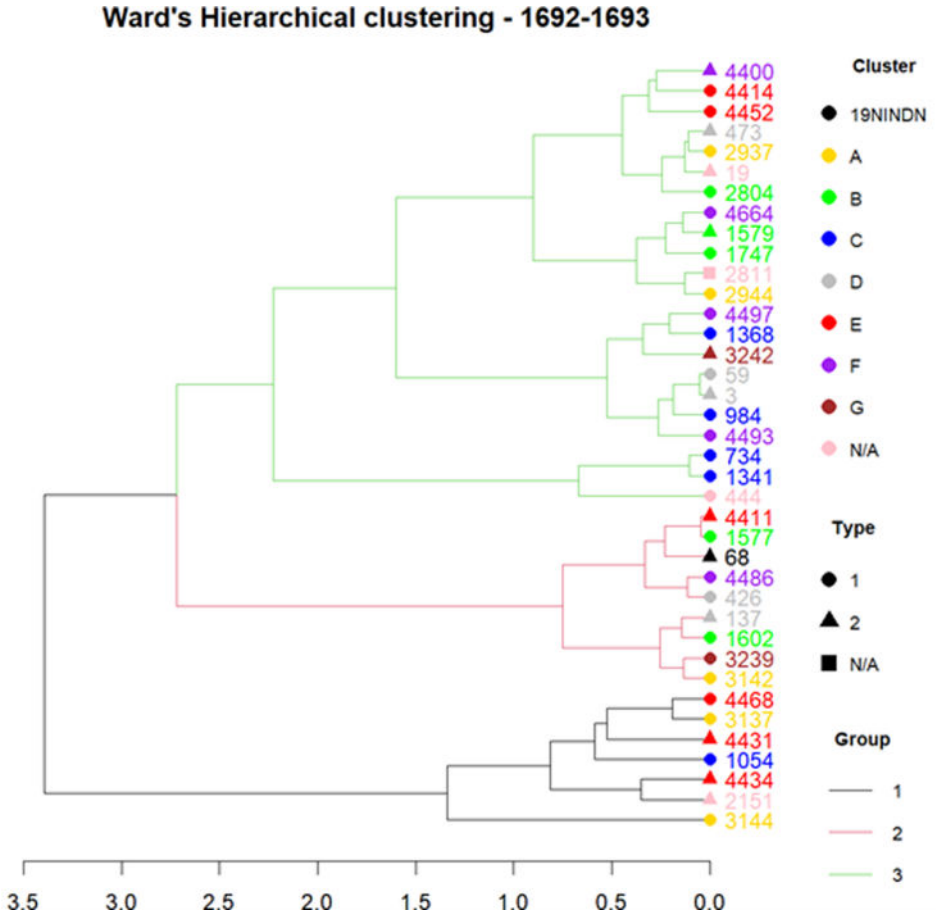


Fig. 8. Ninove Doorn Noord – Ward's Hierarchical clustering of the charcoal assemblages from the 1692–1693 encampments.

3.2. Second period of occupation: 1745

The four dominant taxa represent at least 90 % of the assemblage in each cluster, except for the two not attributed structures (Fig. 9), which may explain the abundance of Maleae (25 %) and the absence of ash. The assemblages of the different structure types are similar (Fig. 10). In conclusion, it seems that there are no differences in taxa hierarchy between clusters or types of structures.

The nMDS results show that clusters of structures cannot be differentiated, as the charcoal assemblages exhibit greater variation within clusters than between clusters (Fig. 11). The same observation can be made regarding the types of military structures. Clusters and types of structures are not effective variables for explaining differences between structures. The structures were grouped into three classes by unsupervised classification (Fig. 12): the first group is characterized by a high proportion of Salicaceae and includes 17 structures; the second group is dominated by a high proportion of ash and contains five structures; the third group is heterogenous. In conclusion, the assemblages are similar and the observed variability cannot be explained by clusters or types of structures.

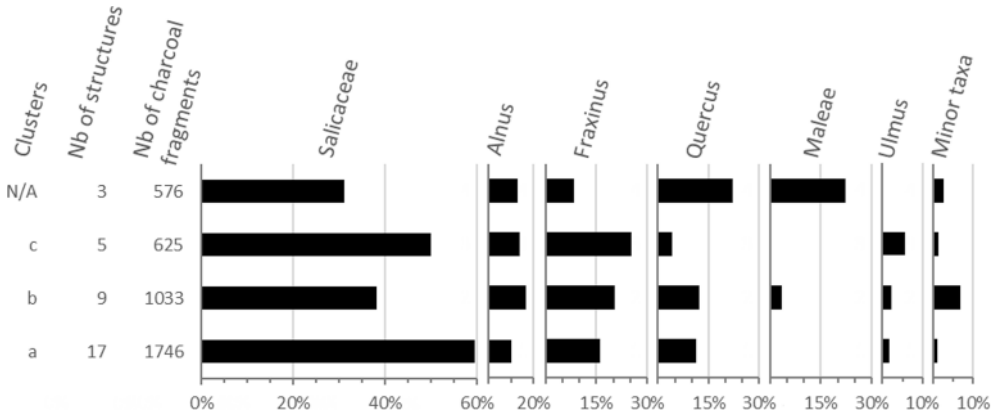


Fig. 9. Ninove Doorn Noord – Anthracological results for each cluster of the 1745 encampment.

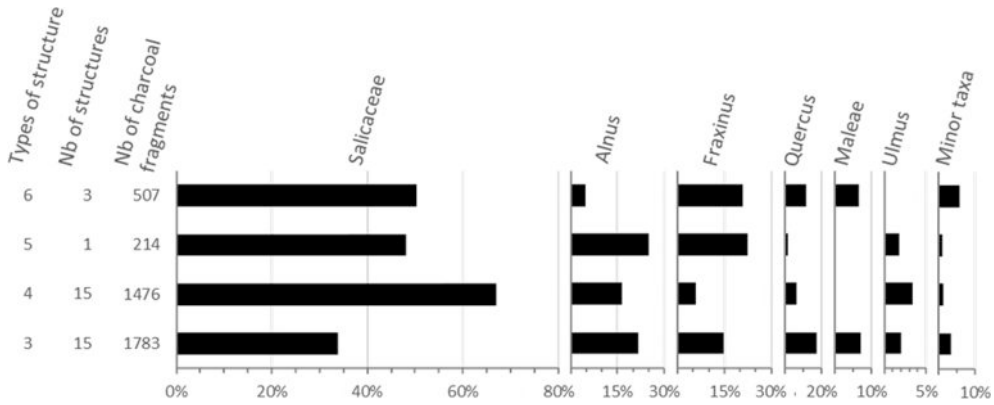


Fig. 10. Ninove Doorn Noord – Anthracological results for each structure type of the 1745 encampment.

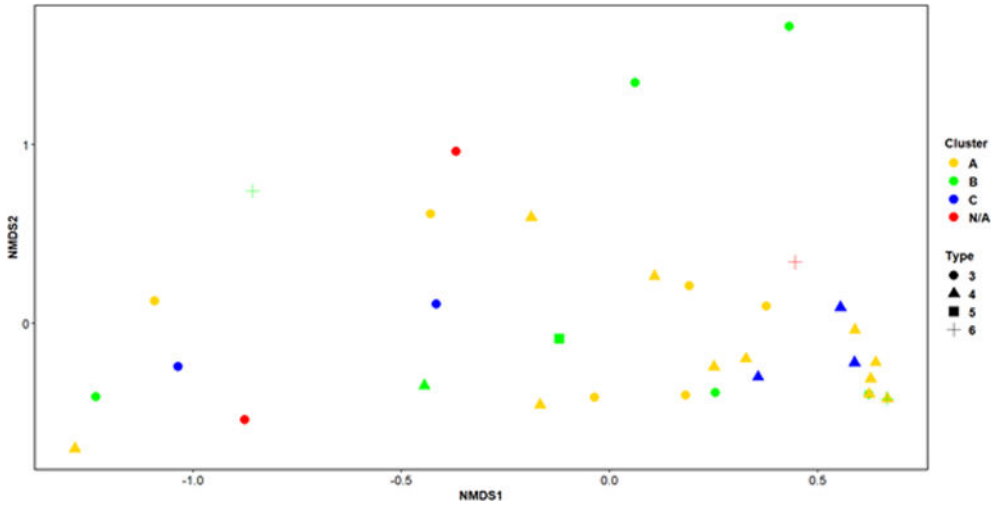


Fig. 11. Ninove Doorn Noord – Non-Metric multidimensional scaling (nMDS) of the charcoal assemblage from the 1745 encampment.

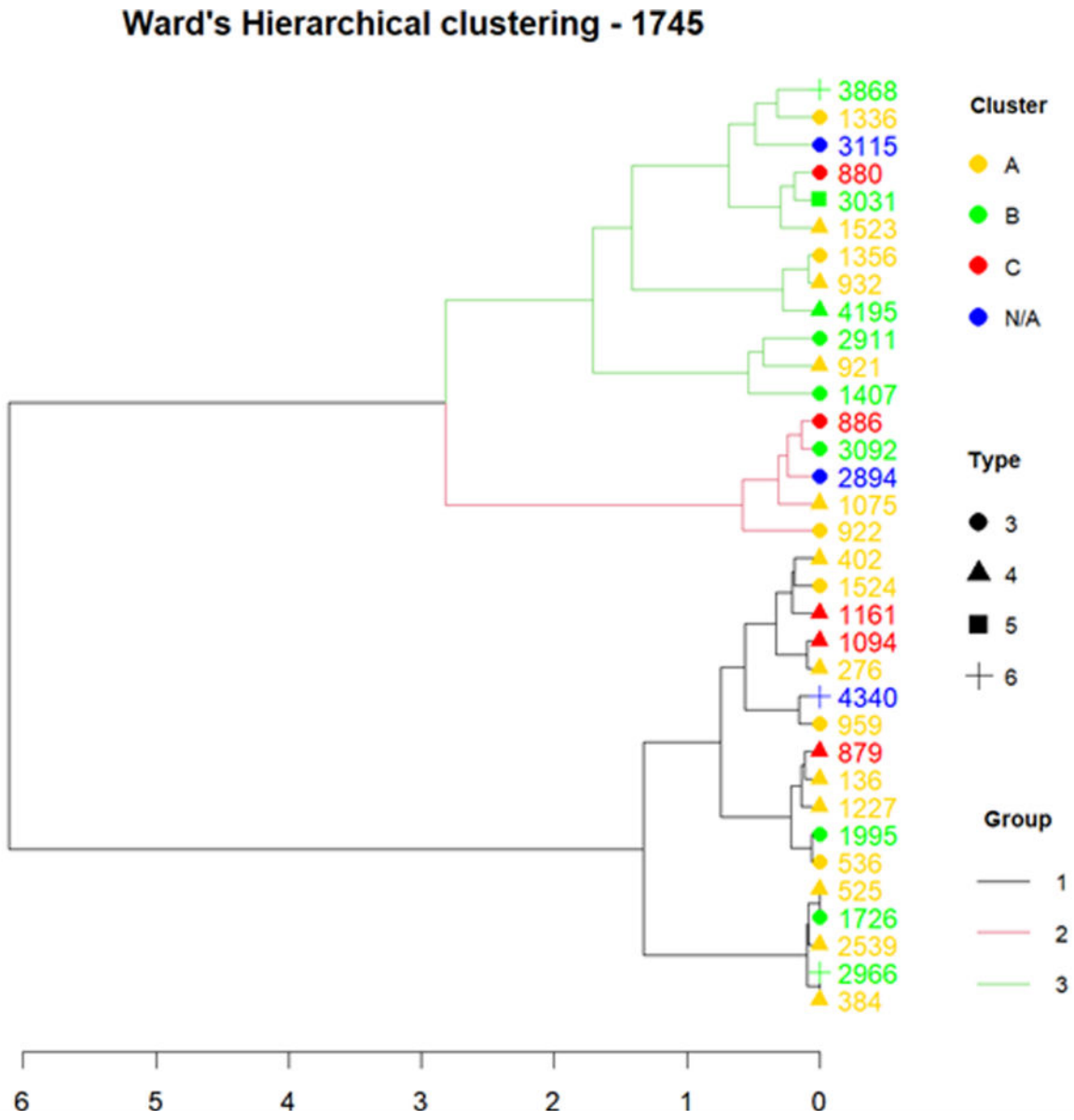


Fig. 12. Ninove Doorn Noord – Ward's Hierarchical clustering of the charcoal assemblage from the 1745 encampment.

4. Discussion

4.1. Phytosociological study

4.1.1. Riparian woodlands

The Ninove encampments were settled in a region rich of watercourses, with the river Dender as the main waterway. Willow, alder and ash are the main components of riparian forests in this area (Noirfalise, 1984). These forests exhibit a high taxonomic diversity, explained by the dynamic nature of these alluvial environments (Collette et al., 2018). Willow groves represent the initial pioneer shrubby stage of riparian forests. In the absence of any anthropic or natural disturbances, other taxa can develop in addition to willow, such as long-lasting pioneer species (alder and poplar), as well as post-pioneer species, including ash, elm, Prunoideae and Maleae (Dufour & Piégay, 2006).

In the anthracological assemblages, Salicaceae (willow and poplar), alder and ash account for more than 75 % of the total corpus, suggesting that the soldiers exploited the riparian woodlands for heating and cooking. This observation confirms that armies relied on the local environment for their firewood supply.

4.1.2. Mature forests

Oak, beech and hornbeam grow in mature forests. These forests can be managed for the production of large timber which can then be used for making objects, and constructing buildings and ships. Alternatively, coppice management produces smaller diameter wood that is more effective for the production of firewood. According to the Ferraris map (1770–1778), the two main mature forests near Ninove in the 18th century were Liedekerke and Neigembos, more than 5 and 3 km apart, respectively, from the excavated area, and located on the other side of the river Dender (Fig. 13). Therefore, it is unlikely that troops stationed near Ninove exploited the Liedekerke or Neigem forests for collecting firewood, due to these long distances. As a hypothesis, fragments of oak, beech and hornbeam could have originated from the firewood stocks of the local population and/or fuel markets.

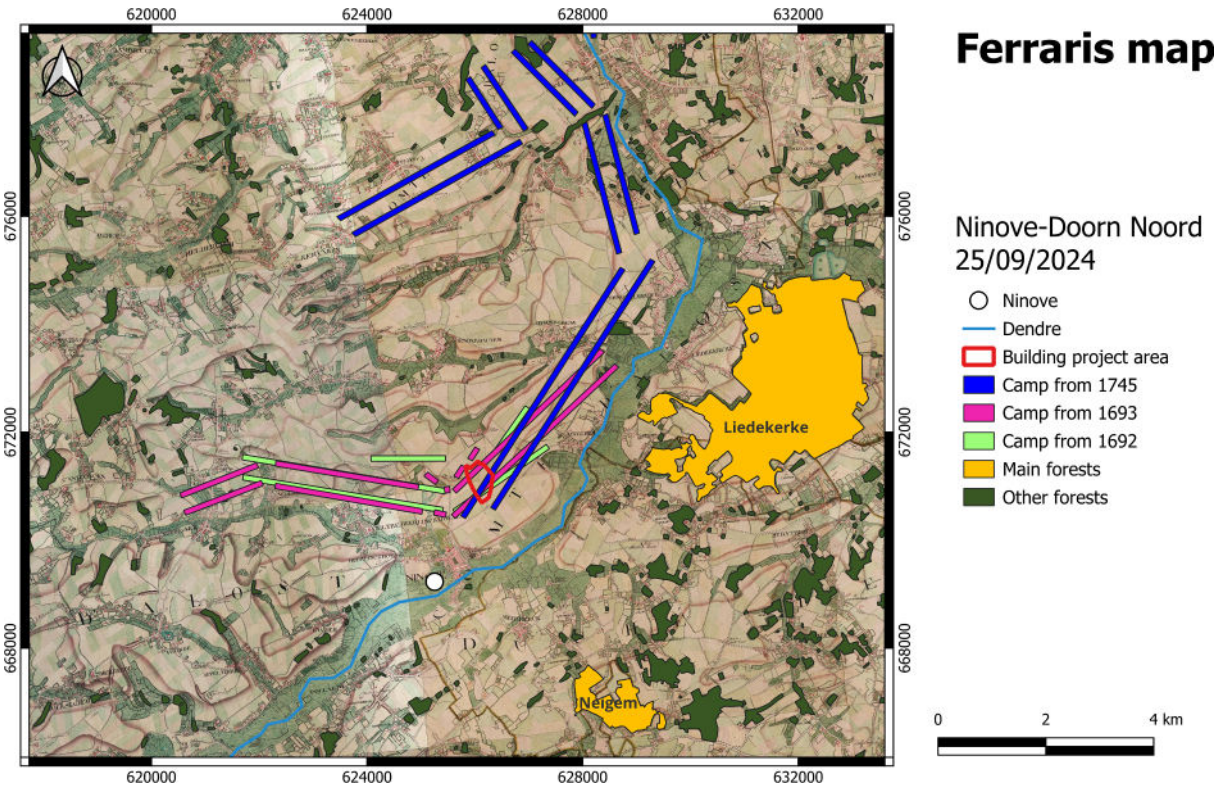


Fig. 13. Ninove-Doorn Noord – Location of the encampments on the Ferraris map (1770–1778).

4.1.3. *Hedges and orchards*

Few Rosaceae (Maleae and Prunoideae) were identified. These plants preferentially grow in riparian forests, forest edges, abandoned areas, or in orchards and hedges around fields. During the 17th and 18th centuries, the territory between the Dender and the Scheldt rivers was dominated by open fields with very few hedges (Verhulst, 1966). This is confirmed by the Ferraris map (Fig. 13), which shows that the only hedges and orchards in the region were situated in Ninove, specifically near the abbey. Although Rosaceae can grow in riparian forests, it is also possible that some firewood was gathered from hedges and orchards near the abbey, located less than one kilometer from the encampment location.

4.1.4. *Burnt objects*

The identification of certain taxa suggests that troops may also have used discarded wooden objects as fuel. Pine, for example, was identified in two structures from the first period of occupation. Although pine was absent from the potential vegetation in northern Belgium, likely since the Late Iron Age, it was reintroduced in the late 18th century, initially in the Campine area (Geudens et al., 2000; Maes et al., 2006). However, as imported pine was frequently used in carpentry and construction (Haneca et al., 2022), the identified pine charcoal fragments could have resulted from the burning of discarded items, such as floorboards, posts or beds.

Walnut is not native to Belgium but was introduced and cultivated for its fruits and wood since the Roman period (Bakels & Jacomet, 2003). But with walnut being sensitive to spring frosts, and thus only occurring sporadically in its wild form, it is unlikely that the walnut used by the troops came from wild trees. However, the abbey had orchards and gardens where walnut could have been cultivated; therefore, the walnut charcoal fragments could have originated from the cutting of cultivated trees in the abbey, as is suggested for Rosaceae. Another hypothesis is that walnut wood could have been sourced from broken or discarded objects, such as military equipment. Indeed, walnut wood was particularly used in military contexts for making the butt ends of crossbows and muskets (Guinier, 1953).

4.2. *Woodland exploitation by early modern armies in the region of Ninove*

4.2.1. *Evolution of the woodland vegetation between the two conflicts (1692–1693 and 1745)*

At Ninove, charcoal analyses have enabled the assessment of woodland evolution over approximately 50 years between two conflicts (1692–1693 and 1745). While the taxonomic diversity is largely similar for both periods, Salicaceae is clearly more important at the expense of alder during the second phase (Fig. 4). This suggests that willow/poplar groves were more extensive in 1745 compared to 1692–1693, indicating a regression of the riparian woodland vegetation to a pioneer state. Such a regression could be attributed to natural phenomena, such as an increased intensity or frequency of floods damaging riverbanks. However, the construction of ten military camps from 1676 and the collection of firewood by soldiers could explain the increase of pioneer species. In addition, according to Philips de Dijn map from 1641 (Rijksarchief te Gent – K144 – 125), the camps were established in an area already strongly depleted in woodland cover.

According to the Ferraris map, several tree rows were planted along roads in the Ninove region, suggesting the practice of pollarding (Petit & Watkins, 2004; Deforce & Haneca, 2015; Thoen, 2019). The increase in Salicaceae observed in 1745 may be attributed to the plantation of willows and/or poplars between the conflicts to replace damaged trees. Under this hypothesis, some of the charcoal fragments identified as Salicaceae, and possibly ash and alder, could have originated from firewood stocks, as is probably the case for oak, beech or hornbeam (cf. 4.1.2).

4.2.2. *Quality of the used firewood*

The firewood quality index shows a reduction between the two camp phases, with ca. 56,000 for the 1692–1693 encampments and ca. 52,000 for the 1745 encampment. This indicates a reduction in the quality of

fuel wood collected in 1745, explained by the increase in Salicaceae (with both *Salix* and *Populus* having a very low wood density) in the charcoal assemblages, likely reflecting environmental degradation between the two periods of occupation.

In addition, the p-value from the Pearson's test is less than 2.2e-16, indicating a significance level well below 5 %. This result demonstrates a significant difference in the proportions of taxa between the assemblages of the two occupation phases. Consequently, this observation supports the hypothesis of environmental degradation between the two periods of occupation.

4.2.3. Armies' procurement during campaigns

The modern period is characterized by the development of armies and the establishment of a strong administrative structure. Logistics were managed by supply officers who relayed information between the front lines and the court (Chagniot, 2001; Lagadec, 2015). To enable the rapid supply of provisions (such as flour, bread, dry fodder) and ammunitions to the front lines, a network of warehouses associated with fortresses was built along the frontier between France and the Spanish Netherlands (Cénat, 2010). However, this supply chain was not sufficient to cover the soldiers' needs during campaigns, especially for firewood; therefore, they had to collect firewood from around their encampments and, to help burn the green wood they had just cut, seize dry wood from the region they occupied through requisitions (De La Chesnaye-Desbois, 1745; Childs, 1991; Cénat, 2010; Chaline, 2016). In 1693, concerning William III's headquarters from 20th September to 16th October, the abbot of Ninove Abbey reported that most of their stock of dry wood had been burned and countless trees had been cut and removed from the region. Similarly, in 1745, French troops committed similar abuses, with damage to the region and the forest of Liedekerke, estimated at least 140,000 guilders (Wauters & Verbrugge, 2022). These testimonies confirm that armies exploited the territory near their encampments.

Nevertheless, until today, no administrative documents concerning firewood requisitions have been found. Local agreements were certainly concluded between suppliers and the army for this procurement, but these documents have probably not been preserved.

5. Conclusion

This study provides evidence of the exploitation of local vegetation around Ninove, which was already largely depleted of woodlands and characterized by a low taxonomic diversity during the 17th and 18th centuries. The dominant taxa in the charcoal assemblages from the two military camps at Ninove indicate that soldiers primarily exploited riparian forests – composed of alder, Salicaceae and ash – during their campaigns. Additionally, taxa such as oak, hornbeam and Rosaceae (Maleae and Prunoideae) suggest that mature forests, as well as orchards and hedges, were also exploited. However, as shown on the Ferraris map, the long distance to mature forests and the rare hedges around Ninove may imply the use of requisitions and/or the presence of a fuel market involving suppliers and armies to provide firewood to troops during the two phases studied. Charcoal fragments of pine and walnut, which do not grow naturally near Ninove, suggest that discarded objects were also used as fuel.

The increase in Salicaceae observed in 1745, compared to 1692–1693 further indicates a degradation of woodland vegetation between the Nine Years' War and the War of the Austrian Succession, likely due to anthropogenic activities, such as the overexploitation of woodland resources by these armies or the planting of willow and poplar rows by the inhabitants.

To conclude, statistical analyses reveal no significant taxonomic differences between clusters or types of structures for each occupation phase, suggesting that soldiers exploited similar firewood sources across different locations.

Comparing the local supply of wood to villages and/or charcoal kilns around encampments by analyzing charcoal fragments could provide a better understanding of woodland diversity and its exploitation during the modern period, and potentially reveal the existence of a firewood market.

Supplementary materials

https://cat.indores.fr/geonetwork/srv/fre/catalog.search#/metadata/b95ae59c-d4ef-4f01-87ff-e540d3f4049e.

CRediT authorship contribution statement

Hello-Laprérie Germain: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Deforce Koen:** Writing – review & editing, Supervision, Resources. **Verbrugge Arne:** Writing – review & editing, Resources, Project administration. **Callou Cécile:** Writing – review & editing, Supervision. **Salavert Aurélie:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

References

Anderson, M. S., 1995. *The war of the Austrian succession, 1740-1748*. Longman, London, New-York.

Bakels, C., Jacomet, S., 2003. Access to luxury foods in central europe during the roman period: The archaeobotanical evidence. World Archaeol. 34 (3), 542–557.

Brosse, J., 2000. *L'aventure des forêts en Occident : de la Préhistoire à nos jours*. J.-C. Lattès, Paris.

BS EN 350-2, 1994. Durability of wood and wood-based products Natural durability of solid wood Part2: Guide to natural durability and treatability of selected wood species of importance in Europe. European Committee for Standardization, London.

Cénat, J.-P., 2010. Le roi stratège : Louis XIV et la direction de la guerre, 1661-1715. Presses universitaires de Rennes, Rennes.

2017. Les enjeux géostratégiques et stratégiques des différents théâtres d'opérations de la France sous Louis XIV. *In* Drévillon, H., Fonck, B., Cénat, J.-P. (dir.). *Les dernières guerres de Louis XIV : 1688-1715*. Histoire. Presses universitaires de Rennes, Rennes.

Chagniot, J., 2001. Guerre et société à l'époque moderne. Presses universitaires de France, Paris, Nouvelle Clio.

Chaline, O., 2016. Les armées du Roi : le grand chantier (XVIIe-XVIIIe siècle). Armand Colin, Paris.

Childs, J.C.R., 1991. The Nine Year's War and the British Army, 1688–1697: the operations in the Low countries. Manchester University Press, Manchester, New-York.

Collette, O., Davreux, T., Bauffe, C., Dancart, D., Dumont, S.-P., 2018. La ripisylve : Intérêts et particularités, travaux, gestion. Silva Belgica 1, 8–25.

De La Chesnaye-Desbois, F.-A., 1745.. Dictionnaire militaire ou, Recueil alphabetique de tous les termes propres à l'art de la guerre, sur ce qui regarde la tactique, le génie, l'artillerie, la subsistance des troupes, & la marine. David fils, Paris.

Deforce, K., 2017. Wood use in a growing medieval city. The overexploitation of woody resources in Ghent (Belgium) between the 10th and 12th century AD. Quat. Int. 458, 123–133. https://doi.org/10.1016/j.quaint.2016.09.059.

Deforce, K., Haneca, K., 2015. Tree-ring analysis of archaeological charcoal as a tool to identify past woodland management: The case from a 14th century site from Oudenaarde (Belgium). Quat. Int. 366, 70–80. https://doi.org/10.1016/j.quaint.2014.05.056.

Desfossés, Y., Prilaux, G., Jacques, A., 2014. Vingt-cinq années d'archéologie de la Grande Guerre dans le Nord-Pas-de-Calais, bilan et perspectives. Revue Du Nord 1–2 (404–405), 375–410. https://doi.org/10.3917/rdn.404.0375.

Dufour, S., Piégay, H., 2006. Forêts riveraines des cours d'eau et ripisylves : Spécificités, fonctions et gestion. Revue Forestière Française 58 (4), 339–350. https://doi.org/10.4267/2042/6704.

El Hage, F., 2017. *La guerre de succession d'Autriche, 1741-1748 : Louis XV et le déclin de la France*. Campagnes & Stratégies. Economica, Paris.

FEM, C. person Lg., 2012. Tree Database, Forest Ecology and Forest Management Group (FEM). Wageningen University. Disponible sur https://www.wur.nl/en/research-results/chair-groups/environmental-sciences/forest-ecology-and-forest-manage

ment-group/education/tree-database/temperate-species.htm, consulté le 29/03/2024.
Galili, T., 2015. dendextend: An R package for visualizing, adjusting and comparing trees of hierarchical clustering. Bioinformatics 31 (22), 3718–3720. https://doi.org/10.1093/bioinformatics/btv428.
Geudens, G., Lust, N., Olsthoorn, A. F. M., 2000. Scots pine in Belgium and the Netherlands. *Investigación agraria. Sistemas y recursos forestales*, 9, 1 : 213-232.
Guinier, P., 1953. Le noyer, producteur de bois. Revue Forestière Française 3, 157–176. https://doi.org/10.4267/2042/26864.
Haneca, K., Deforce, K., van der Laan, J., Nicolaij, S., Lange, S., 2022. WOODAN: An online database of archaeological wooden objects. Veg. Hist. Archaeobot. 31 (5), 541–547. https://doi.org/10.1007/s00334-022-00868-z.
Hello, G., 2013. Le bois de la guerre : quand l'anthracologie contribue à l'histoire des forêts du Nord-Pas-de-Calais (1803-1805). Mémoire de fin d'études, Museum National d'Histoire Naturelle (UMR 7209 Archéozoologie & Archéobotanique), Agrocampus Ouest Angers (INHP), Paris.
Kreike, E., 2021. Scorched earth: environmental warfare as a crime against humanity and nature. Princeton University Press, Princeton.
Lagadec, Y., 2015. Chapitre XVIII. Les sociétés en guerre au XVIIe siècle. *In* Antoine, A., Michon, C. (dir.). *Les sociétés au XVIIe siècle : Angleterre, Espagne, France*. Histoire. Presses universitaires de Rennes, Rennes.
Lynn, J. A., 1999. *The wars of Louis XIV, 1667-1714*. Longman, London, New-York.
Maes, B., Bastiaens, J., Brinkkemper, O., Deforce, K., Röverkamp, C., Van den Bremt, P., Zwaenepoel, A., 2006. *Inheemse bomen en struiken in Nederland en Vlaanderen*. Boom, Amsterdam.
meteoblue.com, s. d. Climate Change Ninove. Disponible sur https://www.meteoblue.com/en/climate-change/ninove_belgium_2790115, consulté le 28/03/2024.
Noirfalise, A., 1984. Forêts et stations forestières en Belgique. Presses agronomiques de Gembloux, Gembloux.
Oksanen, J., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P., O'Hara, R., Simpson, G., Solymos, P., Stevenes, M., Wagner, H., 2012. Vegan: Community Ecology Package. R package version 2.0-2.
Petit, S., Watkins, C., 2004. Pratiques paysannes oubliées. *Études rurales*, 169-170 : 197-214. DOI : 10.4000/etudesrurales.8062.
R Core Team, 2020. European Environment AgencyR: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Disponible sur http://www.R-project.org.
Salavert, A., Hello, G., Lemaire, F., 2016. Firewood of the Napoleonic Wars: The first application of archaeological charcoal analysis to a military camp in the north of France (1803–1805). Antiquity 90 (353), 1334–1347. https://doi.org/10.15184/aqy.2016.174.
Schweingruber, F. H., 1990. *Anatomie europäischer Hölzer: ein Atlas zur Bestimmung europäischer Baum-, Strauch-, und Zwergstrauchhölzer*. Paul Haupt, Bern, Stuttgart.
Scott, D.D., McFeaters, A.P., 2011. The archaeology of historic battlefields: A history and theoretical development in conflict archaeology. J. Archaeol. Res. 19 (1), 103–132. https://doi.org/10.1007/s10814-010-9044-8.
Thoen, E., 2019. Rural economy and landscape organization in pre-industrial Flanders. Sartoniana 32, 243–276.
Verbrugge, A., Wauters, E., Cherretté, B., Poulain, M., Brion, M., 2022. Les campements militaires à Ninove (1667–1748) : premiers résultats des fouilles archéologiques. *In* Poulain, M., Brion, M., Verbrugge, A. (dir.). *The Archaeology of Conflicts: Early modern military encampments and material culture*. BAR Publishing, Oxford.
Verhulst, A., 1966. *Histoire du paysage rural en Flandre de l'époque romaine au XVIIIe siècle*. La Renaissance du livre, Bruxelles.
Wauters, E., Verbrugge, A., 2022. Les campements militaires à Ninove (1667–1748) : instruments de recherche et contexte historico-militaire. *In* Poulain, M., Brion, M., Verbrugge, A. (dir.). *The Archaeology of Conflicts: Early modern military encampments and material culture*. BAR Publishing, Oxford.
Wickham, H., Chang, W., Henry, L., Pedersen, T. L., Takahashi, K., Wilke, C., Woo, K., Yutani, H., Dunnington, D., Brand, T. van den, Posit, PBC, 2024. ggplot2: Create Elegant Data Visualisations Using the Grammar of Graphics.