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Archaeobotanical evidence from the Bandužiai (Žardė) Late Bronze Age to Late Iron Age settlement in western Lithuania

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Keywords

Western Lithuania, Klaipėda, Bandužiai (Žardė) settlement, archaeobotany, agriculture, economic activities, paleoenvironmental reconstruction, Late Bronze Age, Iron Age

Abstract

The Žardė–Laistai–Bandužiai archaeological complex is one of the largest and most unique prehistoric sites in western Lithuania, dating from the 1st millennium BC to the 13th–14th centuries. Within the complex, the ancient settlements of Bandužiai (Žardė) and Bandužiai I are distinguished by the abundance of features linked to production and economic activities. Years of research at the Bandužiai (Žardė) settlement have provided copious amounts of archaeological material, mostly related to metallurgical activities, but its fragmentary nature makes interpretation difficult and highlights the need for an interdisciplinary approach. This paper presents a more comprehensive overview of the Bandužiai (Žardė) settlement through archaeobotanical finds which have been systematically collected but only analysed to a limited extent. The material derives from multiple archaeological contexts, some of which were radiocarbon-dated using AMS. The dates revealed a direct chronology for some archaeological features, extending from the Late Bronze Age to the Late Iron Age, with the exception of the Roman period. The archaeobotanical analysis produced a large dataset of charred and waterlogged plant remains, enabling detailed insights into agricultural practices, settlement structure and environmental conditions over time, and providing rare insights into plant use in production-oriented areas. Results demonstrated that while the main cultivated species varied across different phases, environmental conditions remained relatively stable. Wild and cultivated plants indicated a frequent human presence from the Pre-Roman period, intensifying in later times. Evidence also suggests that the site might have been used differently at certain times, with a clearly defined industrial zone, a possible food preparation zone and even a short-lived domestic zone during the Viking period. These findings provide one of the most comprehensive archaeobotanical datasets from western Lithuania, contributing to wider discussions of agricultural development and human–environment interaction in the eastern Baltic.

Introduction

Recent years have seen an emergence of systematically collected archaeobotanical datasets coming from various archaeological sites in Lithuania. This has allowed researchers to reconstruct prehistoric technological, agricultural and socioeconomic dynamics within a broader region (Pollmann 2014; Minkevičius 2019; 2020; Minkevičius et al. 2020; 2023; 2024a; 2024b; Vengalis et al. 2022a; 2022b). However, the level of representation varies across regions. While eastern Lithuania, for example, is relatively well understood through archaeobotanical

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Figure 1. The Žardė-Laistai-Bandužiai archaeological complex (mapped on an orthophoto from 2019–2021). Map items: 1. Bandužiai (Žardė) settlement; 2. Bandužiai I settlement; 3. Bandužiai II settlement; 4. Žardė I settlement; 5. Žardė II settlement; 6. Žardė III settlement; 7. Laistai settlement; 8. Žardė hillfort with a settlement; 9. Laistai hillfort with a settlement; 10. site of the destroyed Gibišiai hillfort; 11. Bandužiai cemetery; 12. Laistai cemetery. Legend items: 1. present boundaries of the immovable cultural property; 2. archaeologically investigated settlement area; 3. the present hydrography; 4. riverbeds of the Smeltalė and Kretainis Rivers after a map from 1939 (by I. Masiulienė).

research, our knowledge of long-term agricultural, environmental and social changes in western Lithuania remains fragmentary — mostly because earlier collected archaeobotanical assemblages were often biased and unrepresentative (Piličiauskas et al. 2017, p. 188). Western Lithuania is particularly under-represented, as there are only a few systematically studied sites, such as the Late Bronze Age (1100–400 BC) Kukuliškiai hillfort and the two phases — Roman period (0–400 AD) and Viking period (800–1200 AD) — of the Iron Age Bilioniai hillfort (Minkevičius 2019; Minkevičius et al. 2020), each covering only limited periods, leaving long-term area and site changes unstudied.

One of the most explored archaeological sites in western Lithuania is the Bandužiai (Žardė) settlement. Dating from the Late Bronze Age (1100 – 400 BC) to the Late Iron Age (900 – 1200 AD), it is unique not only in terms of the numerous production-oriented activities identified within its territory but also with regard to the amount of archaeological evidence, including rich archaeobotanical material, gathered during many years of excavations. Although much of this material still awaits analysis, the study of archaeobotanical remains is particularly significant.

The systematically collected archaeobotanical data from the Bandužiai (Žardė) settlement offers a valuable glimpse into the long-term changes in the economy, human–environment interactions and sociocultural landscape of western Lithuanian prehistoric communities. This site is unique in terms of a clearly established and multi-phased industrial zone, offering exceptional insights into plant use within these production-oriented areas. Combining previously gathered archaeological evidence with newly examined macrobotanical remains from Bandužiai (Žardė) settlement allows for the reconstruction of the settlement structure, agricultural practices and environmental change over time. The aim of this paper is to present these findings in order to allow further understanding of long-term economic strategies, human–environment interactions, and social dynamics within the prehistoric landscape of western Lithuania and shed light on the broader cultural trajectories of the Baltic region.

1. Research history

The Bandužiai (Žardė) settlement was first identified in 1990, when survey investigations between Jūrininkų Avenue, Žardupė Street and the Kretainis stream revealed the earliest traces of human activity. Although no cultural layers were recorded in most of the trenches, one trench revealed an iron-smelting furnace with slag. This find provided the first clear evidence of metallurgy in the area (Genys 1991; 1992) (Figs. 2 and 3).

A major turning point occurred in 2006 with the construction of a logistics centre and related infrastructure works. This development prompted large-scale archaeological investigations, resulting in the inclusion of the settlement in the Register of Cultural Properties and the establishment of its protection zone (Masiulienė 2007; 2007a). In 2006, 2008, 2011, 2015 and 2016, the research team of Klaipėda University Institute of Baltic Region History and Archaeology systematically investigated the central and western parts of the site. In total, an area of about 7 hectares was excavated, and 554 archaeological features were documented which revealed highly diverse activities: hearths, fireplaces, postholes of temporary structures, bog ore prospecting and washing pits, furnaces, charcoal production pits, and three wooden wells, while the function of some features remains unidentified (Masiulienė 2007; 2007a; Masiulienė 2009; Bliujienė and Masiulienė 2011; Masiulienė 2012; 2012a; Balsas 2016; Balsas et al. 2016; Balsas 2017; Balsas and Masiulienė 2018). Archaeological material, together with AMS radiocarbon dates, indicates long-term, though not necessarily continuous, use of the area from the 1st millennium BC to the beginning of the 2nd millennium AD. Isolated Neolithic and Bronze Age finds further extend this chronological horizon (Masiulienė 2009).

From 2017 to 2020, excavations were continued by other archaeological organisations (Songailaitė 2018; 2018a; 2021; 2021a; Sprindys 2019; 2019a; Ziabreva 2019; Ziabreva and Songailaitė 2019; Tarasova 2020). The investigations were carried out mostly in the western and southern

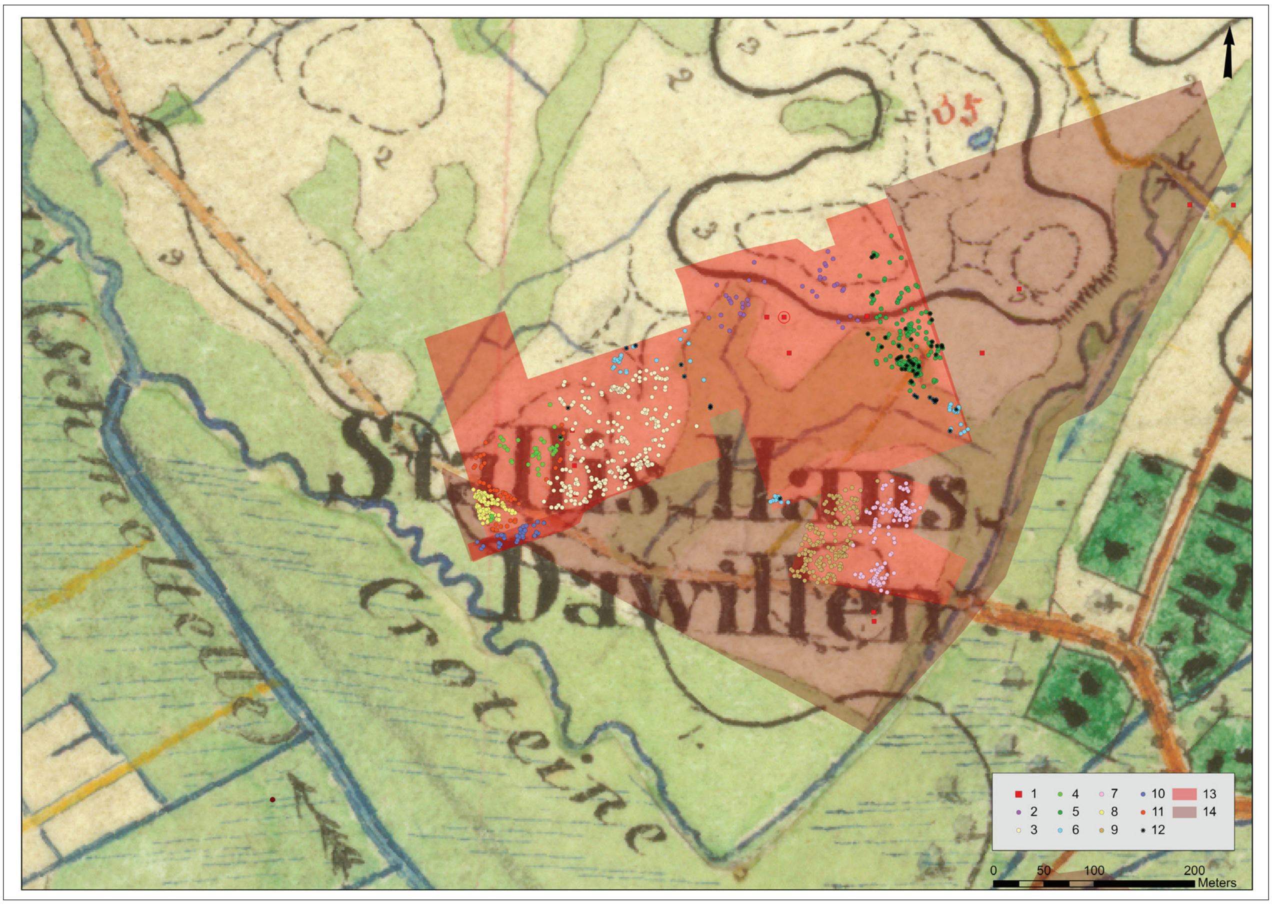

Figure 2. The Bandužiai (Žardė) settlement (mapped on a topographic plan from 1860): 1. 1990 trenches, with the furnace site marked by a circle (Genys 1991; 1992); 2. 2006 features (Masiulienė 2007a; 2007b); 3. 2008 features (Bliujienė and Masiulienė 2011; Masiulienė 2009); 4. 2011 features (Masiulienė 2012a; 2012b); 5. 2015 features (Balsas 2016; Balsas et al. 2016); 6. 2016 features (Balsas 2017; Balsas and Masiulienė 2018); 7. 2017 features (Songailaitė 2018a; 2018b); 8. 2018 features (Sprindys 2019a; 2019b); 9. 2018 features (Ziabreva 2019; Ziabreva and Songailaitė 2019); 10. 2019 features (Tarasova 2020); 11. 2020 features (Songailaitė 2021a; 2021b); 12. structures sampled for archaeobotanical research; 13. archaeologically investigated settlement area; 14. present boundaries of the immovable cultural property (by I. Masiulienė).

parts of the settlement, covering about 4 hectares and uncovering 397 additional archaeological features (Figs. 2 and 3). Most of these features, such as bog ore extraction pits and wooden structures, were associated with iron prospecting and production. In addition, several hearths containing handmade pottery were identified and dated to the 1st millennium BC to early 2nd millennium AD. One of the more notable structures was a wooden well, AMS-dated to 777–986 cal AD, which was later subjected to archaeobotanical analysis (Sprindys 2019; 2019a; Grikpėdis 2021, pp. 87–88, 223–224). Several recorded negative features may have been of non-archaeological origin, as they lacked structural characteristics or other evidence of human activity. Most of the remaining archaeological features were attributed to the Iron Age.

In summary, archaeological investigations conducted at the Bandužiai (Žardė) settlement between 1990 and 2020 covered an area of approximately 11 hectares and documented around 950 features. The site is characterised by a fragmented cultural layer and numerous sunken structures, primarily associated with economic and productive activities, as well as food preparation, though the function of some features remains unidentified and a few may be of non-archaeological origin. Chronologically, the settlement dates from the 1st millennium BC to the early 2nd millennium AD, while isolated Neolithic finds attest to an even earlier human presence in the area.

2. Site description

The Žardė–Laistai–Bandužiai (*Ger.* Szarde–Leisten–Bandhuszen) archaeological complex, located in the southern part of Klaipėda, 1–3 km east of the Curonian Lagoon, is one of the largest and most significant prehistoric sites in western Lithuania. The complex comprises three hillforts (Žardė, Laistai and Gibišiai — the latter destroyed), several prehistoric settlements (Bandužiai (Žardė), Bandužiai I–II, Žardė I–III and Laistai), and two cemeteries (Bandužiai and Laistai) (Genys 2018; Masiulienė 2018) (Fig. 1). It stands out not only for the number

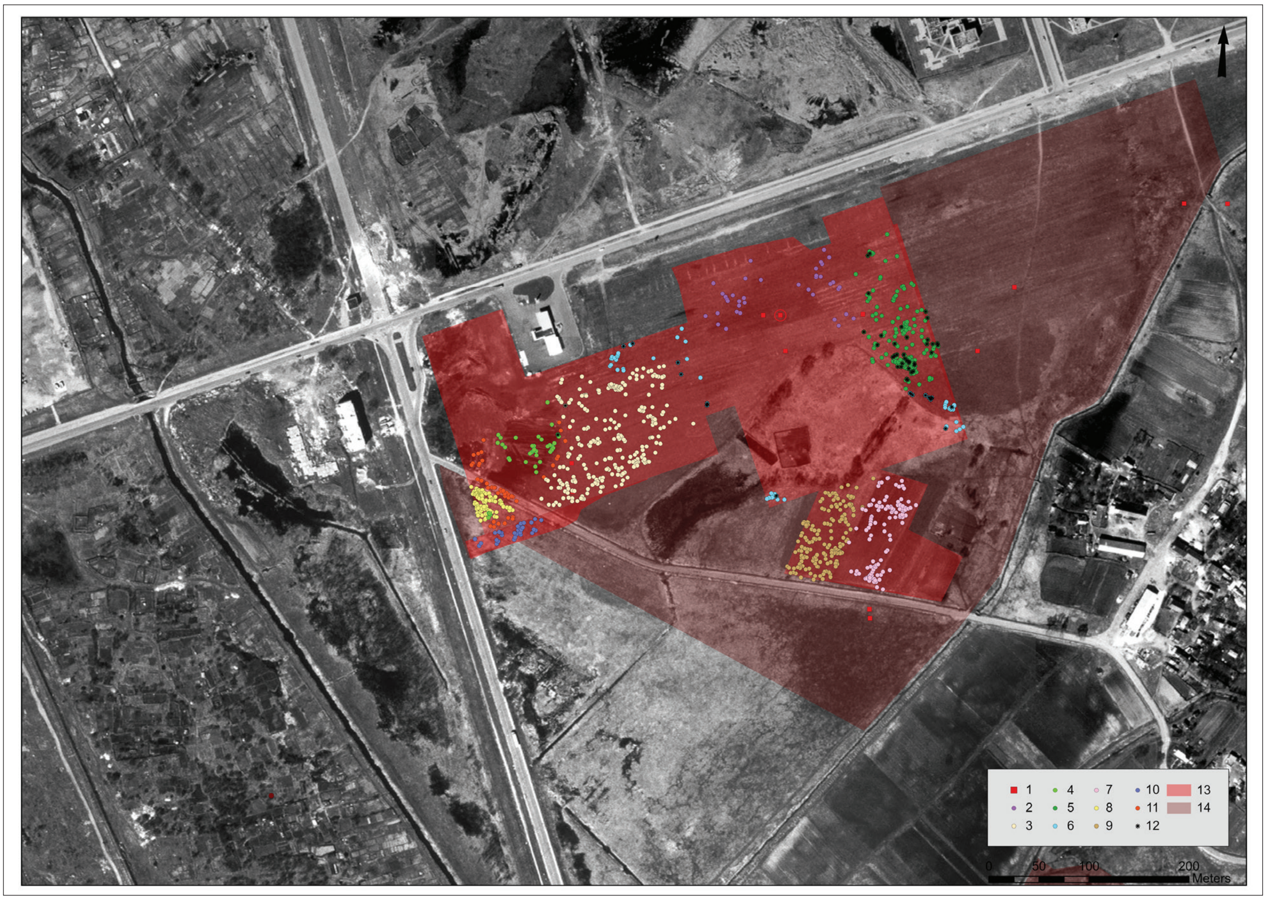

Figure 3. The Bandužiai (Žardė) settlement (mapped on an orthophoto from 1995): 1. 1990 trenches; with the furnace site marked by a circle (Genys 1991; 1992); 2. 2006 features (Masiulienė 2007a; 2007b); 3. 2008 features (Bliujienė and Masiulienė 2011; Masiulienė 2009); 4. 2011 features (Masiulienė 2012a; 2012b); 5. 2015 features (Balsas 2016; Balsas et al. 2016); 6. 2016 features (Balsas 2017; Balsas and Masiulienė 2018); 7. 2017 features (Songailaitė 2018a; 2018b); 8. 2018 features (Sprindys 2019a; 2019b); 9. 2018 features (Ziabreva 2019; Ziabreva and Songailaitė 2019); 10. 2019 features (Tarasova 2020); 11. 2020 features (Songailaitė 2021a; 2021b); 12. structures sampled for archaeobotanical research; 13. archaeologically investigated settlement area; 14. present boundaries of the immovable cultural property (by I. Masiulienė).

and concentration of its archaeological monuments but also for the diversity of economic and production activities documented, particularly in the Bandužiai (Žardė) and Bandužiai I settlements (Masiulienė 2008; 2012b; 2013; 2018).

Archaeological evidence indicates that the complex began to form in the 1st millennium BC, when hillforts and settlements developed along the Smeltalė (*Ger.* Schmeltelle) River, while zones of economic activity emerged near the Kretainis (*Ger.* Croteine) stream (Masiulienė 2018). The Bandužiai cemetery, dated to the late 1st century to the first half of the 13th century, was located in the northern part of the complex, near the Kretainis stream, while the Laistai cemetery, situated further south of the Smeltalė River, is dated to the 2nd–12th centuries. Over time, this territory became an important centre of trade and crafts in the Curonian land of Pilsotas, particularly during the Viking period (Genys 2018). In the 13th–14th centuries, the complex declined due to military conflicts with the Teutonic Order; however, from the 16th century onwards, farmsteads, manors and villages (belonging to the Duchy of Prussia and later the Kingdom of Prussia) reappeared in the area, as documented in historical and cartographic sources (Elertas 2005).

Today, the protected territory of the Bandužiai (Žardė) settlement is bounded by Jūrininkų Avenue to the north, Taikos Avenue to the west, and by the straightened Kretainis stream and Žardupė Street to the east and south. The construction of Jūrininkų Avenue and the development of a residential district in the late 20th century significantly altered the natural environment (Figs. 1 and 3).

Topographic maps from 1860 and later show that a hill once stood in the northeastern part of the settlement, while wetlands formed by the Kretainis stream occupied the central and southwestern areas (Fig. 2). In the 19th century, the stream flowed along the eastern, southern and western margins of the settlement and discharged into the Smeltalė River about 350 m to the northwest. The relief sloped gradually from the northeast (ca. 10.0 m a.s.l.) towards the southwest (ca. 4.0 m a.s.l.).

During the late 19th–20th centuries, large-scale reclamation radically transformed the landscape: the Kretainis was straightened and drained, the northeastern hill was levelled, and extensive works were carried out in the southern part of the area. Until 2006, prior to major archaeological excavations, the territory was used as ploughed meadows (Masiulienė 2007, p. 75; Masiulienė 2012a, p. 92) (Fig. 3). At present, parts of the

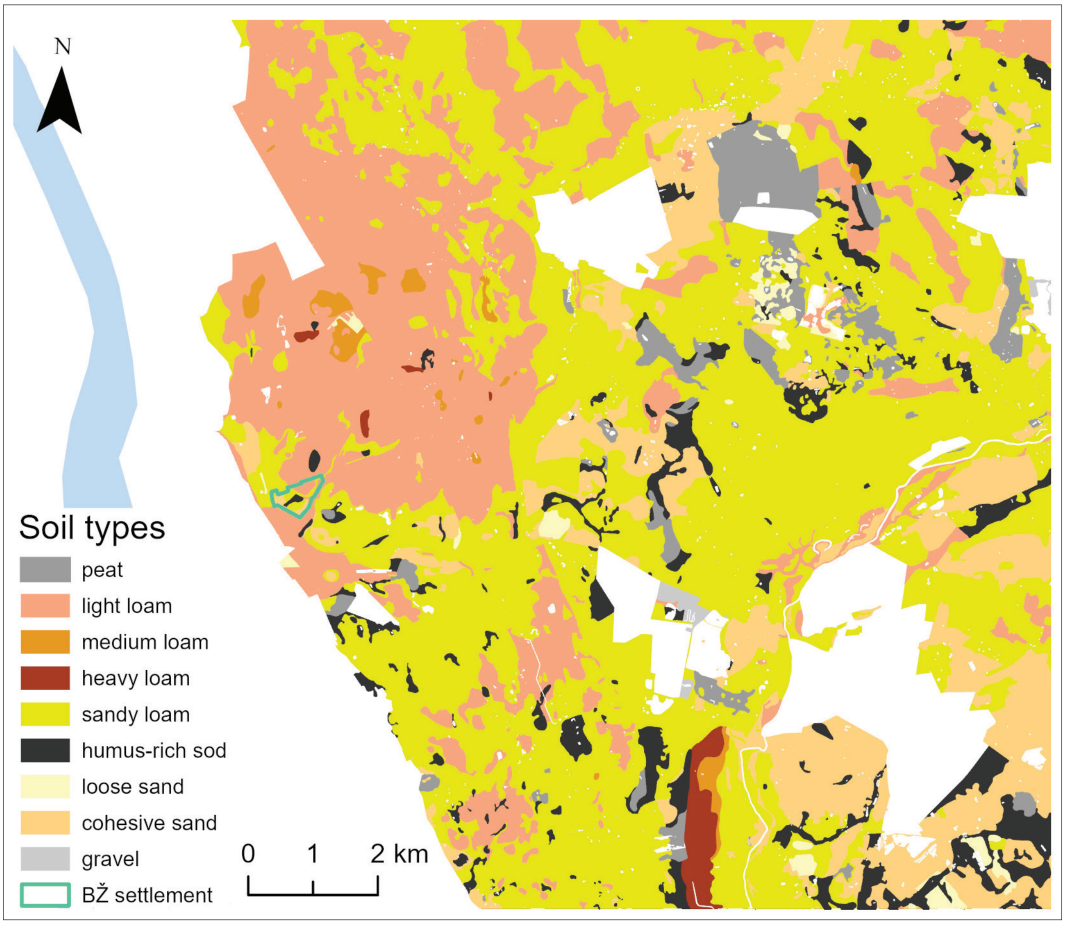

Figure 4. Present-day soil type distribution in the area (by K. A. Bojarskaitė).

settlement are built over with logistics facilities and car parks.

Geomorphologically, the site lies within the limnoglacial plain of the marginal moraine zone (Masiulienė 2007, p. 75). The area is dominated by light loam and sandy loam soils, with patches of sand, peat, humus-rich sod and medium-heavy loam further afield (Fig. 4).

Archaeological investigations have revealed that the Bandužiai (Žardė) settlement, dating from the Late Bronze Age to the Late Iron Age, is characterised by a fragmented cultural layer and numerous sunken features. Most of these were associated with economic and productive activities, primarily bog ore extraction, processing and washing (pits, fireplaces, wooden wells), as well as iron smelting (furnaces). In addition, hearths and fireplaces used for food preparation were identified, along with a large number of pits of uncertain function. Certain features were located in elevated areas, while those related to metallurgical processes were most often concentrated near former water bodies or wetlands. These findings reflect the entire chain of iron metallurgy — from bog ore extraction, preparation and smelting to possible subsequent processing (Masiulienė 2018).

The artefacts recovered from archaeological features at the Bandužiai (Žardė) settlement reveal a diverse material culture associated with both productive activities and food preparation. The largest group consists of ceramics — hand-built, brushed, rusticated and wheel-thrown; in some cases, clusters of sherds from complete vessels were identified. A significant part of the assemblage is related to iron metallurgy: fragments of furnace shaft walls, various types of slag and pieces of both roasted and natural ore attest to intensive ore processing and iron smelting. Metallurgical activity is further evidenced by stone pestles, tools and whetstones used for ore crushing and processing, although some may also have been employed in domestic contexts. In addition, fragments of amber, flint artefacts and a small number of bronze and metal artefacts were found. The assemblage is complemented by abundant animal bones, fish remains and occasional eggshell fragments, providing insights into the dietary practices of the community (Table 1).

Table 1. General information about the archaeobotanically analysed features from the Bandužiai (Žardė) settlement.

Feature ID	*Interp.*	*Artefact types*	*Feature surface, m a.s.l.*	*Research year(s)*	*Source*
84	Pit	-	4.19	2008	Bliujienė and Masiulienė 2011; Masiulienė 2009
312	Fire pit	Cluster of brushed pottery sherds	4.27	2015	Balsas 2016; Balsas et al. 2016
313	Hearth	Pottery fragments, roasted ore (?)	4.26–4.37	2015	Balsas 2016; Balsas et al. 2016
321A	Hearth	Clusters of rusticated pottery belonging to two pots, worked (?) and natural amber, 5 stone pestles, burnt clay, animal bones	5.92–6.10	2015	Balsas 2016; Balsas et al. 2016
329	Pit	Wood fragment, animal bone, fish scales	4.17–4.22	2015	Balsas 2016; Balsas et al. 2016
332	Pit	-	4.07	2015	Balsas 2016; Balsas et al. 2016
333	Pit	-	4.15	2015	Balsas 2016; Balsas et al. 2016
341	Pit	Animal bone	4.70–4.75	2015	Balsas 2016; Balsas et al. 2016
346	Pit	Burnt clay, animal bone, fish scales	4.38	2015	Balsas 2016; Balsas et al. 2016
351A	Pit	Animal bones	4.54–4.66	2015	Balsas 2016; Balsas et al. 2016
351B	Pit	Stone pestle, charred wood, animal bones	4.19–4.54	2015	Balsas 2016; Balsas et al. 2016
353	Pit	Animal bones	5.01	2015	Balsas 2016; Balsas et al. 2016

Feature ID	*Interp.*	*Artefact types*	*Feature surface, m a.s.l.*	*Research year(s)*	*Source*
354	Pit	Burnt clay, animal bone	4.95–5.04	2015	Balsas 2016; Balsas et al. 2016
369	Furnace	Furnace shaft wall and slag fragments (ca. 11.3 kg), roasted ore, burnt clay, animal bone, worked wood fragment	4.43–4.57	2015	Balsas 2016; Balsas et al. 2016
371C	Pit	Furnace shaft wall and slag fragments, burnt clay, animal bone	4.60–4.64	2015	Balsas 2016; Balsas et al. 2016
375	Pit	Pottery fragments, furnace slag, burnt clay, animal bones, fish scales	5.46	2015	Balsas 2016; Balsas et al. 2016
379	Pit	Burnt clay fragments (ca. 62.6 kg), furnace slag, animal bones, fish scales	5.53–5.56	2015	Balsas 2016; Balsas et al. 2016
381	Pit	Burnt clay fragments (ca. 96 kg), animal bones	6.15–6.25	2015	Balsas 2016; Balsas et al. 2016
382	Wooden well	Pottery fragments, 7 stone pestles, wood fragment, burnt clay, animal bones, fish scales	4.87	2015	Balsas 2016; Balsas et al. 2016
383	Hearth	-	5.63	2015	Balsas 2016; Balsas et al. 2016
401	Pit	Animal bones	5.42	2015	Balsas 2016; Balsas et al. 2016
406	Pit	Burnt clay fragments (ca. 12.4 kg), stone pestle	6.15	2015	Balsas 2016; Balsas et al. 2016
437	Pit	Cluster of fine-rusticated pot sherds, burnt clay, eggshells	7.14–7.46	2015	Balsas 2016; Balsas et al. 2016
444	Hearth	Hand-built pottery and rusticated pottery sherds, stone tools and pestles, burnt clay	8.68–8.74	2015	Balsas 2016; Balsas et al. 2016
446	Hearth	Pottery fragments, stone whetstone, stone tools and pestles, burnt clay	8.69–8.80	2015	Balsas 2016; Balsas et al. 2016
457	Furnace	Furnace shaft wall and slag fragments (ca. 1.1 kg), natural and roasted ore fragments	4.58–4.63	2015	Balsas 2016; Balsas et al. 2016
459	Furnace	Furnace shaft wall and slag fragments (ca. 10.7 kg), roasted ore, charred wood	4.65–4.84	2015	Balsas 2016; Balsas et al. 2016
464	Pit	Animal bone, fish scales	4.65–4.70	2015	Balsas 2016; Balsas et al. 2016
466	Pit	-	4.60–4.76	2015	Balsas 2016; Balsas et al. 2016
467	Pit	Stone pestle, slag fragments, animal bones	4.71–4.81	2015	Balsas 2016; Balsas et al. 2016
474	Hearth	Pottery fragments, 2 stone pestles, burnt clay, animal bones	5.95–6.07	2015	Balsas 2016; Balsas et al. 2016
478	Pit	Pottery fragments, burnt clay, animal bones	6.25	2015	Balsas 2016; Balsas et al. 2016
479	Pit	Pottery fragments, burnt clay, animal bones	6.42	2015	Balsas 2016; Balsas et al. 2016
480	Pit	Burnt clay, animal bones	6.44	2015	Balsas 2016; Balsas et al. 2016
481	Pit	Pottery fragments, stone tool, burnt clay	6.65–6.70	2015	Balsas 2016; Balsas et al. 2016

Feature ID	*Interp.*	*Artefact types*	*Feature surface, m a.s.l.*	*Research year(s)*	*Source*
482	Pit	Pottery fragments, burnt clay, animal bones, flint	6.76–6.79	2015	Balsas 2016; Balsas et al. 2016
492	Fire pit	Pottery fragments, burnt clay, animal bones	4.44	2016	Balsas 2017; Balsas and Masiulienė 2018
498	Fire pit	Pottery fragments, animal bones	4.57	2016	Balsas 2017; Balsas and Masiulienė 2018
499	Fire pit	Cluster of hand-built pot, animal bones	4.62	2016	Balsas 2017; Balsas and Masiulienė 2018
500	Fire pit	Pottery fragments, animal bones	4.62–4.65	2016	Balsas 2017; Balsas and Masiulienė 2018
501	Fire pit	Cluster of hand-built pot, animal bones, fish scales	4.57	2016	Balsas 2017; Balsas and Masiulienė 2018
502	Fire pit	Animal bones	4.57	2016	Balsas 2017; Balsas and Masiulienė 2018
505	Pit	Animal bones	3.50–3.56	2016	Balsas 2017; Balsas and Masiulienė 2018
506	Pit	-	3.94	2016	Balsas 2017; Balsas and Masiulienė 2018
507	Hearth	-	4.02	2016	Balsas 2017; Balsas and Masiulienė 2018
510	Wooden well	Pottery fragments, iron artefacts, stone tools, furnace slag, animal bones, fish scales	3.24–3.34	2016	Balsas 2017; Balsas and Masiulienė 2018
531	Hearth	Pottery fragments, bronze brooch (8th–9th c.), knife (?) handle, furnace slag, burnt clay, animal bones	5.51–5.57	2016	Balsas 2017; Balsas and Masiulienė 2018
533	Pit	Pottery fragments, burnt clay	5.54–5.61	2016	Balsas 2017; Balsas and Masiulienė 2018
539A	Hearth	Pottery fragments, 2 stone pestles, wood fragment, animal bones, fish scales	4.17–4.28	2016	Balsas 2017; Balsas and Masiulienė 2018
539B	Pit	Pottery fragments, animal bones, fish scales	4.19	2016	Balsas 2017; Balsas and Masiulienė 2018
540	Pit	-	4.81–4.87	2016	Balsas 2017; Balsas and Masiulienė 2018
541	Hearth	Stone tool (?), burnt clay	4.80	2016	Balsas 2017; Balsas and Masiulienė 2018

3. Materials and methods

3.1. Archaeobotanical analysis

Soil samples for macrobotanical analysis were collected by a team of archaeologists from Klaipėda University Institute of Baltic Region History and Archaeology during four excavation seasons at the Bandužiai (Žardė) settlement in 2008, 2011, 2015 and 2016. The samples were taken from undisturbed archaeological structures and cultural layers by applying a systematic sampling strategy and a mixture of point, scatter and column sub-sampling strategies (d'Alpoim Guedes and Spengler 2014). The summary of archaeological features sampled and analysed here can be found in Table 1.

The analysis of macrofossils can be divided into two stages: the first set of samples (collected in 2008 and 2011) was examined in 2013 by a team of researchers led by Dalia Kisielienė (Kisielienė et al. 2013), and the remaining samples (collected in 2015 and 2016) were analysed in 2023 (Bojarskaitė 2023) and 2024 by Kotryna Alma Bojarskaitė. The archaeobotanical results from excavation seasons 2015 and 2016 will be used as the main focus for this study. The results of the 2013 analysis were obtained using multiple methodologies: palynological analysis, diatom analysis and plant macrofossil analysis, and the results are reported in Kisielienė et al. 2013.

The archaeobotanical samples were processed using manual bucket flotation (Fairbairn 2005). The soil was manually broken down in water by stirring, then the water was poured into the receiving steel sieve (250 µm mesh size) so all the flot was caught. The process was repeated five to six times. All the remaining heavy fraction was wet-sieved for bones, fish scales and artefacts on 500–1000 µm mesh size glass-fibre net. All the samples were dried and later analysed in the laboratory. Using different sized sieves (mesh sizes 2800 µm, 1400 µm and 500 µm), samples were separated into three fractions which were analysed using a binocular stereo microscope with magnification power of x7 to x40. The plant macrofossils were identified using archaeobotanical atlases (Jacquat 1988; Cappers et al. 2012; Kirleis 2019) and other scientific literature (Jacomet 2006). Plant taxonomy is presented based on official (WFO 2025) and accepted archaeobotanical (Zohary et al. 2012) nomenclature. All the identified plants were assigned to different ecological groups according to their typical growing conditions. In addition, they were assessed using Ellenberg's Indicator values (Hill 1999). There were 84 (329.05

Table 2. AMS ^{14}C dates from the Bandužiai (Žardė) settlement published in this study. LBA — Late Bronze Age; PRIA — Pre-Roman Iron Age; MP — Migration period; VP — Viking period.

Feature ID	*Period*	*Interpretation*	*Sample*	*Lab code*	*^{14}C date (BP)*	*cal age (95.4%)*
84	LBA	Pit	Organics	Poz-58576	2730 ± 40	979–806 cal BC
312	LBA	Firepit	Charcoal	Poz-85903	2435 ± 30	751–406 cal BC
437	PRIA	Pit	Charcoal	Poz-85937	2230 ± 30	387–200 cal BC
321A	MP	Hearth	Charcoal	Poz-85905	1505 ± 35	437–645 cal AD
444	MP	Hearth(?)	Charcoal	Poz-85938	1495 ± 30	541–643 cal AD
375	VP	Pit	*Hordeum vulgare*	FTMC-QQ62-161	1157 ± 28	772–979 cal AD
379	VP	Pit	Charcoal	Poz-85934	1080 ± 30	892–1023 cal AD
381	VP	Pit	Charcoal	Poz-85935	1235 ± 30	680–883 cal AD
382	VP	Wooden well	Waterlogged wood	Poz-85936	1050 ± 30	895–1035 cal AD
446	VP	Hearth	Charcoal	Poz-85939	1275 ± 30	665–822 cal AD
457	VP	Furnace	Charcoal	Poz-85940	1205 ± 30	704–941 cal AD
459	VP	Furnace	Charcoal	Poz-85941	1220 ± 30	687–888 cal AD
479	VP	Pit	Charcoal	Poz-85942	1180 ± 30	771–973 cal AD
507	VP	Hearth	Charcoal	Poz-85863	1250 ± 30	674–877 cal AD
510	VP	Wooden well	Waterlogged wood	Poz-85866	1095 ± 30	890–1017 cal AD

l of soil) samples from 51 negative features ranging from 0.15 to 7.5 l in size that were analysed in total.

3.2. AMS 14C dating

A total of 15 samples from archaeological features were radiocarbon-dated using AMS in the Poznań Radiocarbon Laboratory in Poland and in the Mass Spectrometry Laboratory at the Centre for Physical Sciences and Technology in Lithuania. Archaeological features for dating were selected from clearly identifiable features such as iron smelting furnaces, wells, hearths and firepits, as well as from some pits of uncertain function. In addition, charcoal samples from archaeological features associated with different types of pottery were selected for dating in order to refine the chronology of the ceramics. Samples were pretreated following standard acid-alkali-acid procedures (charcoal and wood) and conventional botanical sample protocols. The results were calibrated using OxCal v. 4.4 and the IntCal20 atmospheric calibration curve (Ramsey 2009; Reimer et al. 2020) and are presented with a 95.4% probability range (Table 2).

A few points should be noted. Several radiocarbon determinations fall within the transitional range between the Migration period and the Viking period. For the sake of consistency with site phasing, archaeological context and functional zoning, these dates are assigned to the Viking period. It is acknowledged, however, that some of these determinations may in fact belong to the late Migration period, and future advances in dating methods may allow for more precise attribution. Nevertheless, given the current evidence, their placement within the Viking period provides the most coherent interpretive framework.

4. Results

4.1. Chronology

Out of all the contexts analysed in 2013, only one was directly dated (feature 84), and out of 51 analysed negative features that were examined as the second batch of samples, 14 were directly dated (Table 2, Fig. 5). The radiocarbon dates spanned a broad chronological range, from the Bronze Age to the Late Iron Age. The archaeological features were attributed to four distinct periods: the Late

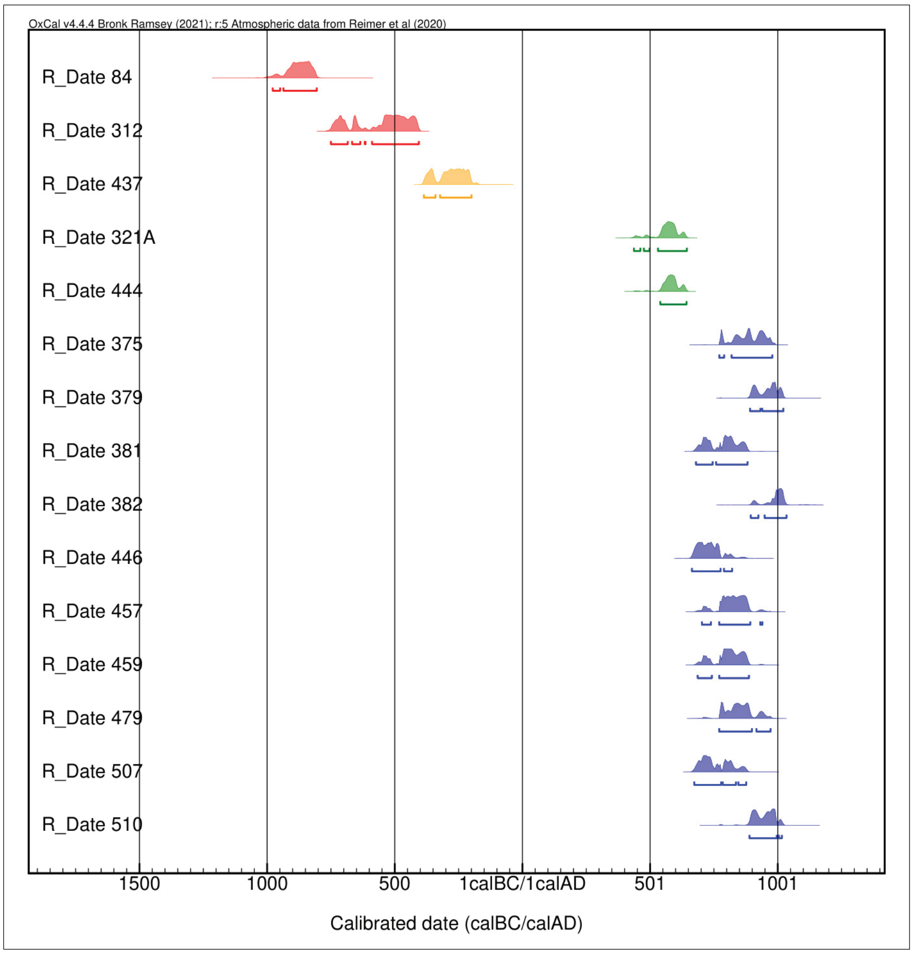

Figure 5. Calibration plot of AMS radiocarbon dates. Colours indicate periods: red — Late Bronze Age; orange — Pre-Roman Iron Age; green — Migration period; blue — Viking period (by K. A. Bojarskaitė).

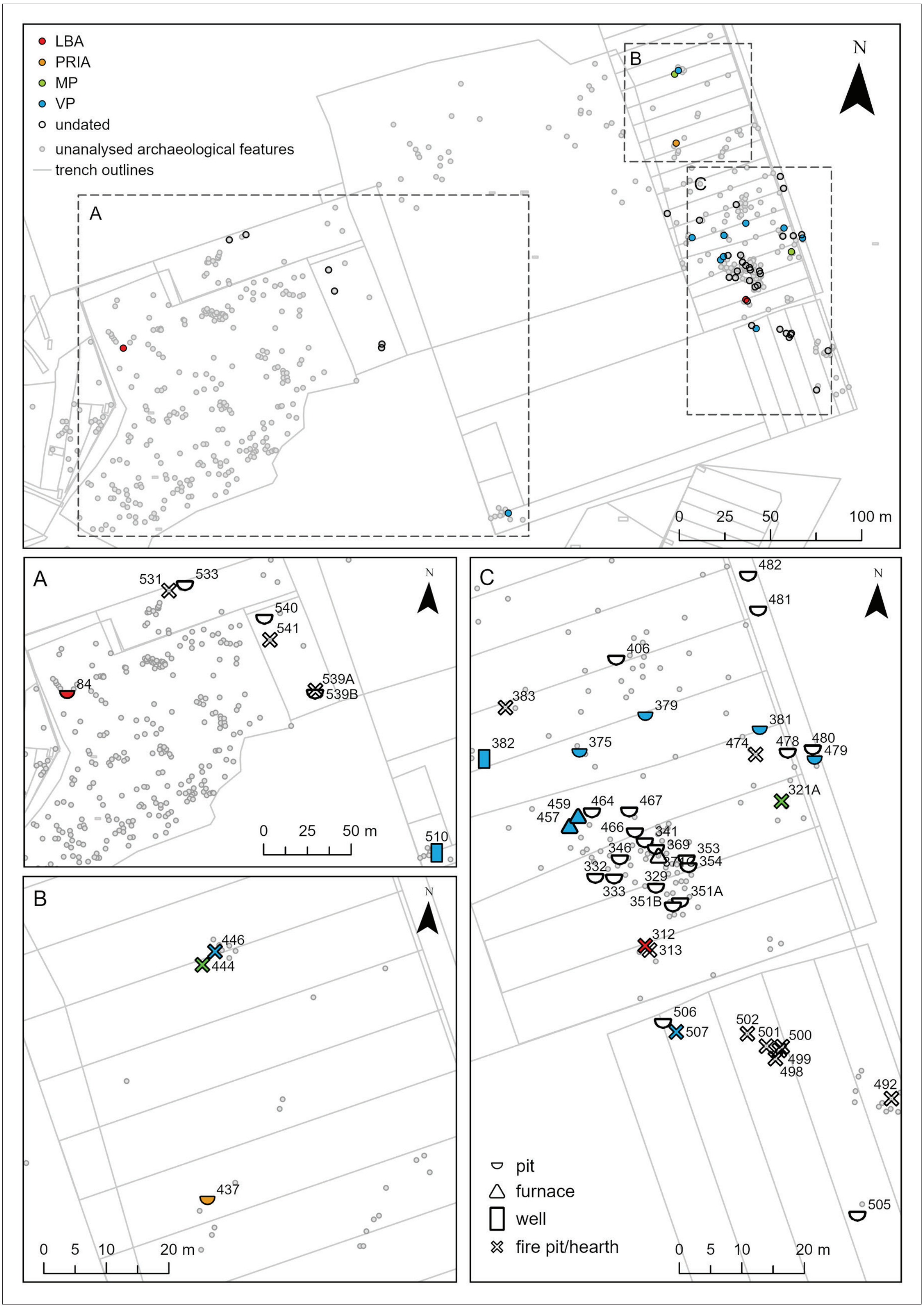

Figure 6. Distribution and interpretation of archaeobotanically analysed and unanalysed, as well as directly dated and undated, archaeological features in the excavated areas of the Bandužiai (Žardė) settlement (by K. A. Bojarskaitė).

Bronze Age (1100–400 BC), Pre-Roman Iron Age (400–0 BC), the Migration period (400–800 AD) and the Viking period (800–1200 AD). No AMS dates corresponding to the Roman period (0–400 AD) were observed. It is worth noting that some pottery types within other archaeological structures could be attributed to the Roman period, even though no direct dates have been identified.

Two features, an unidentified pit (feature 84) and a fireplace (feature 312), were dated to the Late Bronze Age. Only one feature, an unidentified pit (feature 437), was dated to the Pre-Roman Iron Age. After that time, no dates were identified within a gap spanning several centuries. Two features were dated to the Migration period, both hearths (features 321A and 444). And the remaining directly dated, archaeobotanically analysed features are attributed to the Viking period (features 375, 379, 381, 382, 446, 457, 459, 479, 507 and 510), which made up the majority of the dated contexts (Fig. 6).

4.2. Composition of the archaeobotanical assemblage

The overall results presented are from 84 archaeobotanical samples that were collected from 51 negative features during the 2015 and 2016 excavation seasons. The assemblage was primarily composed of charred plant remains, although several waterlogged contexts preserved uncharred plant macrofossils. In total, 19,175 charred and 8,247 waterlogged plant macrofossils were identified (Table 3). Charred remains accounted for 69.93% of the assemblage, while waterlogged remains constituted 30.07%.

Plant remains were classified into six groups, based on their ecological representation. Cultivated plants formed the most abundant category and were recovered from 27 archaeological features (Fig. 7). These were overwhelmingly represented among the charred remains (91%, n = 17,449) and were also minimally present in waterlogged contexts (0.44%, n = 36). At least ten taxa of charred cultivated plants were identified (Table 4), along with only one taxon among the uncharred remains.

Among the cultivated species, barley (*Hordeum vulgare*) was the most frequently encountered, comprising 48.84% (n = 8,494) of the charred crop remains. It was found in 18 archaeological features, often being the only cultivated species in its context (Fig. 8). Two varieties of barley were identified: hulled barley (*H. vulgare* var. *vulgare*), which dominated the assemblage, and a small quantity (at least 69 grains) of naked barley (*H. vulgare* var. *nudum*), recovered from a single archaeological feature (feature 321A).

Rye (*Secale cereale*) constituted the second most abundant taxon, accounting for 25.25% (n = 4,392) of the charred remains. Both grains and chaff of rye were present. Evidence of rye was found in 12 archaeological features, however, the majority of remains came only from two furnaces (Fig. 8). Without these contexts, rye would only be the fourth most prominent species.

Other cultivated species appeared in lower percentages. Charred remains of hulled and free-threshing wheats (*Triticum* sp.) made up 1.04% (n = 181). Among these, hulled wheats were more prevalent (0.95%, n = 166), found in six negative features (Fig. 8). Some grains or glume bases were better preserved or had more prominent identifiable features, so in some cases it was possible to distinguish both spelt (*T. spelta*, 0.01%, n = 1) and emmer (*T. dicoccon*, 0.33%, n = 57). Some grains of free-threshing wheat (*T. aestivum/durum*) were present as well (0.03%, n = 6).

The rest of the cultivated species were a lot less prominent. Broomcorn millet (*Panicum miliaceum*) was recorded in both charred (0.06%, n = 11) and waterlogged (100%, n = 36) forms. The latter consisted entirely of millet husks. Millet was found in seven archaeological features (Fig. 8). Only a few charred grains of oat (*Avena* sp.) genus were recovered from five contexts (0.07%, n = 12) (Fig. 8). Some pulses (0.07%, n = 12), including broad bean (*Vicia faba*, 0.03%, n = 5), grass pea (*Lathyrus sativus*, 0.01%, n = 2), and pea (*Pisum sativum*, 0.01%, n = 1), were recovered as well. The rest of the cultivated legumes seeds remained unidentified (0.02%, n=4). The remainder

Table 3. Overall results from archaeobotanically analysed contexts from 2015–2016.

Ecological group	***Charred remains (n)***	***Charred remains (%)***	***Waterlogged remains (n)***	***Waterlogged remains (%)***
Cultivated plants	17449	91.00	36	0.44
Weeds and ruderal plants	183	0.95	5348	64.85
Meadow and pasture plants	22	0.11	371	4.50
Wetland plants	49	0.26	1961	23.78
Woodland and clearing plants	1	0.01	45	0.55
Unspecified ecology	1471	7.67	486	5.89
Total	**19175**	**100**	**8247**	**100**

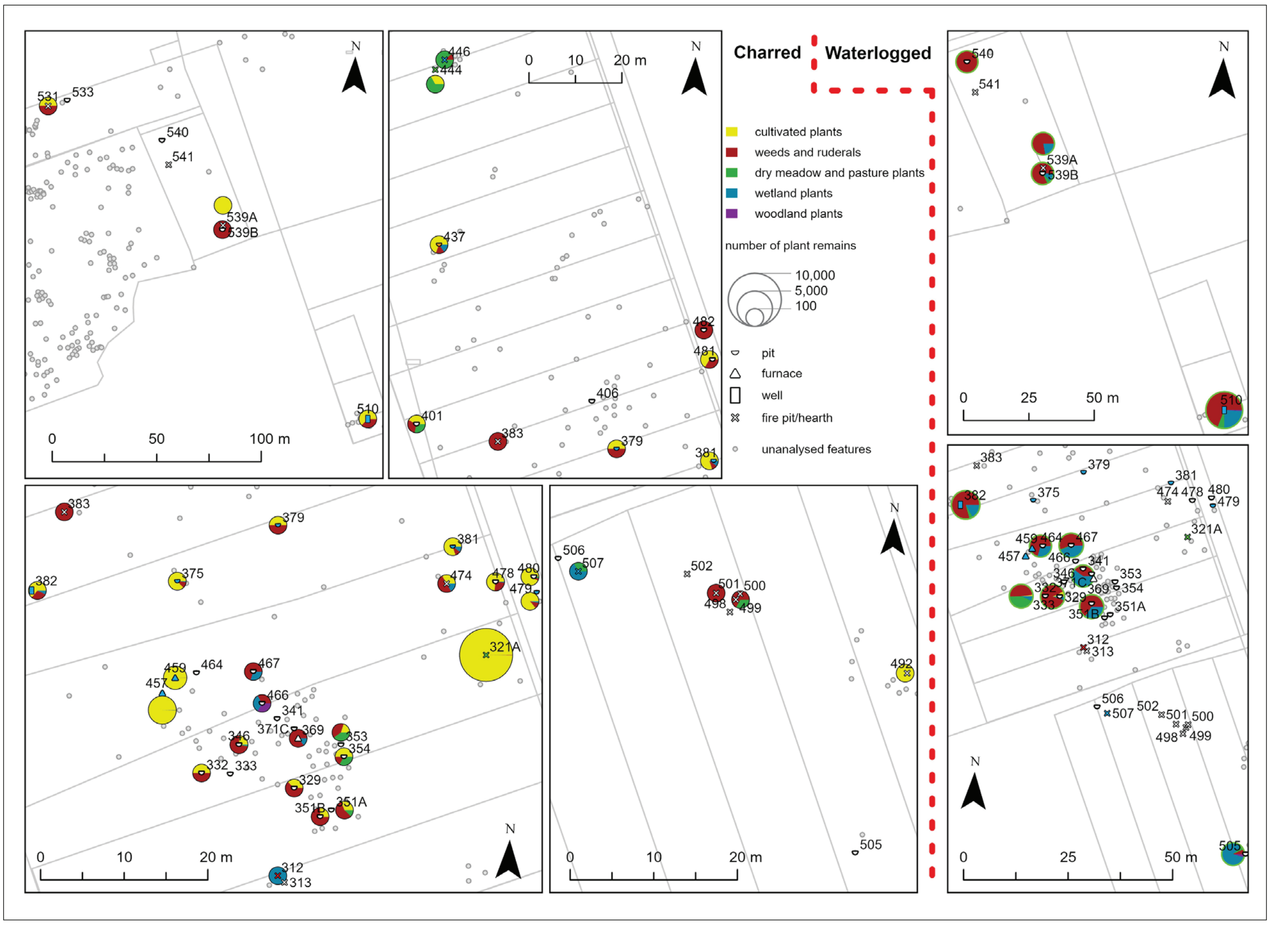

Figure 7. Distribution of charred (left) and waterlogged (right) plant remains according to their ecological groups within the settlement (by K. A. Bojarskaitė).

Table 4. Overall results of cultivated plants in the Bandužiai (Žardė) settlement (n — number of charred (ch) and uncharred (un) finds, % — percentage of all charred cultivated plants, obj(n) — number of negative features it was found in).

	Hordeum vulgare L.	*Secale cereale* L.	*Triticum dicoccon/spelta*	*Triticum dicoccon* Schrank ex Schübl.	*Triticum spelta* L.	*Triticum aestivum/durum*	*Triticum* sp.	*Avena* sp.	*Panicum miliaceum* L.	*Cerealia*	*Vicia faba* L.	*Lathyrus sativus* L.	*Pisum sativum* L.	Fabaceae (cult.)	
	Barley	Rye	Glume wheats	Emmer	Spelt	Free-threshing wheats	Wheat	Oat	Broomcorn millet	Cereals	Bean	Grass pea	Pea	Legume family	TOTAL
n(ch)	8494	4392	108	57	1	6	9	12	11	4347	5	2	1	4	**17449**
%	48.68	25.17	0.62	0.33	0.01	0.03	0.05	0.07	0.06	24.91	0.03	0.01	0.01	0.02	**100**
n(un)	-	-	-	-	-	-	-	-	36	-	-	-	-	-	**36**
obj(n)	18	12	4	3	1	3	6	5	7	15	3	1	1	1	

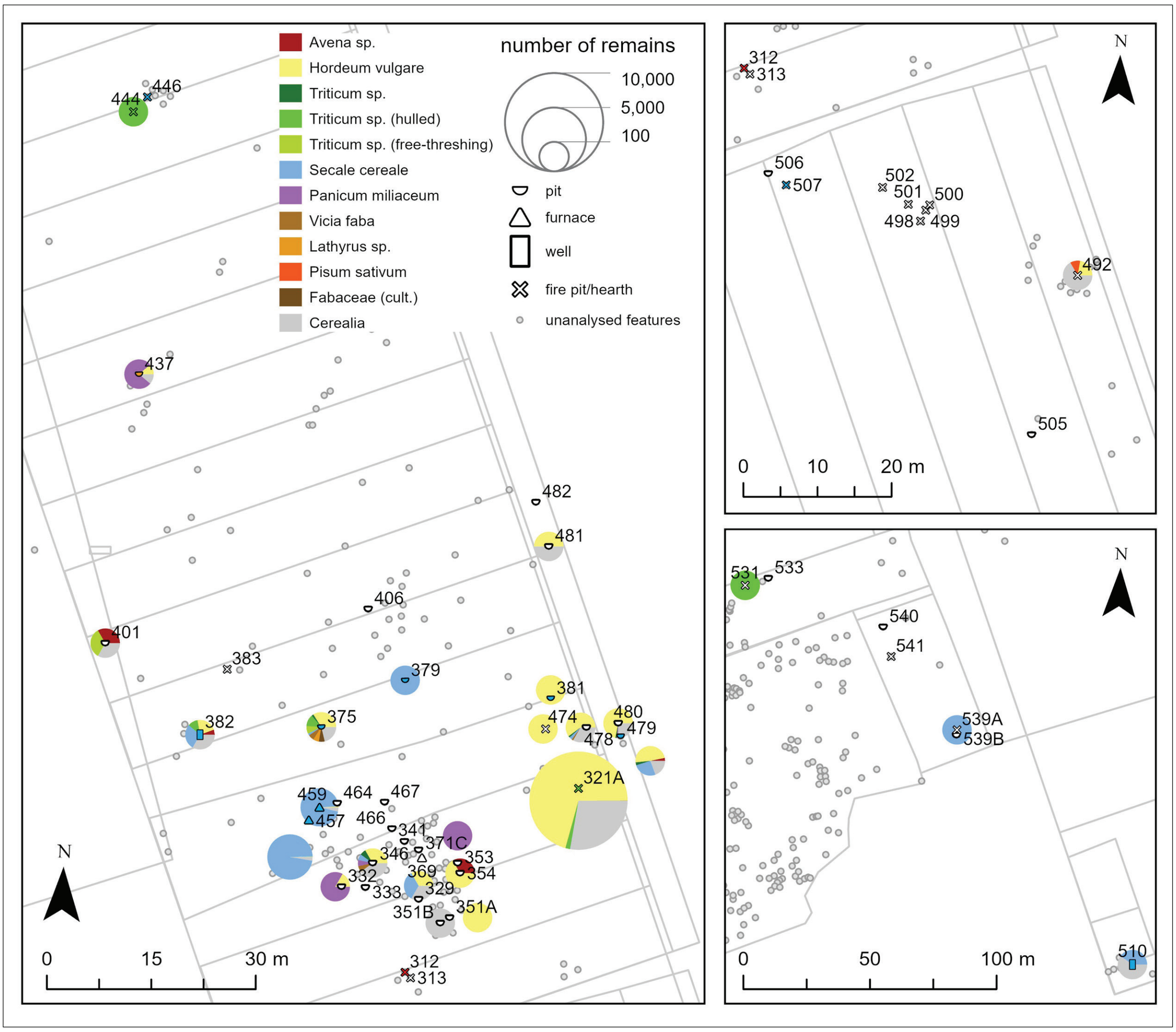

Figure 8. Distribution of cultivated plant remains by species within the settlement (by K. A. Bojarskaitė).

of the cereal macrofossils were unidentifiable (24.91%, n = 4347) because they were badly damaged and lacked identifiable features.

The second most prominent ecological group consisted of weeds and ruderal plants, found in almost all the contexts (Fig. 7). It made up 0.95% (n = 183) of charred and 64.85% (n = 5,348) of waterlogged macrofossils. Other ecological groups were represented to a lesser extent. Wetland flora accounted for 0.26% (n = 49) of the charred and 23.78% (n = 1,961) of the waterlogged assemblage. Meadow and pasture species comprised 0.11% (n = 22) of charred and 5.32% (n = 439) of waterlogged macrofossils. Forest flora and shade-tolerant plants were only minimally present, with 0.01% (n = 1) of charred and 0.55% (n = 45) of waterlogged specimens identified.

4.3. Changes in the archaeobotanical assemblage over time

The summarised archaeobotanical results from different periods are presented in Tables 5 and 6 and Figures 9 and 10.

4.3.1. The Late Bronze Age

The plant assemblage from the Late Bronze Age is limited and represented by relatively few charred macrobotanical remains (n = 23), which were found in a fire pit context (feature 312). The majority of them belong to wetland plants (82.61%, n = 19). The elements of flora identified in the samples — such as fruits of *Carex* sp. and *Ranunculus acris* — suggest that the surrounding environment was relatively open and humid during this period. The presence of *R. acris* also indicates soils low in nitrogen and with a neutral to alkaline pH.

Table 5. Charred cultivated plants found in directly dated negative features

	437	321A	444	375	379	381	382	457	459	479	510
	PRIA	MP		VP							
Avena sp. — grains	-	1	-	-	-	-	1	-	-	-	-
cf. *Avena* sp. — grains	-	7	-	-	-	-	-	-	-	1	-
Hordeum vulgare L. — grains	1	8327	-	15	-	-	4	5	11	15	-
Hordeum vulgare L. — chaff	-	1	-	-	-	8	-	-	-	-	-
cf. *Hordeum vulgare* L. — grains	-	3	-	1	-	-	-	-	-	-	-
cf. *Hordeum vulgare* L. — rachis seg.	-	-	-	-	-	-	-	-	1	-	-
Hordeum vulgare/*Triticum* sp. — grains	-	2	-	1	-	-	-	-	-	-	-
Lathyrus sativus L. — seeds	-	-	-	2	-	-	-	-	-	-	-
cf. *Lathyrus* sp. — seeds	-	-	-	1	-	-	-	-	-	-	-
cf. *Lathyrus* sp./*Pisum sativum* — seeds	-	-	-	2	-	-	-	-	-	-	-
Panicum miliaceum L. — grains	5	-	-	-	-	-	-	-	-	-	-
cf. *Panicum miliaceum* L. — grains	2	1	-	-	-	-	-	-	-	-	-
Secale cereale L. — grains	-	7	-	-	-	-	-	82	53	8	-
Secale cereale L. — rachis seg.	-	1	-	-	1	-	4	2726	1413	-	2
cf. *Secale cereale* L. — grains	-	-	-	1	-	-	-	5	-	-	-
cf. *Secale cereale* L. — rachis seg.	-	-	-	-	-	-	1	31	52	-	-
Secale cereale L. / *Triticum* sp. — grains	-	5	-	-	-	-	-	1	-	-	-
Triticum sp. — grains	-	-	-	1	-	-	-	-	-	1	-
cf. *Triticum* sp. — grains	-	4	-	-	-	-	-	-	-	-	-
Triticum aestivum/durum — grains	-	-	-	4	-	-	-	-	-	-	-
Triticum cf. aestivum/durum — grains	-	-	-	-	-	-	-	1	-	-	-
Triticum diccocon Schrank ex Schübl. — grains	-	54	1	-	-	-	-	-	-	-	-
Triticum diccocon Schrank ex Schübl. — glume bases	-	1	-	-	-	-	1	-	-	-	-
Triticum spelta L. — glume base	-	-	-	-	-	-	1	-	-	-	-
Triticum diccocon/spelta — grains	-	99	-	6	-	-	-	2	-	-	-
Vicia faba L. — seeds	-	-	-	2	-	-	-	-	-	-	-
cf. *Vicia faba* L. — seeds	-	-	-	1	-	-	-	-	-	-	-
Cerealia — grain frag.	1	4124	-	9	-	-	6	47	35	6	3
Cerealia — chaff	-	-	-	-	-	-	-	31	23	-	-
Fabaceae (cult.) — seeds	-	-	-	1	-	-	-	-	-	-	-
TOTAL	**9**	**12638**	**1**	**47**	**1**	**8**	**18**	**2931**	**1588**	**31**	**5**

The results of the earlier analysis, conducted in 2013, can be considered here as well (Kisielienė et al. 2013). The results come from an unidentified pit (feature 84), dated to the Late Bronze Age, which yielded some uncharred macrobotanical remains (n = 60). It was reported that most of the remains belonged to wetland flora (83.33%, n = 50), with some weeds/ruderals (10%, n = 6), dry meadow and pasture plants (5%, n = 3) and woodland plants (1.67%, n = 1). Most of this assemblage indicates a predominantly wet environment. Several other species characteristic of human living environments were also identified, including *Chenopodium album* and *Persicaria lapathifolia*. Some of these plants, such as *Fallopia convolvulus*, may be associated with agricultural activities like tilling. However, the isolated nature of these finds and the small total number of plant macrofossils do not provide reliable evidence for this assumption.

4.3.2. The Pre-Roman Iron Age

This period is also represented by a small plant assemblage (n=16) from a single negative feature (feature 437). However, the Pre-Roman Iron Age context yielded a greater variety of botanical remains and provided the earliest evidence of agriculture in the settlement. The macroremains primarily consisted of cultivated crops (56.25%, n = 9), along with some weeds and ruderal species (12.5%, n = 2) and wetland flora (12.5%, n = 2). Broomcorn millet was the most abundant crop (n = 5), followed by possible millet grains (n = 2), a probable barley caryopsis (n = 1), and one unidentified cereal fragment (n = 1) (Table 5). The presence of wild taxa such as *Carex* sp. and *Persicaria lapathifolia* possibly indicates a humid environment with nitrogen-rich soils and a neutral to alkaline pH.

4.3.3. The Migration period

This period is better represented than the previous ones (n = 12,695), with plant remains recovered from two archaeological features dated to the Migration period (features 321A and 444). However, only one of the structures — interpreted as a hearth (feature 321A) — was particularly rich in cultivated plant remains and comprised almost all of the remains dated to the Migration period. Adjacent to the stone-built hearth, there was a small layer visibly rich in charred grains, which likely represented a food storage context. There were multiple samples taken from those contexts and finds in them accounted for the highest number of plant remains in the whole assemblage.

Cultivated crops dominated the Migration period assemblage (99.55%, n = 12,638), followed by small amounts of weeds and ruderal species (0.24 %, n = 31), representatives of open dryland and pasture flora (0.02%, n = 3), and wetland plants (0.02%, n = 2). Barley dominated the storage context, constituting the majority of all cultivated remains of this period (65.92%, n = 8,331) (Table 5). Most grains were identified as hulled barley. However, several dozen (at least n = 69) grains of naked barley were also found within the grain-rich storage layer, mixed with the hulled barley.

A smaller portion of the crop remains consisted of glume wheats (1.23%, n = 156) found in both archaeological features (Table 5). This included emmer (n = 57) and a few unspecified wheat caryopses (0.03%, n = 4). Other cultivated crops included probable oat grains (0.06%, n = 8), rye remains (0.06%, n = 8) and a single possible broomcorn millet grain (0.01%, n = 1). The rest of the cultivated plant macrofossils belonged to unspecified cereals (32.68%, n = 4,131).

The wild plant taxa suggests that the area might have been open and humid during this period, with soils that were neutral to alkaline in pH. Several species indicative of high nitrogen levels were present as well. The occurrence of taxa such as *Chenopodium album*, *Polygonum aviculare* and *Persicaria lapathifolia* points to anthropogenic activity in the area during the Migration period.

4.3.4. The Viking period

The Viking period was the most archaeobotanically represented phase of the settlement. Ten archaeological features (features 375, 379, 381, 382, 446, 457, 459, 479, 507 and 510) were dated to this period and yielded the most diverse charred (n = 5,961) and waterlogged (n = 5,647) plant assemblage overall.

Two of these features — identified as furnaces (features 457 and 459) — accounted for nearly 97% of the total Viking period charred plant remains, resulting in highly skewed data. These plants were deliberately used in the iron-smelting process, where they were exposed to ideal charring conditions, allowing for exceptional preservation.

Cultivated plant remains dominate the assemblage (77.65%, n = 4,629) (Fig. 9). Weeds and ruderal species (0.5%, n = 30), wetland taxa (0.29%, n = 17) and dry meadow plants (0.13%, n = 8) account for only a small number of remains (Fig. 9). A significant portion of the assemblage remains were unidentified (21.42%, n = 1,277), largely due to heat damage from high furnace temperatures. These unidentifiable fragments consist mostly of stem remains, many of which likely originated from cultivated cereals, given the abundance of cereal chaff in the furnace contexts.

The Viking period assemblage reflects the most diverse crop composition among all analysed phases. At least eight economically significant taxa were identified (Table 5, Fig 9). Rye was the most dominant cereal (94.68%, n = 4,377) of all cultivated plant remains, found in seven archaeological features (Table 5). This dominance is especially pronounced in the furnace contexts, where thousands of charred rye rachis internodes, accompanied by a relatively small number of grains, were recorded. Rye was also present in other features, though in much lower quantities.

Hulled barley was the second most prominent crop (1.3%, n = 60), found in six contexts (Table 5). This figure is likely underrepresented due to the overwhelming abundance of rye. When furnace data are excluded, barley becomes the most common cultivated cereal of the period. Remains of glume wheats (0.22%, n = 10), including both glumes and grains, were also identified (Table 5). Two wheat glume bases enabled further identification: one as emmer and the other as spelt. Free-threshing wheat types were present as well (0.11%, n = 5). Oats (*Avena* sp.) were represented by

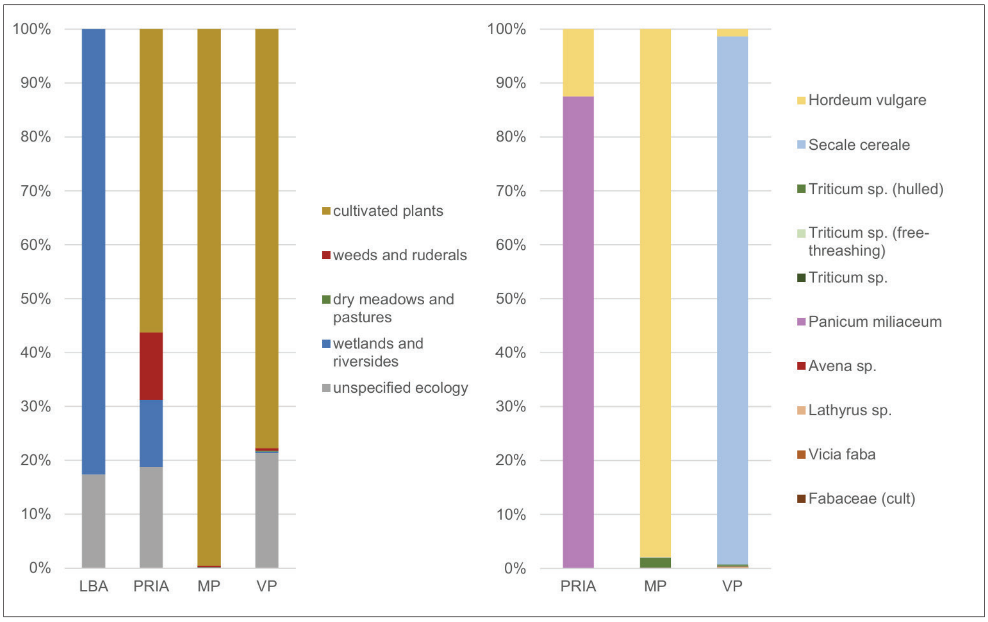

Figure 9. Distribution of plants by ecological group (left) and cultivated species (right) in different periods (by K. A. Bojarskaitė).

two grains (0.04%, n = 2), found in two features (Table 5), although the absence of diagnostic floret fragments and abscission scars makes it difficult to determine whether they were cultivated.

Some seeds of pulses were also recorded. These include grass pea (0.04%, n = 2) and broad bean (0.02%, n = 1). Additional remains were assigned to the vetchling (*Lathyrus* sp.) genus (0.06%, n = 3), and one fragment was attributed to the legume family (Fabaceae) (0.02%, n = 1). The remaining cultivated plant remains were unidentified cereal fragments (3.46%, n = 160).

Table 6. Distribution of charred remains of wild plant species in different periods.

Name of species	LBA	PRIA	MP	VP
Weeds and ruderals	**n**	**n**	**n**	**n**
Bromus sp.	-	-	1	2
cf. *Bromus* sp.	-	-	1	-
cf. *Bromus* sp. / *Festuca* sp.	-	-	1	-
Chenopodium album L.	-	-	4	7
Echinochloa crus-galli (L.) P.Beauv.	-	-	-	1
Echinochloa crus-galli / *Setaria* sp.	-	-	-	1
Euphorbia helioscopia L.	-	-	-	1
Fallopia convolvulus L.	-	-	-	1
cf. *Fallopia convolvulus* L.	-	-	-	1
Galeopsis tetrahit L.	-	-	-	2
Galium cf. *mollugo* L.	-	-	-	2
Galium cf. *spurium* L.	-	-	-	1
Galium sp.	-	-	1	-
Persicaria lapathifolia (L.) Delarbre	-	2	19	4
Polygonum aviculare L.	-	-	2	1
Rumex acetosella L.	-	-	-	1
Rumex crispus L.	-	-	-	1
Setaria viridis (L.) P.Beauv.	-	-	-	1
Setaria sp.	-	-	-	1
cf. *Setaria* sp.	-	-	2	-
Solanum nigrum L.	-	-	-	2
Dry meadow and pasture plants				
Hypericum perforatum L.	-	-	1	-
Stellaria graminea L.	-	-	2	8
Wetland plants				
Carex sp.	11	1	2	12
cf. *Carex* sp.	-	1	-	-
Galium cf. *palustre* L.	-	-	-	1
Juncus sp.	-	-	-	1
Mentha cf. *arvensis* L.	-	-	-	1
Ranunculus acris L.	8	-	-	-
Silene cf. *flos-cuculi* (L.) Greuter & Burdet	-	-	-	1
Solanum dulcamara L.	-	-	-	1
Unidentified ecology plants	1	3	21	1277
TOTAL	**20**	**7**	**57**	**1332**

The wild plant assemblage suggests that the surrounding environment was still relatively damp (Table 6). The presence of taxa such as *Chenopodium album*, *Persicaria lapathifolia*, *Euphorbia helioscopia*, *Fallopia convolvulus* and

Figure 10. Cultivated plant remains found in the BŽ settlement: a, b. *Panicum miliaceum* (broomcorn millet) grain; c. *Avena* sp. (oat) grain; d, e. *Hordeum vulgare* var. *nudum* (naked barley) grain; f. *Hordeum vulgare* var. *vulgare* (hulled barley) grain; g, h. *Secale cereale* (rye) grains; i, j. *Secale cereale* rachis fragments; k. *Triticum dicoccon* (emmer) glume base; l. *Triticum spelta* (spelt) glume base; m. *Triticum dicoccon* grain; n. *Vicia faba* (broad bean) seed; o. *Lathyrus sativus* (grass pea) seed (by K. A. Bojarskaitė).

Galeopsis tetrahit indicates fertile soils with moderate to high nitrogen levels and a neutral to basic pH. While these high fertility indicators dominate the assemblage, species such as *Stellaria graminea* and *Rumex acetosella* suggest the presence of more acidic, less fertile sandy soils as well. The environment most likely had a mosaic structure with humus-rich neutral and sandy slightly acidic soils, as indicated by the identified species.

4.3.4.1. Wells

The Viking period assemblage is unique within the settlement because it is represented by not only charred but also waterlogged remains. These remains were recovered from two wells, where a high groundwater table created exceptional preservation conditions for plant remains. Because charred and waterlogged materials tend to capture different activity areas and local vegetation signals, this directly affects interpretation. For this reason, the uncharred assemblage from wells is treated separately from the settlement's predominantly charred contexts.

The formation processes of well contexts reflect a life cycle which comprises at least several stages (construction, exploitation and abandonment) during which plant remains may be introduced either deliberately or accidentally. Because of difficult depositional processes, such contexts rarely form an obvious stratigraphic sequence (Minkevičius 2020, p. 51), making their interpretation particularly challenging. Nevertheless, wells are exceptional sources of detailed environmental information, because of usually excellent preservation of waterlogged remains, which offers unique opportunities for in-depth analysis.

Two wells dated to the Viking period were sampled for macrobotanical analysis (features 382 and 510). Due to their waterlogged conditions, they both yielded exceptionally well-preserved, uncharred botanical remains, which resulted in a rich assemblage (n = 5,640). Some charred remains were also identified in the contexts (n = 73). In addition, the wells contained bone fragments, many of which belonged to fish, along with fish scales and some ceramic fragments.

Samples were collected from multiple depths within each well, providing insights into plant use and environmental conditions during different phases of their life cycle. Feature 382 yielded five sampled contexts: four from different infill depths and one from a pit fill that formed above the wooden structure long after the well's abandonment. Feature 510 was represented by three samples taken from different infill depths. The number of plant remains was the lowest in the pit fill which formed long after the use of well 382, and was higher in the lower samples, closer to groundwater level. The samples from well 510 produced higher quantities of plant material, with higher concentrations found in the two lowest samples. The sampled depths and overall composition of charred and waterlogged plant remains from the wells and their distribution by depth are presented in Table 7 and Figure 11.

The uncharred assemblage was predominantly composed of weeds and ruderal species (70.08%, n = 3,950). Wetland plants formed the second most abundant group (22.45%, n = 1268), followed by meadow and pasture species (4.25%, n = 240), and a small number of taxa associated with woodland environments (0.55%, n = 31).

Both wells showed similar results: the percentage of weeds and ruderals among the waterlogged remains is relatively high, decreasing with the well's depth, while

Table 7. Archaeobotanical composition of features 382 and 510.

Name of species	**Feature 382**					**Feature 510**		
Depth	*Pit filling above well*	*0–15 cm*	*15–30 cm*	*30–40 cm*	*40–45 cm*	*1st wooden curb*	*2nd wooden curb*	*3rd wooden curb*
CHARRED REMAINS								
Cultivated plants								
Avena sp. — grains	-	-	-	-	1	-	-	-
Hordeum vulgare L. — grains	-	-	1	3	-	-	-	-
Secale cereale L. — rachis seg.	-	-	-	1	3	-	-	2
cf. *Secale cereale* L. — rachis seg.	-	-	-	1	-	-	-	-
Triticum dicoccon Schrank ex Schübl. — glume base	-	1	-	-	-	-	-	-
Triticum spelta L. — glume base	-	-	-	1	-			
Cerealia — grain frag.	-	2	-	3	-	1	-	2
cf. Cerealia — grain frag.	-	-	-	-	1	-	-	-

Name of species	Feature 382					Feature 510		
Depth	Pit filling above well	0–15 cm	15–30 cm	30–40 cm	40–45 cm	1st wooden curb	2nd wooden curb	3rd wooden curb
Weeds and ruderals								
Bromus sp.	-	-	-	-	-	1	-	-
Echinochloa crus-galli (L.) P.Beauv.	-	-	-	-	-	1	-	-
Galium cf. spurium L.	1	-	-	-	-	-	-	-
Persicaria lapathifolia (L.) Delarbre	1	-	-	3	-	-	-	-
Setaria viridis (L.) P.Beauv.	1	-	-	-	-	-	-	-
Setaria sp.	-	-	-	-	-	-	-	1
Solanum nigrum L.	1	-	-	1	-	-	-	-
Wetland plants								
Carex sp.	1	-	-	-	-	-	-	-
Galium cf. *palustre* L.	-	-	-	1	-	-	-	-
Unspecified ecology plants	7	4	1	14	-	1	3	7
TOTAL	**12**	**7**	**2**	**28**	**5**	**4**	**3**	**12**
WATERLOGGED REMAINS								
Weeds and ruderals								
Aethusa cynapium L.	-	1	-	-	-	-	1	1
Chenopodium album L.	-	166	149	103	7	30	111	162
Cirsium arvense (L.) Scop.	-	-	-	-	-	-	4	4
Euphorbia helioscopia L.	-	3	1	1	-	1	2	1
Fallopia convolvulus L.	-	1	5	7	-	2	13	5
Fumaria officinalis L.	-	-	1	-	-	-	-	-
Galeopsis sp.	-	-	-	-	-	-	5	-
Lamium album L.	-	-	3	2	-	-	-	-
Lamium cf. album L.	-	1	-	-	-	-	-	-
Lamium cf. purpureum L.	-	-	-	-	-	1	-	-
Lapsana communis L.	-	-	2	7	-	-	3	4
Malva sylvestris L.	-	-	-	-	-	-	-	1
Nepeta cataria L.	-	-	-	-	-	-	7	-
Persicaria lapathifolia (L.) Delarbre	-	5	51	28	6	8	37	22
Polygonum aviculare L.	-	1	30	43	7	13	225	225
Potentilla anserina L.	-	-	3	1	-	6	21	26
Rumex acetosella L.	-	2	10	29	3	3	23	25
Rumex crispus L.	-	-	1	4	-	1	2	6
Scleranthus annuus L.	-	-	-	1	-	-	-	-
Setaria sp.	-	-	-	1	-	-	-	-
cf. *Setaria* sp.	-	-	-	1	-	-	-	-
Solanum nigrum L.	-	-	-	-	-	-	-	11
Stellaria media (L.) Vill.	-	-	5	5	-	4	7	13
Thlaspi arvense L.	-	-	-	-	-	-	-	1
Urtica dioica L.	-	102	146	122	12	397	717	398
Urtica urens L.	-	12	114	88	4	3	53	30
cf. *Valerianella dentata* (L.) All.	-	-	-	1	-	-	-	-
Viola arvensis Murray	-	-	6	4	-	-	3	4
Dry meadow and pasture plants								
Filipendula vulgaris Moench	-	-	-	-	-	-	-	1
Hypericum perforatum L.	-	-	-	4	-	-	1	2

Name of species	**Feature 382**					**Feature 510**		
Depth	*Pit filling above well*	*0–15 cm*	*15–30 cm*	*30–40 cm*	*40–45 cm*	*1st wooden curb*	*2nd wooden curb*	*3rd wooden curb*
Potentilla cf. argentea L.	-	6	12	34	-	7	22	45
Potentilla argentea / erecta	-	2	1	-	-	-	6	20
Potentilla cf. erecta (L.) Raeusch.	-	-	-	3	-	5	12	48
Prunella vulgaris L.	-	-	-	-	-	-	1	-
Silene dioica / latifolia	-	-	2	-	-	-	-	-
Silene nutans L.	-	-	-	1	-	-	-	-
Silene sp.	-	-	-	1	-	-	2	1
Stellaria graminea L.	-	-	-	-	-	1	-	-
Wetland plants								
Alisma plantago-aquatica L.	-	-	-	-	-	-	-	1
Callitriche palustris L.	-	-	-	-	-	-	-	1
Carex sp.	-	7	4	16	3	28	71	211
Cyperus fuscus L.	-	-	-	-	-	-	9	39
Filipendula ulmaria (L.) *Maxim.*	-	-	-	1	-	2	-	-
Juncus sp.	-	-	-	10	-	-	26	30
Lycopus europaeus L.	-	-	3	1	-	-	-	12
Mentha cf. aquatica L.	-	-	-	-	-	-	1	-
Mentha arvensis L.	-	-	-	-	-	-	6	14
cf. *Menyanthes trifoliata* L.	-	-	-	-	-	1	-	-
Persicaria hydropiper (L.) *Delabre*	-	2	33	124	11	12	255	72
Ranunculus acris L.	-	-	5	1	1	-	-	-
Ranunculus acris / repens	-	-	-	-	1	1	-	-
Ranunculus cf. repens L.	-	-	-	-	-	1	4	10
Ranunculus sceleratus L.	-	2	4	3	1	2	49	63
Ranunculus sp.	-	-	-	-	-	-	5	-
Rorippa palustris Besser	-	-	-	4	1	2	6	4
Solanum dulcamara L.	-	1	18	16	1	9	32	-
Stachys cf. palustris L.	-	-	4	6	1	1	2	1
Woodland plants								
Corylus avellana L.	-	-	-	-	-	-	2	-
Fallopia cf. *dumetorum (*L.) Holub	-	-	-	-	-	-	-	1
Fragaria vesca L.	-	-	-	-	-	-	3	2
cf. *Fragaria vesca* L.	-	-	-	-	-	-	2	1
Rubus idaeus L.	-	-	-	-	-	3	1	3
Rubus cf. *caesius* L.	-	1	-	-	-	-	1	1
Rubus sp.	-	-	-	-	-	1	6	-
cf. *Vaccinium* sp.	-	-	-	-	-	-	-	2
Pinaceae	-	-	-	1	-	-	-	-
Unidentified ecology plants	-	2	9	24	8	13	32	63
TOTAL	**-**	**317**	**622**	**698**	**67**	**558**	**1791**	**1587**

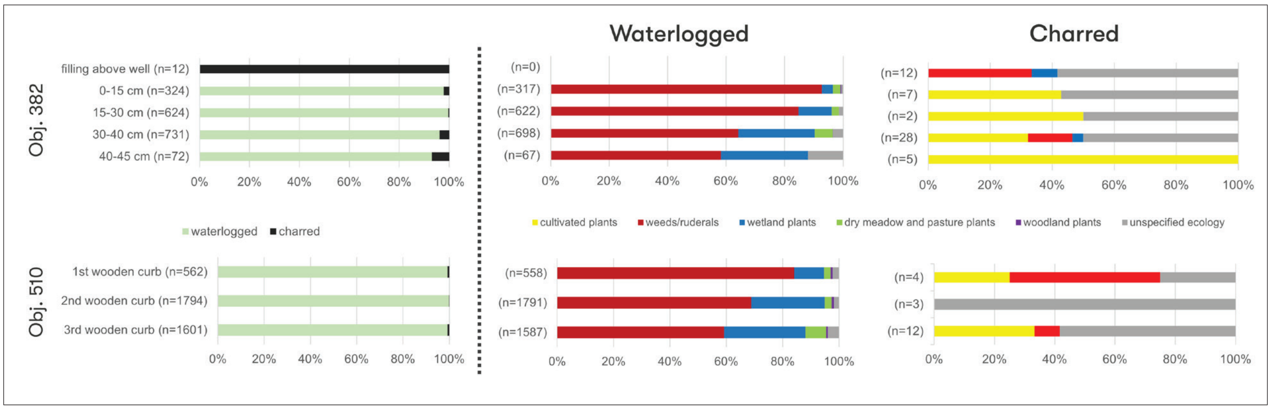

Figure 11. Distribution of plant remains in wells (features 382 and 510) by depth: left — percentage of charred and waterlogged remains; middle — distribution of waterlogged remains by ecological group; right — distribution of charred remains by ecological group (by K. A. Bojarskaitė).

the relative amount of wetland and dry meadow species increases (Fig. 11). Disregarding the results from the fill above the wooden construction of wells 382 , which formed long after the well's use, the plant species are also very similar in both wells and at all depths (Table 7). Ruderal and weed species like *Chenopodium album*, *Urtica dioica*, *U. urens*, *Persicaria lapathifolia*, *Polygonum aviculare* dominated both assemblages. These species, together with *Stellaria media*, *Euphorbia helioscopia* and *Lamium album*, are very indicative of high anthropogenic influence, favouring nitrogen-rich neutral to alkaline soils. However, especially in the lower depths, there is a noticeable increase in species like *Rumex acetosella*, *Potentilla argentea*, *P. erecta*, *Ranunculus acris* and *R. reptans* that are characteristic of nitrogen-poor, sometimes more acidic, soils. In addition, there was a greater presence of species like *Rumex acetosella*, *Viola arvensis* and *Cirsium arvense* which prefer lighter and more sandy substrates, rather than heavier clayey soils.

The lowest sample from feature 382, collected at a 40–45 cm depth, most likely came from a context formed during the construction of the well and reflects the earliest phase. It is less informative than the others, containing fewer plant remains per equal volume of soil than other samples. It also yielded the highest percentage of wetland plants, suggesting that the well was constructed in a humid environment, close to a body of water. The presence of nitrogen-loving weeds and ruderals, together with some charred cultivated plants, suggests that the area was actively visited or inhabited by humans.

The formation stage of the other contexts is more difficult to determine. Their plant composition is very similar, showing only slight changes in the uppermost samples. The top samples, from 0–15 cm from the top of feature 382 and at the level of the first curb in well 510, show smaller numbers of waterlogged plant remains, most likely because they were located higher above groundwater level. These layers also contained larger percentages of weeds and ruderals within them. Overall, the species of the wild plants are consistent across the samples, which could show that the environment changed only slightly, if at all. It appears to be heavily influenced by anthropogenic activity and actively lived in.

5. Discussion

5.1. Agriculture

5.1.1. Pre-Roman Iron Age

The earliest archaeological structures in the settlement are dated to the Late Bronze Age (features 84 and 312). However, no evidence of cultivated crops was found in them. The first archaeobotanical signals of agricultural activities come from the single Pre-Roman Iron Age context (feature 437). Because our knowledge of farming practices during this period is very limited, this makes the Bandužiai (Žardė) finds even more significant. They also represent the first evidence of crop cultivation during the Pre-Roman Iron Age in western Lithuania.

At least two species of cultivated plants were recovered from this period: millet and barley. The most abundant one was millet, however, given the relatively small number of finds, its economic importance for the community remains uncertain. Regionally, millet was one of the most economically significant crops during the Late Bronze Age (Antanaitis-Jacobs et al. 2002; Pollmann 2014; Minkevičius et al. 2020; Piličiauskas et al. 2022). However, archaeobotanical evidence suggests that the importance of millet began to decline around the Pre-Roman Iron Age (Vengalis et al. 2022a; Minkevičius et al. 2024a). This trend is further supported by stable isotope data from human remains (Simčenka et al. 2022) and by charred organic residues in pottery (Podėnas et al. 2023). Similar patterns have been observed in neighbouring areas, such as northern Europe, where millet was also economically important during the Late Bronze Age but was gradually replaced by other crops.

These tendencies indicate that in both the northern European as well as the southeastern Baltic regions, millet was replaced as the most important crop by barley and hulled wheats during the Pre-Roman Iron Age (Vengalis et al. 2022a; Minkevičius et al. 2024a). However, its importance varied in other places, as for example in eastern Europe it remained relatively significant up until the Roman period (Salova et al. 2024). The presence of millet grains at the Bandužiai (Žardė) settlement suggests that the crop may have retained local importance here as well, at least during the early Pre-Roman Iron Age. However, these inferences are limited due to the small number of finds.

5.1.2. Migration period

There were no directly dated archaeological structures or crop remains from the Roman period. The next archaeobotanically represented period in the settlement is the Migration period (features 321A and 444). There was a rich plant assemblage recovered — mainly from a single storage context (feature 321A). This assemblage was dominated by barley, which accounted for more than 66% of all cultivated plant remains in this period.

Barley was a key crop during the Migration period, as it had been throughout much of Lithuanian prehistory. It was surpassed by other crops only after the early 2nd millennium AD (Minkevičius 2020). In regional Migration period assemblages, it typically comprises 27%–47% of cultivated plants (Minkevičius 2020, pp. 65–89), and its nutrient demands are often interpreted as evidence of field fertilisation (Engelmark 1992, p. 372). Stable isotope studies indicate that from the Late Bronze Age, barley was moderately fertilised and grown in open, irrigated fields (Minkevičius et al. 2023; 2024a). Hulled barley dominated the Bandužiai (Žardė) assemblage and was the prevailing variety in prehistoric Lithuania and much of northern and western Europe (Engelmark 1992, pp. 371–374; Viklund 1998, p. 37; Lister and Jones 2013, p. 442; Larsson 2018, p. 420), its hardiness favoured during the climatic downturn at the end of the Bronze Age (Engelmark 1992, p. 372).

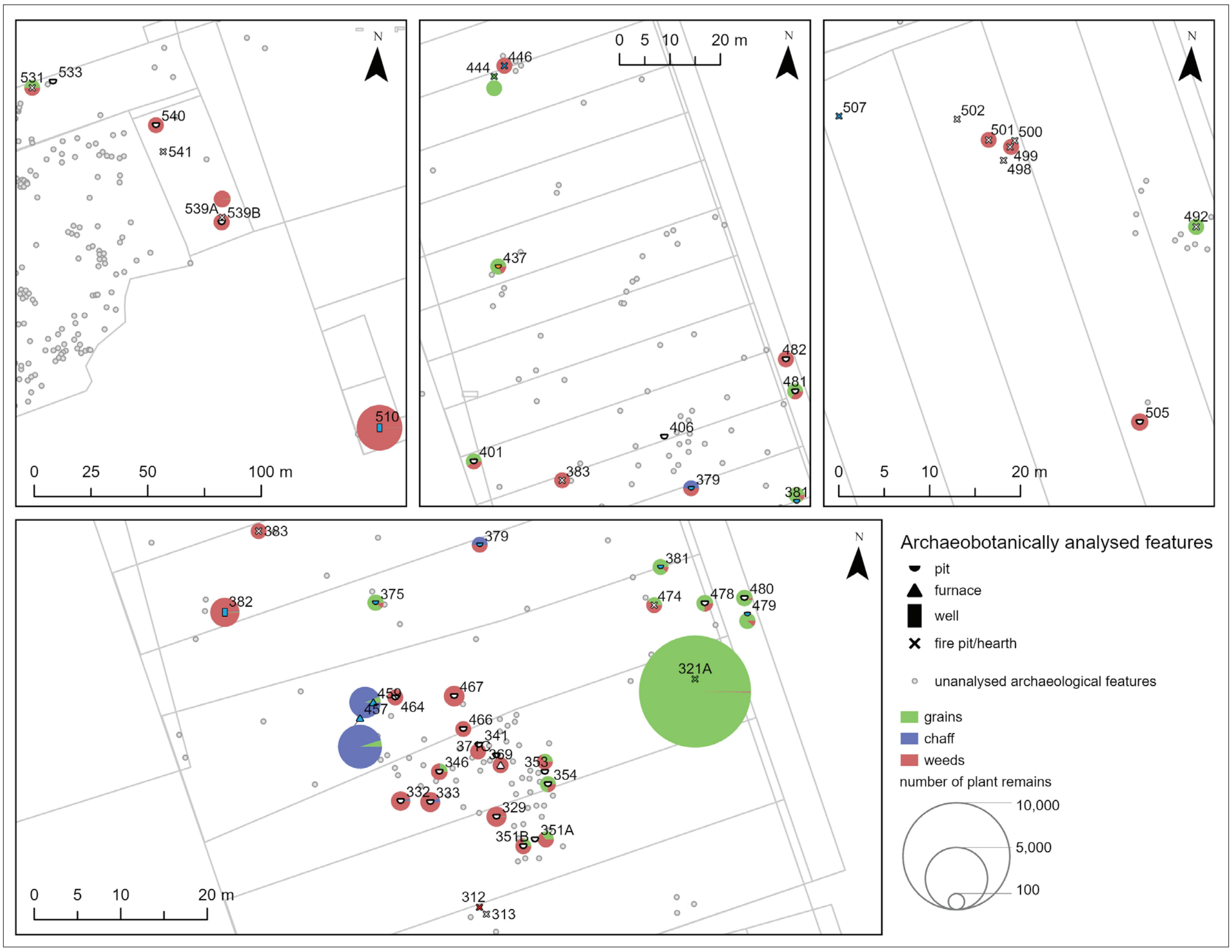

Figure 12. Distribution of negative features and their grain/chaff/weed ratio (by K. A. Bojarskaitė).

Naked barley, by contrast, is rare in Lithuanian Iron Age contexts, occurring mainly in Late Bronze Age and Roman period contexts (Minkevičius 2020; Minkevičius et al. 2023; 2024b). In the Bandužiai (Žardė) settlement, several dozen grains were found among large quantities of hulled barley, likely incidental admixtures (in feature 321A). In broader European contexts, naked barley played a more prominent role during the Neolithic and Bronze Age, but was later largely replaced by hulled barley, although it did not disappear entirely (Engelmark 1992, p. 372; Lister and Jones 2013, pp. 442–443; Grabowski 2013, p. 165). In Finland, Sweden and Denmark, naked barley persisted into the Middle Ages, but in small quantities (Hjelmqvist 1992; Vanhanen 2012, p. 63; Grabowski 2013). A small-scale cultivation was recorded in Denmark during the Roman period to Migration period transition (Grabowski 2013, pp. 187–188). Naked barley's ease of processing may have offered economic or social advantages, but in the Migration period it likely played only a marginal role in the local economy.

Other Migration period crops at Bandužiai (Žardė) (features 321A and 444) fit typical Lithuanian patterns. Many wheat grains were identified, almost all from hulled species, with no free-threshing wheats. This differs slightly from other Migration period sites, where emmer and spelt dominated until the late 1st millennium AD, after which free-threshing wheats became more common (Minkevičius 2020, pp. 81–85). The choice for hulled wheats may have been economic, social or ecological: emmer and spelt husks protect against disease and pests but require more processing, indicating deliberate selection. The ecological conditions may have favoured these crops; emmer tolerates lighter, moister soils, while spelt prefers heavier, low-nitrogen soils (van der Veen 1992, p. 145). Today's soil distribution (Fig. 4) and wild plant finds from both of the Viking period well contexts (features 382 and 510) (Fig. 13) suggest local soils were sandy and light, making emmer the more likely main crop, also supporting earlier suggestions of its longer cultivation in western Lithuania (Minkevičius 2020, p. 83).

Other, less abundant, finds included rye, oat and possibly millet. It is generally accepted that rye and oat were introduced to the region during the Roman period (Minkevičius 2020; Vengalis et al. 2022b; Minkevičius et al. 2024b). The small quantity of rye at Bandužiai (Žardė) makes it difficult to assess the extent of its cultivation. In other Lithuanian sites, rye becomes more significant around the Roman period (Minkevičius 2020, pp. 72–78). As for oat, the recovered macroremains could not be identified to the species level.

5.1.3. Viking period

The Viking period was the most archaeologically and archaeobotanically represented period at Bandužiai (Žardė) (Tables 5 and 6). Most botanical remains came from two furnaces (features 457 and 459), whose formation processes, described in detail by Danish researchers (Mikkelsen 1997; 2003; Mikkelsen and Nørbach 2003), preserved thousands of cereal chaff fragments. As a result, rye dominated, comprising nearly 95% of cultivated crops (Table 5; Fig. 9). Excluding furnace data, rye lowers to 14%, still indicating increased importance. Barley formed just over 1% of the total but rose to 41% when furnace data was excluded, aligning with broader regional trends (Minkevičius 2020, p. 70).

Wheat grains and chaff were also recovered, with the first finds of free-threshing wheats at Bandužiai (Žardė) (Table 5). There were twice as many hulled wheats identified compared to free-threshing varieties, contrasting with the Lithuanian trend whereby free-threshing species began to dominate from the Migration period onward (Minkevičius 2020, pp. 78–85). Previous research on other parts of the Bandužiai (Žardė) settlement, excavated in 2018 (Ziabreva 2019; Ziabreva and Songailaitė 2019; Sprindys 2019a; 2019b) and in 2020 (Songailaitė 2021a; 2021b), suggested an increased importance of free-threshing wheat in the settlement as well. In two contexts directly dated to the Viking period, free-threshing wheats comprised from 24% to 36.5% of all cultivated plants, and by contrast, glume wheats were rare, comprising only 1.6%–4% (Grikpėdis 2021, pp. 223–224). It has been reported that some rachis segments were identified as belonging to hexaploid bread wheat (*Triticum aestivum*) (Grikpėdis 2021, p. 88). The contrasting results from different parts of the settlement may reflect chronological differences or even spatial variation within the settlement. Different parts of the settlement may have served distinct functions over time, as will be discussed further, and it might be reflected in plant choices.

Legumes first appear in the Viking period assemblage, including grass pea, broad bean and unidentified *Lathyrus* species, all from a single feature (Table 5). Broad beans have been present in Lithuania since the Late Bronze Age, but their economic role increased by the end of the Migration period and into the Viking period (Minkevičius 2020, pp. 90–91; Minkevičius et al. 2020). Grass pea and other *Lathyrus* species are mainly known from contexts dating to the 1st–2nd millennium AD transition in Kernavė (Vengalis 2021; Minkevičius et al. 2024a). As nitrogen-fixers, legumes improve soil fertility (Gan et al. 2015) and were likely important for crop rotation, soil health and economic resilience (Fuller and Harvey 2006; Zohary et al. 2012, p. 75; Volsi et al. 2022).

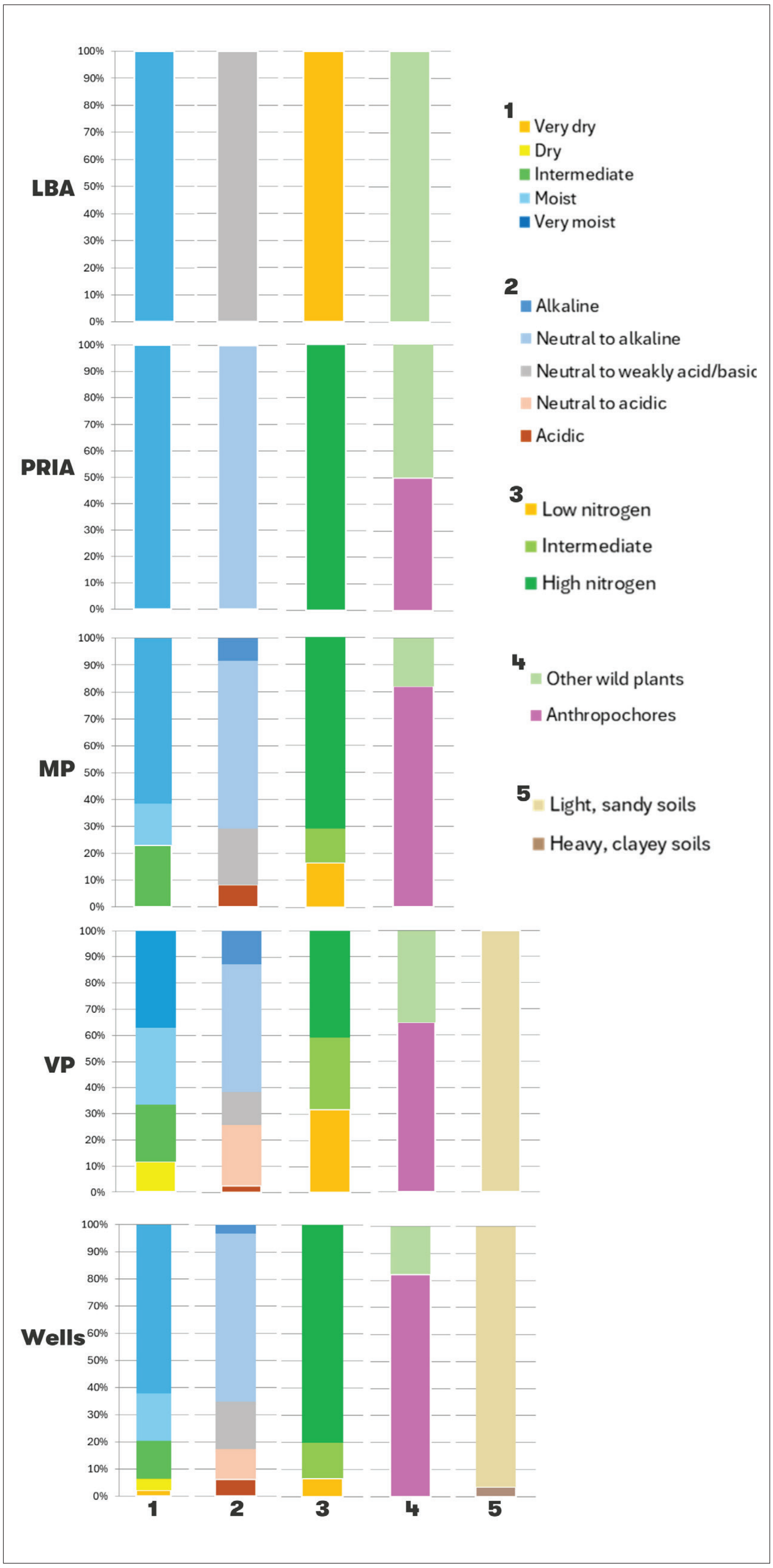

Figure 13. Distribution of wild plants by period, grouped by environmental indicators: 1. moisture; 2. pH; 3. fertility; 4. human activity; 5. soil texture (by K. A. Bojarskaitė).

It is worth mentioning the finds of flax (*Linum usitatissimum*) remains in Viking period dated contexts which were obtained during previous research (Grikpėdis 2021, pp. 223–224). It is difficult to assess the extent to which this plant was cultivated at the site because no further flax finds were found within the rest of the Bandužiai (Žardė) assemblage. Flax finds are generally very rare in Lithuanian prehistoric sites because the plant was used primarily for fibre, and the texture and consistency of its seeds demand exceptional preservation conditions (Märkle and Rösch 2008). This makes it difficult to understand their overall importance

5.2. Settlement Structure Indications

The archaeological structures at the Bandužiai (Žardė) settlement span a wide chronological range, reflecting multiple phases of use. However, this long timeframe does not imply continuous occupation. Instead, the site represents successive, episodic phases of activity with varying functional uses over time, as evidenced in both the archaeological and archaeobotanical records (Fig. 12). Archaeobotanical material, just like archaeological artefacts, undergo a life cycle before entering the archaeological context (Schiffer 1972). Based on ethnographic models, it has been established that botanical finds may result from harvesting, threshing, cleaning, sorting, storage, food preparation, consumption and the disposal of the remaining waste (Hillman 1984, pp. 4–6; Jones 1984). Identifying one of these stages of use at which they were discarded can help to determine different human activities and settlement zones. They can be traced through the ratio of clean edible plants to inedible chaff and wild weeds (Henriksen and Robinson 1996, p. 2). This is because each stage has a filtering effect, during which certain parts of the total harvest are removed and are subsequently deposited in their final location.

5.2.1. Settlement during the Late Bronze Age

The Late Bronze Age is poorly represented, with only unidentified pit (feature 84) and fire pit (feature 312), which were not very archaeobotanically informative. Maps from 1860 show that they were located in a marshy place, close to a body of water (Fig. 2). This is also confirmed by the presence of wetland flora in the macrobotanical samples. No cultivated plants were found in the contexts of either structures, making it difficult to determine whether they were connected to domestic activities. A broader interpretation of settlement patterns during this period remains speculative due to the lack of additional dated contexts.

5.2.2. Settlement during the Pre-Roman Iron Age

Similarly, the Pre-Roman Iron Age phase is difficult to interpret in detail. Only one directly dated pit (feature 437) of unidentified function was analysed. The presence of clean cereal grains suggests food processing, however, the overall evidence remains inconclusive due to limited finds. A broader interpretation of settlement structure during this period requires further archaeobotanical and chronological data.

5.2.3. Settlement during the Migration period

Two hearths (features 321A and 444), dated to the Migration period, provide slightly greater insight into the use of the area at that time. One of them, feature 321A, was especially informative. This negative feature consisted of at least several structural parts: at the centre was a hearth pit surrounded by a circular arrangement of burnt and fractured stones; around 30 cm to the northwest from it there was an oval-shaped grain-dense pit; and another distinct feature was observed around 30 cm to the southeast from the firepit, characterised by fragments of burnt clay and charcoal.

The negative structure, comprising a hearth pit and a grain-dense pit, produced an assemblage with roughly 98% cultivated plant remains, which was dominated by processed hulled barley grains and minimal weed seeds or chaff. Such purity suggests the pit was used for storing or temporarily keeping food reserves, with the impurities likely accidental, because typically, different types of crops were stored separately (Volkaitė-Kulikauskienė 1978, p. 60). It is somewhat unusual to find a storage pit in such close proximity to a hearth, as these two features were usually kept separate to minimise the chances of grain loss (Grabowski 2014, p. 10). Close proximity to a fire source indicates that the crops were stored there temporarily and abandoned due to a fire accident.

The hearth likely served a food preparation function, which is supported by the presence of animal bone fragments, stone grinders and concentrations of rusticated pottery. Even without the grain pit contents, the archaeobotanical assemblage was rich, further implying domestic use before the area's abandonment. However, no postholes or cultural layer were found, leaving the possibilities that the hearth was outdoors or that building traces were later destroyed by agricultural or industrial activities.

Another hearth, also dated to the Migration period, was located further away in the northeastern part of the excavated settlement area. It yielded only minimal data: the context contained an emmer grain and a few wild plant remains. The hearth's exact purpose remains inconclusive due to limited archaeological and archaeobotanical data. It is possible that while feature 321A may have belonged to a domestic zone later destroyed or built over, feature 444 may reflect other, undefined, activity. It may have served a production-oriented purpose as there are minimal domestic indicators. Further dated archaeobotanical analysis is needed to clarify the settlement's organisation during the Migration period.

5.2.4. Settlement during the Viking period

The Viking period is the best-represented phase at the site, with ten directly dated and archaeobotanically analysed features (features 375, 379, 381, 382, 446, 457, 459, 479, 507 and 510). The most distinct zone is in the eastern part of the settlement, where numerous negative features cluster, likely forming an industrial area, which lasted a few centuries. Two iron smelting furnaces (features 457 and 459) and a well (feature 382) were part of this zone. The well possibly supplied water for ore washing or other domestic use. This is indicated by iron-rich soil, in which all wells were constructed, possibly after the ore had first been extracted. The water must have been highly ferruginous and it was unlikely to have been used for consumption. Archaeobotanical analysis of the well revealed both cultivated plants and many weeds, with nearly half of the cultivated remains being cereal chaff, likely waste discarded during or after its use. Finds of fish bones, scales and pottery sherds further support this interpretation. Given the metallurgical focus, food processing at that time probably took place slightly further away.

Some nearby negative features, such as features 375 and 379, may reflect domestic activity, with feature 375 yielding at least six cultivated plant taxa, possibly linked to food preparation or other routine activities. To the east, directly dated pits (features 381 and 479) and features containing smooth-surfaced pottery (features 474 and 481) produced cereal grains and animal bones, suggesting a possible food preparation or even domestic zone. These finds are very reminiscent of Iron Age Scandinavian sites, where smelting often occurred close to homes and farmsteads (Mikkelsen 2003, p. 89). This allowed an efficient time management because labour-consuming iron smelting would take place alongside other routine domestic duties.

However, the absence of postholes or clear building traces complicates the interpretation of this zone. The lack of building indicators, together with a fragmentary cultural layer, has led to the suggestion that the area was used mainly for iron production, with habitation located elsewhere, closer to hillforts (Masiulienė 2018, p. 267). Yet archaeobotanical evidence points to possible domestic activity in the area — numerous and varied economic plant remains were found concentrated not very far away from the iron production zone, which were likely lost there during routine activities. It is therefore possible that the area was inhabited for a certain period, with further evidence perhaps lying in the eastern, as yet unexcavated, area of the Bandužiai (Žardė) settlement. It is important to emphasise that habitation might have been episodic and short-lived. Earlier excavations of prehistoric settlements closer to Žardė hillfort revealed a thick cultural layer with abundant signs of habitation, including buildings and even streets (Genys 2012; 2018). There, domestic activities are very clear, and the occupation lasted considerably longer. By contrast, at the Bandužiai (Žardė) settlement, people might have settled only for shorter periods, yet still leaving traces of their lives, pointing to a continual if not constant human presence in the area.

Routine activities are also indicated by the presence of cultivation waste. It is scattered across the area, present in several features, notably in wells. This suggests that crop cultivation and processing may have taken place in the area. Although such remains are not abundant in this part of the settlement, earlier studies, which examined the western and southern parts of the settlement, revealed larger quantities of cereal chaff (Grikpėdis 2021, pp. 87–88, 223–224). They were certainly by-products of wheat pounding and sieving. It would be expected that such activities would take place closer to domestic areas and cultivated fields, rather than within solely iron-production oriented zones.

Another well (feature 510), situated further away, showed a similar archaeobotanical composition to feature 382, including cereal chaff, weeds, fish bone remains, scales and pottery. The remains found in the well likely represent waste disposal, however, the timing of deposition remains uncertain. Earlier studies obtained a radiocarbon age of 1216 ± 42 BP from a pig humerus recovered inside the well (Bliujienė et al. 2020). Recalibrated with the latest OxCal v. 4.4 and the IntCal20 atmospheric curve, this corresponds to 676–946 cal AD at 95.4% probability. The dates of the bone and the well's structure slightly overlap, and this could suggest that the humerus entered the context during or shortly after the well's primary use. It is also possible that the bone may be residual and might have been introduced with backfill from nearby deposits when the well was infilled. The well was also constructed in iron-rich soil and together with the plant composition this could hint at a purpose for the well similar to that of feature 382.

Moreover, near well 510, two archaeological features related to metallurgy were also uncovered. They were two pits — features 509 and 512 (Balsas 2017) — which had slag fragments within them. Both of these pits, together with well 510, were situated in areas of iron-rich subsoil, occasionally containing limonitised sediments or iron-rich nodules. This could suggest that all these features were likely associated with metallurgical activities, as indicated by their surroundings.

Overall, the Viking period settlement appears to be organised around a central industrial zone for iron production, with probable domestic or food preparation areas to the east. The lack of residential structures and cultural layers had previously suggested that habitation areas were located closer to the Smeltalė River or hillforts. However, the archaeobotanical remains show indications for a domestic zone which may have been episodic and might remain in unexcavated areas or have been destroyed by intensive 19th–20th-century agriculture.

5.3. Undated possible settlement zones

Only a minority of the analysed structures were directly dated, leaving most unassigned to a specific period. Nevertheless, the archaeobotanical assemblage as a whole indicates that many of these negative features contained cultivated plants and weeds associated with everyday human activity, suggesting varied activities conducted at different times. Without direct dates or diagnostic finds, the chronological boundaries between activity zones remain unclear.

Two features, features 332 and 333, were notable for their archaeobotanical composition. Both contained peat layers at the base, which were rich in waterlogged plant remains, with millet husks being the most prominent. Other taxa were largely anthropochorous weeds typical of cultivated fields. This composition suggests secondary refuse from crop processing, specifically waste from cleaning harvested millet. Located near but not within the iron smelting zone and lacking slag, these features likely represent non-metallurgical activity. The presence of millet husks could indicate a period when this crop had greater economic significance.

Features 346 and 478 contained a more diverse range of cultivated plant remains, along with animal bones, clay plaster, fish scales and pottery fragments — indicators of routine domestic activity. Both also yielded rye, a crop introduced to Lithuania only during the Roman period (Minkevičius 2020, pp. 73–74). While the macroremains themselves are undated, the presence of rye supports a 1st to early 2nd millennium AD chronology for these contexts.

In the southern part of the dense feature cluster, features 329, 351A, 353, and 354 contained only small numbers of cultivated plant grains. While archaeobotanically less informative, these remains still suggest some degree of everyday activity nearby, though probably not directly tied to residential areas. Such features may reflect low-intensity use of space, with habitation possibly located farther away.

Thus, even undated features can offer traces of human presence and activity. Direct dating is essential to establish their exact chronology, particularly given the likelihood that earlier archaeological layers may have been destroyed by later intensive agricultural activities. Future research should focus on the area east of the already excavated area, which has not yet been investigated archaeologically. This area may contain more features that could help identify additional activity zones.

5.4. Surrounding nature

The Late Bronze Age environment reconstruction is limited by the small quantity of wild plant remains. The identified species in both negative features (features 84 and 312) suggest an open local landscape with wet surroundings (Fig. 13). Indicators of human presence occur in one of the structures (feature 84), but their low proportion suggests that activity was likely sporadic. However, the scarcity of macrofossils means interpretation of human activity during this period must remain cautious.

The Pre-Roman Iron Age shows a few notable environmental shifts. While open-landscape vegetation persisted, there was a reduction in wetland flora, perhaps reflecting either slightly drier conditions or differences in proximity to water between sampled features rather than broader natural change. Soil indicators point to relatively fertile, nitrogen-rich conditions. These factors, together with increased signs of human activity, suggest a more active local community, though the main settlement zone remains unidentified.

In the Migration period, a wider variety of wild plant taxa was recovered, indicating both a greater diversity of habitats and more intense human activity. Open-habitat flora still dominated, alongside species preferring moist soils. High soil fertility indicators, combined with the presence of weeds such as *Chenopodium album*, *Persicaria lapathifolia* and *Polygonum aviculare*, suggest manuring practices aimed at improving barley yields. The grain storage context (feature 321A) also provides direct insight into cultivated fields, with weed seeds likely originating from the same soils as the crops themselves.

The Viking period yielded the largest number of wild plant remains, including both charred and waterlogged specimens, particularly from two dated wells that provided exceptionally well-preserved uncharred assemblages. Most taxa were open-habitat species, while shade-tolerant and forest-associated plants — such as hazel (*Corylus avellana*), wild strawberry (*Fragaria vesca*), raspberry (*Rubus idaeus*) and dewberry (*Rubus caesius*) — can be found in open areas as well. The absence of strong forest indicators supports the view of a predominantly open landscape, consistent with the demands of intensive iron smelting, for which wood for charcoal may have been transported from outside the immediate area. It is worth noting that pollen analysis, not examined here in detail, indicated the presence of forests (Kisielienė et al. 2013). Since pollen tends to disperse over greater distances than fruits and seeds, this may reflect woodland located only slightly further away.

Soil conditions in the Viking period largely mirrored earlier periods, remaining quite moist. Many light-soil-preferring species, especially those adapted to sandy substrates, were identified in both charred and waterlogged assemblages, consistent with modern soil distribution. These conditions may have influenced crop selection, favouring emmer over spelt or free-threshing wheat.

Despite continued overall fertility, more species indicative of poorer soils appeared in the Viking period, perhaps reflecting nutrient depletion from prolonged cultivation. This may explain a shift from barley to rye, which tolerates less fertile conditions. The abundance of anthropochorous species confirms strong and sustained human activity in the area, reinforcing the interpretation of the settlement as a key zone for the community's economic and daily life during the Viking period.

Conclusions

The archaeobotanical study of the Bandužiai (Žardė) settlement revealed over two millennia of human presence and varied economic activity, underscoring the area's long-standing attractiveness to different communities with diverse cultural, social and subsistence needs. The earliest signs of human activity were dated to the Late Bronze Age, but the area may not have been the main locus of habitation or farming at the time. By the Pre-Roman Iron Age, the archaeobotanical evidence became more substantial, indicating stronger human presence and the cultivation of broomcorn millet and barley. Anthropogenic activity intensified from the Migration period onward, showing signs of possible food preparation, storage and domestic zones. These communities cultivated various types of crops: barley, especially hulled varieties, remained central to the economy, with glume wheats, rye and naked barley grown alongside. The Viking period marked the most intensive occupation, with clearer functional zoning that included an iron smelting area and a possible domestic or food preparation zone. The cultivated plant assemblage reflected a very diverse crop package in which rye dominated, followed by barley, with smaller amounts of free-threshing and glume wheats and some pulses. All of these crops most likely served an important role in crop rotation practices and demonstrate the adaptability of the local community.

Future work should focus on minimising the limitations of interpretation. Many of the archaeobotanically analysed negative features were not directly dated. However, they may help to identify more settlement zones within the area and fill in the chronological gap evident in the Roman period. Combining direct dating with as much data as possible from both excavated and still uninvestigated parts of the site is recommended. Although a considerable amount of information already exists, it has largely not been analysed in detail.

Overall, this article has demonstrated that a rich, systematically collected archaeobotanical assemblage such as that from Bandužiai (Žardė) can not only help to reconstruct agricultural practices and environmental conditions but also provide an important tool for interpreting the function of archaeological features and activity zones. Plant remains combined with other archaeological evidence can aid in distinguishing between activity areas that might otherwise remain ambiguous. In this way, archaeobotanical data not only enriches our understanding of subsistence and agriculture of prehistoric communities but also sheds light on site organisation and thus the relationship between productive, domestic and other types of settlement areas. The Bandužiai (Žardė) settlement is therefore unique in terms of the evidence for an intense economic and productive activities and its archaeobotanical record offers a rare opportunity to explore how communities in western Lithuania structured their livelihoods in such settlements and adapted to the environment and their socioeconomic needs for over more than two millennia.

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Abbreviations

Archaeol. Baltica – Archaeologia Baltica

ATL – Archeologiniai tyrinėjimai Lietuvoje … / *Archaeological Investigations in Lithuania*…, Vilnius

Dan. J. Archaeol – Danish Journal of Archaeology

Environ. Archaeol. – Environmental Archaeology

FA – Fennoscandia Archaeologica

Interdiscip Archaeol – Interdisciplinaria Archaeologica – Natural Sciences in Archaeology

J. Anc. Hist. – Journal of Archaeology and Ancient History

J. Archaeol. Sci. Rep. – Journal of Archaeological Science: Reports

Lietuvos arch. – Lietuvos archeologija / *Lithuanian Archaeology*, Vilnius

Sci Rep – Science Reports

Veget Hist Archaeobot – Vegetation History and Archaeobotany

WFO – World flora online

Institutions

LII – Lietuvos istorijos institutas / Institute of Lithuanian History

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Archeobotaniniai duomenys iš Bandužių (Žardės) vėlyvojo bronzos amžiaus – vėlyvojo geležies amžiaus gyvenvietės Vakarų Lietuvoje

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Santrauka

Žardės–Laistų–Bandužių archeologinis kompleksas, esantis pietinėje Klaipėdos dalyje, yra vienas didžiausių ir išskirtinių priešistorinių objektų Vakarų Lietuvoje. Jo formavimasis prasidėjo I tūkst. pr. Kr., vėliau kompleksas išaugo į svarbų kuršių Pilsoto žemės centrą, o XIII–XIV a. nunyko dėl konfliktų su Vokiečių ordinu. Kompleksą sudaro trys piliakalniai, du kapinynai ir kelios gyvenvietės,

tarp kurių išsiskiria Bandužių (Žardės) ir Bandužių I gyvenvietės, pasižyminčios gausiomis ūkinės ir gamybinės veiklos liekanomis (1–4 pav.).

Bandužių (Žardės) gyvenvietėje kelerius metus vykdyti archeologiniai tyrimai atskleidė fragmentišką kultūrinį sluoksnį ir įvairios paskirties struktūras: rūdos kasimo ir plovimo duobes, anglies degimo duobes, geležies lydymo rudneles, židinius, laužavietes, šulinius ir kitus neaiškios paskirties objektus. Dalis struktūrų leidžia atkurti visą geležies gamybos procesą – nuo rūdos išgavimo iki lydymo (5–13 pav.). Paleoreljefo tyrimai papildė žinias apie pakrantės zonos geomorfologinius pokyčius ir ilgalaikę žmogaus bei aplinkos sąveiką. Nors archeologinės medžiagos sukaupta gausiai, bet dėl fragmentiškumo sunku ją interpretuoti, taigi būtina taikyti tarpdisciplininius metodus.

Vienas iš tokių metodų yra archeobotaniniai tyrimai, leidžiantys spręsti interpretacines problemas. Šiame straipsnyje pirmą kartą išsamiai pristatoma sistemiškai rinkta Bandužių (Žardės) gyvenvietės archeobotaninė medžiaga. Tyrimų metu surinkta gausi degusių ir nedegusių augalų liekanų kolekcija iš įvairių archeologinių struktūrų ir kontekstų, kurių dalis buvo tiesiogiai datuota AMS metodu (5 pav.). 15 naujai skelbiamų datų leido nustatyti archeologinių struktūrų chronologiją nuo vėlyvojo bronzos amžiaus iki vėlyvojo geležies amžiaus. Tačiau tarp jų nebuvo romėniškuoju laikotarpiu tiesiogiai datuotų struktūrų.

Analizės rezultatai rodo, kad pagrindinių kultūrinių augalų sudėtis kito įvairiais laikotarpiais, o aplinkos sąlygos iš esmės išliko stabilios – drėgnos ir gana derlingos. Laukinių ir kultūrinių augalų radiniai liudija nuolatinę žmonių veiklą bent jau nuo geležies amžiaus pradžios, o vėlesniais laikais ji dar labiau suintensyvėjo. Archeobotaniniai duomenys taip pat leido identifikuoti skirtingai naudotas gyvenvietės erdves: vikingų laikotarpiu funkcionavo ūkinė-gamybinė zona, maisto ruošimo vietos ir, tikėtina, bent trumpalaikė gyvenamoji zona.

Apibendrinant galima teigti, kad Bandužių (Žardės) gyvenvietės archeobotaniniai duomenys yra vieni išsamiausių Vakarų Lietuvoje. Jie ne tik papildo žinias apie vietos žemdirbystės raidą, gyvenviečių struktūrą ir žmogaus bei aplinkos sąveiką, bet ir yra reikšmingi platesniame kontekste, prisideda prie Rytų Baltijos regiono priešistorinių bendruomenių tyrimų.