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# Adaptability and resilience: Farming practices in Lithuania during the Roman Iron Age

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**Keywords**

Lithuania, agriculture, landscape, archaeobotany, stable isotopes

**Abstract**

This paper integrates archaeological, environmental and isotopic data from Roman Iron Age (1–400 AD) settlements in Lithuania to present an updated framework for understanding the development of farming and agricultural landscapes during this period. The study dates the introduction of new crop species, such as rye and oats, to around 100–200 cal AD. Notably, rye quickly became one of the most economically important crops, coinciding with the adoption of the infield-outfield cultivation system. This system combined intensively farmed fields in open, well-irrigated areas near settlements with more distant swiddens used for extensive farming. Archaeobotanical analysis, along with $\delta^{15}N$ and $\delta^{13}C$ isotopic measurements of charred crop assemblages, reveals a high level of diversification in both species composition and cultivation strategies. These findings suggest that Roman Iron Age farmers employed complex farming methods aimed at increasing agricultural productivity and expansion while maintaining adaptability and resilience in response to environmental challenges.

## Introduction

The Roman Iron Age (ca. 1–400 AD) in Lithuania was marked by significant advancements in technology, economy and social organisation among local communities. Key developments during this period included local iron production, an increasing inflow of artefacts from other regions, shifts in burial practices and changes in settlement patterns. Together, these transformations highlight broader changes occurring in the southeastern Baltic region during the pre-Roman to Roman Iron Age transition. Among these advancements, agriculture also evolved, though the precise chronology and social and environmental implications of these changes remain relatively underexplored.

Aspects of Roman Iron Age farming have been discussed since the early archaeobotanical studies of Lithuanian sites (Regelis 1927), addressing issues such as the timeline for the introduction of new crop species (Matlakówna

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1925; 1929; Lideikytė-Šopauskienė 1935; Kulikauskas 1955), various agricultural practices (Kulikauskas 1955; Dundulienė 1963, pp. 11–36; Kulikauskas et al. 1961, pp. 250–252), farming tools and technologies (Antonevičius 1964; Dundulienė 1966) and the impact of agriculture on the surrounding landscape (Stančikaitė 2004; Stančikaitė et al. 2004). The debate eventually expanded to encompass more complex issues relating to agricultural systems, cultivation regimes and farming intensity (Kulikauskas 1955; Michelbertas 1986, pp. 199–203; Tautavičius 1996, pp. 22–26; Bliujienė 2013, pp. 148–276).

However, due to the scarcity of archaeobotanical finds and related archaeological, radiometric and environmental evidence, the applicability of Roman Iron Age agricultural models (Kulikauskas et al. 1961, pp. 250–252; Volkaitė-Kulikauskienė 2001, pp. 246–248) for analysing the geographical, social and economic contexts of this period remains limited. Recent studies of the earliest stages of agriculture in Lithuania illustrate the potential of combining legacy data with more modern research methods to address these gaps. Efforts such as redating the origins of agriculture in the region (Piličiauskas et al. 2017; 2021), providing evidence for the spread of early cereal species (Piličiauskas et al. 2022) and examining farming technologies during the 1st millennium BC (Minkevičius et al. 2020; 2023) have contributed to a clearer understanding of early farming practices.

Recent discoveries of Roman Iron Age assemblages at Bilioniai, Gediminas Hill, Kernavė, Lieporiai, Skudeniai and Vilūnai suggest that a similar approach could help construct an updated framework for 1st millennium AD agriculture. Therefore, this study re-examines legacy archaeobotanical material and integrates it with recent archaeological and archaeobotanical evidence, $\delta^{15}N$ and $\delta^{13}C$ analysis, and AMS $^{14}C$ dating. We aim to address questions related to crop composition, cultivation techniques and the landscape setting of agricultural activities in ca. 1–400 AD Lithuania. By doing so, we seek to explore diverse cultivation strategies and their reflection in cultural landscapes, facilitating further studies into diet, economy and settlement dynamics during the Roman Iron Age.

## 1. Material and methods

This study integrates archaeobotanical, radiometric and stable isotope data from twelve sites in Lithuania dated to the Roman Iron Age (Table 1). The radiocarbon dates indicate that two sites — Gediminas Hill (245–540 cal AD) and Kernavė (255–563 cal AD) — potentially extend the chronology beyond these boundaries. However, radiocarbon dates and the chronology of associated finds from Gediminas Hill suggest that the assemblage likely dates to the 3rd–5th centuries AD (Kontrimas 2020). Meanwhile, the stratigraphy at Kernavė indicates that samples from the enclosed hilltop settlement there predate the 5th-century fire (Vengalis and Vėlius 2019), whereas samples taken from the valley could not be dated more precisely by means of pottery type chronology and radiocarbon dating.

Only charred remains of cultivated plants dating to this period were included in the analysis. Material was collected from 2018 to 2023, comprising samples from legacy excavations at the Archaeological Site Museum of Kernavė, the National Museum of Lithuania and the Vytautas the Great War Museum, as well as new archaeobotanical samples collected during recent excavations (Minkevičius 2020; Vengalis et al. 2022b; Minkevičius et al. 2023; 2024). The dataset also includes previously unpublished archaeobotanical data from Aukštadvaris, Bakšiai, Birsčiai, Pypliai, Veliuona and Vilūnai. Archaeobotanical material was sourced from both hillfort sites and unenclosed settlements.

Additionally, light stable nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) isotopic measurements were conducted on samples from nine of the sites — Aukštadvaris, Bakšiai, Bilioniai, Gediminas Hill, Kernavė, Lieporiai, Naukaimis, Skudeniai and Vilūnai (Table 3). Raw isotopic values for $\delta^{15}N$ and $\delta^{13}C$ were adjusted to account for charring effects (Nitsch et al. 2015). The $\Delta^{13}C$ values were calculated using the AIRCO2_LOESS data calibrator (Ferrio et al. 2005). Radiocarbon dates for the charred cereals were calibrated using OxCal v. 4.4 with the IntCal20 atmospheric curve (Bronk Ramsey 2009; Reimer et al. 2020), and results are presented with a 95.4% probability.

## 2. Shifting patterns in crop cultivation

The analysis of the cultivated crop composition plays a crucial role in understanding the development of prehistoric farming practices. However, direct chronological and regional comparisons are often hindered by the availability and quality of surviving material. While archaeobotanical assemblages from the Roman Iron Age provide a relatively representative view of crop cultivation in Lithuania, variations within the dataset are unavoidable due to differences in the nature of sampled contexts, settlement duration and the scope of archaeological investigations. Although the examination of changes over time is essential for this analysis, comparing datasets from earlier periods remains challenging. Patterns of crop cultivation in Late Bronze Age Lithuania are relatively well explored (Minkevičius et al. 2020; 2023), but the dataset from the pre-Roman Iron Age remains limited (Minkevičius et al. 2024). As a result, aspects such as regional variation and local agricultural practices may continue to be addressed to a limited degree.

**Table 1.** AMS $^{14}$C measurements of charred plant macrofossils from the sites analysed in this study.

| | **Sample** | **Lab. code** | **$^{14}$C date (BP)** | **cal BD/ cal AD (95,4 %)** | **After:** |
|---|---|---|---|---|---|
| | **Aukštadvaris** | | | | |
| 1 | *Triticum spelta* grain | FTMC-QQ62-153 | 1928 ± 30 | 25-205 cal AD | Minkevičius 2024 |
| 2 | *Hordeum vulgare* grain | FTMC-QQ62-154 | 1891 ± 29 | 76-230 cal AD | Minkevičius 2024 |
| | **Bakšiai** | | | | |
| 3 | *Triticum spelta* grain | FTMC-QQ62-152 | 1885 ± 28 | 80-233 cal AD | Minkevičius 2024 |
| 4 | *Hordeum vulgare* grain | FTMC-EP14-3 | 1776 ± 49 | 133-409 cal AD | Minkevičius 2020 |
| | **Bilioniai** | | | | |
| 5 | *Triticum spelta* grain | FTMC-24-3 | 1877 ± 41 | 32-246 cal AD | Minkevičius 2020 |
| | **Birsčiai** | | | | |
| 6 | *Hordeum vulgare* grain | FTMC-UJ17-5 | 1880 ± 28 | 82-234 cal AD | Provided by R. Vengalis and G. Piličiauskas |
| | **Gedimino kalnas** | | | | |
| 7 | *Hordeum vulgare* grain | FTMC-QQ62-155 | 1636 ± 29 | 365-540 cal AD | Minkevičius 2024 |
| | *Pisum sativum* seed | FTMC-QQ62-156 | 1715 ± 30 | 250-414 cal AD | Minkevičius 2024 |
| 8 | *Hordeum vulgare* grain | FTMC-CK63-7 | 1738 ± 34 | 245-404 cal AD | Provided by D. Kontrimas |
| | **Kernavė** | | | | |
| 9 | *Hordeum vulgare* grain | FTMC-EF07-23 | 1680 ± 28 | 258-426 cal AD | Minkevičius et al. 2024 |
| 10 | *Hordeum vulgare* grain | FTMC-EF07-19 | 1674 ± 29 | 257-527 cal AD | Minkevičius et al. 2024 |
| 11 | *Hordeum vulgare* grain | FTMC-IM-1 | 1694 ± 28 | 255-420 cal AD | Minkevičius et al. 2024 |
| 12 | *Hordeum vulgare* grain | FTMC-PJ25-5 | 1570 ± 27 | 427-563 cal AD | Minkevičius et al. 2024 |
| 13 | *Triticum spelta* grain | FTMC-PJ25-6 | 1679 ± 28 | 257-428 cal AD | Minkevičius et al. 2024 |
| 14 | *Triticum spelta* grain | FTMC-PJ25-7 | 1599 ± 27 | 419-541 cal AD | Minkevičius et al. 2024 |
| | **Lieporiai** | | | | |
| 15 | *Hordeum vulgare* grain | FTMC-PJ25-8 | 1763 ± 26 | 234-365 cal AD | Minkevičius 2024 |
| 16 | *Hordeum vulgare* grain | FTMC-PJ25-9 | 1835 ± 27 | 126-311 cal AD | Minkevičius 2024 |
| | **Naukaimis** | | | | |
| 17 | *Avena sativa* grain | POZ-109751 | 1725 ± 30 | 249-409 cal AD | Minkevičius 2020 |
| | **Pypliai** | | | | |
| 18 | *Hordeum vulgare* grain | FTMC-QQ62-151 | 1774 ± 28 | 219-361 cal AD | This study |
| | **Skudeniai** | | | | |
| 19 | *Hordeum vulgare* grain | FTMC-UU26-5 | 1816 ± 26 | 131–329 AD | Vengalis et al. 2022b |
| 20 | *Cerealia* grain | FTMC-UU26-6 | 1856 ± 25 | 125–239 AD | Vengalis et al. 2022b |
| 21 | *Triticum dicoccon/spelta* grain | FTMC-UU26-7 | 1867 ± 26 | 120–238 AD | Vengalis et al. 2022b |
| 22 | *Triticum dicoccon/spelta* grain | FTMC-UU26-4 | 1842 ± 26 | 125–248 AD | Vengalis et al. 2022b |
| 23 | *Cerealia* grain | FTMC-DG81-3 | 1885 ± 27 | 81–232 AD | Vengalis et al. 2022b |
| | **Veliuona** | | | | |
| 24 | *Secale cereale* grain | FTMC-QQ62-159 | 1748 ± 31 | 240-401 cal AD | This study |
| | **Vilūnai** | | | | |
| 25 | *Corylus avellana* shell frag. | FTMC-QQ62-157 | 1975 ± 34 | 44-124 cal AD | Minkevičius 2024 |
| 26 | *Pisum sativum* seed | FTMC-QQ62-158 | 1959 ± 29 | 41 cal BC - 152 cal AD | Minkevičius 2024 |

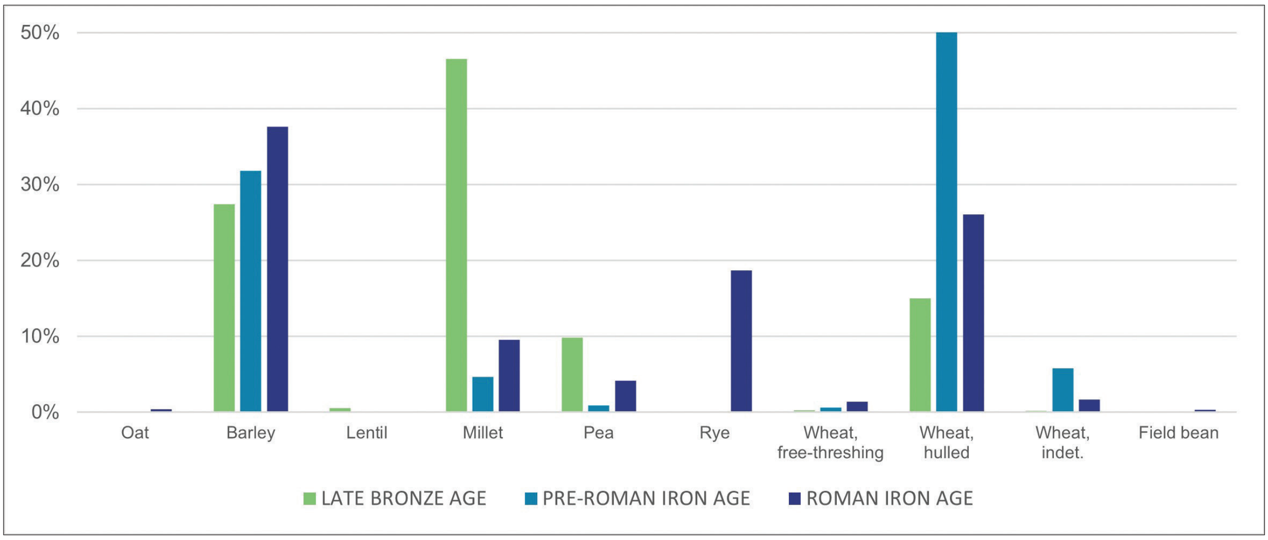

Figure 1. Changes in species composition of cultivated crops in Lithuania from the Late Bronze Age to the Roman Iron Age (Data from Minkevičius 2020; Minkevičius et al. 2020; 2023; 2024; Vengalis et al. 2022b; this study).

The comparison between Roman Iron Age and Late Bronze Age/pre-Roman Iron Age assemblages reveals a significant shift in the composition of cultivated taxa, beginning at the end of the 1st millennium BC. Studies of Late Bronze Age agriculture in Lithuania indicate that barley, broomcorn millet and glume wheats — specifically emmer and spelt — were the primary cultivated species, constituting nearly 90% of agricultural remains from ca. 800–400 BC (Fig. 1). These staples were complemented by minor crops such as free-threshing wheat, pulses (field bean, lentil, pea), and oil and fibre crops like false flax (Pollmann 2014; Minkevičius 2020; Minkevičius et al. 2020; 2023). Pre-Roman Iron Age assemblages suggest continuity in crop patterns, with the notable exception of a marked decline in millet cultivation (Vengalis et al. 2022a; Minkevičius et al. 2024).

Charred millet grains from Lithuanian Roman Iron Age deposits were first reported in the analysis of the Naukaimis (Gabrieliškė) assemblage (Matlakówna 1925). Archaeobotanical reports indicate that millet comprised up to 4% of the total volume of cereal remains (Lideikytė-Šopauskienė 1935). This finding was confirmed by a recent reassessment of legacy material revealing that *Panicum* grains at Naukaimis make up 1.93% of the identified crop remains (Table 2, Fig. 2). Similar proportions are observed at other sites, where millet grains comprised less than 1% of identified crop macrofossils at Aukštadvaris, 2.63% at Vilūnai, and 5.15% at Skudeniai. In contrast, sites with smaller assemblages, such as Bakšiai, Birsčiai, Lieporiai and Pypliai, yielded no evidence of millet.

The scarcity of archaeobotanical material from 400–1 BC deposits presents significant challenges in assessing millet's changing role from the Late Bronze Age to the Roman Iron Age. However, other archaeological data provide valuable insights. Stable $\delta^{13}C$ and $\delta^{15}N$ isotope analysis of human skeletal remains, for instance, suggests that $C_4$ plants like millet played a significant role in the human diet during the Late Bronze Age (Antanaitis-Jacobs et al. 2009). In contrast, isotopic analysis of skeletal remains from pre-Roman Iron Age (Simčenka et al. 2022) and Roman Iron Age (Bliujienė et al. 2020) graves shows no evidence of a $C_4$ component in the diet. Similarly, studies of charred food residues from Late Bronze Age to Roman Iron Age pottery indicate that millet was an important dietary component from 1000–400 BC, with consumption of *Panicum* diminishing in later periods (Podėnas et al. 2023).

This trend may suggest a decline in millet farming after the Late Bronze Age, though such a shift may not have been universal. While declines in millet consumption are reported from parts of Europe (Marinval 1992; Plecerová et al. 2020; Orfanou et al. 2024), other regions, especially eastern Europe, provide evidence of millet consumption persisting into the 1st millennium AD (Reitesma and Kozłowski 2013; Halffman and Velemínský 2015; Chmiel-Chrzanowska and Fetner 2024). Similar patterns of variation are also evident at Lithuanian sites. For example, Kernavė provides substantial evidence for millet cultivation continuing up to the 5th century (Minkevičius et al. 2024). The large volume of samples at Kernavė, with consistently high concentrations of millet grains, suggests that millet was an integral part of the broader agricultural economy rather than an isolated occurrence. This pattern likely reflects a strategic approach by the local population to boost agricultural yield and resilience.

Another significant development at the start of the Roman Iron Age was the introduction of two secondary domesticates — oats and rye. These species were not part of the original agricultural package that spread from the Near

**Table 2**. Overview of the spatial and chronological distribution of crop macrofossils (minimum number of individuals, MNI) in Lithuania. H = house deposit; Set = settlement activity context (e.g. pit, posthole, well); St = storage deposit. (Data from Račas 2019; Kontrimas 2020; Minkevičius 2020; Minkevičius et al. 2024; Piličiauskienė 2021; Pranckėnaitė 2021; Vengalis et al. 2022b; this study).

| **Site** | **Chronology** | **Context** | **No. of samples** | **Avena sp.** | **A. sativa** | **Hordeum vulgare** | **H. vulgare var. nudum** | **H. vulgare var. vulgare** | **Panicum miliaceum** | **Pisum sativum** | **Secale cereale** | **Triticum aestivum/ durum** | **T. diccoccon** | **T. spelta** | **Triticum sp. (hulled)** | **Triticum sp.** | **Vicia faba** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aukštadvaris | 1st-3rd c. | H/Set | 2 | 1 | - | 12 | 1 | 1 | 4 | - | - | 16 | 75 | 181 | 119 | - | - |
| Bakšiai | 1st-4th c. | H/Set | 4 | - | - | 38 | - | 25 | - | - | 6 | - | - | - | 2 | - | - |
| Bilioniai | 1st-3rd c. | H/Set, St | 7 | 60 | 1 | - | - | - | 1 | 2 | 77 | 42 | 864 | 2733 | 383 | 71 | - |
| Birsčiai | 1st-3rd c. | H/Set | 1 | - | - | 96 | 2 | 90 | - | - | - | - | - | - | 1 | - | - |
| Gediminas Hill | 1st-6th c. | H/Set | 1 | - | - | 143 | - | - | 12 | 11 | - | 1 | - | 3 | - | 1 | - |
| Kernavė | 3rd-6th c. | H/Set | 26 | - | - | 3 | - | - | 664 | 12 | 2 | 3 | 6 | 5 | 29 | 15 | 37 |
| Lieporiai | 2nd-4th c. | H/Set | 18 | - | - | - | - | - | - | - | 2 | 2 | - | 1 | - | - | - |
| Naukaimis | 3rd-4th c. | H/Set, St | 5 | 204 | 11 | 116 | - | 45 | 145 | - | 5429 | - | 28 | 48 | 480 | 855 | - |
| Pypliai | 3rd-4th c. | H/Set | 2 | - | - | 29 | - | 13 | - | - | - | - | 2 | - | - | - | - |
| Skudeniai | 1st-4th c. | H/Set | 19 | 1 | - | 45 | - | - | 10 | 4 | 4 | - | 4 | 2 | 10 | 6 | - |
| Veliuona | 3rd-4th c. | H/Set | 1 | 1 | - | 106 | - | 25 | 2 | - | 1805 | - | - | - | 13 | - | - |
| Vilūnai | 1st-2nd c. | H/Set | 14 | - | - | 49 | - | 50 | 1 | 8 | 11 | - | 2 | - | - | - | - |

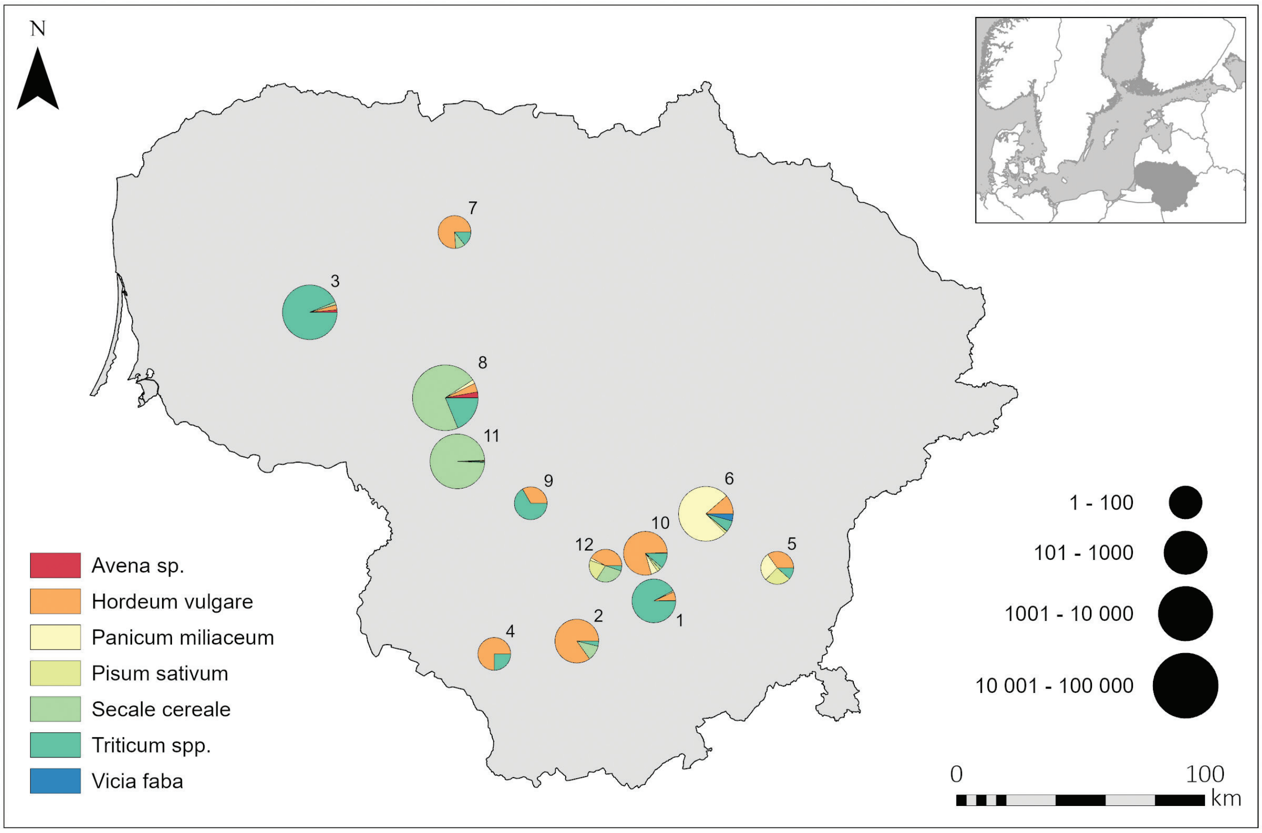

Figure 2. Distribution of the main cultivated taxa in different archaeological sites in Lithuania during the Roman Iron Age. Sites: 1. Aukštadvaris; 2. Bakšiai; 3. Bilioniai; 4. Birsčiai; 5. Gediminas Hill; 6. Kernavė; 7. Lieporiai; 8. Naukaimis; 9. Pypliai; 10. Skudeniai; 11. Veliuona; 12. Vilūnai (Data from Račas 2019; Kontrimas 2020; Minkevičius 2020; Minkevičius et al. 2024; Piličiauskienė 2021; Pranckėnaitė 2021; Vengalis et al. 2022b; this study).

East into Europe during the Neolithic period (Zohary et al. 2012, pp. 59–69). The wild ancestors of oats and rye likely arrived in Europe as weeds in fields of common crops like wheat and barley and were only domesticated much later, around the 1st millennium BC (Behre 1992; Shewry 1999). The complex history of the domestication and introduction of these species, especially rye, has sparked long-standing debate within Lithuanian archaeology. Chronological estimates for the adoption of rye have varied, with suggestions ranging from as early as the beginning of the Roman Iron Age (Kulikauskas 1955; Michelbertas 1986, p. 200; Grikpėdis and Motuzaitė Matuzevičiūtė 2016) to the end of the 1st millennium AD (Laužikas 2013; Žulkus and Jarockis 2013, p. 294). Recent studies, using radiocarbon dating of charred rye grains from sites such as Bakšiai, Naukaimis and Lieporiai, have more securely placed the widespread cultivation of rye between the 2nd and 4th centuries AD (Minkevičius 2020). However, newer evidence suggests that in certain contexts, rye cultivation may have begun even earlier. Charred rye grains from Skudeniai have been dated to 130–240 cal AD (Vengalis et al. 2022b), while samples from Vilūnai have been dated to 41 cal BC–152 cal AD (Table 1), suggesting that rye cultivation in Lithuania could have started as early as the 1st to 2nd centuries AD. Such a relatively early date for the introduction of rye should not be surprising as the evidence for rye cultivation across northern Europe starts appearing at around the same time (Grabowski 2011; Mueller-Bieniek et al. 2015; Hald et al. 2024).

Interestingly, while oats remained a minor crop, archaeobotanical evidence shows that rye quickly gained major economic significance. Rye grains make up 9.52% of the identified crop remains in Lieporiai, 11.32% in Bakšiai and 28.95% in Vilūnai. In some cases, the proportion is even higher — 72.10% in Naukaimis and 98.69% in Veliuona. This suggests that once rye was introduced, it expanded into ecological niches previously occupied by other species, such as millet. A closer analysis of archaeobotanical material from Kernavė sheds light on this possibility. While both the adoption of rye and the decline of large-scale millet cultivation at Kernavė are relatively late — around the 5th century AD — the millet-rich and rye-rich samples are chronologically distinct (Minkevičius et al. 2024). This is particularly notable because both crops are drought-resistant and thrive in poor soils, making them well-suited to unfavourable environments (Behre 1992; Marinval 1992). Millet's short growth cycle and surplus potential likely explain its widespread use during the early stages of farming (Filipović et al. 2020). However, the economic advantages of rye cultivation eventually surpassed those of millet. Rye is autotolerant, enabling prolonged monocropping, and its status as an autumn-sown cereal in northern latitudes allows for more efficient labour distribution (Squatriti 2016; Westling and Jensen 2020; Filatova et al. 2021).

## 3. Inter-site variation

It is important to note that crop cultivation patterns during the Roman Iron Age were not consistent across Lithuania (Fig. 2). A closer examination of each assemblage reveals notable variation in species composition between sites. Interestingly, the closest parallels to the overall trends are found in sites with some of the smallest archaeobotanical assemblages, which limits the reliability of broader comparisons. For instance, rye grains account for 11.32% of the identified crop remains in Bakšiai, 9.52% in Lieporiai and 28.95% in Vilūnai. However, the total count of identified remains in these sites is relatively low, at 53, 31 and 38 specimens, respectively. In contrast, sites with larger assemblages deviate significantly from the overall trend.

Notable examples of rye-dominant sites include Naukaimis and Veliuona, whereas Bilioniai stands at the opposite end of the spectrum. The Naukaimis assemblage dated to the 3rd–4th centuries AD is overwhelmingly dominated by charred rye grains, which comprise 72.10% of the material (n=7530). However, archaeological data indicates that this sample came from a burnt storage deposit (Michelbertas 1986, p. 200), which would naturally lead to an overrepresentation of a single species. Similarly, the rye-rich assemblage from Veliuona dated to the 3rd to 4th centuries AD shows rye making up 98.69% of the remains (n=1829). However, this material comes from a single test pit and lacks supplementary contextual information, making it difficult to interpret definitively. Nevertheless, the dominance of a single taxon, coupled with the absence of other crops, small weeds and chaff, suggests that this too could represent another storage context as opposed to the broader agricultural patterns within the region.

In contrast, a grain-rich deposit (n=8730) from the Roman Iron Age layer at Bilioniai dated to the 1st to 3rd centuries AD contained no rye macrofossils at all. Similar to Naukaimis and possibly Veliuona, this deposit was also a storage context. Alongside a large accumulation of charred cereal grains, charred fragments of what may have been a bucket made out of birch bark were discovered, with 91.18% of the grains identified as hulled wheats (Minkevičius 2019). Both emmer and spelt grains, along with their glume fragments, were recorded, but there was an almost complete absence of other species. This again suggests that the deposit originated from a storage context and likely represented stored food surplus rather than the overall crop cultivation patterns of the local community. Notably, the absence of rye in this storage context does not necessarily imply that it was not cultivated by the Bilioniai community during the Roman Iron Age. As in the cases of Naukaimis and Veliuona, any broader regional analysis is limited by the specific depositional pathways of storage deposits, which may not fully reflect agricultural practices.

In addition to geographical variation, chronological differences in rye cultivation are also evident. Most sites provide evidence of rye cultivation beginning in the 3rd to 4th centuries, or even earlier in places like Skudeniai and Vilūnai. Kernavė, however, stands out as an exception. Archaeobotanical data indicates that rye cultivation there began significantly later, around the 5th century AD. Notably, this chronological discrepancy is unlikely to be the result of depositional factors, as the sample size from Kernavė is larger and more representative than those from other Roman Iron Age sites. This suggests that the prolonged cultivation of millet at Kernavė, which persisted until the mid-1st millennium, may be closely linked to the delayed introduction of rye. The extended reliance on millet could have influenced both the timing and agricultural decisions regarding rye cultivation.

Another interesting case comes from Skudeniai, central Lithuania. Excavations conducted in 2020 revealed the remains of an unenclosed Roman Iron Age settlement that was inhabited for a relatively short period, estimated at around 100 years (Vengalis et al. 2022b). Notably, the site shows no signs of human occupation during other periods, offering a unique opportunity to analyse archaeobotanical evidence from a single occupational horizon. This potentially provides a more accurate reflection of the agricultural practices of the local community. The archaeobotanical material from Skudeniai was predominantly composed of charred barley grains, which accounted for 78.87% of the identified crop macrofossils. Millet and wheat were present in much smaller quantities, comprising 5.15% and 11.34% of the remains, respectively. Interestingly, while a few charred rye grains were also identified, they represented only 2.06% of the total crop remains. This suggests that while rye may have been cultivated locally, it was not grown on a significant scale. The limited presence of rye might indicate either that its cultivation remained marginal or that any attempts by the local population to grow rye on a larger scale were ultimately abandoned.

## 4. Cultivation technologies during the Roman Iron Age transition

In addition to the adoption of new species, the nature and role of farming regimes — such as slash-and-burn agriculture — have been central to the broader debate on agricultural technologies in 1st millennium AD Lithuania.

Although the dominance of extensive farming methods has been questioned repeatedly (e.g. Kulikauskas 1955; Michelbertas 1986, p. 202), the prevailing narrative until recently emphasised that slash-and-burn was the primary farming mode during later prehistory (e.g. Kulikauskas et al. 1961, pp. 250–252; Tautavičius 1996, pp. 24–25; Girininkas 2013, p. 191). However, recent studies on the subsistence economies of Late Bronze Age hilltop communities have brought new insights to this discussion (Minkevičius et al. 2023).

The latest findings, based on archaeobotanical evidence and stable isotope analysis of charred crop assemblages from fortified settlements, alongside archaeological investigations, reveal a significant absence of evidence supporting reliance on extensive farming methods during this period (Minkevičius et al. 2020; 2023). A diverse range of cultivated crops, including various species of cereals, legumes and oil/fibre plants, points to a well-diversified crop package (ibid.). Moreover, the presence of exostoses — bone pathologies at the distal ends of metacarpal bones — consistent with those found in draught animals, suggests the potential existence of arable farming (Micelicaitė et al. 2023; Minkevičius et al. 2023).

Other evidence, such as the long-term occupation of settlements (Podėnas 2022), as well as the presence of fossilised field systems that may date back to the 1st millennium BC (Nemickienė 2015), further reinforces the likelihood of permanent field cultivation practices. Collectively, these findings challenge the long-held assumption that extensive, shifting agricultural techniques like slash-and-burn dominated, suggesting instead that more intensive farming of the permanent fields was in use.

Additional insights have been gained from stable carbon (C) and nitrogen (N) isotope analysis of charred cereal grains. $\delta^{13}$C values in plant tissues reflect photosynthesis rates and responses to environmental stress, such as limited water or sunlight, while $\delta^{15}$N values are linked to the use of manure in field fertilisation (Fiorentino et al. 2015). These analyses allow for a more detailed examination of both environmental conditions and farming practices. In eastern Lithuania, the stable C isotope analysis of $C_3$ plants — barley, wheat and spelt — from hilltop settlements showed no signs of environmental stress. The $\Delta^{13}$C values were consistent with crops grown in well-watered conditions, suggesting that at sites like Mineikiškės, Garniai I and Gediminas Hill these species were cultivated in open, well-irrigated landscapes (Minkevičius et al. 2023). This contradicts the assumption of swidden (slash-and-burn) farming, where lower $\Delta^{13}$C values would typically be expected due to the canopy effect (Bonafini et al. 2013) and potentially reduced water availability. Furthermore, the stable N isotope analysis of barley, wheat and millet from these same sites revealed elevated $\delta^{15}$N levels, indicating that these crops were grown in fields that received moderate to high levels of manure (Minkevičius et al. 2023).

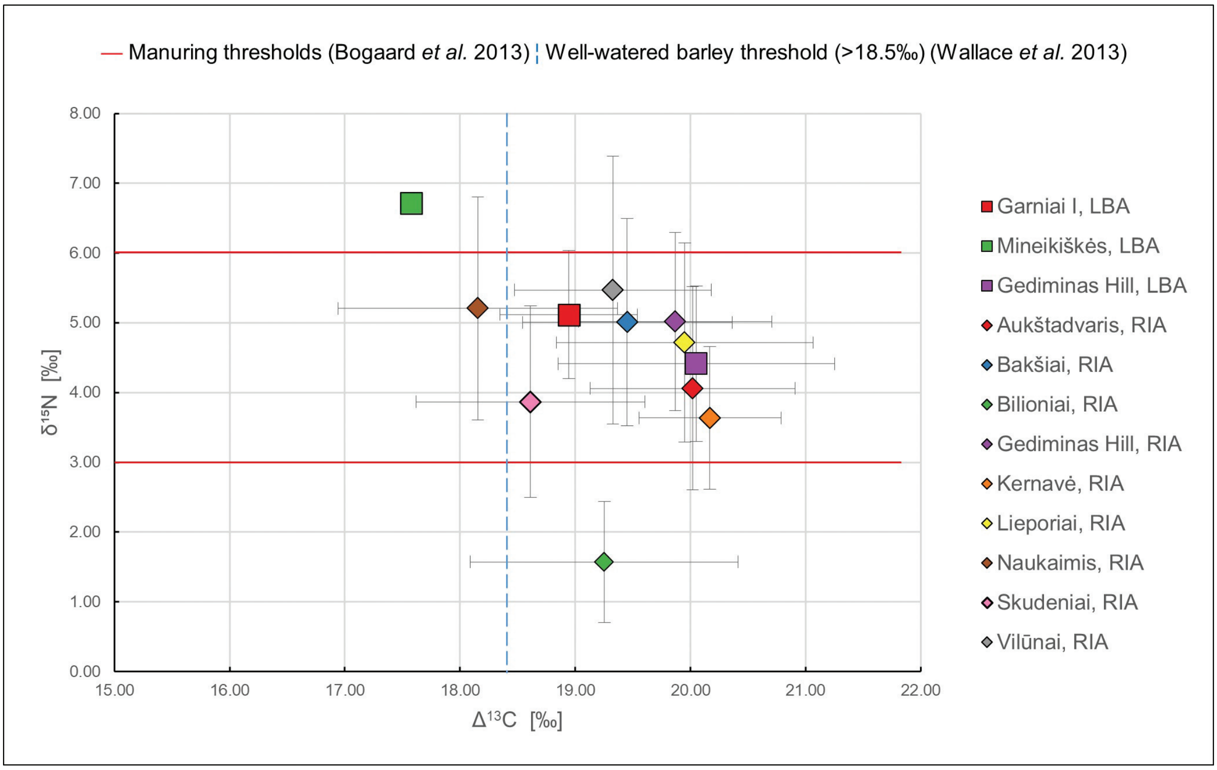

Figure 3. Mean $\delta^{15}$N and $\Delta^{13}$C values of charred barley grains from Late Bronze Age and Roman Iron Age sites in Lithuania. LBA = Late Bronze Age, RIA = Roman Iron Age. (Data from Minkevičius et al. 2023; Minkevičius 2024).

Table 3. Summary statistics for $\delta^{15}$N and $\Delta^{13}$C values included in this study. LBA = Late Bronze Age, RIA = Roman Iron Age. (Data from Minkevičius et al. 2023; Minkevičius 2024).

| Site | Period | Cereal species | $\delta^{15}$N (‰) | | | | $\Delta^{13}$C (‰) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Range | (Min; Max) | Mean | SD | Range | (Min; Max) | Mean | SD |
| Garniai I | LBA | *Hordeum vulgare* | 2.93 | (4.06; 6.98) | 5.12 | 0.92 | 1.61 | (18.06; 19.67) | 18.94 | 0.60 |
| Mineikiškės | LBA | *Hordeum vulgare* | - | (6.72; 6.72) | 6.72 | - | - | (17.57; 17.57) | 17.57 | - |
| Gedimino kalnas | LBA | *Hordeum vulgare* | 3.79 | (2.81; 6.60) | 4.41 | 1.11 | 4.22 | (17.84; 22.06) | 20.05 | 1.20 |
| Aukštadvaris | RIA | *Avena* sp. | - | (2.75; 2.75) | 2.75 | - | 0.00 | (17.16; 17.16) | 17.16 | - |
| Aukštadvaris | RIA | *Hordeum vulgare* | 3.82 | (1.67; 5.50) | 4.06 | 1.46 | 2.68 | (18.18; 20.86) | 20.02 | 0.89 |
| Aukštadvaris | RIA | *Triticum aestivum/ durum* | 1.32 | (3.14; 4.46) | 3.63 | 0.50 | 2.53 | (17.09; 19.61) | 18.41 | 1.05 |
| Aukštadvaris | RIA | *Triticum dicoccon* | 2.48 | (0.93; 3.41) | 1.87 | 0.96 | 2.28 | (16.66; 18.94) | 17.75 | 0.86 |
| Aukštadvaris | RIA | *Triticum spelta* | 5.92 | (1.40; 7.32) | 3.63 | 1.68 | 1.96 | (17.72; 19.68) | 18.56 | 0.60 |
| Bakšiai | RIA | *Hordeum vulgare* | 4.34 | (3.28; 7.62) | 5.01 | 1.48 | 3.43 | (18.07; 21.49) | 19.45 | 0.91 |
| Bakšiai | RIA | *Secale cereale* | 7.23 | (1.32; 8.55) | 3.61 | 3.33 | 1.37 | (16.89; 18.26) | 17.47 | 0.58 |
| Bilioniai | RIA | *Avena* sp. | 1.63 | (2.01; 3.65) | 2.91 | 0.60 | 0.87 | (17.85; 18.72) | 18.34 | 0.33 |
| Bilioniai | RIA | *Hordeum vulgare* | 2.02 | (0.66; 2.68) | 1.57 | 0.87 | 3.08 | (17.34; 20.43) | 19.25 | 1.16 |
| Bilioniai | RIA | *Triticum dicoccon* | 2.48 | (0.93; 3.41) | 1.87 | 0.96 | 2.28 | (16.66; 18.94) | 17.75 | 0.86 |
| Bilioniai | RIA | *Triticum spelta* | 2.34 | (1.31; 3.64) | 2.11 | 0.98 | 2.17 | (16.54; 18.71) | 17.77 | 0.90 |
| Gedimino kalnas | RIA | *Hordeum vulgare* | 3.08 | (3.28; 6.36) | 5.02 | 1.28 | 1.98 | (19.02; 21.00) | 19.87 | 0.84 |
| Gedimino kalnas | RIA | *Triticum aestivum/ durum* | - | (7.79; 7.79) | 7.79 | - | - | (19.66; 19.66) | 19.66 | - |
| Gedimino kalnas | RIA | *Triticum spelta* | 4.54 | (4.78; 9.33) | 7.05 | 3.21 | 1.38 | (18.78; 20.16) | 19.47 | 0.98 |
| Kernavė | RIA | *Hordeum vulgare* | 3.63 | (1.27; 4.89) | 3.64 | 1.02 | 1.94 | (19.28; 21.22) | 20.17 | 0.62 |
| Kernavė | RIA | *Secale cereale* | 2.40 | (3.01; 5.41) | 4.15 | 1.13 | 2.99 | (17.59; 20.58) | 19.14 | 1.40 |
| Kernavė | RIA | *Triticum aestivum/ durum* | 2.78 | (3.42; 6.21) | 4.96 | 1.41 | 1.30 | (19.81; 21.11) | 20.26 | 0.73 |
| Kernavė | RIA | *Triticum dicoccon* | 3.52 | (3.46; 6.98) | 4.63 | 1.20 | 2.84 | (16.68; 19.53) | 18.36 | 0.93 |
| Kernavė | RIA | *Triticum spelta* | 4.62 | (2.77; 7.39) | 4.80 | 1.38 | 6.88 | (17.08; 23.96) | 19.25 | 1.48 |

Table 3. Continuation.

| Site | Period | Cereal species | $\delta^{15}N$ (‰) | | | | $\Delta^{13}C$ (‰) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Range | (Min; Max) | Mean | SD | Range | (Min; Max) | Mean | SD |
| Lieporiai | RIA | *Hordeum vulgare* | 3.80 | (2.33; 6.13) | 4.72 | 1.43 | 3.17 | (18.04; 21.21) | 19.95 | 1.11 |
| Lieporiai | RIA | *Secale cereale* | - | (1.62; 1.62) | 1.62 | - | - | (17.00; 17.00) | 17.00 | - |
| Lieporiai | RIA | *Triticum aestivum/ durum* | - | (4.34; 4.34) | 4.34 | - | - | (19.10; 19.10) | 19.10 | - |
| Naukaimis | RIA | *Avena* sp. | 0.74 | (4.42; 5.17) | 4.83 | 0.33 | 2.70 | (18.10; 20.80) | 18.90 | 1.09 |
| Naukaimis | RIA | *Hordeum vulgare* | 3.55 | (3.50; 7.05) | 5.21 | 1.60 | 2.65 | (17.00; 19.64) | 18.15 | 1.21 |
| Naukaimis | RIA | *Secale cereale* | 0.82 | (3.19; 4.01) | 3.65 | 0.36 | 1.68 | (17.54; 19.22) | 18.42 | 0.69 |
| Naukaimis | RIA | *Triticum dicoccon* | 2.43 | (2.59; 5.02) | 4.10 | 0.96 | 1.16 | (16.44; 17.60) | 16.81 | 0.47 |
| Naukaimis | RIA | *Triticum spelta* | 0.80 | (2.95; 3.75) | 3.42 | 0.34 | 1.81 | (16.49; 18.30) | 17.34 | 0.69 |
| Skudeniai | RIA | *Hordeum vulgare* | 3.39 | (2.85; 6.24) | 3.87 | 1.38 | 2.04 | (17.88; 19.92) | 18.61 | 0.99 |
| Skudeniai | RIA | *Secale cereale* | 2.75 | (3.16; 5.91) | 4.90 | 1.25 | 2.55 | (16.85; 19.41) | 18.39 | 1.12 |
| Skudeniai | RIA | *Triticum dicoccon* | 1.53 | (3.72; 5.24) | 4.38 | 0.65 | 3.41 | (15.90; 19.30) | 17.97 | 1.46 |
| Skudeniai | RIA | *Triticum spelta* | - | (4.02; 4.02) | 4.02 | - | 1.45 | (17.59; 19.04) | 18.31 | 1.02 |
| Vilūnai | RIA | *Hordeum vulgare* | 5.02 | (3.72; 8.75) | 5.47 | 1.92 | 2.24 | (18.65; 20.89) | 19.33 | 0.85 |
| Vilūnai | RIA | *Secale cereale* | 1.88 | (2.10; 3.98) | 3.16 | 0.87 | 3.19 | (16.63; 19.82) | 18.04 | 1.19 |
| Vilūnai | RIA | *Triticum dicoccon* | 1.66 | (1.88; 3.54) | 2.71 | 1.17 | 0.86 | (17.13; 17.99) | 17.56 | 0.61 |

This evidence supports the argument for an intensive form of agriculture typical for the permanent field cultivation, rather than extensive slash-and-burn techniques.

The dataset of carbon and nitrogen isotopic values from Late Bronze Age cereals, compared with those from Roman Iron Age assemblages, offers an opportunity to explore potential shifts in crop cultivation methods between the late 1st millennium BC and the early 1st millennium AD. Interestingly, a comparison of isotopic values in barley, the predominant crop in prehistoric Lithuania and the only taxon present at all analysed sites, reveals no significant differences in agricultural regimes across these periods (Fig. 3). The mean $\delta^{15}N$ values for barley from Late Bronze Age sites range from 4.41‰ (σ 1.11) at Gediminas Hill to 5.12‰ (σ 0.92) at Garniai I, with a notable outlier of 6.72‰ recorded from a single grain at Mineikiškės (Table 3). For Roman Iron Age sites, the mean $\delta^{15}N$ values range from 3.64‰ (σ 1.02) at Kernavė to 5.47‰ (σ 1.92) at Vilūnai. These nitrogen isotopic values, which consistently fall between 3.00‰ and 6.00‰, align with the typical $\delta^{15}N$ range for crops cultivated on moderately manured soils (cf. Bogaard et al. 2013), showing no substantial difference from the earlier period. In the case of slash-and-burn farming with crops gown on recently cleared land, the elevation of $\delta^{15}N$ values in cereals would not be expected (Styring et al. 2013).

One notable outlier from the Roman Iron Age dataset comes from a charred crop assemblage from Bilioniai hillfort, dated to approximately the 2nd to 3rd centuries AD. Here, the mean $\delta^{15}N$ value of barley is just 1.57‰ (σ 0.87), significantly lower than those recorded at other sites. Intriguingly, this material originates from a storage context, deposited during a fire event (Minkevičius 2019). This could indicate either the absence of manuring at this site or that the duration of manuring prior to deposition was too short for the practice to be reflected in the nitrogen levels of the grains (Kanstrup et al. 2011).

In addition to nitrogen, Δ$^{13}$C values in charred barley grains suggest that crops were grown in similar landscape settings during both the Late Bronze Age and Roman Iron Age. Δ$^{13}$C values for barley range from 18.94‰ (σ 0.60) at Garniai I to 20.05‰ (σ 1.02) at Gediminas Hill, indicating cultivation in open, well-watered landscapes during the 1st millennium BC. A slightly lower value of 17.57‰ was recorded from a single barley grain at Mineikiškės, yet this too is consistent with moderately watered environments (Wallace et al. 2013). Comparatively, Δ$^{13}$C values from Roman Iron Age sites range from 18.15‰ (σ 1.21) at Naukaimis to 20.17‰ (σ 0.62) at Kernavė. These results indicate no significant change in the environmental conditions of crop cultivation compared to the earlier period, suggesting that barley continued to be grown in open, well-irrigated fields in both periods.

## 5. Landscape adaptations during the Roman Iron Age

A closer examination of the isotopic values in cereals from Roman Iron Age assemblages reveals interesting patterns, which may indicate distinct cultivation strategies among the various sites. The data suggests a degree of variation in

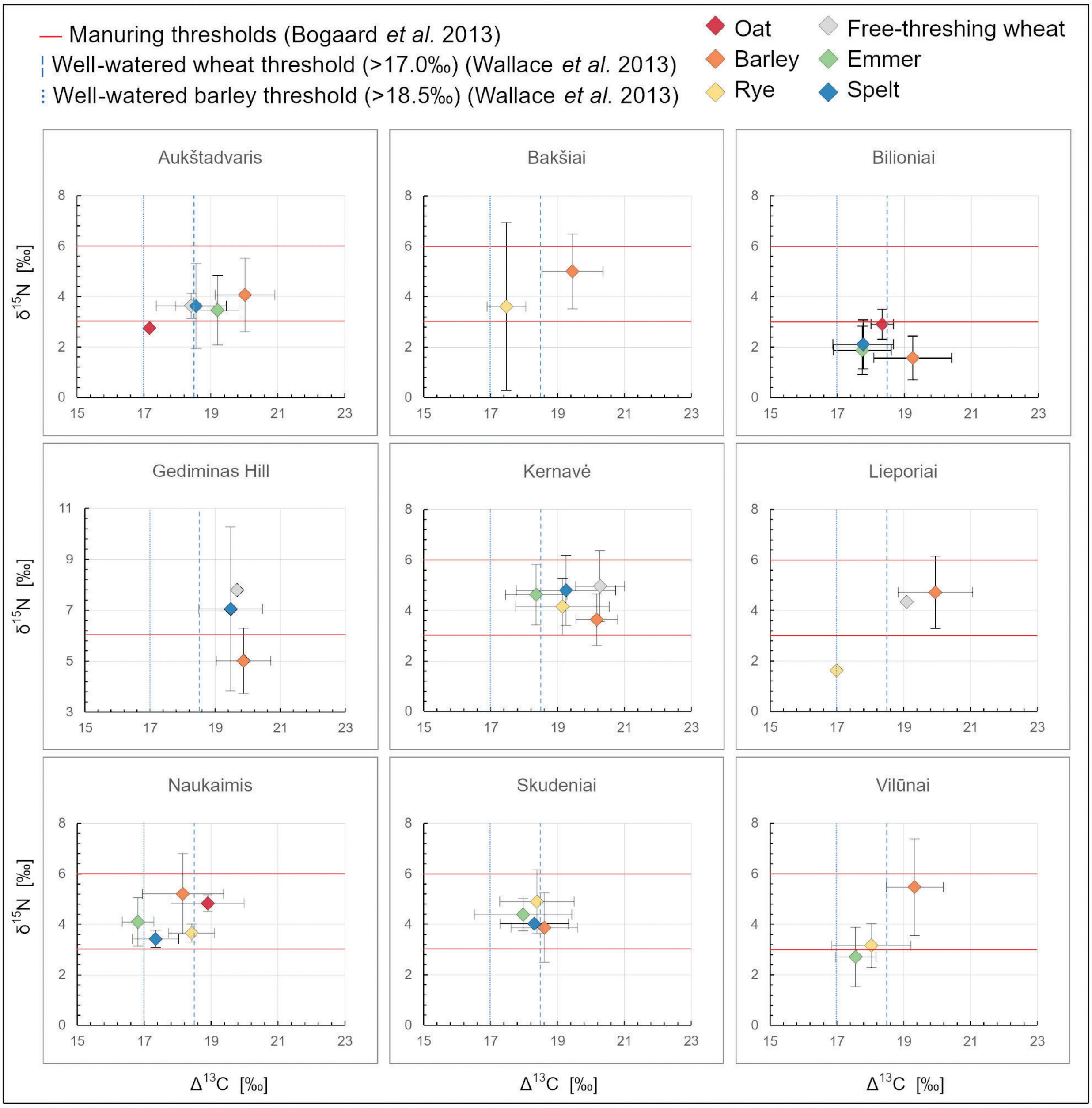

Figure 4. Mean δ$^{15}$N and Δ$^{13}$C values of various crop species from different Roman Iron Age sites in Lithuania (Data from Minkevičius 2024).

the environmental conditions under which barley and rye were cultivated. In some instances, both crops appear to have been grown in similar settings, while in others, they seem to have been cultivated under noticeably different conditions (Fig. 4).

The most pronounced differences in carbon and nitrogen isotope values between barley and rye grains are observed at three sites — Bakšiai, Lieporiai and Vilūnai. For barley, the mean $\delta^{15}$N values are 5.01‰ (σ 1.48) at Bakšiai, 4.72‰ (σ 1.43) at Lieporiai and 5.47‰ (σ 1.92) at Vilūnai. In contrast, rye from the same sites shows significantly lower values: 3.61‰ (σ 3.33), 1.62‰ and 3.16‰ (σ 0.87), respectively. These figures suggest that barley was grown in fields receiving moderate levels of manure, while little to no manure was used to fertilise rye fields. A similar pattern is evident in the $\Delta^{13}$C measurements. The mean $\Delta^{13}$C values for barley are 19.45‰ (σ 0.91) at Bakšiai, 19.95‰ (σ 1.11) at Lieporiai and 19.33‰ (σ 0.85) at Vilūnai. By comparison, rye from these same sites shows lower $\Delta^{13}$C values: 17.47‰ (σ 0.58), 17.00‰ and 18.04‰ (σ 1.19). These lower values indicate that rye was likely grown in more water- or light-limited environments compared to barley.

While some inter-species variation is expected, the notable disparity between the isotopic values of barley and rye points to distinct cultivation practices. Rye is naturally more resilient to harsher conditions, owing to its deeper root system, which allows it to access moisture and nutrients from lower soil layers (Lazauskas 1980, p. 7). If barley and rye were cultivated under similar conditions, we would expect the isotope values for rye to be comparable or even higher than those for barley. The fact that rye shows consistently lower values in these cases suggests that it was cultivated separately from barley, potentially using different farming techniques and in distinct landscape settings. This pattern, observed at sites such as Bakšiai, Lieporiai and Vilūnai, indicates that rye was intentionally grown under different environmental conditions, reflecting a more complex approach to crop management.

The data from the analysed sites indicates that this pattern was not universal across all sites. The isotopic values of rye and barley from Kernavė and Skudeniai show a closer relationship, suggesting a different approach to crop cultivation in these areas. At Kernavė, the mean $\delta^{15}$N values for barley are 3.64‰ (σ 1.02) and for rye, 4.15‰ (σ 1.13). Similarly, at Skudeniai, the $\delta^{15}$N values for barley are 3.87‰ (σ 1.38), while those for rye are 4.90‰ (σ 1.25). The mean $\Delta^{13}$C values show a similar pattern, with barley at 20.17‰ (σ 0.62) at Kernavė and 18.61‰ (σ 0.99) at Skudeniai, compared to 19.14‰ (σ 1.40) and 18.39‰ (σ 1.12) for rye. This suggests that during the Roman Iron Age, at least in some regions, rye and barley were cultivated under comparable environmental conditions, and both crops were likely subject to similar levels of manuring.

Further support for this notion comes from the archaeobotanical assemblages at various sites. The most extensive dataset is from Kernavė, with 26 samples dated to the 3rd–6th centuries AD. Analysis of this material suggests that during this period, the primary farming activity took place in the floodplain area on the northern bank of the Neris River, near the Iron Age settlement. The presence of macrofossils from wild plants, found in both barley-rich and rye-rich assemblages, reinforces the idea that the crops were grown under similar conditions — open landscape in the proximity of water bodies (Minkevičius et al. 2024). Additionally, isotopic data from Naukaimis reveals a similar pattern. The $\Delta^{13}$C values of barley and rye in this location are almost identical, at 18.15‰ (σ 1.21) and 18.42‰ (σ 0.69), respectively, suggesting they were grown in the same type of landscape. However, the more significant difference in $\delta^{15}$N values — 3.04‰ higher for barley — indicates that different cultivation regimes were employed, pointing to more intensive manuring for barley.

Isotopic measurements of cereals, combined with archaeobotanical analysis, suggest that open landscapes with lighter, well-irrigated soils were generally favoured for crop cultivation during the Roman Iron Age. This preference for particular agricultural landscapes mirrors trends observed in other parts of Europe both before and during the Roman Iron Age (Arnoldussen 2008; Kreuz and Schäfer 2011; Macklin et al. 2014). In Lithuania, this pattern is corroborated archaeologically by the discovery of ard furrows at several sites. A notable example is from Kernavė (Fig. 5A), where ard marks were identified in 1992 by Algis Kuzmickas. These furrows, dating to the 5th century AD, are located on the floodplain within the area known as Žemutinis miestas. Another instance of ard marks was recorded at the Pypliai settlement in 2017 (Fig. 5B). This site, positioned on the upper terrace of the Nemunas River, lies just 100 m south of Pypliai hillfort. A charred emmer grain discovered near an iron-smelting furnace in the same vicinity was radiocarbon-dated to 219–361 cal AD, suggesting that the ard marks may date to the same period.

However, the notable differences in carbon and nitrogen isotopic values between barley and rye at sites such as Bakšiai, Lieporiai and Vilūnai indicate that crop cultivation may not have been confined to the most optimal soils in every case. This deviation from the ideal landscape could reflect local adaptations or constraints. While it is not yet possible to fully assess the reasons for these choices, it is plausible that some communities were compelled to expand cultivation into less suitable areas due to limitations in the availability of prime agricultural land. Population pressure may have been a contributing factor,

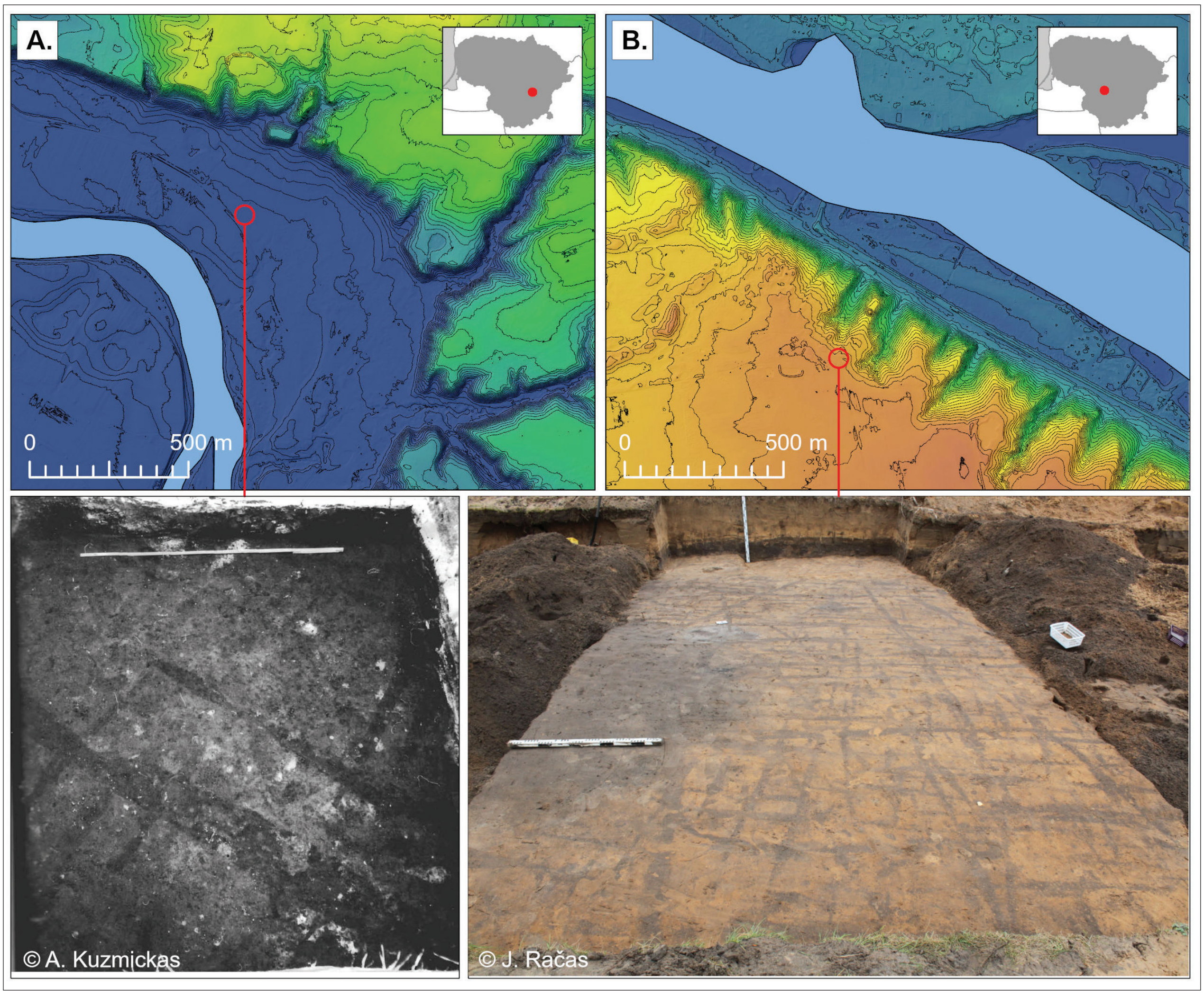

Figure 5. Ard furrows from the Roman Iron Age uncovered at Kernavė (a) and Pypliai (b). Photographs by Kuzmickas and Račas.

pushing farmers to extend their cultivation beyond the most fertile soils.

Additionally, examining local soils and topography can provide valuable insight into the cultivation strategies of specific farming communities. Skudeniai presents an interesting case where isotopic values for both barley and rye suggest favourable conditions for crop cultivation, including relatively fertile soils and well-irrigated, open landscapes. However, archaeobotanical analysis of 2nd–3rd century assemblages at the site reveals a notably low quantity of rye macrofossils (Vengalis et al. 2022b). Although the presence of Secale indicates that rye was cultivated at the site, its minimal proportion compared to other species suggests that it was grown on a much smaller scale. Yet the landscape of the site may help explain this choice. Skudeniai is located on hilly terrain with clayey, poorly draining soils, which present significant challenges for the cultivation of winter crops like rye. The spring thaw, for example, could lead to waterlogging, which suffocates plant roots by trapping excessive moisture in the soil (Brundza 1948, p. 348). Furthermore, temperature fluctuations could damage the roots of winter cereals, causing crop failure (Lazauskas 1980, p. 10). Cultivating winter crops in such environments often requires advanced drainage systems (Bogužas et al. 2013, p. 89) that were likely unattainable in this period, particularly before the introduction of the mouldboard plough. Thus, the low proportion of rye in the Skudeniai archaeobotanical assemblage could be explained by the environmental and technological limitations resulting in increased risks for winter crop cultivation. These constraints may also explain the preference for other crops of the local community. Moreover, cases where increasingly poor water drainage led to site abandonment have been documented elsewhere in Europe (Stevens and Fuller 2018). It is therefore plausible that similar agricultural challenges may have played a role in the eventual abandonment of the Skudeniai site.

## 6. Agrarian landscape of the Roman Iron Age

The updated archaeobotanical dataset, combined with stable isotope measurements and new archaeological findings, offers a refined framework for understanding agriculture in Lithuania during the Roman Iron Age. The data indicates that early 1st millennium AD farming technologies retained several key characteristics from previous periods. Intensive, permanent field cultivation remained the dominant farming method, characterised by arable practices, continual field management and regular manuring to replenish soil fertility. To mitigate soil erosion, farmers employed crop diversity, as demonstrated by the variety of plants found in the archaeobotanical assemblages. The crop package included a broad range of cereals, such as barley, hulled and free-threshing wheat, rye, millet and oats, alongside pulses like field beans, lentils and peas. Additionally, macrofossils of wild plants present in the samples indicate that portions of farmland were regularly left fallow and used for animal grazing. This practice served multiple purposes: providing fodder for livestock, fertilising the land through animal manure and aiding in the restoration of soil quality.

The selection of suitable farmland likely played a key role in determining settlement locations. Archaeological evidence suggests that permanent fields were situated near hillforts and farmsteads, providing convenient access and oversight of crops. These areas were likely chosen to accommodate the farming practices of the Roman Iron Age, which favoured relatively light, well-irrigated soils. The hypothesis that heavier, clay-rich soils were cultivated during this period seems less plausible, particularly given the lack of archaeological evidence for more advanced arable technology, such as the mouldboard plough. The most favourable areas for cultivation were likely situated on river floodplains with light, sandy soils, regularly enriched by alluvial deposits, or near large bodies of water. Additionally, archaeobotanical and isotopic evidence suggests that these areas were cleared of woodland, creating open landscapes that were optimal for crop cultivation.

The Roman Iron Age also marked a notable period of agricultural expansion, both spatially and technologically. Evidence of increased human activity and the rapid opening of the landscape is reflected in pollen records from several archaeological sites. However, pollen diagrams in Lithuania typically offer only approximate dating for 1st millennium AD sediments, limiting the precision of off-site landscape analysis (Minkevičius 2020). That said, the pollen record at Juodoniai, which includes a segment directly dated to the Roman Iron Age (Stančikaitė et al. 2004), suggests that at least in certain regions of Lithuania, this opening of the landscape can be tracked. Further research is needed to confirm these observations more broadly.

The introduction of two new crops — rye and oats — during this period represents one of the most significant technological advances. These additions enabled agriculture to spread into less favourable and potentially more remote areas, creating a more diverse cultivation cycle. The rise in deforestation reflected in the pollen record likely correlates with this agricultural expansion, particularly as rye, a hardy autumn-sown crop, could have been cultivated in swiddens using extensive, low-labour farming techniques in some cases. This shift in crop species, combined with the proximity of farmland to settlements, contributed to the development of a more complex ‘infield-outfield’ cultivation system. This model, with its intensively farmed permanent fields near settlements and more distant, less frequently cultivated lands, helped optimise the use of available resources (Christensen 1978; Grabowski 2013). The introduction of rye, in particular, facilitated more efficient labour distribution. As an autumn-sown crop, rye allowed farmers to stagger their workload across seasons, leading to better-organised labour practices while simultaneously boosting agricultural output.

A key characteristic of the agricultural landscape during the Roman Iron Age was the diversity in farming approaches. While certain sites, like Bakšiai, Lieporiai and Vilūnai, exhibit the use of the infield-outfield farming model, other communities seem to have significantly deviated from this system. Although spatial expansion is often considered one of the defining features of the period, it appears to have played a secondary role compared to local adaptations, environmental challenges and social necessities. In some cases, nearby farmlands may have sufficed, but the expansion into more distant areas with poor soil quality was likely driven by the need to increase crop yields to feed a growing population.

Adaptations in farming strategies can also be seen in the range of cultivated crops. Avoiding agricultural failure is crucial for subsistence-based societies, and one of the key ways to build resilience is through crop diversification (Fuller and Lucas 2017). This strategy is clearly reflected in the Roman Iron Age crop package, which included a wide variety of cereals and pulses, alongside the introduction of new species more tolerant of suboptimal soil and climatic conditions. Despite these efforts, success was not guaranteed, as evidenced by sites such as Skudeniai, where environmental challenges may have limited agricultural productivity, and Bilioniai, where cultural factors seem to have played a role. Nevertheless, the agricultural strategies of this period were designed to improve adaptability and resilience across varied environments. At the same time, these strategies aimed at territorial expansion and the more efficient organisation of labour, both of which were key to ensuring the sustainability of communities during the Roman Iron Age.

## Conclusions

The dataset presented in this study identifies important agricultural innovations used by Roman Iron Age farmers in Lithuania. These include the introduction of rye and oats as new crops and the adoption of the infield-outfield cultivation system. In this system, permanent fields were located on open, well-irrigated land near settlements, while more distant areas were used for swidden cultivation. This diversified strategy aimed to improve agricultural efficiency and enhance the adaptability of farming communities to different environmental conditions.

The updated framework offers new opportunities to explore regional settlement patterns and agricultural practices during the Roman Iron Age. It also provides a basis for analysing the economic choices of individual farming communities at specific sites. However, significant limitations remain, such as the limited evidence of agricultural tools, the lack of directly dated pollen records, and insufficient analysis of isotopic variation between crop species. Therefore, further research into these aspects is essential to gain a deeper and more nuanced understanding of Roman Iron Age agriculture through the integration of archaeological, isotopic and environmental data.

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## Abbreviations

Acta Soc. Bot. Pol. – Acta Societatis Botanicorum Poloniae

Archaeol. Baltica – Archaeologia Baltica

Arch. Lituana – Archaeologia Lituana

J. Archaeol. Sci. – Journal of Archaeological Science

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

Lietuvos Arch. – Lietuvos archeologija. Vilnius

MAD'A – Lietuvos TSR Mokslų akademijos darbai. A serija. Vilnius (1955–1989)

Rev. Anthropol. – Anthropological Review

Rev. Palaeobot. Palynol. – Review of Palaeobotany and Palynology

RCM – Rapid Communications in Mass Spectrometry

Sci. Rep. – Scientific Reports

Sci. Technol. Archaeol. Res. – STAR: Science and Technology of Archaeological Research

Veget Hist Archaeobot – Vegetation History and Archaeobotany

World Archaeol. – World Archaeology

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# Prisitaikymas ir atsparumas: žemdirbystės praktikos Lietuvoje romėniškuoju laikotarpiu

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## Santrauka

Priešistorinės žemdirbystės tyrimuose romėniškasis laikotarpis (I–IV a.) išsiskiria staigiais ir ryškiais pokyčiais, pasireiškiančiais bendru žemės ūkio suaktyvėjimu, bemiškių plotų plėtra ir naujų rūšių – rugių ir avižų – kultivavimu. Įvairūs šio laikotarpio žemdirbystės aspektai Lietuvos archeologijoje analizuojami jau nuo tarpukario, tačiau dėl archeobotaninės ir archeologinės medžiagos fragmentiškumo, radiometrinių ir gamtinės aplinkos tyrimų duomenų trūkumo tikslesnis šio laikotarpio agrarinio kraštovaizdžio vaizdas išlieka mažai pažįstamas.

Vis dėlto pastaraisiais metais Lietuvoje suaktyvėjus žemdirbystės raidos tyrimams, atsiveria galimybė detaliau pažvelgti į pagrindinius romėniškojo laikotarpio žemės ūkio bruožus – pasėlių rūšis, ūkininkavimo strategijas, žemdirbystės technologijas ir agrarinės veiklos įtaką gyvenamajai aplinkai. Bendra naujos ir ankstesnių tyrimų metu surinktos medžiagos archeobotaninė analizė kartu su radioanglies datavimu bei stabiliųjų anglies ir azoto izotopų tyrimais leidžia įvairius žemės ūkio aspektus analizuoti remiantis tiesioginiais duomenimis.

Tyrime analizuoti ir apibendrinti duomenys iš 12 romėniškojo laikotarpio gyvenviečių – Aukštadvario, Bakšių, Bilionių, Birsčių, Gedimino kalno, Kernavės, Lieporių, Naukaimio, Pyplių, Skudenių, Veliuonos ir Vilūnų. Archeobotaninės analizės ir AMS $^{14}$C datavimo rezultatai rodo, kad I tūkstantmetyje pr. Kr. pagrindine žemės ūkio kultūra išliko miežiai (1, 2 pav.). Sorų reikšmė gerokai sumenko, užleisdama vietą naujiems augalams – rugiams, Lietuvoje pradėtiems auginti apie I–II a. po Kr. (1, 2 lent.). Kartu auginta nemažai skirtingų rūšių kviečių – *Triticum aestivum / durum*, *Tr. dicoccon* ir *Tr. spelta*. Mažiau – avižų, kurios taip pat imtos kultivuoti laikotarpio pradžioje. Ankštinių kultūrų – žirnių, pupų, lęšių – auginta tik nedideliais kiekiais.

Azoto ($\delta^{15}$N) ir anglies ($\delta^{13}$C) izotopų tyrimai rodo, kad pasėliai daugiausia auginti atviruose, gerai drėkinamuose, organinės kilmės azotu (greičiausiai – guvulių mėšlu) tręštuose plotuose (3, 4 pav., 3 lent.). Papildomos informacijos suteikia Kernavėje ir Pypliuose rastos arimo vagos (5 pav.), leidžiančios manyti, kad šiuo laikotarpiu tinkamiausios kultivuoti vietos galėjo būti smėlinguose upių slėniuose ar užliejamose pievose, pasižyminčiose lengvai įdirbamomis, tačiau pakankamai derlingomis dirvomis. Izotopų matavimai taip pat rodo, kad tręšiamų dirvų derlingumas laipsniškai augo. Vis dėlto Bilionių ir Skudenių pavyzdžiai leidžia įtarti, kad pavieniais atvejais žemdirbių pastangos galėjo baigtis ir nesėkmingai.

Bakšių, Lieporių ir Vilūnų medžiaga iliustruoja, kad atskirose vietose galėjo būti taikoma mišrios žemdirbystės strategija. Čia rugiai auginti atskirai nuo kitų kultūrų – sausesnėse, tankiau apaugusiose ir ne tokiose derlingose vietose. Tikėtina, kad tai gali būti siejama su Šiaurės Europos istorinėje, archeologinėje ir etnografinėje medžiagoje žinomu gretimų–nutolusių laukų sistemos taikymu, kai arčiau sodybų esantys plotai yra nuolat tręšiami ir prižiūrimi, o atokiau esantys gamtiniai ištekliai eikvojami ekstensyviau. Tokiu atveju daugiau priežiūros reikalaujantys augalai kultivuoti netoli gyvenviečių, o rugiai, kaip daug atsparesnė ir ne tokia reikli kultūra, galėjo būti sėjami specialiai įrengtuose lydymuose.

Turimi tyrimų duomenys leidžia teigti, kad į romėniškojo laikotarpio gyvenamąją aplinką reikėtų žvelgti kaip į gana skirtingų agrarinių kraštovaizdžių visumą, kurioje atsispindi tiek santykinai paprasto, tiek ir gana sudėtingo ūkininkavimo strategijos. Viena vertus, pagrindinė šio laikotarpio žemės ūkio veikla gali būti siejama su panašia gamtine aplinka – šalia sodybviečių buvusiomis atviromis, užliejamomis pievomis ir erdvine bei technologine žemdirbystės plėtra. Antra vertus, tiek galimų nesėkmių atvejai, tiek ir pati žemdirbystės strategijų įvairovė rodo aktyvius romėniškojo laikotarpio žemdirbių veiksmus, siekiant didinti gamybinio ūkio atsparumą aplinkos poveikiui, prisitaikymą prie vietos sąlygų ir galimų gamtinių iššūkių.