УДК 561:581.33:631.95(470)
DOI: 10.35102/CBG.2025.46.40.003

ПЕРИОДЫ СЕЛЬСКОХОЗЯЙСТВЕННОЙ ТРАНСФОРМАЦИИ В ЗОНЕ ХВОЙНО-ШИРОКОЛИСТВЕННЫХ ЛЕСОВ ЕВРОПЕЙСКОЙ ЧАСТИ РОССИИ ПО ДАННЫМ ПАЛИНОЛОГИЧЕСКОГО АНАЛИЗА

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АННОТАЦИЯ

В статье рассмотрены девять спорово-пыльцевых последовательностей ископаемых отложений позднего голоцена и их сокращенные диаграммы из зоны широколиственно-хвойных лесов в пределах Псковской, Смоленской, Тверской и Московской областей. Палинологические данные представлены на единой временной шкале, охватывающей период последних 5000 лет. Участие таксонов-антропогенных индикаторов (АИ), включая недревесную пыльцу, культурные злаки (Cerealia), *Artemisia* и *Urtica*, были соотнесены с изменениями содержания лесообразующих таксонов (*Picea*, *Quercus*, *Ulmus*) в рамках общей хронологии. Предварительно установлена общая модель поэтапного развития производящего хозяйства и изменения интенсивности антропогенного воздействия в пределах зоны хвойно-широколиственных лесов. В рамках этой модели выделено пять фаз антропогенных изменений растительности и ландшафта: 1) Условный период неолита-бронзового века, примерно с 4500–4000 до 3000 кал. л.н., с наиболее ранними находками пыльцы культурных злаков (около 6000 кал. л.н.). В этот период антропогенные индикаторы отражают хозяйство «лесного неолита», характеризующееся минимальной вырубкой лесов и очень спорными и редкими свидетельствами выращивания культурных злаков; 2) Ранний железный век, датируемый 2800–2500 кал. л.н.; 3) период Великого переселения народов и Раннее Средневековье 1700–1300 кал. л.н.; 4) Раннее Средневековье включая Эпоху Викингов и Древнерусский период (1400–800 кал. л.н.), характеризующееся выраженным увеличением земледелия; 5) Период Нового Времени (400–100 кал. л.н.), в течение которого большинство диаграмм показывают пиковые значения антропогенных индикаторов, а также максимальное сведение коренных лесов.

Ключевые слова: земледелие, культурные злаки, пыльца, палинология, поздний голоцен, хвойно-широколиственные леса, история, антропогенные индикаторы, Европейская Россия

Цитирование:

Носова М.Б., Ершова Е.Г., Кренке Н.А., Лавренов Н.Г. 2025. Периоды сельскохозяйственной трансформации в зоне хвойно-широколиственных лесов европейской части России по данным палинологического анализа. *Нов. бюл. ГБС.* 1(3–4): 33–51. DOI: 10.35102/CBG.2025.46.40.003

Редактор: И.А. Шанцер

Получена: 15.12.2025

Ревизия: 23.12.2025

Принята к публикации: 24.12.2025

Опубликована: 30.12.2025

AGRICULTURAL TRANSFORMATION OF LANDSCAPES IN THE MIXED FOREST ZONE OF EUROPEAN RUSSIA: PERIODS IDENTIFIED FROM POLLEN DIAGRAMS

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Citation:

Nosova M.B., Ershova E.G., Krenke N.A., Lavrenov N.G. 2025. Agricultural transformation of landscapes in the mixed forest zone of European Russia: periods identified from pollen diagrams. *New Bull. MBG*. 1(3–4): 33–51. DOI: 10.35102/CBG.2025.46.40.003

Editor: I.A. Schanzer

Received: 15.12.2025

Revision: 23.12.2025

Accepted: 24.12.2025

Published: 30.11.2025

ABSTRACT

The article discusses nine pollen sequences and their summary diagrams from the Pskov, Smolensk, Tver, and Moscow regions of European Russia, within the mixed (broadleaved-coniferous) forests zone. The sequences are aligned on a unified timescale extending to 5,000 cal yr BP. Selected anthropogenic indicators (AI), including non-arboreal pollen (NAP), Cerealia, *Artemisia*, and *Urtica*, were correlated with major primary forest taxa (*Picea*, *Quercus*, *Ulmus*) using this common chronology. A relatively consistent pattern of stepwise agricultural development and human impact within the broadleaved-coniferous forest zone is preliminarily established. Within this pattern, five more or less distinct phases of human-induced vegetation and landscape change are identified: 1) The conventional period attributed to the Neolithic–Bronze Age, from approximately 4,500–4,000 (extending to 3,000) cal yr BP, with earlier but doubtful evidences of agriculture (up to 6,000 cal yr BP). During this phase, the AIs reflect a "Forest Neolithic" type of economy, characterized by minimal deforestation and debatable cereal cultivation; 2) The Early Iron Age period, dating to (3,000) 2,800–2,500 cal yr BP; 3) The Migration Period, 1,700–1,300 cal yr BP; 4) The Early Medieval period including the Viking Age and Old Russian period (1,400–800 cal yr BP), featuring a pronounced increase in cultivation and rapid changes in forest composition; 5) The Period of New Times (400–100 cal yr BP), during which most diagrams show peak values for anthropogenic indicators, as well as maximum deforestation.

Key words: agriculture, Cerealia, pollen, palynology, Late Holocene, broadleaved-coniferous forest, history, anthropogenic indicators, Europaean Russia

INTRODUCTION

Some of the most discussed questions in archaeology and palaeoecology are: when, how and with whose help natural (virgin) forests were transformed to semi-open agricultural landscapes with patches of different variants of primary and secondary forests and then to open agrarian landscapes. Besides archeology itself, this issue is traditionally studied using the palynological method on the basis of anthropogenic indicators (AI) – pollen types, which indicate anthropogenic-caused environmental changes (Behre, 1996). AI include pollen types associated with trampling, grazing, open landscapes, arable lands, eutrophic sites. A group of cultivated plants (cereals, *Brassica, Pisum, Cannabis, Fagopyrum*) is distinguished separately.

Correlations of anthropogenic caused vegetation changes have already been studied over the Europe: in Estonia (Poska et al., 2004), Germany (Kalis et al., 2003), North-West Europe (Berglund, 2003) and Czech Republic (Kuneš et al., 2015). Several macro-regional model-based reconstructions were made for all Europe (Fyfe et al., 2015; Githumbi et al., 2021) and major regions of Europe (Lechterbeck et al., 2014; Woodbridge et al., 2014). The results of these reconstructions are expressed as high-level landscape or vegetation units. This modern quantitative approach is more evidentiary but traditional correlations of pollen sequences allow highlighting of low-scale human impact which did not cause significant transformation of the landscapes.

Historically there were not a lot of well-dated and detailed pollen sequences in Central European Russia. Modern and well ^{14}C-dated pollen sequences were produced in the temperate forest zone of European Russia during last two decades (Wohlfarth et al., 2006; Novenko et al., 2009, 2015, 2019; Nosova et al., 2017, 2019; Tarasov et al., 2019; Mazei et al., 2020; Tarasov et al., 2021) but only few generalizations were made (Novenko et al., 2014; Novenko et al., 2016; Shumilovskikh et al., 2018; Tarasov et al., 2019).

Regions and especially microregions, where more than one diagram have been investigated are of particular interest because such overlapping demonstrates whether the synchronicity we observe in pollen digrams is accidental or natural. For example, three sequences sampled within one huge Polistovo-Lovatsky mire massif (Nosova et al., 2017, 2017a, 2019) showed high similarity of the stages of anthropogenic-caused vegetation transformation. Early periods of agriculture in the temperate forest zone did not lead to significant changes in the landscape and could be similar to natural changes in vegetation. Forest grazing of domestic cattle and large herbivores grazed in the forests affect pollen spectra similarly.

Russian archaeologists worked out detailed classificarion and time scale of archaeological cultures for the west and center of the European part of Russia (Oshibkina, 1996; Mikliaev, 1995; Archaeology, 2006; Krenke, 2019). Thereby, we can try to determine several stages of human-induced vegetation changes based on palynological data, then we could to correlate them with main archaeological periods and agricultural practices of the time.

MATERIALS AND METHODS

We discuss 9 pollen sequences and their reduced diagrams combined on the timescale of 5,000 years long and included selected anthropogenic indicators (Cerealia, *Artemisia* and *Urtica*) together with main taxa of primary forests (*Picea* and broadleaved trees). Age limitation of 5,000 cal yr BP was chosen because finds of pollen of cultivated plants older than 5,000 years are still very rare and their number is still insufficient for any correlations. The following criteria were applied for the selection of sites suitable for inclusion to the study: 1) three or more 14C dates per sequence; 2) more than 500 (with rare exceptions) pollen grains counted per sample.

This pool of diagrams from Moscow, Tver, Smolensk, and Pskov regions, displayed on the Figure 1, allows some generalizations over a large area and characterizes human-induced vegetation changes within similar climatic and vegetation conditions.

The territory involved into correlation belongs to the temperate continental climate zone (according to Koeppen Climate Classification Map – Kottek et al., 2006), with small West-East gradient of moisture and mildness of climate, influenced by the Atlantic.

In the modern vegetation zonation, all sites included in our analysis belong to the subtaiga subzone (Safronova et al., 1999). An alternative viewpoint classifies broadleaved-coniferous forests as a separate vegetation zone (Gribova et al., 1980). The latter interpretation better reflects the characteristic features and specific conditions of the landscape in which the production economy developed. Therefore, we prefer to classify the study area as the broadleaved-coniferous forest zone. Several local patches of south-taiga forests exist within different parts of the zone; for example, the Staroselie site represents one such inclusion.

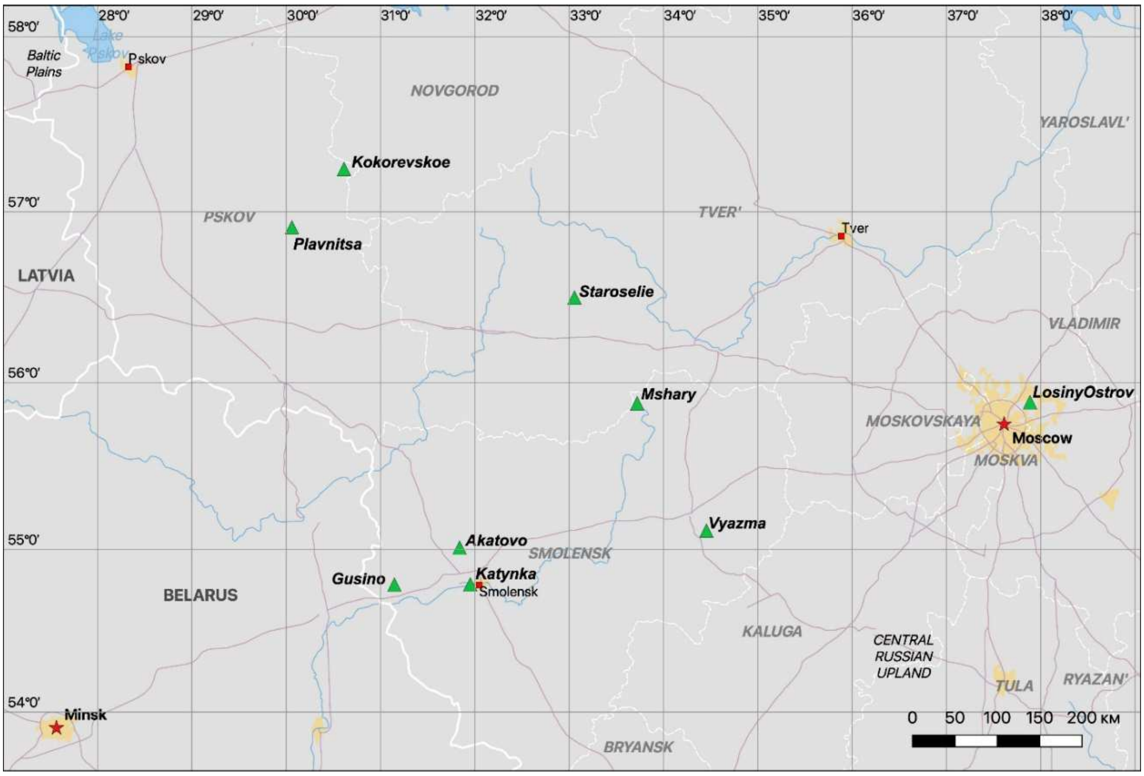

Figure 1. The map of the study sites location within European Russia

Рисунок 1. Расположение изученных объектов на карте в пределах Европейской части России

A brief description of the sampling sites (administrative locality, coordinates, analyst, and references) is provided in Table 1. Further important details describing the local conditions of the sites are given below.

Kokorevskoe and **Plavnitsa** core sites is situated in the western part of the Polistovo-Lovatskaya Mire System (largest in Europe). The present-day vegetation at both sites is a hummock-and-hollow complex, open or covered by sparse pine forest. The vegetation of dry lands around mire composed of small-leaved and mixed forests of 30–70 years old covering abandoned agricultural land and clearings. Archaelogical sites explored in the vicinity of the mire system (not closed to the boring sites) belongs to Iron Age and Middle Ages.

The **Staroselie** peatbog lies on the edge of Central Forest State Natural Biosphere Reserve (CFSNBR), on the Great Watershed of Russian Plain. Natural and seminatural spruce forests prevail on the territory today. This poorly drained loamy plain on the watershed area has never been densely populated and were extensively used for cultivation. No archaeological sites explored here except for modern villages of Late Medieval origin.

The **Gusino** core site (Radomskiy Mokh bog) is located in 50 km to the West from Smolensk near Russian-Belarus border. Northern and central parts of the bog were used for peat extraction and damaged in battles during World War II. The southern part, which is untouched by peat extraction and exploisons, was selected for sampling. Currently the whole bog is covered by sparse pine forest and surrounded by mixed spruce-broadleaf forest with boreal grass complex. There are no archaeological sites in 10 km radius from the bog are known.

Table 1. Pollen sequences included into analysis

Таблица 1. Спорово-пыльцевые диаграммы, включенные в анализ

Site name	**Region, District, Closest settlement**	**Type of basin**	**N- latitude E- longitude**	***Analyst*, reference**
Kokorevskoe	Pskov, Bezhanitskyi, Polistovsky Reserve	ombrotrofic mire	N 57.258593 E 30.606367	*Nosova*, Nosova et al., 2019
Plavnitsa	Pskov, Bezhanitskyi, Polistovsky Reserve	ombrotrofic mire	N 57.039679 E 30.331210	*Nosova*, Nosova et al., 2017
Staroselie	Tver, Nelidovskyi, Central Forest Reserve	ombrotrofic mire	N 56.466446 E 32.954374	*Nosova*, Novenko et al., 2009
Gusino	Smolensk, Krasninskyi, Gusino, Komissarovo	ombrotrofic mire	N 54.732131 E 31.253349	*Lavrenov*, Lavrenov et al., 2021
Katynka	Smolensk suburban, Katyn’	the former riverbed in the floodplain	N 54.767880 E 31.743683	*Ershova*, Ershova et al., 2020
Akatovo	Smolensk, Demidovskyi, Akatovo	ombrotrofic mire	N 55.935834 E 33.853220	*Lavrenov*, Lavrenov, 2025
Mshary	Smolensk, Sychevskyi, Bocharovo	ombrotrofic mire	N 55.863321 E 33.668174	*Lavrenov*, Lavrenov et al., 2024
Vyazma	Smolensk, Vyazminskyi, Krasnyi Kholm	transformed mesotrophic	N 55.073606 E 34.531941	*Lavrenov*, Lavrenov, 2025
Losiny Ostrov	Moscow suburb, Losiny Ostrov National Park	ombrotrofic mire	N 55.870085 E 37.825644	*Ershova, Miagkaya*, Miagkaya et al., 2020

The **Akatovo** core was extracted from a small unnamed bog near the Akatovo lake. The site is located in 44 km to the NNW from Smolensk. The current vegetation of the bog is presented by dense birch forest and complex of oligotrophic bog herbs including *Eriophorum vaginatum*, *Carex rostrata*, *C. vesicaria* and *Drosera rotundifolia*. Samples were obtained from the center of the bog. Two archaeological sites attributed to Migration Period and Medieval times are located in 1 km radius from the core-site.

Mshary bog is located on the North-East of the Smolensk region in 160 km to the east from Smolensk (near the border with Tver Region). Its’ current vegetation is quite similar to *Kokorevskoe* and *Plavnitsa* bogs and presented by hummock-and-hollow complex, open or covered by sparse pine forest and complex of oligotrophic herbs from Cyperaceae and Ericaceae families mostly. There are no archaeological sites in 10 km radius from the bog are known.

The **Vyazma** core was extracted from the unnamed bog located near Krasny Kholm village in 160 km to the SEE from Smolensk. The northern part of the bog was exposed to experimental afforestation (with pine) in the middle of XX century. Its' untouched southern part was selected for the core extraction. Current vegetation of the bog is heterogenous due to mentioned afforestation. The drained northern part is covered by dense pine plantation while vegetation of the southern part is presented by typical for transitional oligo-mesotrophic bog plant complex.

The **Katynka** core was obtained from organic deposits of the former old riverbed of the Katynka River at its inflow into the Dnieper River, 15 km from Smolensk and 8 km from the Gnezdovo archaeological complex. Now it is an agricultural landscape, with a high concentration of archaeological monuments from the Neolithic to the Middle Ages.

The core **Losiny Ostrov** was obtained from the unnamed mesotrophic mire, which is situated on the south edge of National Park "Losiny Ostrov" in the suburban of Moscow City. This reserve has historical origin and since the XV century it has been protected as a territory for royal hunts. Today the vegetation of the territory is a combination of coniferous, broadleaved-coniferous and small-leaved forests. Archaeological heritage of the territory includes settlements and burials of Old Russian period and later.

Peat and mineral samples were processed in a similar way and pollen counted according to standard techniques described by Moore et al. (1991). ^{14}C dates were received in A.E. Lalonde AMS Laboratory, University of Ottawa — UOC (Gusino, Katynka, Akatovo, Mshary, Vyazma), in Laboratory of radiocarbon dating and electronic microscopy of the Insitute of Geography RAS — IGAN (Kokorevskoe, Plavnitsa) and in the Institute of Geology RAS — GIN (Staroselie). The chronologies of the cores was calculated using linear chronology in Tilia program (Tilia 3.0.1 software) and using Bayesian deposition model in OxCal (Ramsey, 2008; Ramsey, Lee, 2013). Radiocarbon dates were calibrated using calibration scales IntCal 13 for Kokorevskoe, Plavnitsa and Staroselie (Reimer et al., 2013) and IntCal 20 (Reimer, 2020) for other sites.

Diagrams were constructed using C2 software (Juggins, 2007). The percentages of pollen taxa we calculated as a percentage of total terrestrial pollen grains, and the percentage of spores as a percentage of the total number of pollen and spores. Zonation of the diagrams reflects generalized notions of major archaeological eras (described in Table 2) in the temperate zone of European Russia. Early and Late Middle Ages conditionally divided by the upper edge of Old-Russian period as significant and well dated milestone of culture transition.

Although the archaeological context of the studied area is more or less similar, each site has its own local peculiarities. While some of them are distanced for miles from all the known archaeological sites, the others are located in the vicinity of them.All the cores from Smolensk Region were used in palaeoenvironmental investigations associated with Gnezdovo archaeological complex for vegetation and climate reconstructions (Ershova et al. 2020; Lavrenov et al. 2021).

Table 2. Archaeological periods in temperate forest zone of Central European Russia from the Neolithic Period to Modern Times (on a combination of sources: Oshibkina, 1996; Mikliaev, 1995; Archaeology, 2006; Krenke, 2019)

Таблица 2. Археологические периоды в зоне хвойно-широколиственных лесов Европейской части России от неолита до Нового времени (на основе комплекса источников: Ошибкина, 1996; Микляев, 1995; Археология, 2006; Кренке, 2019)

Age	Culture	Date, cal yr BP	Type of economy
End of Neolith	Verkhnevolzskaya Lyalovo	To 5,000(4,500)	Hunt, gathering
Eneolith	Volosovo	4,700–4,200	Hunt, gathering
Early Bronze	Corded Ware (Fatyanovo, Middle Dnieper, Globular amphora)	4,200–3,500	Cattle farming, hunt, gathering, small-scaled crop farming
Middle Bronze	Abashevo	3,500–3,200	Cattle farming, hunt, gathering, small-scaled crop farming
Late Bronze	Textile Ware (Pozdnyakovo)	3,500–2,700	Cattle farming, slash-and-burn cultivation, hunt, gathering
Early Iron Age	Dyakovo, Dnepro-dvinsksja	2,600–1,700	Cattle farming, slash-and-burn cultivation, hunt, gathering
Migration Period	Late Dyakovo Moschinskaya, Pskov Long Barrows, Tushemlinskaja/Kolochinskaja, pre Big barrows culture	1,700–1,200	Cattle farming, slash-and-burn cultivation, hunt, gathering
Early Middle Ages	Smolensk Long barrows, Big barrows (Sopok) culture, Old Russian	1,300–800	Arable and cattle farming
Late Middle Ages		800–500	
Modern Times		Since 500	

RESULTS AND DISCUSSION

First, the assumption that we can determine several periods of agricultural expansion in the forest zone of the European Russia, arose on the basis of pollen data from **Plavnitsa** and **Kokorevskoe** cores (Nosova et al., 2017; Nosova et al., 2019) within Polistovo-Lovatskaya mire system. The graph (Fig. 2) of numbers of nonarboreal pollen types (NAP) per sample of 500 arboreal pollen grains shows for Plavnitsa core several peaks: at 4,200 years ago, about 3,000 years ago, 1,100 years ago and after 400 years ago. The first peak correlates with absolute limit (C^0 according to Vuorela, 1986) of Cerealia pollen, continues and goes into the second one, coincided with transition from Bronze Age to Iron. The third starts with the beginning of Old-Russian period, and the forth coincides with the maximum of agricultural activity last 400 years, which began after the end of political and economic crisis in the 16–17th centuries AD, called “Time of Troubles”. The second core Kokorevskoe from the same mire complex showed the similar picture (Nosova et al., 2019). Then we compared this graphs with the diagram of tree taxa and anthropogenic indicators (reduced diagrams of Plavnitsa and Kokorevskoe on the Fig. 3) and found that these “waves” correlate with periods when *Picea* and summarized broadleaved pollen curves (further — QM — Quercetum Mixtum) decrease whereas Cereals and other anthropogenic indicators increase. We allocate here four periods of agricultural transformation of forest cover: 4,200–4,000 cal yr BP, 2,500–2,300 cal yr BP, 1,000 cal yr BP, 400 cal yr BP and later. Each of these stages was accompanied by the progressive degradation of zonal forests. After 800 cal yr BP zonal broadleaved-coniferous forests partly restore their position despite of cooling and due to depopulation that was a result of chain of military, climatic and economic events. Therefore, we can carefully assume that Little Ice Age was less significant factor of vegetation changes than socio-economic reasons.

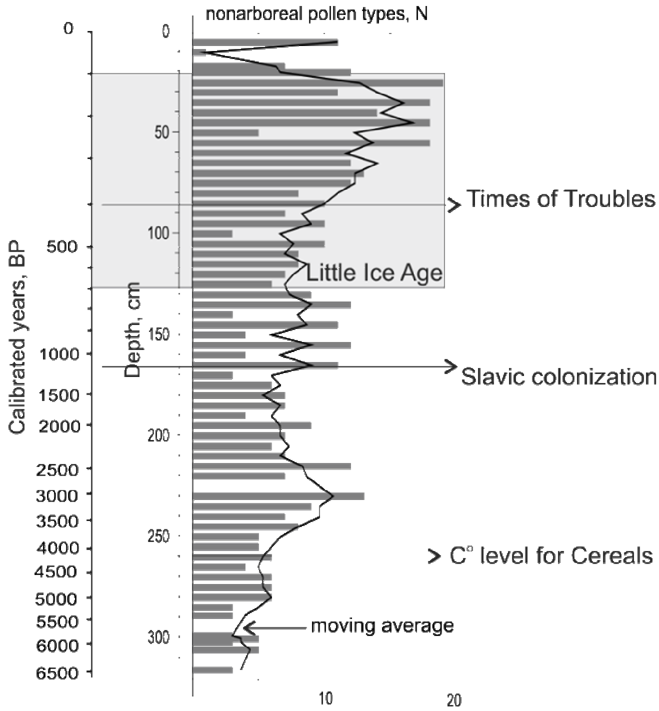

Figure 2. Changes in diversity of NAP standardized relative to 500 arboreal pollen grains in the core Plavnitsa (Polistovo-Lovatskaya Mire System, Pskov Region, Russia) during the last 6,500 years (Nosova et al. 2017)

Рисунок 2. Изменение числа таксонов недревесной пыльцы, стандартизированное относительно 500 пыльцевых зерен деревьев, в разрезе Плавница (Полистово-Ловатская болотная система, Псковская область, Россия) за последние 6500 лет (Nosova et al. 2017)

When we combined Cerealia (as cultivation indicator), *Artemisia, Urtica* (as pastoral pollen types) and sum of NAP together with *Picea, Quercus* and *Ulmus* from different cores (Fig. 3), it seems that there is no West –East gradient of agriculture pervasion. Cerealia pollen appears for the first time (C^o-level) in different cores in very different periods. The earliest appearance of Cerealia pollen we observed in two cores: 1) Katynka, in 5,700 cal yr BP (not included into diagram) and the next – at about 4,000 cal yr BP; 2) Plavnitsa, in 4,200 cal BP. Both occurences are single pollen grains and they are not accompanied by the significant changes of vegetation. In the most eastern cores Vyazma and Losiny Ostrov the first pollen grains of Cerealia arise at about 3,400–3,500 cal yr BP, whereas Gusino, Mshary and Staroselie show the start of cultivation at about 2,800–2,900 cal yr BP. In the core Kokorevskoe the start of Cerealia dates back only to 2,300 years ago, which may be due to the large distance (more than 2 km) from the coring site to the dry and potentially arable lands. The latest appearance of Cerealia pollen (1,400 cal yr BP) is in the core Akatovo, possibly due to the long time interruption in peat deposits between bottom and floating mat and break in sediments sampled.

Below we discuss the dynamics of anthropogenic changes for each diagram separately (Fig. 3).

C°-level in the core Gusino belongs to the beginning of the Iron Age (2,900–2,800 cal yr BP) and accompanies by decreasing of QM and increasing of NAP. Further occurrences of Cerealia are observed in the time span of 2,000–1,500 cal yr BP which finished by the sharp decline of QM. There are no Cerealia pollen contemporary to Old Russian period, but we distinguish a peak of *Artemisia* at 1,200 cal BP. Continuous curve of Cerealia pollen begins above the level 800 cal yr BP. Its increase is interrupted by a temporary decrease in agricultural activity and the restoration of zonal forests about 500 cal yr BP (“Time of Troubles”). More complete pollen diagram which includes other anthropogenic indicators (Lavrenov et al., 2021), shows wider frames of transformation periods.

Core site Katynka, which is situated in the floodplain, sets a great example of early and abrupt deforestation and rapid transition of landscapes from natural to agricultural. The first stage of transformation belongs to Bronze Age, when only single pollen grains of Cerealia observed (5,700 and 4,100 cal yr BP) and clearings were minimal. The next stage began at about 2,200 cal yr BP (Iron Age) together with increase of continuous Cerealia curve and accompanied by the abrupt changes of forest cover and composition. Broadleaved and broadleaved-coniferous forests practically disappeared and replaced by the secondary forests with significant role of spruce. This was a time of climate cooling, thus not only humans potentially could cause these changes. The Cerealia curve interrupts from 1,000 to 500 cal yr BP but changes in arboreal pollen types and AI in complete pollen diagram (Ershova et al., 2020) show that there was not zonal forest remission in LIA and high agricultural activity continued up to now.

There are not Cerealia pollen in the bottom layers of the core Akatovo which dates as 3600–3,300 cal yr BP, but *Artemisia* pollen occurs here in large quantities. This suggests that in the Bronze Age the area was dominated by cattle husbandry. Cerealia appears at about 1,300 cal yr BP and we observe a dramatic change are that sharp decrease and increase of *Picea* about 800 cal yr BP. Here as well as in previous cores the antiphase of Cerealia and QM are clearly visible.

On the north of Smolensk Region in the core Mshary the earliest and quite intense at once the signs of animal husbandry and cultivation date back to the transition period Late Bronze/early Iron Age (about 2,800 cal yr BP). Some pollen signs of cattle farming we can distinguish from 4,100 cal yr BP. Significant deforestation correlated with intensity of agriculture began from 1,500 cal yr BP, intensified 1,000 cal yr BP and have a maximum after 500 cal yr BP. The last period is accompanied by decreasing of both *Picea* and QM.

The most eastern core in Smolensk region, Vyazma, is not detailed in lowermost layers. In the layer corresponding to the age of 3000 years the single pollen grain of Cerealia is observed. Above we do not observe clear signs of anthropogenic impact until the Old-Russian period (1,000 cal yr BP). The increasing of NAP and decreasing of QM and *Picea* follow the elevation of Cerealia curve.

As the cores from Pskov Region (Kokorevskoe and Plavnitsa) were discussed above, we should only note that there were stable anthropogenic signal and no significant signs of deforestation in Late Iron Age and only small shift of human activity in Early Medieval Time.

The core Staroselie was obtained from the territory of the Central Forest Natural Reserve, which lies at the Greate Watershed of Russian Plain. The first and single occurences of Cerealia pollen refers to the time 2,900 cal yr BP and 2,000 cal yr BP. The next stage began about 1,500 cal yr BP when NAP start to increase. Notable human influence to landscapes began since 1,000 cal yr BP and had a peak after 400 cal yr BP. The population level was very low even in XIX–XX centuries. This territory with specific microclimate and poorly drained loamy soils was covered with low disturbed taiga-faced forests.

The most eastern core of considered is Losiny Ostrov. The first appearance of Cerealia 3,400 cal yr BP follow the reducing the role of QM and replacing them with spruce. The next period (from 2,900 to 2,100 cal yr BP) demonstrate more regular and high level peaks of Cerealia. Simultaneously with the increase of Cerealia the participation of *Artemisia* and NAP increases. The remission of broadleaved forests came 1,400 cal yr BP, mainly due to oak, and lasted until 1,100 cal yr BP when new "wave" of agricultural expansion began. After 750 cal yr BP short remission of broadleaved-coniferous forests occurs again. Then about 500–600 cal yr BP it turned to degradation towards the minimum. In early New Times forests of the territory regenerated again mainly with spruce because this forestlands was the Tsar's hunting reserve after 1500-th. Human impact reach here its maximum in XV–XVI centuries.

Possible local archaeological context, which is not always known, and the distance of archaeological site from the sampling point play the great role. For example, Gusino, Mshary, Staroselie and Losiny Ostrov show crop cultivation since 2,900 BP, whereas there are no archaeological sites of Late Bronze and Early Iron Age known in close vicinity.

A careful study of the published data for the territory under discussion allowed us to draw conclusions that the indicated periods are also distinguished in the articles of other authors.

Five sequences investigated by Tarasov et al. (2019) within the watershed of Western Dvina (Daugava) and Lovat', demonstrate quite different C^{o}-level. The common feature of all these diagrams is smooth first period of deforestation during Neolith 7600–5,000 cal yr BP. and abrupt changes in Old Russian Period. Bronze and Iron Age differ from each other in sense of human impact depending of local conditions. Authors express their opinion that it is connected with low density and irregularity of population as well as uneven culture level of tribes living on the territory. Two main periods of anthropogenic transformation were distinguished by the authors: Late Bronze 4,200–3,700 cal yr BP and Early Medieval 1,400–1,000 cal yr BP. Taking into account the results of our current research, we can see that periods of Bronze/Iron Age transition (3,000–2,800 cal yr BP) and Late Iron Age (1,500 cal yr BP) are also observed in some of these diagrams.

The site Krivetski Mokh, lying within the same vegetation zone, was investigated by Mazei et al. (2020) and shows similar steps: Late Bronze/Early Iron transition about 3,000 cal yr BP, Late Iron Age or Migration Period 1,900–1,400 cal yr BP, Early Medieval period about 1,000 cal yr BP and maximum after 500 cal yr BP. All of these periods coincide with declines of QM and/or *Picea* curves.

We can preliminary distinguish more or less clear intervals of the stepwise changes of agricultural activity in the past.

Until now, the question of the existence of Neolithic agriculture within the forest zone of the European part of Russia remains open. Finds of Cerealia pollen are rare and are not sufficient for correlations yet, but we consider it our duty to mention that more and more data, including palynological ones, are emerging in favor of the existence of small-scale hoe farming in floodplains. The cultural and technological development of the Neolithic population in the forest zone was heterogeneous, and within the described territory, a number of cultures of this time are distinguished (Oshibkina, 1996; Mazurkevich et al., 2016) including rare traces of contacts with Dnepro-Donetskaya and Linear Pottery cultures, which could bring to the mixed forest zone early agricultural traditions. On the territory of forest belt in East European and Baltic counties Neolithic occurences of Cerealia pollen are rare but regular (Poska et al., 2004; Poska, Saarse, 2006; Wacnik, 2009; Zernitskaya, Mikhailov, 2009) and become more rare when moving towards the Central European Russia. Sporadic evidences of farming were found in soils, lake and mire sediments of Neolithic age in Novgorod region – in the floodplain of Lake Ilmen (Königsson, Possnert, 1997), on the north of Smolensk Region and on the south of Pskov Region (Tarasov et al., 2019; Mazurkevich et al., 2009), Lake Ladoga (Alenius et al., 2020) and in Moscow Region (Ershova et al., 2014).

According the conclusions of Tarasov et al. (2019) we do not find Cerealia pollen in Neolithic layers in the large accumulation basins, which collect regional spectra. Vice versa, in soil profiles and local accumulation basins closed to Neolithic archaeological site, Cerealia pollen occurs more regularly (Ershova et al., 2014; Aleksandrovskiy et al., 2018). Low intensity and secondary role of early agricultural practices leads to the fact that small cultivated areas were surrounded by forests. According to special investigations of palynologists, were found out that only small amount of NAP pollen penetrates under and carries out of the forest canopy as a result of filtering effect of forest edge (Dimbleby, 1961a; Vuorela, 1975). Due this fact, the pollen percentage of cultivated plants in forest belt very rarely exceeds 10% (Vuorela, 1986). Thereby the absence of AI in local deposits connected first with presence/absence of settlements/agricultural lands and with presence/absence of forest barrier between the source of pollen and accumulation basin.

The population of the Bronze Age in European Russia forest zone belonged to the Fatyanovo culture, which has a wide range from the river Volga to the Baltic Sea. Cattle husbandry among the Fatyanovo tribes does not raise doubts (Krenke, 2019). At present, the signs of agriculture in pollen spectra dated back 5,000–4,000 cal yr BP is also beyond doubt in all over zone of mixed forests (Poska et al., 2004; Zernitskaya, Mikhailov, 2009; Zernitskaya et al., 2019; Tarasov et al., 2019; Novenko et al., 2018, 2019, current article). The interval of the first appearance of Cerealia (4,200–3,900 cal yr BP), which is often found in the diagrams, is apparently associated with the migration of the population used corded ware ceramic tradition into the forest zone, practicing cattle farming and hoe agriculture. The next concentration of the dates belongs to the period 3600–3,400 cal yr BP, but agriculture at this time is quite rare and it gravitates towards the southern part of the forest zone (Losiny Ostrov and Katynka). The signs of cattle farming are much more common (Akatovo, Mshary, Losiny Ostrov, Katynka). Pozdniakovo Culture and Mesh Ceramic Culture of Late Bronze Age (3700–2600 cal yr BP) replaced the Fatyanovo Culture, maintaining (or adopting) their husbandry practices. The scale of vegetation transformation remains at about the same level. Smallscale agriculture in Bronze Age visible better in local basins and archaeological profiles directly in the zone of influence of the settlement (Spiridonova et al., 2009; Ershova et al., 2016).

At the turn of the 2nd to the 1st millennium BC (c. 3000 cal yr BP), a Bronze Age crisis occurred (Kaniewski et al., 2013). This event, primarily documented for the Mediterranean and the Middle East, evidently impacted all neighboring regions of the Old World. The transition to the Iron Age coincided with the emergence of the Dyakovo and Dnieper-Dvinian cultures in the territory of western and central European Russia, which introduced more advanced agricultural practices to the forest zone.

As a result, we identify the next period of environment transformation about 3,000–2,900 cal yr BP. The signs of a significant transformation of natural communities, including slash-and-burn agriculture, are recognized in most of the sites studied and described in the literature. The existence of cereal cultivation in the Iron Age have been described on the base of archaeobotanical data (Krenke, 2019) and slash-and-burn cultivation has already been proven by the charcoals from buried soils under the Slavic barrows in Moscow Region dated as 2000–1800 cal yr BP (Ponomarenko et al., 2021). From this moment, a significant degradation of zonal forest vegetation begins, and at first, broad-leaved and mixed forests were cut down, since they grow on more fertile soils.

During the Migration Period the Dyakovo and Late Dyakovo Cultures were gradually replaced by the cultures Moschinskaya, Pskov Long Barrows, Tushemlinskaja/Kolochinskaja and pre Big barrows, which existed within this area until the beginning of the 9th century and disappeared already under the influence of the main wave of Slavic colonization of the territory. At the time, slash-and-burn practices leave a significant traces in palynological diagrams: a decrease in pollen percentage of QM and spruce, and presence of cultivated plants and other AI. Nevertheless, while maintaining agriculture as such, its scale seems to be decreasing (Plavnitsa, Staroselie, Losiny Ostrov, Katynka). Despite of this, degradation of QM continues, at the some sites they are replaced by spruce or birch. This changes can have, in addition to anthropogenic, climatic causes or a combination of them.

It seems that anthropogenic disturbances of zonal forests in the reconstructed periods of cooling 4,000–3,700 cal yr BP, around 2500 cal yr BP, about 1500 cal yr BP (Dark Ages cooling) and Little Ice Age (Novenko, 2016) lead to irreversible changes, when declining of agriculture intensity did not lead to restoration of the same forest composition but forests restored to more boreal version such as increasing of spruce for example. We see this for example on the diagrams Katynka, Vyazma, Losiny Ostrov. Thus, significant disturbances were possibly a trigger for vegetation rearrangements, and the climate was a driver. Similarly, the bark-beetle (*Ips typograpus*) operates last 10 years on the territory of European Russia. After the big draught in 2010 it caused Norway spruce dieback in some regions to promote the restoration of broadleaf trees in the place of former spruce forests (Ulanova et al., 2011).

The Slavic colonization and then formation of the Old Russian state in the period from 1,400 to 800 cal yr BP is accompanied by an increase in the Cerealia pollen in the diagrams everywhere in temperate zone of European Russia. Since 1,400 cal yr BP we distinguish the period which we conditionally called the Early Medieval stage, including Old Russian Period. The establishment of the path from the Varangians to the Greeks as an economic basis within the zone of habitation of the Slavic tribes already coming here, as well as cultural exchange along the trade route, apparently, contributed to the improvement of agricultural practices and the expansion of arable areas. Broadleaved trees and spruce suffered the sharpest and often catastrophic decline at this period.

Several diagrams show the recovery of zonal forests, including broadleaved trees, during the Little Ice Age despite the climate deterioration. In the article discussed the vegetation changes within Polistovo-Lovatskaya Mire System (cores Kokorevskoe and Plavnitsa) we showed that such a simultaneous increase of both spruce and broadleaved taxa percentages along with climate deterioration confirms the assumption that reduction of broadleaved and spruce forests was caused more by human activity then climate (Nosova et al., 2017, 2019).

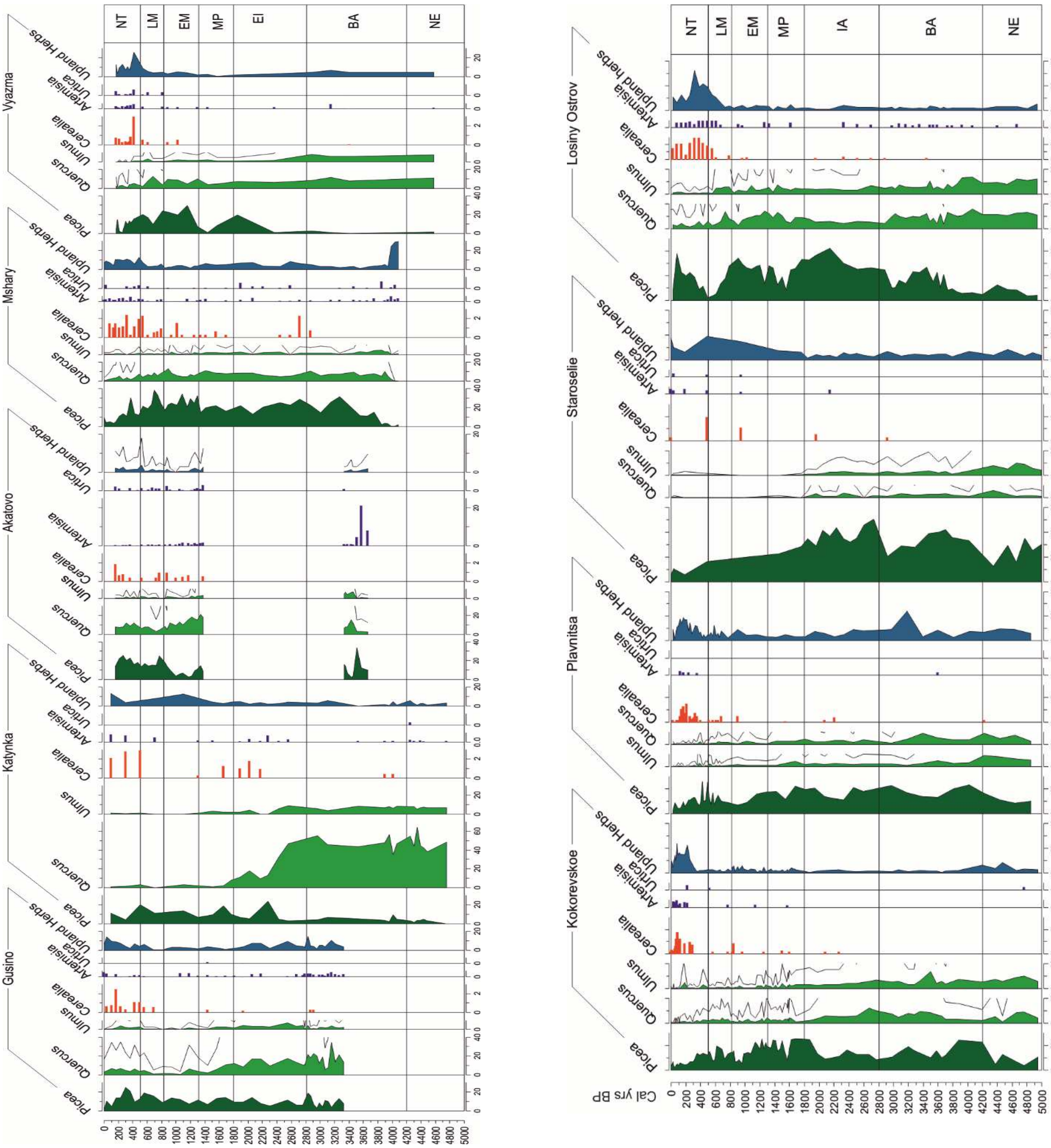

Figure 3. Combined pollen diagram with selected taxa of nine peat cores from Smolensk, Pskov, Tver and Moscow regions. Abbreviation of the zones are: NE – Neolith; BA – Bronze Age; EI – Iron Age; MP – Migration Period; EM – Early Middle Ages excluding Old-Russian period; LM – Late Middle Ages including Old-Russian period; NT – New Times and later

Рисунок 3. Объединенная пыльцевая диаграмма, включающая избранные таксоны девяти торфяных разрезов из Смоленской, Псковской, Тверской и Московской областей. Сокращения зон: NE – неолит; BA – бронзовый век; EI – железный век; MP – период Великого переселения народов; EM – Раннее Средневековье, за исключением Древнерусского периода; LM – Позднее Средневековье, включая Древнерусский период; NT – новое время и более поздний период

The last period since 500–400 cal yrs BP is identified on the all diagrams and discussed by many authors. Even low disturbed areas as Central Forest Reserve (Novenko et al., 2009) were under the human activity in degree enough for reaching empirical limit for Cerealia. This is the period of maximum deforestation on the Russian Plain, which, combined with the Little Ice Age, led to a decrease in the participation of broadleaf species and spruce to a minimum.

CONCLUSIONS

Preliminary we define a relatively common pattern for stepwise development of agriculture and human impact in broadleaved-coniferous forest zone. Within this pattern we can distinguish five more or less evident milestones of human induced changes in vegetation and landscapes:

1. The conventional period of the "Neolithic-Bronze age" 4,500–4,000(3,000) BP and earlier (to 6,000 BP), when AI reflect the "Forest Neolithic" type of economy with the minimum of deforestation. At this time, zonal vegetation in discussed region was represented by mixed broadleaved-coniferous and broadleaved forests. Findings of Cerealia pollen mostly belongs to timespan 4,200–3,400 cal yr BP. They are very rare and insufficient to correlation, but confirm low scale hoe farming. Two wave of agricultural transformation (4200 and 3400 cal ye BP) we distinguish in the Bronze Age.

2. Early Iron Age period with dates (3,000)2,800–2,500 cal yr BP seems to be coincided with Bronze Age/Iron Age cultural and economic transition. Cereal pollen grains as well as AI remain sparse but appear regularly. Crop cultivation was evident from that time and was accompanied by the increase of deforestation with slash-and-burn practices.

3. Migration Period (1,700–1,300 BP). This stage of landscape transformation resulted from the colonization wave of Moschinskaya and Pskov Long Barrows cultures. Some of the diagrams show significant decline of broadleaved trees. There are no significant increase of AI, but deforestation goes on.

4. Early Medieval stage (1,400–800 BP) including Old Russian period began when arable lands expanded, and new technologies were brought by the Slavic tribes. Cerealia and AI reach their empiric limit (their graphs become continuous). Primary forests degraded significantly. Several diagrams have a period of 800–500 BP when the agriculture declined, and zonal forests temporary recovered despite the Little Ice Age began. Possibly, it was due to the socio-economic reasons and great depopulation of 13th–17th cent.

5. The New Times (400–100 BP). Most diagrams show the maximum of AI and grassland indicators, caused by the population growth and agriculture expansion following the end of the Times of Troubles in the 17th century. It was accompanied by the ultimate decrease of spruce and broadleaved forests.

FUNDING

The study was funded by the institutional research project no. 122042700002–6, and the Russian Foundation for Basic Research (Российский фонд фундаментальных исследований), projects 14–04–01405, 17–04–01034, 19–04–01246 A.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

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