Insight in the late Holocene vegetation history of the East European forest-steppe: case study Sudzha (Kursk region, Russia)

Lyudmila S. Shumilovskikh

Dep. Palynology and Climate Dynamics, Georg-August-University Göttingen, Untere Karspüle 2, 37073 Göttingen, Germany; Laboratory of taxonomy and phylogeny of plants, Faculty of Biology, Tomsk State University, Lenin Ave 36, 634050 Tomsk, Russia

Alla Troshina

Municipal Budget Organization "Kolomna Archaeology Centre", Kremlevskaya street 5, 140400 Kolomna, Russia

Vlasta Rodinkova

Department of Archaeology of the Migration Period and the Early Middle Ages, Institute of Archaeology of the Russian Academy of Sciences, Dm. Uljanova str. 19, 119036 Moscow, Russia

Aleksandra Rodionova

Siberian Federal University, Institute of Ecology and Geography, Department of Ecology and Environmental Studies, Svobodny pr., 79, 660041 Krasnoyarsk, Russia

Elena Novenko

Department of Physical Geography and Landscape Science, Faculty of Geography, M.V. Lomonosov Moscow State University, Leninskie gory 1, 119991, Moscow, Russia; Laboratory of Evolutional Geography, Institute of Geography Russian Academy of Science, Staromonetny lane, 29, 119017, Moscow, Russia

Ekaterina Ershova

Dep. Geobotany, Faculty of Biology, Moscow State University, 1-12 Leninskie Gory, 119991, Moscow, Russia; Institute of International Relations, History and Oriental Studies, Kazan Federal University, 1/55 Pushkina 420008, Kazan, Russia

Dmitry Kiselev

Department of Preservation of Archaeological Heritage, Institute of Archaeology of the Russian Academy of Sciences, Dm. Uljanova str. 19, 119036 Moscow, Russia

Svetlana A. Sycheva

Institute of Geography RAS, Staromonetniy per., 29, 119107, Moscow, Russia

Elya Zazovskaya

Department of Soil Geography and Evolution, Institute of Geography Russian Academy of Science, Staromonetny lane, 29, 119017, Moscow, Russia

Frank Schlütz

Lower Saxony Institute for Historical Coastal Research, Viktoriastr. 26/28, 26382 Wilhelmshaven, Germany

Jens Schneeweiß

Leibniz Institute for the History and Culture of Eastern Europe (GWZO), Dep. Man and Environment, Specks Hof, Reichsstraße 4-6, 04109 Leipzig, Germany

Abstract

Today the East-European forest-steppe is an agricultural landscape with very few remains of the former natural vegetation. The history of the transformation from natural vegetation to a human-made landscape in the area of Sudzha (Kursk region, Russia) is studied here. Therefore, we compare the off-site pollen record Sudzha with three on-site pollen records obtained from the archaeological site Kurilovka-2. The sediment core Sudzha covering the last 2500 years was taken from an oxbow lake in an area with archaeological sites of the early Slavonic period (3rd – 8th cent. CE). The Sudzha pollen record indicates dominance of broadleaf forests and meadow steppes in the area from 2500 to 200 cal yr BP with two major settlement phases one between ~2000 and 1600 cal yr BP (~50 BCE to 350 CE) and the other between 1100 and 600 cal yr BP (850 to 1350 CE) followed by a total deforestation and transformation to an agricultural landscape over the last 200-300 years. Noteworthy, however, the record Sudzha does not provide an intensive signal of human impact during the main settlement period of Kurilovka-2 (3rd – 8th cent. CE). This points to a quite restricted spatial influence of the Early Slavonic settlements on the vegetation, leading to a relative low contribution of palynological anthropogenic indicators to the regional pollen rain signal.

Keywords: East-European forest-steppe; palynology; vegetation history; non-pollen palynomorphs; anthropogenic impact; Late Holocene

Introduction

The forest-steppe zone of the East-European plain is stretching from NW to SE over few hundreds kilometres (Fig. 1a). Based on climatic conditions, it should be represented by meadow steppe with patches of broadleaf trees (Bohn et al. 2003). However, this huge territory covered largely by chernozem soils was transformed to an agricultural landscape and beside the crop fields it is difficult to find any areas covered with natural vegetation. Timing of this transformation is unclear due to difficulties to find appropriate pollen archives, the vegetation history of this large zone is very fragmentary studied (e.g. Shumilovskikh et al. 2017).

In this paper we would like to present vegetation and environmental reconstructions from the sediment core Sudzha, taken from the oxbow lake in the forest-steppe zone (Fig. 1b). The studied oxbow lake is located in the vicinity of the archaeological site Kurilovka-2, representing a promising archive for study human environmental interaction. The settlement Kurilovka-2 is a part of an archaeological complex at the village Kurilovka (Fig. 1c). Archaeological data reveal traces of human presence on site in the Neolithic and in the following Bronze Age. However, the first period of intensive settlement activities falls in the 3^{rd} – 8^{th} cent. CE. This activities were carried out by the bearers of Proto- and Early Slavic archaeological cultures such as Kiev (3^{rd} - the first half of the 5^{th} cent. CE), Kolochin (the second half of the 5^{th} – the third quarter of the 7^{th} cent. CE) and Sakhnovka stage of Volyntsevo (the end of the 7^{th} – 8^{th} cent. CE). From the end of the 1^{st} millennium CE the settlement Kurilovka-2 was abandoned. The new period of its settlement began in the 17^{th} cent. CE and continued to the second half of the 20^{th} cent. CE.

The aim of this study is to reconstruct the vegetation history and environmental changes in the forest-steppe ecotone in Sudzha region during the late Holocene. In scope of the study, we set following specific questions: 1) What was the general vegetation development in the region? 2) How did change the local environment and vegetation at the study site? 3) How strong was the anthropogenic impact of different cultures on the vegetation? 4) When did a transformation to the agricultural landscapes take place? In order to answer these questions, we provide the details of pollen and non-pollen palynomorphs analysis of the sediment core Sudzha. Furthermore, we compare it to the existing but still not published on-site pollen profiles from Kurilovka-2 and archaeological information in order to identify the intensity of the human impact on forest-steppe through the time.

Study area

The study area is situated on the Russian-Ukrainian border in the south-west of the Kursk Oblast' (Russia). The archaeological site Kurilovka-2 is located on the remnant of a low terrace at the confluence of the Sudzha and Psiol Rivers, belonging to the Dnieper River basin of the Black Sea catchment area. The site is surrounded by oxbow lakes of former meanders of the Sudzha and the Psiol Rivers, in one of which the off-site core Sudzha was obtained (Fig 1c).

The climate of the region is cold temperate and classified as Dfb according to Köppen and Geiger. Annual average temperature in Sudzha town is 6.5 °C with 19.5°C in July and -7.6°C in January. The annual precipitation is 598 mm with highest precipitation in July (76 mm) and lowest in February (32 mm). The investigated area is a part of the forest-steppe zone with zonal soils as typical chernozems with different degrees of erosion. Interstream areas are composed mainly of chalky rocks, clays and loess-like loams, low terraces and floodplains consist of sands and sandy loams.

The study site is situated to the middle of the forest-steppe zone represented by alternating meadow steppes and dry grasslands with temperate deciduous forests. The forests are composed by *Quercus robur*, *Tilia cordata*, *Ulmus glabra*, *U. laevis*, *Fraxinus excelsior*, *Acer platanoides*, *A. campestre* and *A. tataricum*, growing together with shrubs of *Corylus avellana, Rhamnus cathartica, Prunus spinosa* and *Cerasus fruticosa* (Bohn 2003). However, the major part of the area is today covered by an agricultural landscape. The potential natural vegetation at the site Kurilovka-2 is estimated to consist of alluvial hardwood forests (Bohn 2003). Until the 1990th, the site was intensively used for plowing. Today it is covered by a ruderal vegetation and used for haymaking.

Numerous archaeological investigations in the Sudzha region provide a list of 148 archaeological sites (Fig. 2, Table 1). Among them there are 118 settlements (including a large number of multilayer ones) commonly in valleys of Sudzha, Psiol and their tributaries and 41 burial grounds mostly located on watershed (Fig. 2, Table 1; Kashkin 2000 updated by V. Rodinkova). The most of burials (38 sites) are kurgans with largely unclear chronological attribution. The settlement materials show presence of humans in the Sudzha region since the early or mid-Paleolithic (one site) and sporadically during the late Paleolithic (two sites) and the Neolithic (seven sites). The settlement activity was the highest in the Bronze Age (mid 3rd – begin of 1st millennium BCE) with known 64 sites. In the early Iron

Age (7th-1st cent. BCE), the density of the archaeological sites decreases (25 sites). Materials of the Roman time (1st – 5th cent. CE) are registered on 21 sites. The objects of the late Roman Period (3d - the first half of the 5th cent. CE) belong to Cherniakhov and Kiev cultures. In the mid-5th cent. CE, the Cherniakhov culture disappeared, while the Kiev culture transformed to the Kolochin culture (14 sites), which was the only archaeological culture of the Migration Period (the second half of the 5th – the 7th cent. CE) in the Sudzha region, and later to Volyntsevo (the end of the 7 – 8 cent. CE) settlements (2 sites). In the Early Middle Ages (9th-10th cent. CE), number of recovered archaeological sites increased up to 29 represented by the Romny-Borshevo culture, while the Kievan Rus time (11-13 cent. CE) decreased to 15 settlements. After a period of abandonment of the territory due to the danger from nomad tribes, the settlement process started again in the 17th century, when Sudzha region was included into the Moscow State and natives of the Polish–Lithuanian Commonwealth and other parts of Russia settled here (Babin 2015).

Materials and methods

In order to provide vegetation and environmental reconstructions, in 2010 we obtained a sediment core from the oxbow lake located in a distance of about 100 m from the archaeological site Kurilovka-2. For a potential comparison with off-site record Sudzha, pollen data from three on-site soil profiles from Kurilovka-2 are presented here. Since these profiles were studied by different laboratories and in different time and were not published until now, here we present the laboratory treatment for every archive in detail.

Sediment core Sudzha

The sediment core Sudzha (51°08′15′′ N, 35°17′17′′ E, 134 m above sea level) is composed of organic-rich material from 20 to 200 cm covered by 20 cm of water and changing to transition zone between 200 and 215 and finally to bluish green clays below 215 cm. The bottom (253-267 cm) is rich in sand. At 30 cm and 50 cm *Phragmites* rhizomes occur, while from 137 to 152 cm a few narrow clay layers appear. For chronology, AMS radiocarbon dates of one peat-bulk and two plant remains (Table 2) were carried out in the Radiocarbon Laboratory of Poznan (Poland) and Erlangen (Germany). An establishment of the age-depth model (Fig. 3) was carried out using the Clam 2.2 package (Blaauw 2010) and the Intcal13 calibration curve (Reimer et al. 2013).

A total of 29 subsamples were collected in 6 to 10 cm intervals from the sediment core Sudzha. The laboratory treatment included demineralization with cold hydrochloric acid (10%), followed by cold hydrofluoric acid (70%) overnight, acetolysis (Erdtmann, 1960) and sieving at 200 µm metallic mesh and 6 µm nylon mesh using ultrasound bath (less than 1 minute). One tablet of *Lycopodium* spores (Batch number 177745 or 1031) was added at the beginning of the preparation in order to calculate the concentration of microfossils (Stockmarr, 1971). Prepared subsamples were stored in glycerin and counted under 400× to 1000× magnification. Counts of 300 pollen grains of terrestrial plants per sample were made, in case of low pollen concentration about 100 pollen grains were counted if possible. Pollen identification and taxonomy follows Beug (2004) and Moore et al. (1999). Beside pollen and plant spores, non-pollen palynomorphs (NPP) and charcoal particles were identified and counted. For NPP identification we mostly used Pals et al. (1980), van der Wiel (1982) as well as the NPP database http://nonpollenpalynomorphs.tsu.ru/. Pollen and NPP are expressed as percentages of the total sum of pollen excluding water and wetland plants. All diagrams (Figs. 4 - 7) were constructed using C2 version 1.5.6 (Juggins, 2007).

The Holocene changes in forest coverage in the area of 20 km around the site Sudzha were reconstructed using the Best Modern Analogue (BMA) technique (Overpeck et al. 1985; Nakagawa et al. 2002). The details of this approach are described in our previous publications (Novenko et al., 2014; Shumilovskikh et al., 2017). In this study we used squared-chord distances (SCD) as the index of dissimilarity between modern and fossil pollen spectra with a threshold T=0.4 and use 8 best analogues to calculate an average value of reconstructed forest coverage. The dataset of modern analogues consist of 720 surface pollen assemblages from a wide variety of landscapes in Europe and West Siberia (Novenko et al. 2014). Forest coverages around the surface pollen spectra were derived from MODIS satellite images (Hansen et al. 2003).

The plant remains larger than 200 µm were studied for botanical composition of the organic-rich parts of the sediment. Samples were analyzed with a binocular microscope with magnifications of 100× and 400×. Plant macrofossils were identified with Katz et al. (1977) and Dombrovskaya et al. (1959). The plant macrofossil content is presented by volume percentages for each taxon, estimated in steps of 5% and subsequently calculated for the total volume.

On-site records Kurilovka-2

Three soil profiles were studied from the archaeological site Kurilovka-2 (Fig. 1c).

Profiles 2/15 and 3/15 are located on the NE slope of the remnant facing the River Sudzha, on border of the archaeological site. Profile 2/15 is situated closer to the water, while profile 3/15 is about 5 m further up the slope. Both profiles represent alternating layers of organic-rich sandy loam and sand (Fig. 6 and 7). The upper parts of both profiles contain mollusc shells. In profile 3/15, pottery fragments of the Neolothic, the Early Slavonic and Modern periods were found. Subsampling of the soil profiles 2 and 3 was carried out in the field in July 2015 with intervals of 5 cm in profile 2 (11 samples) and in profile 3 (12 samples). Chemical preparation of the samples was carried out using 10% HCl, 10% KOH and heavy liquid (KI, CdI_2) with density of 2.35 (Grichuk 1938, 1940; Chernova 2004). One tablet of *Lycopodium* spores (Batch number 177745) was added at the beginning of the preparation in order to calculate the concentration of microfossils (Stockmarr, 1971). Prepared subsamples were stored in glycerin and counted under 400× magnification up to at least 300 pollen grains.

Soil profile 10/16 is located on the lower northern part of the remnant, inside the archaeological site. It is composed of sandy loam in the upper part changing to the heavy loam in the middle and to the silty loess-like loam in the lower part of the profile (Fig. 8). In total, 12 samples were collected in the field from the soil profile 10 in November 2016. The samples (10 g of soil) were processed as recommended for mineral soils, using acidification with 10% HCl, with one tablet of *Lycopodium* spores (Batch number 3862) boiling in 10% KOH, and centrifuging with sodium polytungstate (Torresan 1987). Counting was carried out with a magnification of 400× up to 100 pollen grains per sample due to the low pollen concentration. Pollen of all three soil profiles are expressed as percentages of the total sum of pollen of terrestrial plants.

Results

Off-site diagram Sudzha

Pollen

In total, 96 pollen taxa were documented in the core Sudzha. Based on changes of pollen taxa percentages, the pollen diagram Sudzha was divided in three local pollen zones (Fig. 4).

The lowest part of the sediment (260-240 cm) is characterized by very low pollen concentrations of 160 to 700 pollen/ml. Due to low counts the data are not presented in the pollen diagram. Its pollen spectra are represented by *Pinus diploxylon*-type and Chenopodiaceae accompanied by the *Pinus haploxylon*-type, *Ephedra distychya*-type and *E. fragilis*. Algae are presented by the green algae *Pediastrum* and *Botryococcus* and fungi by spores of the mycorrhizal fungus *Glomus*.

Pollen spectra of the zone Sud-1 (240-220 cm, ~2.8-2.5 cal ka BP) is dominated by broadleaf tree taxa like *Quercus robur*-type (18-31%), *Ulmus* (5%), and *Tilia* (7%) as well as maxima in the pioneer *Betula* (10%) and the wetland tree *Alnus* (16%). Non-arboreal pollen (NAP) spectra are dominated by *Artemisia* (4-8%) and Poaceae (6-10%). Algal assemblage change from *Pediastrum* and *Botryococcus* at 234 cm to HdV 128 associated with remains of Cyanobacteria (sheaths of *Gleotrichia*-type, heterocysts of *Rivularia*-type), Zygnemataceae and dinoflagellate cysts. For the first time, testate amoebae, oocytes of Rhabdocoela and saprotrophic fungi appear.

The zone Sud-2 (220-48 cm, 2.5-0.2 cal ka BP) is characterized by a dominance of the *Quercus robur*-type (40-74%) and the presence of the anthropogenic indicators. The zone is divided in two subzones. In the subzone Sud-2a (220-130 cm, 2.5-1.3 cal ka BP), *Pinus diploxylon*-type (1-16%), *Ulmus* (3-10%) and *Betula* (2-7%) are dominant beside *Quercus robur*-type (42-74%) with an increase of *Corylus* up to 9% to the end of the subzone. NAP is characterized by a dominance of Poaceae (14%) and *Artemisia* (1-3%) and the regular presence of *Plantago major-media*-type, Cichorioideae, *Rumex acetosella*-type, *Ranunculus acris*-type, Cannabaceae and Chenopodiaceae with a maximum between 190-150 cm corresponding to a period between 2000 and 1600 cal yr BP (Fig. 4a in grey shadow). In the subzone 2b (130-48 cm, 1.3-0.2 cal ka BP), *Quercus robur*-type reduces to 40-53% while *Tilia* (3-6%), *Alnus* (6-13%) and *Betula* (5-8%) increase. NAP is similar to the previous subzone, but exhibit the first appearance of *Secale* and regular presence of Cerealia-type, *Ranunculus acris*-type, Cannabaceae, Chenopodiaceae and *Plantago lanceolata*-type. Maximum of values occur between 120-80 cm corresponding to 1100 and 600 cal yr BP (Fig. 4a in grey shadow).

Pollen assemblages of wetland and water plants are similar for the entire zone Sud-2. They are represented by Cyperaceae, *Lythrum*, *Filipendula*, *Sparganium*-type, *Lemna*, *Nuphar*, *Nymphaea*, *Myriophyllum spicatum*, *Sagittaria sagittifolia* and *Potamogeton*. From 182 cm upwards, mucilaginous hairs and trichosclereids of Nymphaceae are present in the sediment. Algal assemblages are dominated by HdV 128 and several maxima of *Gleotrichia*-type and Zygnemataceae. *Pediastrum* is more common in the subzone Sud-2b.

Animal remains are more frequent in the subzone Sud-2a with testate amoebae, Rhabdocoela, eggs of Rotatoria and Tardigrada, several NPP as well as helminth eggs of *Dicrocoelium* and *Diphyllobothrium*. Lignicolous fungi (*Diporotheca, Helicoon, Savoriella*) are more frequent in Sud-2a, while spores of coprophilous fungi occur sporadically during Sud-2. There is a characteristic charcoal maximum at 182 cm.

The zone Sud-3 (48-20 cm, 0.2 cal ka BP - present) shows a dominance of NAP with Poaceae (24-36%), *Artemisia* (3-9%), Chenopodiaceae (3-10%), Cerealia-type (1-6%), *Secale* (2-7%), *Fagopyrum* (1%), and Cannabaceae (3-18%). Several other herb types have increased occurrence such as *Ranunculus acris*-type, *Rumex acetosella*-type, *R. scutatus*-type, Cichorioideae, *Plantago major-media*-type, *P. lanceolata*-type, *Xanthium strumarium*, *Centaurea cyanus* and *Polygonum aviculare*. Pollen assemblages of wetland and water plant are quite diverse including *Rumex aquaticus*, *Hottonia palustris*, *Persicaria maculosa*-type, and *Typha latifolia*-type. While algae, animal remains and saprotrophic fungi do not change significantly, the coprophilous fungal spores *Podospora* and *Sordaria* occur more frequent. The charcoal maximum of the diagram is noted at 28 cm depth.

Plant macroremains

The organic-rich part of the sediment core Sudzha is represented by eutrophic peat (Fig. 5). The diagram of plant macrofossils can be divided into three main zones (Fig. 5). MRZ 1 (215-178 cm, 4 samples) is dominated by the fragments of bark and wood of *Alnu*s and the remains of *Humulus lupulus,* while *Calla palustris* remains are sporadically. In the MRZ 2 (depth 178-55 cm, 12 samples), the plant assemblages are getting more diverse. *Nuphar lutea* 15-30%, *Phragmites* sp. 10-15%, *Calamagrostis lanceolata* 5-15%, *Comarum palustre* and *Carex cespitosa* are important components together with *Alnus* remains (55-90%). In the upper zone MRZ 3 (55-22 cm, 5 samples), *Phragmites* dominates (40-95%) together with *C. palustris* (10-15%), *Typha angustifolia* (5-20%) and *C. cespitosa* (5-15%).

On-site diagrams of Kurilovka-2

<u>Soil profile 2/15</u>

In total 67 pollen taxa were documented. The pollen diagram was divided in three local pollen zones KII (Fig. 6). The zone KII-1 (92-112 cm) is characterized by the dominance of NAP (up to 80%), composed by Poaceae (7-10%), Asteraceae (5-10%), Cichorioideae (12-21%), Rosaceae (4-14%), Fabaceae, Ranunculaceae and other. Tree taxa are presented by *Pinus* (6-12%), *Alnus* (6-11%) and broadleaf trees such as *Tilia* (6%), *Quercus* (2%), *Ulmus* and *Acer*. During the zone KII-2 (92-63 cm), the amount of AP decrease to 22%, while Poaceae (13%) increase together with Cerealia-type (4%) and *Fagopyrum* (2%) as well as ruderal taxa such as Chenopodiaceae, Onagraceae, *Urtica*, *Plantago*, *Artemisia*. The zone KII-2 is followed by a pollen sterile sand layer (63-32 cm). In the zone KII-3 (32-42 cm), *Pinus* (17-24%) and *Salix* (3-10%) increase while most broadleaf taxa decrease. The NAP is dominated by Chenopodiaceae (17-28%). Characteristic is an increase in *Potamogeton* (up to 30%) and in spores of Bryales (up to 75%).

Soil profile 3/15

In total, 47 pollen taxa were identified. The pollen diagram is divided in five zone (Fig. 7). The first zone KIII-1 is represented by one sample at 66 cm depth. Its spectrum is dominated by AP (62%) with *Alnus* (38%), *Tilia* (11%) and *Betula* (9%). Within NAP, Cichorioideae (12%) and Poaceae (6%) have the highest percentages, while Cerealia-type and *Fagopyrum* are present. A rapid decline in AP (27-34%) characterizes the zone KIII-2 (63 – 42 cm) due to an increase in Cerealia-type together with Cichorioideae (up to 23%) and Chenopodiaceae (up to 23%). Zone KIII-3 (42 – 28 cm) is characterized by a strong increase in *Pinus* (19-26%) and a maximum in Chenopodiaceae (up to 29%). Moreover, there is an increase in *Potamogeton* (6%) and a maximum in spores of Bryales (up to 52%). In the zone KIII-4 (28-17 cm), the role of *Pinus* (10%) decreases with an increase in *Alnus* (22%) and Tilia (6%). Poaceae increase up to 16% together with the Cerealia-type (4%), *Artemisia*, Ranunculaceae, *Campanula*, and *Urtica*. Wetland and water plants show maxima of 13% and 6%, respectively. In the upper zone KIII-5 (17 – 3 cm), there is an increase in AP up to 68% with *Alnus* (31%), *Pinus* (21%), *Quercus* (7%) and *Tilia* (5%). NAP is dominated by Poaceae (10%) and Chenopodiaceae (5-13%).

Soil profile 10/16

The samples are characterized by very low pollen concentrations and poor pollen preservation, therefore only five from 12 samples could be analysed (Fig. 8) and just 20 pollen taxa were verified. The two lower most samples (70-75 cm and 65-70 cm) show about

50% of AP with dominance of *Betula* (28%) together with *Tilia* (9%), *Quercus* (3-5%) and *Alnus* (6%). NAP is represented mainly by *Artemisia* (23%) and other Asteraceae (19%). In addition, Apiaceae, Onagraceae, Fabaceae, Chenopodiaceae were found. As primary anthropogenic indicators, pollen of the Cerealia-type and *Fagopyrum* as well as panicoid forms of phytoliths are present. The samples are rich in charcoal particles (not shown on diagram). The sample from 40-50 cm shows an increase in *Pinus* (13%), disappearance of broadleaf tree taxa (*Quercus robur*-type, *Tilia*) and a high Cerealia-type value up to 20%. The upper two samples (10-15 cm and 0-1.5 cm) are characterized by the dominance of *Pinus* (38-44%), Poaceae (10-24%), Cichorioideae (4-13%) and the Cerealia-type (12-18%). Other present NAP taxa are Chenopodiaceae and Fabaceae, while *Polygonum aviculare* appears for the first time.

Discussion

In the discussion, we present the regional vegetation change reconstructed from the sediment core Sudzha as well as the local development of the site, followed by the reconstructions from on-site records in Kurilovka-2 and finally we compare our palynological reconstructions with archaeological and historical data from the Sudzha region.

Regional vegetation change reconstructed from the pollen diagram Sudzha

The pollen spectra from the core bottom indicate the presence of conifers such as *Pinus sibirica*, *Picea* and dry steppes indicators such as *Ephedra*. In absence of radiocarbon dates and taken into account low pollen concentration, it is highly speculative to make a correlation with other records. However, we compare this phase palynologically with the late Glacial or beginning of the Holocene from the core SV-8 in floodplain of the Svapa River, tributary of the Seim River, about 60 km north from Sudzha (Borisova et al. 2006) and profile Avdeevo in the Seim River near Kursk (Panin et al. 2017). Alternatively these pollen assemblages may also result from an erosion as a local event in the river channel or as a fire event sometime during the Holocene. High amount of *Glomus*-type at the basis of the core clearly indicates erosion.

The first zone (pollen zone Sud-1) reflects the dominance of broadleaf trees, suggesting the spread of mixed oak forests and elder-willow carrs by strong reduction of pine in the surroundings. Considering low pollen concentration and minerogenic composition of the sediment, this zone most probably represent mixed assemblages on the basis of the oxbow lake.

The pollen zone Sud-2 reflects a very stable environment with filling of the oxbow lake between 2500 and 200 cal yr BP (Fig. 4). The sediment accumulation rate for this period is 12 to 14 yr/cm. The pollen reflects the presence of mixed oak forests and forest patches with elm, lime, hazel and ash. The forest cover varied between 30 and 36% suggesting open landscapes covered by herb-rich meadows or meadow steppe with broadleaf and birch-poplar patches.

Compilation of the records from the forest-steppe region shows that Sudzha was located in the forest-steppe ecotone, close to the southern border of closed deciduous forests (Shumilovskikh et al. 2017). Located in the south, Sudzha has the highest values of broadleaf tree taxa in comparison to the northern records but a comparable forest cover between 50% in Klukva (Novenko et al. 2015) and 20% in Podkosmovo (Novenko et al. 2014). The more eastern record Krasivo in the western Belgorod region (Ershova et al. 2017) has lower values of broadleaf forests and higher of pioneers such as *Betula* due to the more continental climate. Similarly, pollen data from the basin of the Don River demonstrate the presence of the forest-steppe vegetation during the late Holocene (Spiridonova 1991).

Later on, human-forced changes can be traced in the Sudzha area. Between ~2000 and 1600 cal yr BP (~50 BCE to 350 CE), there is a pronounced phase of agricultural (Cerealia-type, secondary anthropogenic indicators) and pastoral (spores of coprophilous fungi) activities, including deforestation (decrease in AP, spread of *Corylus*, Poaceae maximum) and burning (maximum in charcoals). This signal corresponds well to the general pattern of increased anthropogenic activities in the Mid-Russian Plain since the Iron Age (Khotinsky 1993, Shumilovskikh et al. 2017). Interesting that the charcoal maximum in Sudzha coincides with maximum of macrocharcoals in the Selikhovo record (Novenko et al. 2016) as well as in the Podkosmovo record (Novenko et al. 2014), indicating increased fire activities over the whole region that could have anthropogenic or climatic reason.

Starting from about 1500 cal yr BP (450 CE), an increase of *Alnus* indicates a general paludification of the region possibly due to the ongoing filling of the oxbow lakes. The second pronounced occupation phase is indicated between 1100 and 600 cal yr BP (850 to 1350 CE). The further decrease in oaks suggests deforestation, maxima in Cerealia-type and *Secale* indicate agricultural activities, a general increase in anthropogenic indicators with the first occurrence of *Plantago lanceolata*-type*, Cirsium,* and *Xanthium strumarium* points to higher anthropogenic pressure than before. However, low charcoal values might indicate that settlements were located further away from the studied oxbow lake.

The last 200 years (18^{th} cent., Sud-4) reflect strong and rapid changes in the area. Total deforestation took place with a reduction of forest cover below 20% mainly due to a lumbering of broadleaf forests but also birch. Ploughing, cereal, rye and buckwheat cultivation are visible from pollen data. These activities led to a strong spread of ruderal plants and weeds also including a general increase of open areas and spread of steppes. Interesting is a maximum of Cannabaceae, which we interpret as hemp rotting in the oxbow lake for hemp fibre production. A charcoal peak suggests the presence of local fires or possibly a settlement in the close vicinity of the site. In addition, pasture is suggested close to the site. Forest cover decrease from 35% to 12-18%, what is comparable with the modern forest cover estimates of 14.2% based on MODIS. With visible and very strong human impact in 17^{th} – 18^{th} cent., Sudzha record is in line with other palynological reconstructions from the Mid-Russian Plain (e.g. Khotinsky 1993, Shumilovskikh et al. 2017).

Local development of the oxbow lake

The local development of the coring site is connected to different processes. The bottom of the core represents the lacustrine conditions, indicated by the dominance of *Botryococcus* and *Pediastrum*. After a hiatus during the mid-Holocene, formation of the oxbow lake has initiated the sedimentation of organic-rich material (pollen zones Sud-1 to Sud-3). Several species identified in the peat layers by pollen and botanical macroremains provide ecological conditions of the site.

In general, the peat composition indicates presence of elder carrs at the shore of the oxbow lake, which was slowly filled during 2500 years. In the lower part (212-60 cm) the sediment was formed under shallow lake conditions by wood and leaves remains of *Alnus* and later by *Nuphar lutea* and peatland plants (Fig. 5). *Humulus lupulus* was covering the trees along the river valleys. *Calamagrostis* grew together with sedge peat hillocks on nutrient-rich grounds. *Comarum palustre* is one of the typical peatland species (Lapshina 2003). *Calla* grew along the banks of standing and flowing waters. Beside *Nuphar lutea*, several other water and wetland plants like *Nymphaea, Lemna, Myriophyllum spicatum, Sagittaria sagittifolia, Potamogeton, Typha angustifolia* and/or *Sparganium, Lythrum,* and *Filipendula* were growing in the oxbow lake and on its shore.

At the top (60-20 cm) the continuing filling of the lake led to the development of *Phragmites* reed and several *Carex* species. *Carex cespitosa* is the edificator of the tussock microlandscape, characterized by two levels of surface: the tops of tussock with an abundance of light and normal moisturizing and pools which are strongly shaded and waterlogged. Pools are filled with water or grown by some hygrophilous species such as *Equisetum fluviatile, Phragmites australis, C. palustre*. *Carex lasiocarpa* and *C. globularis* are typical peatland species, growing in eutrophic and mesoeutrophic conditions with rich ground and mixed nutrition. Newly invading wetland species are documented by pollen such as *Rumex aquaticus*-type, *Hottonia palustiris, Persicaria maculosa*-type, *Typha latifolia*-type, *Caltha*. In general, botanical composition indicate that the peat was formed under eutrophic conditions.

After formation of the oxbow lake, algal assemblages are dominated by HdV 128, cyanobacteria and Zygnemataceae (Fig. 4b). HdV 128 is still not affiliated to any known species but by its palaeoecological records it is related to shallow eu- to mesotrophic open water (Pals et al. 1980; van Geel et al., 1982). Zygnemataceae inhabit shallow, stagnant, oxygen-rich water (van Geel 2001). The presence of *Gleotrichia*-type and *Rivularia*-type indicate an alcaline environment (pH 7.5-8), rich in oxidizable organic compounds (van Geel et al. 1982).

Animal remains are represented by a wide variety of testate amoeba, rotifer eggs, tardigrade eggs, oocytes of Rhabdocoela, and further taxonomical unknown resting eggs, indicating open water conditions (Fig. 4b). Types HdV 179 and HdV 187D indicate stagnant shallow open water with eutrophic conditions (van Geel et al. 1982, 1989). Interesting are finds of helminth eggs in the sediment. The lancet liver fluke *Dicrocoelium* sp. parasitizes bile ducts of a wide range of wild and domestic animals such as Bovidae, rabbits, rodents (Le Bailly et al. 2010). Its eggs found in natural lake sediments indicate presence of the disease in the area and animals close to the site. *Diphyllobothrium* infects mammal and human small intestine through the consumption of raw fish infected by the plerocercoid larvae of the tapeworm (Lardín and Pacheco 2015). An adult tapeworm forms the eggs passing in the feces, which need to be deposited in freshwater for the further development of the worm. Presence of the eggs indicate infected mammals or humans at the shore of the oxbow lake in the first millennium CE.

Fungal assemblages are presented mainly by lignophilous species, which are more common in the zone Sud-2a (Fig. 4b). Their maxima correlates very well with the peat composition of *Alnus* wood and leave remains (Fig. 5). Coprophilous fungi are mainly presented by generalists such as *Cercophora* and sporadically by more strict coprophilous species, suggesting rather low pasture pressure in the surroundings of the lake.

From NPP with unknown taxonomical origin, the occurrence of the type TEP-2 in the upper part of the record is interesting. This microfossil was first described from soil sediments taken in the savannas of Roraima State in Amazonia (Rodríguez-Zorro et al. 2017). It occurred during the dry periods with grassland dominance and correlates with microcharcoal peaks and *Gelasinospora* (Rodríguez-Zorro et al. 2017). In our record, only once TEP-2 corresponds to a charcoal maximum and is present under forested and open landscape conditions. Another NPP of unknown origin UAB-27 was described from an Early Neolithic settlement of La Draga (Revelles et al. 2016) and from lacustrine sediments in Lake Banyoles (Revelles and van Geel 2016) in Spain. It occurs during times of soil erosion, in waterlogged layers and in charred storage structure (Revelles et al. 2016, Revelles and van Geel 2016). In Sudzha it correlates with an increased soil erosion and increased human activities, implied by a peak of microcharcoals and a maximum in *Glomus*-type (Fig. 4b). In our opinion, UAB-27 might be an egg or resting stage of a water or wetland invertebrate, as it was found in the wetland core Kongor from NE Iran (unpubl.) as well.

Vegetation change derived from the on-site soil profiles at Kurilovka-2

Soil profiles 2 and 3 located close to each other at the rim of the archaeological occupation site show similar features in the stratigraphy. Both profiles are composed by sandy loams intercalated with sandy layers, indicating formation of alluvial soils with possibly occurring floods. Based on radiocarbon dates (Table 2), both soil profiles are quite young and do not exceed 500 years. Pottery fragments of the Early Slavonic time included in sandy layer (at a depth of 50-60 cm) in the soil profile 3 seems to be redeposited. In both profiles, AP curves vary mostly between 20 and 40% and never exceed 60%, indicating rather open local conditions. Most possibly vegetation was represented by patches of broadleaf forests and elder-willow carrs alternating with herb-rich meadows and the ruderal vegetation of the settlement.

Changes in tree and ruderal plants in the soil profile 3 indicate at least two occupation phases. In the zone KIII-2, AP decrease to 30% together with an increase in Cerealia-type, Chenopodiaceae, Cichorioideae, and *Rumex*. Furthermore, pollen of buckwheat (*Fagopyrum*) present throughout the profile 3 and low AP values correlate with the zone Sud-4 of the Sudzha record, supporting a chronological position in the last 250-300 years. The second occupation period can be suggested in the zone KIII-4 by maxima of Cerealia-type, Poaceae, *Artemisia*, Ranunculaceae, and *Urtica*. This phase is modern (Table 2) and was followed by a period of abandonment of the territory and recovery of the broadleaf forests in the surroundings. An increase in pollen of the water and wetland vegetation to the top of the record suggests an increase of wetness in the area and possible flooding events in spring or summer.

Soil profile 2 was radiocarbon dated, but the ages are inversed. Even so they do not exceed 16th cent. (Table 2). Similar to the soil profile 3, vegetation had of rather open character with broadleaf forests and meadows. Zone KII-2 shows a settlement phase, indicated by maxima of Cerealia-type, *Fagopyrum*, *Artemisia*, Poaceae and a general decrease of broadleaf trees especially *Tilia*. Remarkable is the missing of *Fagopyrum* in KII-1, possibly indicating that the base of soil profile 2 is older than the beginning of soil profile 3. Palynologically, the occupation in KII-2 correlates with Sud-4 by low AP and presence of *Fagopyrum* and with KIII-2 by low *Pinus*, *Tilia*, maximum in Cerealia-type and presence of *Fagopyrum*. The youngest zone KII-3 shows high *Pinus* and Chenopodiaceae values, indicating abandonment of the settlement and therefore correlating to KIII-3. In addition, maxima in water plants and spores of Bryales correlate well with KIII-3.

Soil profile 10 was taken inside the archaeological site characterized by dry conditions. Therefore, pollen spectra of this profile are very limited due to the poor pollen preservation and should be interpreted with caution (Dimbleby 1985). The general vegetation development is reflected by this record. The bottom of the profile (65-75 cm) indicates presence of the forest-steppe with broadleaf and birch patches in a meadow steppe. Local anthropogenic activities are indicated by few finds of Cerealia-type, *Fagopyrum* and panicoid phytoliths, suggesting slush and burn agriculture. Rare archaeological material of Early Slavonic tradition included in this layer suggest that its accumulation started the 3rd-8th cent. CE. Analysis of the cultural layer (sample 40-55 cm) demonstrate that local agricultural activities increased (20% of Cerealia-type) and a deforestation of broadleaf trees took place. A single radiocarbon date at 50-55 cm (Table 2) indicates that this period was around 13-14th cent. CE. However, this is in contrast to the archaeological finds, presented by Early Slavonic ceramic fragments. The two samples from the modern soil (0-15 cm) show a strong increase in pine values, also reflected in soil records 2/15 and 3/15. In general, the vegetation was rather open and actively used for agriculture as suggested by high Cerealia-type values. The change from birch-oak-lime assemblages to cereals and herb meadow assemblages correlates with the transition Sud-3/Sud-4 of the Sudzha record.

Pollen records in context of archaeological and historical data

The record Sudzha reveals the presence of humans in the area during the last 2500 years with three phases of increased anthropogenic activities.

The first phase from the 1^{st} cent. BCE to 4^{th} cent. CE correlates to the so-called Roman period covering the rather warm and/or dry climate conditions of the Roman Warm Period (Bianchi and McCave 1999). In the Sudzha region, mainly antiquities of the late stage of the Roman Period (3^{d} – the first half of the 5^{th} cent. CE) are presented. These are the Kiev and the Cherniakhov cultures. The latter is known for their well-developed agriculture (Radiush 2015). After collapse of the Cherniakhov culture and during the spread of the Early Slavonic Kolochin culture in the second half of the 5^{th} -7^{th} cent. CE, the mixed oak forests recovered (Fig. 4a). This recovery can be caused by climatic reasons or by a decrease in human impact or both. On one hand, climate reconstructions show the cooling and glacier advances during the “Dark Ages Cold Period”, 400 to 600 CE (Patterson et al. 2010). On the other hand, poor evidence of the Early Slavs (Kiev, Kolochin and Sakhnovka cultures) is the most striking feature of the Sudzha record. We know that the settlements were close to the lake (Fig. 1c), but apparently their way of life must have had a little impact on the natural environment in comparison to the other cultures. Even a very local oak deforestation and slush and burn agriculture at the close-by site Kurilovka-2, suggested by soil profile 10, is not strongly reflected in the pollen diagram of Sudzha, which might have a much bigger pollen source area and reflect therefore regional processes rather than the local site.

The second visible human impact phase occurs in the 9^{th} to 14^{th} cent. CE, corresponding to the Medieval Warm Period (Bianchi and McCave 1999, Mann et al. 2009), which possibly favoured increase of agricultural activities in the area. During this period, Romny-Borshevo culture and later Kievan Rus has established and occupied the high terraces and steep banks of the rivers.

We suggest that density of settlements as well as topographical position of the settlements may have a crucial influence on the composition of pollen rain. On one hand, the density of settlements change considerably through the time with 21 sites during the Roman time (1^{st} –

5th cent. CE), 14 sites during the Migration Period (the second half of the 5th – the 7th cent. CE) and just 2 sites of Volyntsevo (the end of the 7 – 8 cent. CE) and increasing again to 29 sites in the Early Middle Ages (9th-10th cent. CE) and 15 the Kievan Rus time (11-13 cent. CE) (compare section Study area). The periods with higher amount of the sites correspond to the periods of higher anthropogenic activities in the pollen diagram Sudzha. On the other hand, the bearers of different cultures occupied different landscape niches. For example, bearers of the Cherniakhov culture are known for their agricultural activities and preferred higher parts of terraces with chernozem soils outside the floodplain. Kiev, Kolochin and Volyntsevo settlements tended to be located on the remnants of low terraces in the floodplain area. Only in the Early Middle Ages (9th-10th cent. CE), bearers of the Romny-Borshevo culture moved out of the floodplains to the high terraces and steep banks of the rivers, and number of recovered archaeological sites increased up to 29. The 15 settlements of the Kievan Rus time (11-13 cent. CE) are located in similar high topographical situations. Well-developed agriculture and higher topographic location of the settlements of Romny-Borshevo culture, Kievan Rus and possibly of Cherniakhov culture lead to larger areas covered by ruderal plants and easier pollen transport by the wind, so that anthropogenic indicators could be transported on longer distances, contributing to the regional pollen rain. In contrast, small settlements of Early Slavs inside of the alluvial forests are protected by trees and anthropogenic indicators contribute to a very local signal, remaining invisible for regional records. Similar results is achieved from a comparison of the on-site and off-site pollen profiles from the Early Iron Age settlements in the hemiboreal forest zone near Moscow (Ershova and Krenke 2014). This study demonstrates that the early signs of developed agriculture could be seen only in the areas of intensive economic development immediately around the settlements and only with a territorial spread of agriculture, the pollen signal get visible by the regional records.

After a period of abandonment of the territory due to the danger from nomad tribes, the settlement process started again in the 17th century, when Sudzha region was included into the Moscow State and natives of the Polish–Lithuanian Commonwealth and other parts of Russia settled here (Babin 2015). At that time, the active agricultural development of watersheds began, which was connected with the use of improved agricultural tools. This phase of the final forest devastation and spread of agriculture is clearly reflected in the Sudzha record and coincides well with historical data documenting large migration waves from the Polish–Lithuanian Commonwealth to the grown Moscow State in the 17th cent.

(Babin 2015) and the formation of new cities for defence of the borders. Furthermore, Sudzha city was formed in 1661, getting a local centre of trade and crafts and developing to an administrative centre in 1779 (Chistiakov 2015). The first increase of *Secale* and Cerealia-type occur in the mid-18th cent., showing that transformation from natural to agricultural landscapes lasted at least 100 years. Soil profiles 2/15 and 3/15 provide deeper insights in the local occupation history at Kurilovka-2. They indicate at least 2 phases of occupation and abandonment of the territory during the last 400 years.

At the end of the 19th cent., 90.7% of the population in the Sudzha region settled in rural areas and agriculture accompanied by animal husbandry were basis of life (Berezhnaya 2015). The crops were mainly rye, oat, and wheat, much less millet, barley and peas; buckwheat, sun flower, sugar beet, wild tobacco and hemp were planted occasionally (Berezhnaya 2015, Chistiakov 2015). Traditionally, horses and oxen were involved in ploughing, sheep were kept for wool and cows for milk products (Berezhnaya 2015). The pollen record from Sudzha reflects well the regional development of agriculture with *Secale*, Cerealia-type, *Fagopyrum* and Cannabaceae. Interestingly, Cannabaceae pollen is absent in all on-site profiles. We assume that the studied oxbow lake was used for hemp rotting, but the hemp fields were located further from the archaeological site Kurilovka-2.

Conclusions

Palynological data derived from Sudzha provide deeper insights into the vegetation history of the area. They demonstrate the dominance of mixed oak forests between 2500 and 200 cal yr BP with two major settlement phases between ~2000 and 1600 cal yr BP (~50 BCE to 350 CE) and between 1100 and 600 cal yr BP (850 to 1350 CE) followed by a total deforestation and transformation to an agricultural landscape in the last 200-300 years. The on-site soil profiles from the archaeological excavation Kurilovka-2 have very young ages, providing details of the vegetation change around the site probably over the last 300-400 maximum 800 years. The data suggest that the Early Slavs had a very restricted spatial impact on the vegetation, much lower than that of the previous Cherniakhov culture and of the following Early Middle Ages and Kievan Rus. We suggest that this is connected with different land use strategies, population sizes and topographic situation of the sites, explaining different contributions of the palynological anthropogenic indicators to the regional pollen rain signal.

Acknowledgement

The authors are grateful to Maria Belen Tomaselli for sampling and lab preparation of pollen from the Sudzha sediment core. This study was partly supported by the Russian Foundation for Basic Research, research projects 16-35-60083 and 16-36-00293, and by the Georg-August-University of Göttingen (Germany). Reconstruction of forest coverage performed by E. Novenko was supported by Russian Science Foundation (grant 16-17-10045).

References

Babin IP (2015) Istoriya osnovaniya goroda Sudzhi [History of Sudzha city foundation].In: Razdorskiy AI (Ed.) Sudzha i sudzhane v otechastvennoy i zarubezhnoy istorii i kul'ture [Sudzha and its population in Russian and foreign history and culture]. Kursk University, Kursk, 90-107.

Berezhnaya SV (2015) Byt russkogo i ukrainskogo naseleniya Sudzhanskogo uezda v kontse XVIII – nachale XX v. [Daily routine of Russian and Ukrainian populations of Sudzha uezd at the end of XVIII – beginning of XX cent.]. In: Razdorskiy AI (Ed.) Sudzha i sudzhane v otechastvennoy i zarubezhnoy istorii i kul'ture [Sudzha and its population in Russian and foreign history and culture]. Kursk University, Kursk, 172-181.

Beug HJ (2004) Leitfaden der Pollenbestimmung. Verlag Dr. Friedrich Pfeil, München.

Bianchi GG, McCave N (1999) Holocene periodicity in North Atlantic climate and deep-ocean flow south of Iceland. Nature 397:515-517.

Blaauw M (2010) Methods and code for 'classical' age-modelling of radiocarbon sequences. Quaternary Geochronology 5:512–518.

Bohn U, Neuhäusl R, Gollub G, Hettwer C, Neuhäuslová Z, Schlüter H, Weber H (2003) Map of the Natural Vegetation of Europe. Landwirtschaftsverlag, Münster.

Borisova O, Sidorchuk A, Panin A (2006) Palaeogeography of the Seim River basin, Mid-Russian Upland, based on palaeochannel morphology and palynological data. Catena 66:53-73.

Chernova GM (2004) Sporovo-pyl'tsevoy analiz otlotzheniy pleistotsena-golotsena. St. Petersburg University, St. Petersburg.

Chistiakov AYu (2015) Traditsionnye promysly i remesla Sudzhi i Sudzhanskogo uezda v kontse XVIII – XIX v. [Traditional crafts of Sudzha and Sudzha uezd at the end of XVIII – XIX cent.]. In: Razdorskiy AI (Ed.) Sudzha i sudzhane v otechastvennoy i zarubezhnoy istorii i kul'ture [Sudzha and its population in Russian and foreign history and culture]. Kursk University, Kursk, 182-187.

Dimbleby GW (1985) The palynology of archaeological sites. Academic Press, London.

Dombrovskaya AM, Korenev MM, Turemnov SN (1959) Atlas of Plant Remains in Peat. Nauka, Moscow-Leningrad (in Russian).

Erdtmann G (1960) The acetolysis method. Svensk Botanisk Tidskrift 54:561–564.

Ershova EG (2017) Rekonstruktsiya prirodnoy sredy na osnove analiza bolotnykh otlozheniy v basseine verkhnego techeniya Vorskly (Belgorodskaya oblast). Bulleten Moskovskogo obshchestva ispytateley prirody. Otdel Biologiya 122 :71-79 (in Russian).

Ershova EG, Krenke NA (2014) Izuchenie prirodnykh i kulturnykh landshaftov zheleznogo veka v doline Moskvy-reki metodami palinologii i arkheologii. Vestnik arkheologii, antropologii i entografii 3 : 159-172 (in Russian).

Grichuk VP (1938) Novyi metod obrabotki osadochnyh porod dlia tseley pyl'tsevogo analiza. Trudy soveshchaniya sektsii INQUA 3, 159-165.

Grichuk VP (1940) Metodika obrabotki osadochnykh porod bednykh organicheskimi ostatkami dlia tseley pyl'tsevogo analiza. Problemy fizichskoy geografii 8 :53-58.

Hansen M, De Fries RS, Townshend JRG, Carroll M, Dimiceli C, Sohlberg RA (2003) Global percent tree cover at a spatial resolution of 500 meters: first results of the MODIS vegetation continuous fields algorithm. Earth Interactions 7: 1-15.

Juggins S (2007) C2 Version 1.5 User guide. Software for ecological and palaeoecological data analysis and visualisation. Newcastle University, Newcastle upon Tyne, UK.

Kashkin AV (2000) Arkheologicheskaya karta Rossii. Kurskaya oblast. Chast 2. Institute of Archaeology of the Russian Academy of Sciences Press, Moscow (in Russian).

Katz NJ, Katz SW, Skobejewa E (1977) Atlas rastitel'nyh ostatkov v torfah (Atlas of Plant Remnants in Peat). Nedra, Leningradskoje otdelenie, Moscow (in Russian).

Khotinsky NA (1993) Anthropogenic changes in the landscapes of the Russian Plain during the Holocene. Grana, Suppl 2:70-74.

Lapshina ED (2003) Flora bolot yuga-vostoka Zapadnoy Sibiri. Tomsk, Publishing house of Tomsk University.

Lardín C, Pacheco S (2015) Helminths. Handbook for identification and counting of parasitic helminths eggs in urban wastewater. London, IWA Publishing.

Le Bailly M, Bouchet F (2010) Ancient dicrocoeliosis: Occurrence, distribution and migration. Acta Tropica 115:175-180.

Mann ME, Zhang Z, Rutherford S, Bradley RS, Hughes MK, Shindell D, Ammann C, Faluvegi G, Ni F (2009) Global signatures and dynamical origins of the “Little Ice Age” and “Medieval Climate Anomaly”, Science, 362: 1256-1260.

Moore PD, Webb JA, Collinson ME (1999) Pollen Analysis. Blackwell Science, Oxford.

Nakagawa T, Tarasov P, Kotoba N, Gotanda K, Yasuda Y (2002) Quantitative pollen-based climate reconstruction in Japan: application to surface and late Quaternary spectra. Quaternary Science Reviews 21: 2099–2113.

Novenko EY, Eremeeva AP, Chepurnaya AA (2014) Reconstruction of Holocene vegetation, tree cover dynamics and human disturbances in central European Russia, using pollen and satellite data sets. Vegetation History and Archaeobotany 23: 109–119.

Novenko EY, Tsyganov AN, Volkova EM, Babeshko KV, Lavrentiev NV, Payne RJ, Mazei YA (2015) The Holocene paleoenvironmental history of central European Russia reconstructed from pollen, plant macrofossil, and testate amoeba analyses of the Klukva peatland, Tula region. Quaternary Research 83: 459–468.

Novenko EY, Tsyganov AN, Rudenko OV, Volkova EM, Zuyganova IS, Babeshko KV, Olchev AV, Losbenev NI, Payne RJ, Mazei YA (2016) Mid- and late- Holocene vegetation history, climate and human impact in the forest-steppe ecotone of European Russia: new data and a regional synthesis. Biodiversity and Conservation 25: 2453– 2472.

Overpeck JT, Webb T III, Prentice ICA (1985) Quantitative interpretation of fossil pollen spectra: dissimilarity coefficients and the method of modern analogs. Quaternary Research 23: 87–108.

Pals JP, van Geel B, Delfos A (1980) Palaeoecological studies in the Klokkeweel bog near Hoogkarspel (prov of Noord-Holland). Rev. Palaeobot. Palynol. 30:371-418.

Panin A, Adamiec G, Buylaert J-P, Matlakhova E, Moska P, Novenko E (2017) Two Late Pleistocene climate-driven incision/aggradation rhythms in the middle Dnieper River basin, west-central Russian Plain. Quaternary Science Reviews 166: 266-288.

Patterson WP, Dietrich KA, Holmden C, Andrews JT (2010) Two millennia of North Atlantic seasonality and implications for Norse colonies. PNAS 107:5306-5310.

Radiush OA (2015) Issledovaniya pamiatnikov rubezha pozdney antichnosti i rannego srednevekov'ya (III-V vv. n.e.) v verkhov'yakh reki Sudzha [Study of late antique to early Middle Ages sites (III-V cent. AD) in the upper Sudzha River]. In: Razdorskiy AI (Ed.) Sudzha i sudzhane v otechastvennoy i zarubezhnoy istorii i kul'ture [Sudzha and its population in Russian and foreign history and culture]. Kursk University, Kursk, 18-39.

Reimer PJ, Bard E, Bayliss A et al (2013) IntCal13 andMarine13 radiocarbon age calibration curves, 0–50,000 years cal BP. Radiocarbon 55:1869–1887.

Revelles J, van Geel B (2016) Human impact and ecological changes in lakeshore environments. The contribution of non-pollen palynomorphs in Lake Banyoles (NE Iberia). Review of Palaeobotany and Palynology 232:81-97.

Revelles J, Burjachs F, van Geel B (2016) Pollen and non-pollen palynomorphs from the Early Neolithic settlement of La Draga (Girona, Spain). Review of Palaeobotany and Palynology 225:1-20.

Rodinkova VYu, Sycheva SA, Shumilovskikh LS, Ershova YeG, Ponomarenko YeV, Kiselev DI (submitted) Man, soils and landscapes in the western part of the East European Forest-Steppe zone in the late Holocene (based on the materials of the Kurilovka 2 settlement, Kursk region, Russia). Quaternary International.

Rodríguez-Zorro PA, da Costa ML, Behling H (2017) Mid-Holocene vegetation dynamics with an early expansion of Mauritia flexuosa palm trees inferred from the Serra do Tepequém in the savannas of Roraima State in Amazonia, northwestern Brazil. Vegetation History and Archaeobotany 26:455-468.

Shumilovskikh LS, Novenko EYu, Giesecke T (2017) Long-term dynamics of the East European forest-steppe ecotone. Journal of Vegetation Science, in press, Doi: 10.1111/jvs.12585.

Spiridonova EA (1991) Evolutsiya rastitelnogo pokrova basseina Dona v verkhnem Pleistotsene – Golotsene [Vegetation changes of the Don River basin in the upper Pleistocene and Holocene]. Moscow, Nauka.

Stockmarr J (1971) Tablets with spores used in absolute pollen analysis. Pollen et Spores 13:615-621.

Torresan M (1987) The use of sodium polytungstate in heavy mineral separations. U.S. Geological Survey Open-File Report 87-590.

Van der Wiel AM (1982) A palaecological study of a section from the foot of the Hazendonk (Zuid-Holland), based on the analysis of pollen, spores and macroscopic remains. Rev Palaeobot Palynol 38:35-90.

Van Geel B (2001) Non-pollen palynomorphs. In: Smol JP, Birks HJB, Last WM (Eds.) Tracking environmental change using lake sediments. Vol. 3: Terrestrial, Algal, and Siliceous indicators. Kluwer Academic Publishers, Dordrecht, pp. 1-17.

Van Geel B, Hallewas DP, Pals JP (1982) A late Holocene deposit under the Westfriese Zeedijk near Enkhuizen (Prov. of Noord-Holland, The Netherlands): palaeoecological and archaeological aspects. Review of Palaeobotany and Palynology 38:269-335.

Van Geel B, Coope GR, van der Hammen T (1989) Palaeoecology and stratigraphy of the lateglacial type section at Usselo (the Netherlands). Review of Palaeobotany and Palynology 60:25-129.

Figures

Fig. 1. Map of the study area: a) vegetation map of Europe; b) vegetation map of the study region; c) location of pollen record to the archaeological site Kurilovka-2. Vegetation units: F71 – North Ukrainian-south Sarmatian lime-pedunculate oak forests, L3 – subcontinental meadow steppes alternating with Tatarian mapple-pedunculate oak forests, M1 – west and central Pontic herb-rich grass steppes, D57 – Southeast European xerophytic herb- and grass-

rich pine and oak-pine forests, U12 – East Sarmatian hardwood alluvial forests (details in Bohn 2003).

Fig. 2. Archaeological sites of the Sudzha region: a) type of the sites: 1 – kurgan, kurgan cemetery; 2 - burial ground; 3 – hillfort, settlement, temporary site; b) Chronological position of the sites: 1 - kurgan, kurgan cemetery without a clear date; 2 - Stone Age site; 3 - Bronze Age site; 4 - Early Iron Age site; 5 – Late Roman Period site; 6 - Migration Period site; 7 - Early Middle Ages, Middle Ages (Kievan Rus Period), Late Middle Ages site. The numbers of sites on the map correspond to the numbers in the Table 1.

Fig. 3. Age-depth model of the sediment core Sudzha.

Fig. 4. Palynological % diagram of the sediment core Sudzha: a) arboreal pollen (AP) and non-arboreal pollen (NAP), b) spores, pollen of water and wetland plants, algae, animal remains, fungal spores and other non-pollen palynomorphs (NPP). Circles indicate presence of pollen clumps. Grey shadows indicate anthropogenic activity phases.

Fig. 5. Macroremains diagram of the sediment core Sudzha. Stratigraphical description: 1 - *Phragmites* peat, 2 – herbaceous peat, 3 – *Nuphar* peat, 4 – tree leaves peat.

Fig. 6. Pollen diagram of the soil profiles 2/15. Legend to the stratigraphy: 1 – brown loam with mollusc shells; 2 – yellow sand; 3 – grey sand with thin layers; 4 – brown silty loam; 5 – hell brown sand, laminated, with mollusc shells; 6 – dark-brown siltstone; 7 – greyish-green clay.

Fig. 7. Pollen diagram of the soil profile 3/15. Legend to the stratigraphy: 1 – brown loam; 2 – brown loam with mollusc shells; 3 – yellow sand; 4 – litter and turf; 5 – brown silty loam; 6 – hell brown sand, laminated, with mollusc shells; 7 – greyish-green clay; 8 – litter and turf; 9 – brown silty sand with mollusc shells and roots; 10 – hell-grey sand; 11 – yellow sand with ceramic fragments; 12 – greyish-brown sand.

Fig. 8. Pollen diagram of the soil profile 10/16. Stratigraphical description: Ao – sod, dark grey sandy loam, crumb to granular structure, intertwined plant roots; Ap - dark grey sandy loam, firm, crumb to-granular structure, chalk crumbles and ceramic fragments, intertwined plant roots, lower boundary straight, distinct transition in density; AE - grey sandy loam, loose, with off-white skeletans, lower boundary straight, distinct transition in colour and density; 2Ab - dark gray medium textured loam, humified, powdery, granular structure, loose; AEBt - brownish- gray silt loam, homogeneous, skeletans and thin humus-clay cutans.