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ONLINE SUPPORT FOR COMPREHENSIVE ARCHAEOLOGICAL AND GEOGRAPHICAL SURVEYS IN THE SOUTH OF WESTERN SIBERIA

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Abstract. One of the current trends in archaeological geoinformatics in Russia is the creation of web mapping portals that integrate spatial and thematic data on the given areas of concentration of archaeological sites. As part of the study of the life support system of the ancient population of the Tura and Pyshma interfluves (Tyumen region) developed a geoportal on the basis of free and open source software. The server part developed on the basis of GeoServer, provides storage of the information and authorized access to it. Vector data is stored in PostgreSQL database management system using PostGIS add-in. Raster data is stored on the server as GeoTIFF and MrSID files. The technologies used in the development of the client web-application allow using it in modern web-browsers without installing additional software on the user's devices. The geoportal user interface is an interactive map of spatial data layers as well as map control elements. The general control elements include the zoom buttons, the scale setting on the available layer extents, the zoom slider, the scale bar, the geographic coordinates field of the cursor installation, the button enabling the attribute information display mode. Thematic content of the geoportal includes space images with medium (10 m) and extra high (up to 0.3 m) spatial resolution, AW3D relief model (25 m), topographic maps, UAV images of certain areas (orthophotomaps and DEM), vector layers of archaeological sites, hydrography, landscapes restoration, results of archaeological sites borders mapping using GPS-receivers, as well as the results of bathymetry survey. The layer of archaeological site (366 objects) contains attributive information including type, period, description, dating. Geoportal is a convenient tool for management and visualization of the accumulated information arrays for specialists without extensive knowledge in cartography and GIS.

Key words: GIS, Archaeological Geoportal, paleolandscape, resource potential of the territory, paleodemography, Western Siberia

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ВЕБ-ИНФОРМАЦИОННОЕ ОБЕСПЕЧЕНИЕ КОМПЛЕКСНЫХ АРХЕОЛОГО-ГЕОГРАФИЧЕСКИХ ИССЛЕДОВАНИЙ НА ЮГЕ ЗАПАДНОЙ СИБИРИ

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Резюме. Одним из актуальных трендов в археологической геоинформатике в России является создание веб-картографических порталов, интегрирующих пространственные и тематические данные по заданным районам концентрации археологических памятников. В рамках изучения системы жизнеобеспечения древнего населения Туро-Пышминского междуречья (Тюменская область) разработан геопортал на основе свободного программного обеспечения с открытым исходным кодом. Серверная часть, разработанная на основе GeoServer, обеспечивает хранение информации и авторизованный доступ к ней. Хранение векторных данных осуществляется в системе управления базами данных PostgreSQL с использованием надстройки PostGIS. Растровые данные хранятся на сервере в виде файлов в формате GeoTIFF и MrSID. Примененные при разработке клиентского веб-приложения технологии позволяют пользоваться им в современных веб-браузерах без установки на пользовательские устройства дополнительного ПО. Пользовательский интерфейс геопортала представляет собой интерактивную карту слоев пространственных данных, а также элементы управления картой. В состав общих элементов управления входят кнопки изменения масштаба, выставления масштаба по экстенту доступных слоев, ползунок изменения масштаба, масштабная линейка, поле отображения географических координат установки курсора, кнопка включения режима отображения атрибутивной информации. Тематическое наполнение геопортала включает космические снимки со средним (10 м) и сверхвысоким (до 0,3 м) пространственным разрешением, модель рельефа AW3D (25 м), топографические карты, результаты съемки отдельных участков с БПЛА (ортофотопланы и ЦММ), векторные слои археологических памятников, гидрографии, восстановленных ландшафтов, результатов картографирования границ археологических памятников с помощью GPS-приемников, а также результаты батиметрической съемки. Слой археологических памятников (366 объектов) содержит атрибутивную информацию, включающую тип, период, описание, датировку. Геопортал является удобным инструментом для управления и визуализации накопленных массивов информации для специалистов, не обладающих широкими знаниями в области картографии и ГИС.

Ключевые слова: ГИС, Археологический геопортал, палеоландшафт, ресурсный потенциал территории, палеодемография, Западная Сибирь

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Introduction

Inflowing lake systems are characterized by the abundance and diversity of natural resources capable of sustaining local populations. The high concentration of archaeological sites from different periods testifies to the attractiveness of the territory. Nowadays, there are many comprehensive studies of human adaptations to paleoenvironmental conditions. Natural paleo records (lake and boggy deposits) are used to reconstruct the background natural conditions, correlate them with the pace and structure of the human settlement, identify the extent of economic changes and anthropogenic effects (land degradation, deforestation) (Giesecke et al., 2011; Krause, Koryakova, 2013; Borisov, Korobov, 2013; Korobov, 2014; Rosch et al., 2014; Schwarz, Oeggl, 2013; Alenius et al., 2020, and many others). Work has been carried out to create and maintain the Database of the Global Environmental History (HYDE) containing qualitative indicators of demographic and agricultural evolution in the Holocene (Klein Goldewijk et al., 2011; Klein Goldewijk, 2016).

The Andreevsky lake system between the Tura and Pyshma Rivers (south of Western Siberia) was intensively developed in ancient times. To date, more than 350 archaeological sites from the Mesolithic to the Middle Ages have been found in the area (Zakh et al., 2014). The site has been repeatedly surveyed, yet the paleoreconstruction of the environmental conditions, analysis of spatial development and paleodemographic load in various periods, or modelling of the key sustainability features of the ancient population is still insufficient.

After the results of such work are integrated, it becomes necessary to map a vast body of archaeological information, and create a database of archaeological sites. Reconstruction of natural conditions implies creation of a spatial reconstruction of paleolandscapes and paleohydrography. Geoinformation systems appear as the most suitable tools for the spatial integration of heterogeneous data. Web-based geographic information system (GIS) or geoportals are becoming more widespread.

Geoportals, as a means for presenting spatial information, proved to be effective in many areas of economic activities, humanities, and natural sciences (Yamashkin et al., 2019). Geoportals can be applied extensively to both solving global problems, such as data coordination for sustainable global society development (Global Forest Watch Impacts[2]; de Sousa et al., 2020; Mhangara et al., 2019), and a visualization tool for local research data[3].

The use of geoportals in archeology has rather strong potential. Field archaeological surveys are always spatially referenced. It means that the acquired data can be visualized on a map,

[2] https://www.globalforestwatch.org/about/

[3] https://eea.maps.arcgis.com/home/index.html; https://www.geoportal.org/community/guest/general-information

including an online map. An example is Arches, an open-source software platform for cultural heritage data management. It supports spatial data and can be used by researchers to create their archaeological geoportals[4]. In some cases when more customization and functionality is required, researchers prefer to develop dedicated solutions, such as:

– Nurnet: a geoportal for managing and sharing information about the Bronze Age in Sardinia, Italy (Spanu et al., 2017).
– The Italian Geoportal of Archaeological Resources: a project run by the Central Institute of Archeology and the VAST-LAB group to develop a geoportal, a national aggregator for archaeological datasets (Ronzino, Acconcia, Falcone, 2018).
– Yenisei-GIS: a local GIS of the Krasnoyarsk Region (Russia). It contains many maps, including a map of the local cultural heritage (Kadochnikov, 2020).
– The proposal to develop a comprehensive geospatial web platform capable of handling all cultural and natural heritage sites in Nabón, Ecuador (Lerma et al., 2020).
– The Russian Archaeological Sites national GIS within the framework of the Terek information processing system. It features automated mapping and is intended to characterize the spatial and chronological distribution of the available information across the entire territory of Russia. It presents the extent of development of vast territories at various periods, and it can be used to analyze the archaeological sites of certain periods in Russian regions (Makarov et al., 2016).

The study of the Andreevsky lake system aims to reconstruct its natural conditions and dynamics of its development in the ancient times as a flow-through lake system. A probabilistic assessment of the paleodemographic load in different archaeological periods, taking into account the resource potential of the study area, was among the tasks of the comprehensive study of the Andreevsky lake system. The geoportal was chosen as a tool to complete the task since it allows combining different kinds of spatial data.

This paper shares the experience of creating the archaeological geoportal of the Andreevsky lake system (ageoportal.ipos-tmn.ru[5]), including the site architecture, contents, and applications and the result of the reconstruction of the paleodemographic load, taking into account the resource potential of the territory, for one of the periods (2850–2600 cal BP, or the transition period from the Bronze Age to the Early Iron Age, in archaeological terms).

Area of Study

The Andreevsky lake system is located in the southwestern part of Western Siberia between the Tura and Pyshma Rivers, in their lower reaches at their confluence, in the Tobol River basin. It is a large, well-developed flow-through lake system. Nowadays it includes a chain of five lakes (Bolshoye and Maloye Andreevsky, Butorlyga, Pesyanka, Gryaznoye). The area is about 40 sq. km. The lakes are connected by the Duvan River (Fig. 1).

The Andreevsky system at the junction of forest-steppe and sub-taiga landscape zones is categorized as a floodplain-valley water body. Its basin is probably of the erosion-accumulative type. Geologically the Andreevsky lakes and the Duvan River are paleochannels of the Pyshma River. Most lakes of the Tura-Pyshma interfluve area (Chepkul, Kurya, Mostovoye, etc.)

4 https://www.archesproject.org/what-is-arches/
5 Under construction.

are connected to it by waterlogged depressions (Sizov, Zimina, 2012). The Tura and Pyshma Rivers are the north, south and east boundaries of the Andreevsky lakes. We can assume that the major economic activity of ancient people mainly occurred within this interfluve area. For this reason, the area of study was limited to the Tura and Pyshma Rivers. At the northwest along the line connecting Antipino and Perevalovo settlements, the watershed is crossed close to the Zubarevskoye lake. The total study area is 1,100 sq. km.

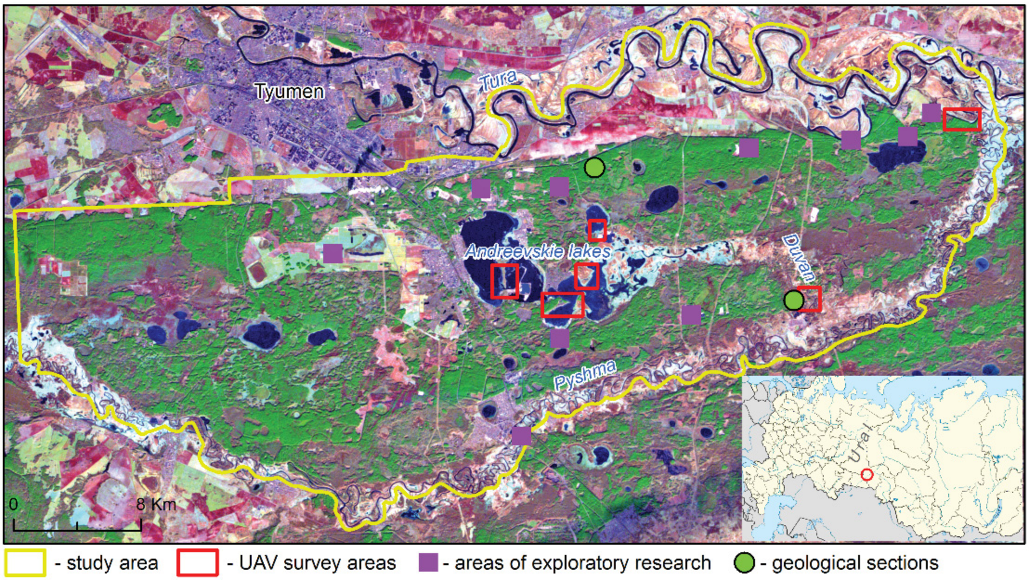


Fig. 1. Overview map of collection of factual material of paleolandscape studies

Рис. 1. Обзорная карта мест сбора фактического материала палеоландшафтных исследований

A large number of archaeological sites indicates the significance of the Andreevsky lake system for the ancient population. Archaeological surveys on the shores of the Andreevsky lakes in the Tura-Pyshma interfluve area are over 100 years old. I.Ya. Slovtsov (Slovtsov, 1885, 1890; Bezborodova, Parkhimovich, 1995, p. 15) was the first to study the shores of Andreevsky lakes more than 100 years ago. In the 20th century researchers from Moscow, Sverdlovsk (Yekaterinburg) and Tyumens studied the archaeological sites in the Andreevsky lake system. As a result of many years of research on the shores of the Andreevsky lake system and the Tura and Pyshma Rivers 366 archaeological sites were discovered. They are fortified and unfortified settlements, walled settlements, burial mounds, subsoil burial grounds, and sanctuaries. Many of them were studied by excavation. In some cases, the archaeological sites contain layers from various periods (Zakh et al., 2014). Despite such regular and long-term studies, new sites can still be found in the Andreevsky archaeological area. This was confirmed by the 2016–2018 surveys when 18 archaeological sites were discovered in the eastern part of the Andreevsky lake system. Today, the archaeological database of the Andreevsky lake system lists 384 archaeological sites.

Since the lake system was quite attractive for habitation throughout the Holocene, many sites are multi-layered. Some of them contain cultural deposits from the Neolithic to the Middle Ages. The area has sites from the Mesolithic (a single site Zvezdny 1); the Neolithic (80 sites); the Chalcholithic (108 sites); the Bronze Age (162 sites); the Early Bronze Age (38 sites); the Late Bronze Age (28 sites); the transitional period from the Bronze to the Iron Age (28 sites); the Early Iron Age (91 site); Middle Ages (75 sites); Late Middle Ages (1 site.) Approximately one third of the sites are not culturally and chronologically attributed. In total, 61 sites in the area as excavated (Fig. 2).

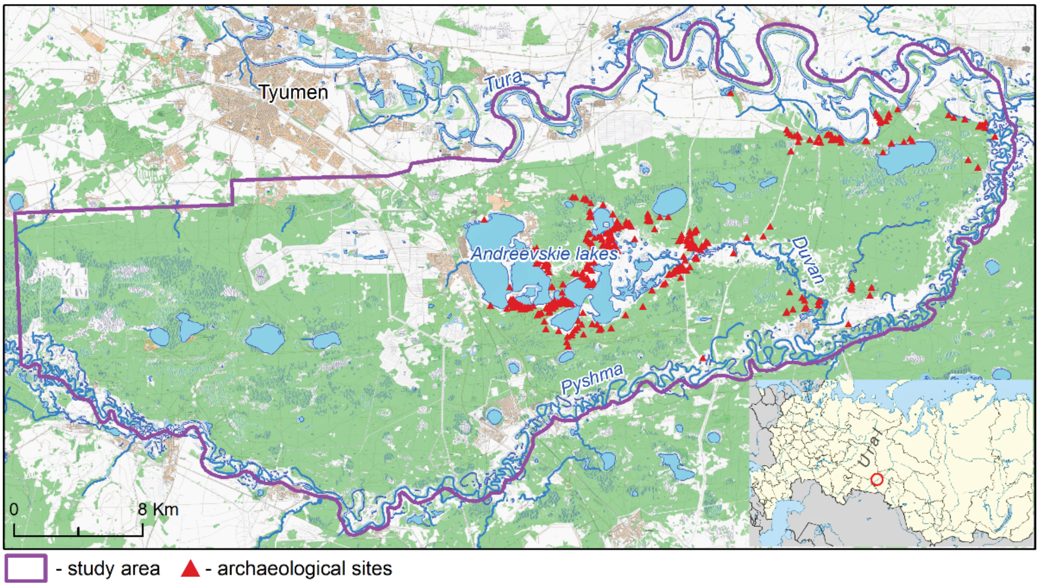


Fig. 2. Overview map of the archaeological sites in the Tura-Pyshma interfluve

Рис. 2. Обзорная карта археологических памятников в Тура-Пышминском междуречье

Among the discovered sites, the majority (265) are not fortified. There are 50 sites with various defense features (from low ramparts not more than 0.2 ... 0,5 m high to impressive ramparts 3 ... 5.5 m high Of the four dozen discovered burial sites, 14 are subsoil burial sites, 27 are burial mounds. There are 13 findspots, 2 accidental discoveries, and one isolated depression.

Most of the Andreevsky lake system is covered with forest, except for the floodplain meadows and inhabited areas. For this reason, the only way to find archaeological sites is through a field survey. In few cases, remote sensing was used to survey ploughed or deforestation areas for archaeological sites. In general, the exact geomorphological position of an archaeological site is important for spatial analysis, reconstruction of the ancient sustainability systems, finding if the cap was seasonal or permanent, identifying the burial patterns and the status of the buried, etc.

Materials and Methods

The Archaeological Geoportal Architecture

We used GIS approaches for creating the geoportal (Sizov et al., 2021). The available data is organized layer-by-layer.

1. Spatial data: the microtopography and geomorphology of the Andreevsky flowing lake system, and the reconstructed paleolandscapes.

2. Archaeological data: site location, cultural and chronological attribution.

The Geoportal uses the conventional client-server architecture (Fig. 3). The server part stores the information and authorizes access to it. The key component of the server part is GeoServer (geoserver.org, developed by OSGeo.) The software is written in Java using Open Geospatial Consortium (OGC) standards, such as Web Map Service (WMS), Web Map Tile Service (WMTS), Web Feature Service (WFS), etc.

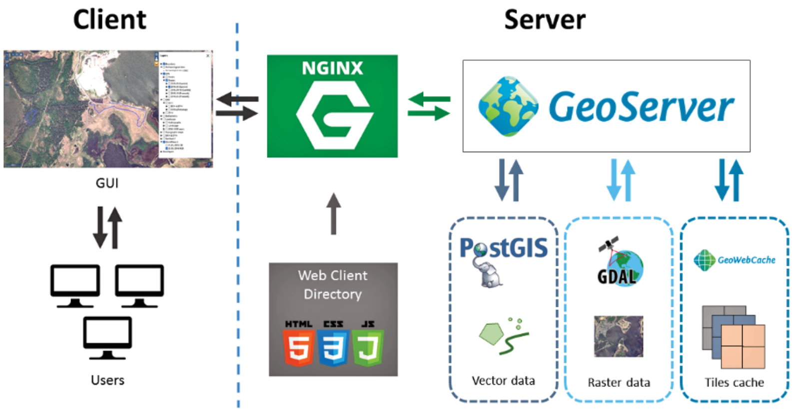


Fig. 3. The Archaeological Geoportal architecture

Рис. 3. Архитектура археологического геопортала

The vector images are stored in the PostgreSQL database management system (www.postgresql.org) using the PostGIS (postgis.net) add-in developed by OSGeo and implementing the OGC Simple Features standard for SQL providing support for storing and handling geographical objects in a database. The raster images are stored on the server as GeoTIFF and MrSID files. The raster images are processed with the Geospatial Data Abstraction Library (GDAL, www.gdal.org) also developed by OSGeo. The raster images are accessed under the WMTS standard: the viewed area is provided by the server as fragments (tiles) created by GeoServer tools. The vector data are accessed under the WFS and Vector Tiles standards developed by Mapbox (www.mapbox.com) and implemented by GeoServer. Layers with a small number of objects are downloaded from the server in the GeoJSON format. Layers containing a large number of objects and complex geometry are downloaded as Mapbox PBF tiles. This approach ensures an optimal balance between image quality and performance. All the tiles generated by GeoServer are stored on the server for subsequent use (GeoWebCache function).

Client requests to GeoServer are routed through an Nginx reverse proxy server (www.nginx.com). It encrypts and compresses the server-client traffic, and handles access to the client web application.

The client web application is in TypeScript with the Preact framework (preactjs.com) and the OpenLayers library (openlayers.org). Preact implements Virtual DOM and supports the JSX syntax for rapid GUI development. It is a compact and fast package. OpenLayers is a library for rapid GUI development to handle spatial data, including GeoServer. The client web application technologies work in popular web browsers. No extra software installation is required.

The geoportal stores any raster, vector, or datasets. The users can upload documents and images in common formats (.pdf, .jpg, .xls, etc.). With such extensive functionality, we were able to store virtually all kinds of spatial information obtained during the project. Below are the brief overviews of each information source.

Basic Geographical Layers of the Archaeological Geoportal

The basic geographic layers include the key types of available spatial data: topographic maps, digital terrain models, and space imagery. All the used data have a precise geographical reference. Heterogeneous data are re-projected and combined "on the fly" by means of GeoServer.

1. Topographic map, 1:25,000 scale. Geoportal offers a current version of the map developed by Gosgiscenter with sparse altitude information (the area is shown as of 2005). With the large-scale topographic map it is possible to convert all the elevations to the unified Baltic System of Heights and to use the official place names. The map is also used to identify man-made objects. Using the topographic map, the current hydrographic network was vectorized with the EasyTrace software (ver. 8.65.). All the lakes, rivers and oxbow lakes in the area of study were digitized, and each object was assigned its elevation.

2. AlosWorld3D30 (AW3D) Digital Surface Model (DSM). Medium spatial resolution DSMs obtained by continuous direct surface elevation measurements are a realistic representation of landforms as a continuous, regular and uninterrupted field of elevation values. DSM makes it possible to identify man-made changes occurring due to sand mining, deforestation, and construction of roads, residential, and industrial structures. The AW3D30 DSM based on automatic processing of 2007–2011 ALOS satellite stereo images was selected for the geoportal (cell size: 25 m/pix).

3. Medium and Ultra-High Spatial Resolution Space Imagery. The geoportal uses a medium-resolution multispectral image from Sentinel-2 (10 m/pix taken on July 1, 2018) in two color synthesis versions: visible and IR colors (RGB and CIR). The Sentinel-2 data are freely available and distributed by the European Space Agency (ESA). The key purpose of such a mid-scale imaging is the landscape mapping and identification of short-term average annual and seasonal evolution of the water levels in lakes depending on the man-made impact and climatic changes. The WorldView-3 ultra-high resolution space image (0.28 m/pix taken on May 25, 2016) is also presented in two color synthesis versions: RGB and CIR. The image was obtained with the GDBX geoplatform. It is intended to better identify the boundaries of the archaeological site and accurately reference the ground-based observations.

4. Here, Bing and OSM Map Layers. These layers fully cover the area and show the current state of the territory at a large scale (larger than the topographic map), including additional objects not shown on the topographic map. They are provided by third-party services. The layers are connected directly in the web-client source code as tile layers. The OSM layer contains publicly available data distributed under the Open Data Commons Open Database License (ODBL) by OpenStreetMap Foundation. It is required the specify the data source and a link to the license. The Here and Bing layers contain proprietary data so their free use

is quota-based. Only one base layer can be activated at a time. The layers available in the geoportal are shown in Table.

Archaeological Geoportal map layers

Слои карт археологического геопортала

Title	Type	Source	Description
HERE – Hybrid	Hybrid	HERE Technologies	Satellite image mosaic from Here with a label layer
HERE – Satellite	Satellite	HERE Technologies	Satellite image mosaic from Here
Bing – Hybrid	Hybrid	Microsoft Corporation	Satellite images mosaic from Bing with a label layer
Bing – Satellite	Satellite	Microsoft Corporation	Satellite image mosaic from Bing
OSM	Map	OpenStreetMap	Vector map from OpenStreetMap

Thematic layers of the Archaeological Geoportal

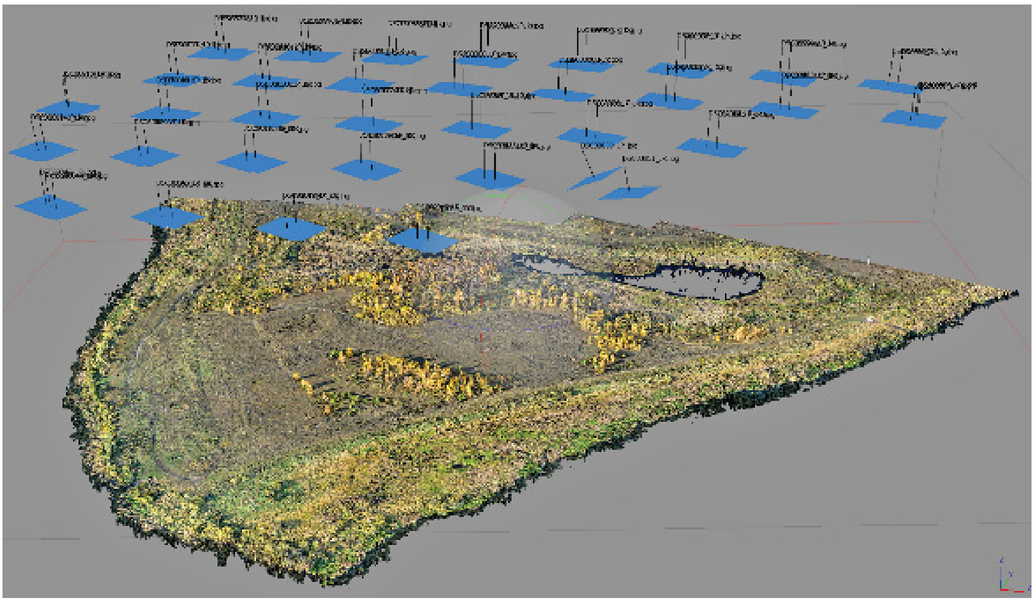


Fig. 4. General arrangements of the photo centers and the resulting point cloud in Agisoft Photoscan. Cape Butorlyzhsky, taken on 12.09.2016

Рис. 4. Общее расположение центров фотографирования и результирующее облако точек в Agisoft Photoscan. Мыс Буторлыжский, снято 12.09.2016

The studies of the Andreevsky lake system produced various thematic data:

1. UAV surveys. For detailed mapping, we used UAV aerial photography. We used a Tarot T960 hexacopter with a SonyAlpha a6000 camera mounted on a three-axis suspension (the 2016 survey), a DJI Phantom 3 Advanced quadcopter (the 2017 survey). We applied the Drone De-

ploy software to plan the survey. It enabled to survey the surface along a specified route at a specified altitude and speed as required to obtain clear. non-blurry images, and to provide the required image overlap (at least 70%). We tested different altitude and flight speed combinations. The total surveyed area was about 670 ha. The images were processed (making orthophotomaps and DSM) in Agisoft Photoscan v.1.3 (Fig. 4). The spatial resolution for the orthophotomaps is 5–8 cm/pix, and 10–15 cm/pix for the DSMs. It is sufficient to accurately identify small surface features and archaeological heritage sites. The methodology aspects and the aerial survey results are presented in detail in papers (Prikhodko et al., 2017; Sizov et al., 2018).

2. Bathymetric Survey Results. To build a digital model of some bottom areas of the Andreevsky Lake we applied continuous high-density echo sounding. The depths in the Butorlyzhsky Peninsula areas were measured on 20.09.2017, and near the Maloe Andreevsky Lake, on 11.10.2017. For the depth measurements we used:

– a remote-controlled ship model carrying a Garmin echoMAP CHIRP 42CV echo sounder (Fig. 5a);
– a small motorboat with a Garmin GPSMap 421s echo sounder (Fig. 5b).

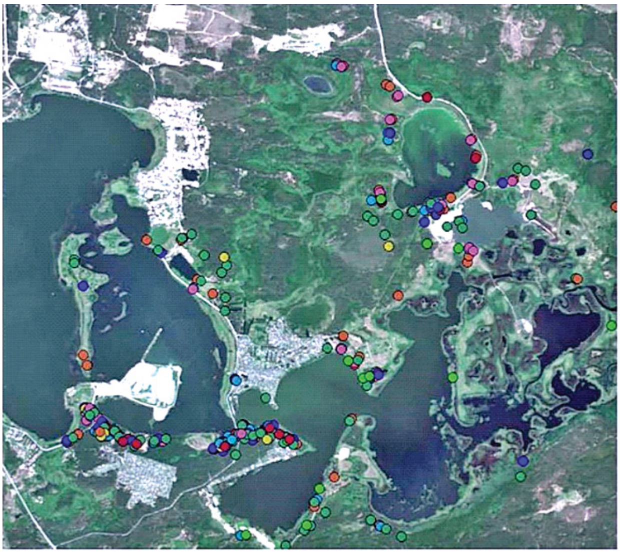
The vessels moved from shore to shore and along the coastal and central lines of the studied water area. The remotely controlled ship model operated on the most vegetation-free part of the water surface. The ship navigated autonomously along the predefined route loaded into its memory. The echo sounder depth measurements were automated as the model navigated along its route. The bottom surface elevation maps were interpolated with 3D Analyst tools in the ArcGIS software package (Sizov et al., 2019.)

a) b)

Fig. 5. Bathymetric survey equipment:
a) autonomous bathymetric vessel; b) boat with an echo sounder

Рис. 5. Оборудование для батиметрической съемки:
а) автономное батиметрическое судно; б) катер с эхолотом

3. Vector maps of the reconstructed plant communities. The reconstructed periods are: 13,000–11,000 cal BP, 7,100–5,500 cal BP, 3,500–3,200 cal BP, and 3,200–2,850 cal BP. The natural conditions were reconstructed by analyzing the bottom sediments of the small closed lake Kyrtym (in the southern part of the Andreevsky lake system) and the Oshukovsky peat bog (in the northern part of the Andreevsky lake system).



	34	Point	0	0	Eneolithic	settlement	21	Butorlyzhsky Cape 5
	206	Point	0	0	Early Iron Age	settlement	50	Butorlyzhsky Cape 5
	154	Point	0	0	Middle Ages	settlement	24	Butorlyzhsky Cape 6
	56	Point	0	0	Eneolithic	settlement	15	Vinnoe 1
	85	Point	0	0	Neolithic	settlement	32	Vinnoe 1
	55	Point	0	0	Eneolithic	settlement	16	Vinnoe 2
	119	Point	0		Bronze Age	settlement	30	Vinnoe 2
	15	Point	0	0	Eneolithic	settlement	44	Vlorava Pereima
	125	Point	0	0	Early Iron Age	settlement	8	Vlorava Pereima
	210	Point	0	0	Early Iron Age	settlement	32	Gruzdevoe 1
	211	Point	0	0	Early Iron Age	settlement	33	Gruzdevoe 3
	212	Point	0	0	Early Iron Age	settlement	34	Gruzdevoe 4
	69	Point	0	0	Neolithic	settlement	19	Gryaznoe 11
	19	Point	0	0	Eneolithic	settlement	51	Gryaznoe 11 (YuAO 20)
	147	Point	0	0	Middle Ages	settlement	15	Gryaznoe 11 (YuAO 20)
	17	Point	0	0	Eneolithic	site	40	Gryaznoe 12
	192	Point	0	0	Early Iron Age	site	16	Gryaznoe 12
	18	Point	0	0	Eneolithic	settlement	47	Gryaznoe 13
	68	Point	0	0	Neolithic	settlement	20	Gryaznoe 13
	126	Point	0	0	Early Bronze Age	settlement	9	Gryaznoe 13
	188	Point	0	0	Early Iron Age	settlement	17	Gryaznoe 13
	200	Point	0	0	Early Iron Age	burial mound	26	Gryaznoe 15
	27	Point	0	0	Eneolithic	settlement	56	Gryaznoe 2
	74	Point	0	0	Neolithic	settlement	24	Gryaznoe 2
	26	Point	0	0	Eneolithic	settlement	55	Gryaznoe 3
	73	Point	0	0	Neolithic	settlement	22	Gryaznoe 3
	200	Point	0	0	Early Iron Age	settlement	30	Gryaznoe 3
	187	Point	0	0	Early Iron Age	fortified settlement	48	Dachnoe
	241	Point	0	0	Early Iron Age	settlement	70	Duvanskoe 18
	240	Point	0	0	Early Iron Age	settlement	68	Duvanskoe 1g
	167	Point	0	0	Middle Ages	fortified settlement	30	Duvanskoe 29
	237	Point	0	0	Early Iron Age	settlement	72	Duvanskoe 3
	163	Point	0	0	Middle Ages	fortified settlement	38	Duvanskoe 29
	260	Point	0	0	Early Iron Age	settlement	31	Dunnoe 1
	148	Point	0	0	Middle Ages	fortified settlement	16	Zhilje (Andreevskoe 2)
	238	Point	0	0	Early Iron Age	settlement	73	Zaduvanskoe 2
	235	Point	0	0	Early Iron Age	settlement	77	Zaduvanskoe 7
	30	Point	0	0	Eneolithic	settlement	26	Zaharkino
	184	Point	0	0	Early Iron Age	settlement	45	Zaharkino
	90	Point	0	0	Bronze Age	settlement	3	Zvezdnoe 1
	183	Point	0	0	Early Iron Age	settlement	44	Ilushino
	190	Point	0	0	Early Iron Age	settlement	23	Iskra 1
	198	Point	0	0	Early Iron Age	settlement	22	Iskra 2
	287	Point	0	0	Early Bronze Age	settlement	10	Iskra 2
	204	Point	0	0	Early Iron Age	settlement	27	Iskra 3
	289	Point	0	0	Early Bronze Age	settlement	12	Iskra 3
	231	Point	0	0	Early Iron Age	site	66	Kazarinivo 2
	295	Point	0	0	Eneolithic	site	16	Kazarinivo 2
	28	Point	0	0	Eneolithic	site	28	Kamatskush 1
	141	Point	0	0	Middle Ages	settlement	21	Kamatskush 2
	178	Point	0	0	Early Iron Age	settlement	39	Kamatskush 3
	284	Point	0	0	Middle Ages	burial	0	Karjer 1a
	283	Point	0	0	Neolithic	settlement	16	Karjer 1b,1v,1g
	96	Point	0	0	Neolithic	settlement, burial	17	Karjer 2
	107	Point	0	0	Bronze Age	settlement, burial	16	Karjer 2
	31	Point	0	0	Eneolithic	settlement	25	Karjer 3
	105	Point	0	0	Early Iron Age	settlement	46	Karjer 4
	106	Point	0	0	Early Iron Age	settlement	47	Karjer 5
	67	Point	0	0	Neolithic	settlement	2	Kozlov Cape 1
	5	Point	0	0	Eneolithic	burial mound?	31	Kozlov Cape 2
	133	Point	0	0	Middle Ages	burial mound	4	Kozlov Cape 2

Fig. 6. The point layer of archaeological sites (fragment of the map)

Рис. 6. Слой археологических объектов (фрагмент карты)

We applied the comparative-geographical method for the reconstruction of landscapes on a 1:150,000 scale for the period from 500 to 13,000 years ago. We extrapolated the modern patterns of successive changes in plant communities following the changes in local climatic conditions and hydrothermal properties of various habitats (the methodology of landscape paleoreconstruction has been described in detail elsewhere (Sizov, Idrisov, Molchanova, 2017; Zimina et al., 2019)). The foundation of landscape reconstruction is the principle of actualism. It assumes that the formation and evolution of ancient landscapes followed the same principles that govern the evolution of modern landscapes.

For mapping, terrain and stow types were used as taxonomic units. The actual data sources for paleolandscape analysis are topographic maps of various scale, space and aerial imagery, historical records of geological and hydrological surveys and peat deposit explorations, archaeological data on ancient settlements, palynological and osteological analyses and our field studies, including deep pitting and drilling (Sizov, Idrisov, Molchanova, 2017). We also considered the water level change simulation results obtained with the AW3D30 DSM. The results of palynological and paleogeographical studies of subaerial, lake, and peat deposits in the Turo-Pyshma interfluve area were also taken into account for the reconstruction. The chronological references and deposits correlation is based on radiocarbon dating of organic remains both from the background natural profiles (sapropel and peat) and from the cultural layers (coal.). We also used absolute dating of the upper Quaternary deposits (AMS, IR-OSL).

4. The point layer of archaeological sites was generated by map vectorizing (Zakh et al., 2014). The layer includes 366 objects with attributes: site name, type (settlement, walled settlement, burial ground), date (relative/absolute), site description, research description (exploration/excavation), historical records/publications. It also shows the site boundaries field

tracked with the AshTech ProMark 120 (L1 band, 0.5–1.0 m positioning accuracy) and Garmin GPSMAP 64st (5 m positioning accuracy) GPS navigators. (Fig. 6).

Results and Discussion

Geoportal-based data can have many applications (environmental monitoring, cultural heritage preservation, etc.) (Global Forest Watch Impacts) and different spatial coverage: from regional to global databases (Makarov et al., 2016; Spanu et al., 2017; de Sousa et al., 2020; Mhangara et al., 2019; Kadochnikov, 2020). The geoportal presented in this article is intended to systematize the materials of the local archaeological site near Tyumen. However, its architecture and technical capacity make it possible to expand the geography of cartographic and remote sensing data research, and to supplement the database with new datasets.

We studied landscapes of ancient rivers with a DSM of the Andreevsky lake system area and simulated the flooding based on the UAV survey data (Sizov et al., 2018). The landscape formation was traced. We focused on the reconstruction of vegetation and climate using palynological and geochemical methods, analysis of macrofossils in the bottom sediments and peats (Ryabogina et al., 2019). We also undertook accurate hypsometric referencing of cultural layers in more than 360 ancient settlements. The modern landforms were mapped on a large scale (Sizov, Idrisov, Molchanova, 2017) as a basis for generating paleolandscape maps for various periods (Zimina et al., 2019) (Fig. 7).

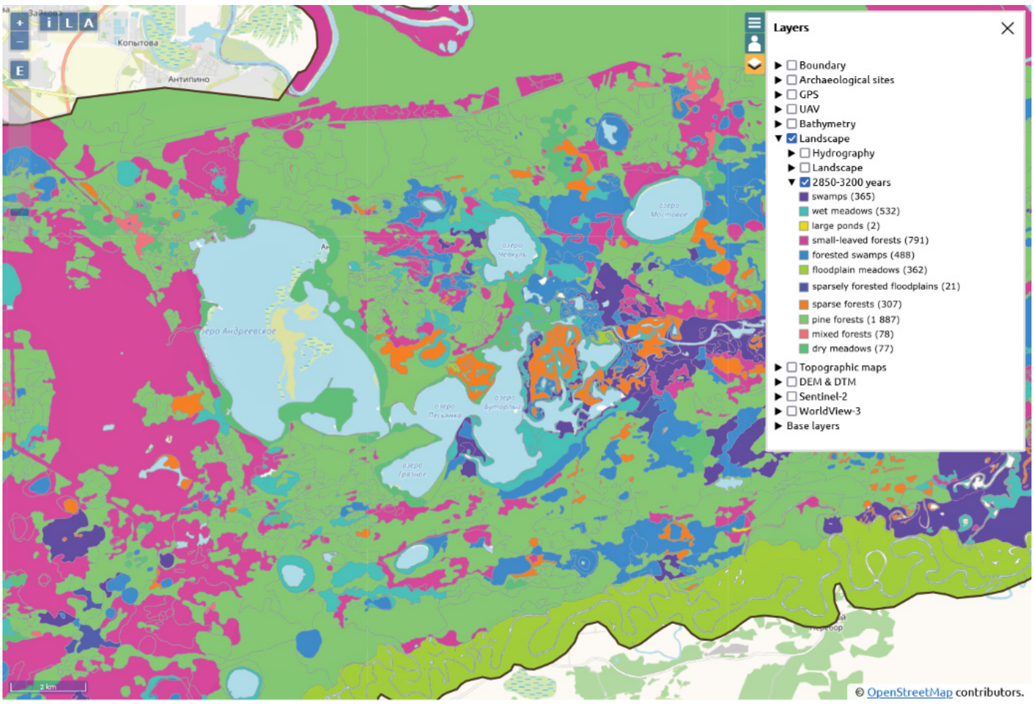


Fig. 7. Generalized paleolandscape map of the Tura and Pyshma interfluve in 3200–2850 cal BP

Рис. 7. Обобщенная палеоландшафтная карта Тура-Пышминского междуречья 3200–2850 л.н.

In particular, the current patterns of plant community changes in a range of habitat types were extrapolated for the period of 2850–2600 cal BP by simulating the degree of drainage and territory drainability and plant succession. During this period, the climatic conditions stabilized with a gradual increase in moisture and snow cover thickness. The water level in reservoirs and water content of the rivers were comparable with that of the present-day or slightly higher, but the lake shores were not outlined by a wide belt of reed and cattail thickets, as they are now. Birch and, to a lesser extent, mixed and pine forests, damp and dry meadows were widespread in the vicinity of the Andreevsky lakes. In the lowland peatlands, a transition to the mesotrophic stage and, later, to the oligotrophic peat accumulation was noted (Zimina et al., 2019).

Based on the assumption that the number of wild animals is consistent with the area occupied by certain plant formations, and applying the modern distribution patterns of ungulates, fur-bearing animals, and birds, we estimated the possible number of major game species for the period of 2850–2600 cal BP. The calculations showed that the number of large ungulates was small (31 elks, 302 roe deer, 14 wild boars). The highest potential could be expected from fishing (total amount of fish caught from the of the Andreevsky lake system: up to 234 tons). For the detailed calculation methods refer to (Sizov et al., 2018; Zimina et al., 2019).

The online geoinformation system enabled paleoeconomic and paleodemographic simulation. The reconstruction of the natural conditions and paleolandscape mapping of the Andreevsky lake system allowed estimation and making assumptions about the resource potential of the area and the number of people who could support themselves with the products of the producing and appropriating economy. The period of 2850–2600 cal BP was chosen to refine the population density estimations. This was the time of transition from the Bronze Age to the Early Iron Age and the time when settlements of the Itkul Culture emerged in the valley of the Tobol River and its tributaries, Tura and Pyshma (Zimina, Zakh, 2009). In the Tura-Pyshma interfluve, 35 settlements of the Itkul Culture are known. All of them are surrounded within ramparts and ditches.

The cultural layer of these settlements contains almost no bone remains preserved. Only few single specimens have been recovered, as the sites are located on sandy soils that poorly preserve organic remains. We consider, that with a large number of sites in the area, and in the absence of direct archaeological evidence for the economic activity and dating (the sites have been understudied by excavations since most of them were discovered or culturally attributed only in the last 10–15 years), the resource availability of the area may be indicative for estimation of the maximum population limit and the number of simultaneously existing settlements of the Itkul Culture. By analogy with monocultural settlements in the Urals, where osteological remains of domestic and wild animals have been found in the cultural layer of the Itkul Culture sites (Kosintsev, Stefanov, 1989), we assume that in the Tura-Pyshma interfluve the population of the Itkul Culture also maintained a complex economy that included producing and appropriating activities, but faunal remains have not been preserved in the aggressive environment of sandy soils.

The determination of population size and its dynamics in various historical periods is one of the subjects of social archaeology. It considers the interaction between humans and the natural environment, use of natural resources, origins of social organization and its major characteristics in the context of producing and appropriating economy (foraging, gatherer-hunter communities vs agricultural and pastoral society), family and household, property inheritance rules, mortality rates, cross-cultural interactions (Chamberlein, 2006; Müller, 2017; etc.).

The population size/density estimations may use different initial data (Müller, 2015), such as "…house size, settlement size and of the area, accessibility and productivity of land surrounding settlements… a cemetery is known to serve a particular settlement… can serve as an independent check on population estimates derived from settlement size or site catchment analysis." (Chamberlein, 2006, p. 12); an observable density of archaeological evidence in the study region (Drennan et al., 2015); investigating long-term regional trends: "….1) Settlement data including site counts; 2) summed estimated settlement sizes, effectively a weighted version of site counts; and 3) SPDs (summed probability distributions) of radiocarbon dates." (Palmisano, Bevan, Shennan, 2017, p. 60).

One of the parameters closely related to demography and population density is the ecological capacity of the territory. Site exploitation territories are identified around settlements, using the Site catchment analysis and the Site Territorial analysis (Vita-Finzi, Higgs, 1970; Jarman, Vita-Finzi, Higgs, 1972; Bailey, Davidson, 1983; Malone, Stoddart, 1994, p. 81–93; Renfrew, Bahn, 2005; Nedashkovsky, 2013; etc.). Among other characteristics, they demonstrate the dynamics of climate change (Nikulina et al., 2018). The area of agricultural activity can be outlined by mapping of ware fragments in stratigraphic sections around settlements; indicators of pastoral-agricultural activity in soil are phosphate content and urease activity (Korobov, Borisov, 2020).

In this case, identifying potential resource zones around specific fortified settlements of the Itkul Culture or their clusters would be the next step in the study. At present, the fortified settlements in this archaeological area are mostly unexcavated, and we have only limited data on the external features and relative dating based on surface findings or findings from survey pits. It is necessary to analyze the localisation patterns for the sites (in the western part of the Andreevsky lake system they are relatively dispersed, while in the eastern part there is one large cluster of sites, the rest are dispersed), and their chronology. Therefore, the purpose of our study was to estimate the number of fortified settlements that could exist simultaneously in the area of the Andreevsky lake system, and the approximate population size based on resource availability.

In the Andreevsky lake system, the sites are grouped into several clusters. The approximate distance between them is 8–10 km. As we assume that the dwellers of the Itkul settlement were engaged in a complex economy — animal husbandry and hunting and fishery (Zimina, Zakh, 2009) — the distance between the settlements in different parts of the Andreevsky lake system roughly correspond to the allocated potential resource areas for hunting-gathering and animal husbandry communities: 10 km for hunting and gathering, and 5 km for the more labor-intensive activities of agriculture, in terms of walking time — two hours and one hour, respectively (Vita-Finzi, Higgs, 1970; Renfrew, Bahn, 2005, p. 173). At the same time, there is evidence of different arrangement of the potential resource areas, depending on the nature of economic activities (Renfrew, Bahn, 2005, p. 174.) For example, indigenous peoples of Western Siberia used hunting grounds located many (20 km or more) kilometers away from their permanent residence place (Martinova, Pivneva, 1999, p. 5, 7).

The calculation of the population size in 2850–2600 cal BP and the number of the Itkul Culture settlements that simultaneously existed on the territory of the Andreevsky lake system are based on indicators obtained from the natural resource estimations: the amount of green biomass required for the cattle; the amount of wild harvest; the amount of fish; the number of wild animals and birds. Based on the fact that the Itkul Culture communities maintained an integrated economy and used the products of both stock-rearing and hunting-fishery sectors (Zimina, Zakh, 2009), calculations were made for both. The energy value of products of animal husbandry, gathering, hunting, and fishing was correlated with human energy expenditures (approximately 3,000–4,000 kcal/day per person; e.g., Smith et al. (2012, p. 7620) give ca. 4,000 kcal·cap-1·d-1 in simple farming societies.) The calculations were adjusted to account for the historical data on the economic activities of the settlement dwellers in the vicinity of Tyumen in the 19^{th} century (Patkanov, 2003), and considering the calculations based on the area of residential structures in the fortified settlements. The parameters of the structures are known from excavations of the Itkul settlements in various Trans-Ural areas (Zimina, Zakh, 2009).

According to calculations, the number of large ungulates was relatively small with larger numbers of game and waterfowl, which is quite consistent with the total area of forests and water bodies. However, the potential for fishing was the most significant. According to the DSM-simulated water level rise, the area of large water bodies in 2850–2600 cal BP was slightly different from modern and equalled 7,800 ha. At present, the fish yield of the Andreevsky lakes is 30 kg/ha. The reconstructed area of potential pastures and hayfields in the analysed period in the territory of the Andreevsky lake system was about 214 km^2. The area and yield of the pastures were significantly higher compared to the areas suitable for hay production, while wet meadows, as estimated, represented the most efficient plant communities for the producing economy. Also, the dwellers of the ancient settlements had fairly good opportunities for gathering wild fruits. In general, the population size calculations detailed in (Zimina et al., 2019) showed that in 2850–2600 cal BP, in the territory of the Andreevsky lake system, including the ancient lakes of the eastern part of the interfluves, about five settlements could exist simultaneously, and the number of dwellers (“carrying capacity”: the size of the population that the environment can support) might have been about 300–400 people.

Conclusions

Analysing the life support system of the ancient population in the Tura-Pyshma interfluves, we tried to develop a comprehensive geoinformation system, an archaeological geoportal integrating the results of many years of archaeological, paleogeographical, and landscape research. The database enables application of spatial analysis to simulate the location of archaeological sites in various eras, identification of potential resource zones of settlements, prediction of possible location of new archaeological sites taking into account the resource potential of the territory.

Geoportal is a convenient tool for collaborative management and visualization of the available archaeological and spatial data. Geoportal does not require installation of any software and can be accessed from anywhere. With its ease of use, Geoportal is accessible for those without extensive knowledge in cartography and GIS.

The key archaeological geoportal applications are:

1. Visualization of the available spatial data in the study area, including 3D representation. The visualization can be used both for ongoing research or presentations.

2. Storage of the database of attributes, including photographs and plans of excavations on a single server (physical or virtual), accessible from any workstation with the Internet access.

3. Fieldwork planning based on the assessment of the study area, transport accessibility, and neighborhood analysis. Geoportal also supports field navigation by directly connecting to a GPS receiver, recording waypoints, and routes.

4. Multi-user editing of spatial data enabled by the client-server architecture supports collaboration when studying large areas or during extensive projects involving multiple research teams.

5. Basic geoanalytical operations:

– search for information by attributes (sampling);
– measurement of distances, areas, coordinates;
– grouping vector objects by type (generating derived thematic maps) (in progress);
– GIS-analysis (in progress): dynamic generation of buffer zones, object density maps, elevation profiles, visibility zones, search for object intersections between layers, etc.

Work on filling the thematic layers is still being carried on. We keep refining the sections on the archaeological sites specifying more accurate coordinates and boundaries, monitoring their conditions and adding new sites.

REFERENCES

Bezborodova L. G., Parkhimovich S. Yu. Archaeological Heritage of I. Ya. Slovtsov. In: Slovtsovskie Chteniia: Materials of the Scientific-Practical Conference, Dedicated to the 150th Anniversary of I. Ya. Slovtsov. Tyumen : Izdatel'sko-poligraficheskoe predpriyatie «Tyumen'», 1995. Pp. 14–17. (*In Russ.*)

Borisov A. V., Korobov D. S. Ancient and Medieval Agriculture in the Kislovodsk Basin: Results of Soil and Archaeological Research. Moscow : Taus, 2013. 272 p. (*In Russ.*)

Zakh V. A., Usacheva I. V., Zimina O. Yu., Skochina S. N., Chikunova I. Yu., Antiques of the Andreevsky Lake System. Vol. 1. Archaeological Sites. Novosibirsk : Nauka, 2014. 225 p. (*In Russ.*)

Zimina O. Yu., Zherebyateva N. V., Idrisov I. R., Sizov O. S., Moskvina N. N., Afonin A. S., Ivanov S. N., Ryabogina N. E. The Andreevskoye Lake System at the Turn of the Bronze and Early Iron Ages: Paleo-Landscape Mapping, Bioproductivity Assessment and Demographic Capacity of the Territory (Tura and Pyshma interfluve, West Siberia). *Vestnik arheologii, antropologii i etnografii = Bulletin of Archaeology, Anthropology and Ethnography.* 2019;2(45):69–84. (*In Russ.*) https://doi.org/10.20874/2071-0437-2019-45-2-069-084

Zimina O. Yu., Zakh V. A. Lower Tobol Basin at the Turn of the Bronze and Iron Ages. Novosibirsk : Nauka, 2009. 232 p. (*In Russ.*).

Korobov D. S., Borisov A. V., New Data on Studying Ancient and Medieval Settlement Off-sites in the Kislovodsk Basin. *Rossijskaya arheologiya = Russian Archaeology.* 2020;4:53–69. (*In Russ.*) https://doi.org/10.31857/S086960630008885-2

Kosintsev P. A., Stefanov V. I. Peculiarities of the Economy of the Population of the Forest Trans-Ural and Priishima Forest-Steppe in the Transition Time from the Bronze Age to the Iron Age. In: Formation and Development of the Producing Economy in the Urals. Sverdlovsk : Izd-vo UrO RAN, 1989. Pp. 105–119. (*In Russ.*)

Makarov N. A., Zelentsova O. V., Korobov D. S., Chernikov A. P., Voroshilov A. N. Russia as an Archaeological Space: Initial Results of Creating of the Russian Archaeological Sites National Geography Information System. *Rossijskaya arheologiya = Russian Archaeology.* 2016;4:5–15 (*In Russ.*)

Martinova E. P., Pivneva E. A. Present State of Traditional Systems of Natural Resources Among the Natives of the Taiga Zone of the Lower Priobje (Octiabrskij and Khanty-Mansijskij Regions of the Khanty-Mansijskij Autonomous Okrug). Studies on Applied and Emergency Ethnology. M. : Izd-vo Instituta etnologii i antropologii RAN, 1999. Vol. 130. 25 p. (*In Russ.*)

Nedashkovsky L. F. Methodical Aspects of Researches of the Complexes of Archaeological Sites in the Region of the Largest Golden Horde Cities of the Lower Volga area. *Povolzhskaya Arheologiya = The Volga River Region Archaeology.* 2013;4(6):118–129. (*In Russ.*) https://doi.org/10.24852/pa2013.4.6.118.129

Nikulina A. V., Zolnikov I. D., Kuzmin Y. V., Sofeikov O. V., Chupina D. A., Glushkova N. V., Pchelnikov D. V. Using GIS Technologies to Analyze the Spatial Localization of Settlements. Case Study: Bronze Age, Early Iron Age and Middle Ages in the Central Part of the Barabinsk Lowland. *Vestnik Tomskogo gosudarstvennogo universiteta = Tomsk State University journal.* 2018;428:117–125. (*In Russ.*) https://doi.org/10.17223/15617793/428/16

Patkanov S. K. Works in 5 volumes. Vol. 3: Economic Life of State Peasants and Foreigners of Tobolsk District, Tobolsk Province. Part 2. Tyumen : Mandr i K, 2003. 12 p. (*In Russ.*)

Prikhodko N. V., Sizov O. S., Ilyaschenko V. A., Zimina O. Yu. An Attempt at the Use of an Unmanned Aircraft (Hexacopter) for Creating Highly Detailed Relief Models for Achaeological Investigations. In: Archaeology and Geoinformatics. Moscow : Izd-vo Instituta arheologii RAN, 2017. Pp. 41–43. (*In Russ.*)

Sizov O. S., Zimina, O. Yu. Particulars of a Life Support System and Spatial Distribution Regarding Settlements of the Itkul Culture in the Low Tobol Basin (VIII–VI cc. BC). *Vestnik arheologii, antropologii i etnografii = Bulletin of Archaeology, Anthropology and Ethnography.* 2012;4(19):155–167. (*In Russ.*)

Sizov O. S., Zimina O. Yu., Prikhodko N. V., Kostomarov V. M., Zakh V. A., Soromotin A. V. Application of Unmanned Aerial Photography and Bathymetric Systems for Reconstruction of Water Level Dynamics in the Andreyevskoe Lake System (Tyumen region). In: Archaeology and Geoinformatics (Electronic resource): on CD-ROM. Issue. 9. Moscow : IA RAN, 2019. (*In Russ.*)

Sizov O. S., Idrisov I. R., Molchanova K. V. An Attempt to Reconstruct the Original Landscapes Using a Large-Scale Mapping of the Territory of the Andreevskoe Lake System (Interfluve of the Tura and Pyshma Rivers). *Vestnik arheologii, antropologii i etnografii = Bulletin of Archaeology, Anthropology and Ethnography.* 2017;4(39):183–190. (*In Russ.*) https://doi.org/10.20874/2071-0437-2017-39-4-205-212

Sizov O. S., Prikhodko N. V., Zakh V. A., Soromotin A. V., Kostomarov V. M. Application of Unmanned Aerial Survey and Bathymetric Systems for Reconstruction of Water Level Evolution in the Andreevsky Lake System (Tyumen Region.). In: Application of Unmanned Aerial Vehicles in Geographical Research. Irkutsk : Izd-vo IG SO RAN, 2018. Pp. 107–111. (*In Russ.*)

Sizov O. S., Tsymbarovitch P. R., Zimina O. Yu., Zakh V. A. Web-GIS Technologies in the Study of the Life Support System of the Ancient Population on the Example of the Turo-Pyshma Interfluve (Tyumen Region) In: Archaeology and Geoinformatics. No. 10. Moscow : IA RAN, 2021. DVD-ROM. (*In Russ.*) https://doi.org/10.25681/IARAS.2021.978-5-94375-342-8.17

Slovtsov I. Ya. Stone Age Artifacts Found near Tyumen in 1883. In: Zap. ZSORGO. Omsk, 1885. Vol. 7, Issue 1. 59 p. (*In Russ.*)

Slovtsov I. Ya. On the Distribution of Barrows and Ancient Settlements in Tobolsk Province. In: Tomsk Imperial Univ. Bulletin. 1890. Part A. Vol. 2. Pp. 76–97. (*In Russ.*)

Alenius T., Gerasimov D., Sapelko T., Ludikova A., Kuznetsov D., Golyeva A., and Nordqvist K. Human-Environment Interaction during the Holocene along the Shoreline of the Ancient Lake Ladoga: A Case Study Based on Palaeoecological and Archaeological Material from the Karelian Isthmus, Russia. *The Holocene.* 2020;30(11):1622–1636. https://doi.org/10.1177/0959683620941071

Bailey G. N., Davidson I. Site Exploitation Territories and Topography: Two Case Studies from Palaeolithic Spain. *Journal of Archaeological Science.* 1983;10(2):87–115.

Chamberlein A. Demography in Archaeology. Cambridge : Cambridge University Press, 2006. 235 p.

de Sousa L. M., Poggio L., Batjes N. H., Heuvelink G. B., Kempen B., Riberio E., & Rossiter D. SoilGrids 2.0: Producing Quality-assessed Soil Information for the Globe. *Soil Discuss.* 2020:1–37. https://doi.org/10.5194/soil-2020-65

Drennan Robert D., C. Adam Berrey and Christian E. Peterson. Regional Settlement Demography in Archaeology. Elliot Werner Publications, Clinton Corners. 2015. 180 p.

Giesecke T., Bennett K. D., Birks H. J.B., Bjune A. E., Bozilova E., Feurdean A., Finsinger W., Froyd C., Pokorny P., Rosch M., Seppa H., Tonkov S., Valsecchi V., and Wolters S. The Pace of Holocene Vegetation Change — Testing for Synchronous Developments. *Quaternary Science Reviews.* 2011;30(19):2805–2814. https://doi.org/10.1016/j.quascirev.2011.06.014

Jarman M. R., Vita-Finzi C., Higgs E. S. Site Catchment Analysis in Archaeology. In: Man, Settlement and Urbanism. Proceedings of a Meeting of the Research Seminar in Archaeology and Related Subjects Held at the Institute of Archaeology, London University. London : Duckworth, 1972. Pp. 61–67.

Kadochnikov A. Experience in the Development a Regional Geoportal for the Krasnoyarsk Region. *InterCarto. InterGIS.* 2020;26:203–214. https://doi.org/10.35595/2414-9179-2020-1-26-203-214

Klein Goldewijk K. A Historical Land Use Data Set for the Holocene; HYDE 3.2. *Geophysical Research Abstracts*. 2016;18:1574.

Klein Goldewijk K., Beusen A., van DrechtG. & de Vos M. The HYDE 3.1 Spatially Explicit Database of Human Induced Land Use Change over the Past 12,000 Years. *Global Ecology and Biogeography.* 2011;20:73–86.

Korobov D. S. Early Medieval Settlements and Land Use in the Kislovodsk Basin (North Caucasus). In: Multi-, Inter- and Transdisciplinary Research in Landscape Archaeology, LAC2014 Proceedings, Vrije Universiteit Amsterdam. Amsterdam : University Library Vrije Universiteit Amsterdam, 2014. Pp. 3–14. https://doi.org/10.5463/lac.2014.2

Krause R. and Koryakova L. N. Multidisciplinary Investigations of the Bronze Age Settlements in the Southern Trans-Urals (Russia). Bonn : Habelt, 2013. 354 p.

Lerma J. L., Heras V., Mora-Navarro G., Rodas P., Matute F. Geoportal Proposal for the Inventory of Cultural Heritage in Nabón (Ecuador). *ISPRS — International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.* XLIII-B2-2020. 2020:1415–1418. https://doi.org/10.5194/isprs-archives-XLIII-B2-2020-1415-2020

Malone C. Stoddart S. The Dissection of a Bronze and Early Iron Age Landscape: Site Territories and Land Use. In: Territory, Time and State: The Archaeological Development of the Gubbio Basin. 1994. Pp. 81–93 (Cambridge University Press).

Mhangara P., Lamba, A., Mapurisa W., Mudau N. Towards the Development of Agenda 2063 Geo-Portal to Support Sustainable Development in Africa. ISPRS *International Journal of Geo-Information.* 2019;8(9):399; https://doi.org/10.3390/ijgi8090399

Müller J. Eight Million Neolithic Europeans: Social Demography and Social Archaeology on the Scope of Change — from the Near East to Scandinavia. In: Kristiansen, K., Smedja, L., Turek, J. (eds.). Paradigm Found. Festschrift on Occasion of Evzen Neustupny's 80th Birthday. Oxford : Oxbow Books, 2015. Pp. 200–214.

Müller J. Inheritance, Population and Social Indentities. Southeast Europe 5200–4300 BCE. In: M. Gori/M. Ivanova (Hrsg.), Balkan Dialogues. Negotiating Identity between Prehistory and the Present. London : Routledge, 2017. Pp. 156–168.

Palmisano A., Bevan A., Shennan S. Comparing Archaeological Proxies for Long-Term Population Patterns: an Example from Central Italy. *Archaeol. Sci.* 2017;87:59–72. https://doi.org/10.1016/j.jas.2017.10.001

Renfrew C., and Bahn P. (ed.) Archaeology: The Key Concepts. 2005. 233 p.

Ronzino P., Acconcia V., & Falcone A. Towards the Integration of Spatial Data through the Italian Geoportal for Archaeological Resources. 2018 3rd Digital Heritage International Congress (DigitalHERITAGE) Held Jointly with 2018 24th International Conference on Virtual Systems & Multimedia (VSMM 2018). 2018. https://doi.org/10.1109/digitalheritage.2018.8810132

Rosch M., Kleinmann A., Lechterbeck J., Wick L. Botanical Off-Site and On-Site Data as Indicators of Different Land Use Systems: A Discussion with Examples from Southwest Germany. *Veget Hist Archaeobot*. 2014;23:647–648. https://doi.org/10.1007/s00334-014-0477-8

Ryabogina N. E., Afonin A. S., Ivanov S. N., Li H.-C., Kalinin P. A., Udaltsov S. N., Nikolaenko S. A. Holocene Paleoenvironmental Changes Reflected in Peat and Lake Sediment Records of Western Siberia: Geochemical and Plant Macrofossil Proxies. *Quaternary International.* 2019;528:73–87 https://doi.org/10.1016/j.quaint.2019.04.006

Schwarz A. S., Oeggl K. Vegetation Change during the Bronze Age Studied in a Multi-Proxy Approach: Use of Wood Linked to Charcoal Analysis. *Veget Hist Archaeobot.* 2013;22:493–507. https://doi.org/10.1007/s00334-013-0402-6

Smith M. E., Feinman G. M., Drennan R. D., Earle T., and Morris I. Archaeology as a Social Science. *Proceedings of the National Academy of Sciences.* 2012;109(20):7617–7621.

Spanu V., Lorrai E., Muscas L., Demontis R. Nurnet — Geoportal. *Archeomatica.* 2017;VIII:26–29. https://doi.org/10.48258/arc.v8i5.1669

Vita-Finzi C., Higgs E. S. Prehistoric Economy in the Mount Carmel Area of Palestine: Site Catchment Analysis. *Proceedings of the Prehistoric Society.* 1970;36:1–37.

Yamashkin S. A., Radovanović M. M., Yamashkin A. A., Barmin N. N., Zanozin V. V., Petrović M. D. Problems of Designing Geoportal Interfaces. *GeoJournal of Tourism and Geosites.* 2019;24(1):88–101. https://doi.org/10.30892/gtg.24108-345

СПИСОК ИСТОЧНИКОВ

Безбородова Л. Г., Пархимович С. Ю. Археологическое наследие И. Я. Словцова // Словцовские чтения: Материалы научно-практической конференции, посвященной 150-летию И. Я. Словцова. Тюмень : Издательско-полиграфическое предприятие «Тюмень», 1995. С. 14–17.

Борисов А. В., Коробов Д. С. Древнее и средневековое земледелие в Кисловодской котловине: итоги почвенно-археологических исследований. М. : Таус, 2013. 272 с.

Зах В. А., Усачева И. В., Зимина О. Ю., Скочина С. Н., Чикунова И. Ю. Древности Андреевской озерной системы. Т. 1. Археологические памятники. Новосибирск : Наука, 2014. 225 с.

Зимина О. Ю., Жеребятьева Н. В., Идрисов И. Р., Сизов О. С., Москвина Н. Н., Афонин А. С., Иванов С. Н., Рябогина Н. Е. Картирование палеоландшафтов, оценка биопродуктивности и демографической емкости территории Андреевской озерной системы на рубеже бронзового и раннего железного веков (междуречье Туры и Пышмы, Западная Сибирь) // Вестник археологии, антропологии и этнографии. 2019. №2 (45). С. 69–84. https://doi.org/10.20874/2071-0437-2019-45-2-069-084

Зимина О. Ю. Зах В. А. Нижнее Притоболье на рубеже бронзового и железного веков. Новосибирск : Наука. 2009. 232 с.

Коробов Д. С., Борисов А. В. Новые данные по изучению ресурсных зон древних и средневековых поселений в Кисловодской котловине // Российская археология. 2020. №4. С. 53–69.

Косинцев П. А., Стефанов В. И. Особенности хозяйства населения лесного Зауралья и Приишимской лесостепи в переходное время от бронзового века к железному // Становление и развитие производящего хозяйства на Урале. Свердловск : Изд-во УрО РАН, 1989. С. 105–119.

Макаров Н. А., Зеленцова О. В., Коробов Д. С., Черников А. П., Ворошилов А. Н. Россия как археологическое пространство: первые итоги работы по созданию национальной географо-информационной системы «Археологические памятники России» // Российская археология. 2016. №4. С. 5–15.

Мартынова Е. П., Пивнева Е. А. Современное природопользование таежного населения Нижнего Приобья (Ханты-Мансийский и Октябрьский районы Ханты-Мансийского А.О.) : Исследования по прикладной и неотложной этнологии. М. : Изд-во Института этнологии и антропологии РАН, 1999. 27 с.

Недашковский Л. Ф. Методические аспекты исследования комплексов археологических памятников округи крупнейших золотоордынских городов Нижнего Поволжья // Поволжская археология. 2013. №4 (6). С. 118–129.

Никулина А. В., Зольников И. Д., Кузьмин Я. В., Софейков О. В., Чупина Д. А., Глушкова Н. В., Пчельников Д. В. Методика использования гис-технологий для анализа пространственной локализации поселений на примере эпохи бронзы, Раннего железного века и средневековья в центральной части Барабинской низменности // Вестник Томского государственного университета. 2018. №428. С. 117–125. https://doi.org/10.17223/15617793/428/16

Патканов С. К. Соч. в 5 т. Т. 3: Экономический быт государственных крестьян и инородцев Тобольского округа Тобольской губернии. Часть вторая. Тюмень : Мандр и К, 2003. 312 с.

Приходько Н. В., Сизов О. С., Ильященко В. А., Зимина О. Ю. Опыт использования БПЛА (гексакоптер) для построения высокодетальных моделей рельефа в целях археологических исследований // Археология и геоинформатика. М. : Изд-во Института археологии РАН, 2017. С. 41–43.

Сизов О. С., Зимина О. Ю. Особенности системы жизнеобеспечения и пространственного размещения поселений иткульской культуры в Притоболье (VIII–VI вв. до н.э.) // Вестник археологии, антропологии и этнографии. 2012. №4 (19). С. 155–167.

Сизов О. С., Зимина О. Ю., Приходько Н. В., Костомаров В. М., Зах В. А., Соромотин А. В. Применение беспилотных аэрофотосъемочных и батиметрических систем для реконструкции динамики уровня воды в Андреевской озерной системе (Тюменская область) // Археология и геоинформатика (Электронный ресурс): на CD-ROM. Вып. 9. М. : ИА РАН, 2019.

Сизов О. С., Идрисов И. Р., Молчанова К. В. Опыт реконструкции исходных ландшафтов с использованием крупномасштабного картирования территории Андреевской озерной системы (междуречье Туры и Пышмы) // Вестник археологии, антропологии и этнографии. 2017. №4 (39). С. 183–190.

Сизов О. С., Приходько Н. В., Зах В. А., Соромотин А. В., Костомаров В. М. Опыт применения беспилотных аэрофотосъемочных и батиметрических систем для реконструкции динамики уровня воды в Андреевской озерной системе (Тюменская область) // Применение беспилотных летательных аппаратов в географических исследованиях. Иркутск : Изд-во ИГ СО РАН, 2018. С. 107–111.

Сизов О. С., Цымбарович П. Р., Зимина О. Ю., Зах В. А. Веб-геоинформационные технологии в исследовании системы жизнеобеспечения древнего населения на примере Туро-Пышминского междуречья (Тюменская область) // Археология и геоинформатика. Вып. 10. М. : ИА РАН, 2021. DVD-ROM. https://doi.org/10.25681/IARAS.2021.978-5-94375-342-8.17

Словцов И. Я. О находках предметов каменного периода близ г. Тюмени в 1883 г. // Зап. ЗСОРГО. Омск, 1885. Кн. 7, вып. 1. 59 с.

Словцов И. Я. Материалы о распределении курганов и городищ в Тобольской губернии // Изв. Имп. Том. ун-та. 1890. Отд. А. Кн. 2. С. 76–97.

Alenius T., Gerasimov D., Sapelko T., Ludikova A., Kuznetsov D., Golyeva A., and Nordqvist K. Human-Environment Interaction during the Holocene along the Shoreline of the Ancient Lake Ladoga: A Case Study Based on Palaeoecological and Archaeological Material from the Karelian Isthmus, Russia. The Holocene. 2020;30(11):1622–1636. https://doi.org/10.1177/0959683620941071

Bailey G. N., Davidson I. Site Exploitation Territories and Topography: Two Case Studies from Palaeolithic Spain. Journal of Archaeological Science. 1983;10(2):87–115.

Chamberlein A. Demography in Archaeology. Cambridge : Cambridge University Press, 2006. 235 p.

de Sousa L.M., Poggio L., Batjes N.H., Heuvelink G.B., Kempen B., Riberio E., & Rossiter D. SoilGrids 2.0: Producing Quality-assessed Soil Information for the Globe. Soil Discuss. 2020:1–37. https://doi.org/10.5194/soil-2020-65

Drennan Robert D., C. Adam Berrey and Christian E. Peterson. Regional Settlement Demography in Archaeology. Elliot Werner Publications, Clinton Corners. 2015. 180 p.

Giesecke T., Bennett K.D., Birks H.J.B., Bjune A.E., Bozilova E., Feurdean A., Finsinger W., Froyd C., Pokorny P., Rosch M., Seppa H., Tonkov S., Valsecchi V., and Wolters S. The Pace of Holocene Vegetation Change — Testing for Synchronous Developments. Quaternary Science Reviews. 2011;30(19):2805–2814. https://doi.org/10.1016/j.quascirev.2011.06.014

Jarman M.R., Vita-Finzi C., Higgs E.S. Site Catchment Analysis in Archaeology. In: Man, Settlement and Urbanism. Proceedings of a Meeting of the Research Seminar in Archaeology and Related Subjects Held at the Institute of Archaeology, London University. London : Duckworth, 1972. Pp. 61–67.

Kadochnikov A. Experience in the Development a Regional Geopotal for the Krasnoyarsk Region. InterCarto. InterGIS. 2020;26:203–214. https://doi.org/10.35595/2414-9179-2020-1-26-203-214

Klein Goldewijk K. A Historical Land Use Data Set for the Holocene; HYDE 3.2. Geophysical Research Abstracts. 2016;18:1574.

Klein Goldewijk K., Beusen A., van DrechtG. & de Vos M. The HYDE 3.1 Spatially Explicit Database of Human Induced Land Use Change over the Past 12,000 Years. Global Ecology and Biogeography. 2011;20:73–86.

Korobov D.S. Early Medieval Settlements and Land Use in the Kislovodsk Basin (North Caucasus). In: Multi-, Inter- and Transdisciplinary Research in Landscape Archaeology, LAC2014 Proceedings, Vrije Universiteit Amsterdam. Amsterdam : University Library Vrije Universiteit Amsterdam, 2014. Pp. 3–14. https://doi.org/10.5463/lac.2014.2

Krause R. and Koryakova L.N. Multidisciplinary Investigations of the Bronze Age Settlements in the Southern Trans-Urals (Russia). Bonn : Habelt, 2013. 354 p.

Lerma J.L., Heras V., Mora-Navarro G., Rodas P., Matute F. Geoportal Proposal for the Inventory of Cultural Heritage in Nabón (Ecuador). ISPRS — International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. XLIII-B2-2020. 2020:1415–1418. https://doi.org/10.5194/isprs-archives-XLIII-B2-2020-1415-2020

Malone C. Stoddart S. The Dissection of a Bronze and Early Iron Age Landscape: Site Territories and Land Use. In: Territory, Time and State: The Archaeological Development of the Gubbio Basin. 1994. Pp. 81–93 (Cambridge University Press).

Mhangara P., Lamba, A., Mapurisa W., Mudau N. Towards the Development of Agenda 2063 Geo-Portal to Support Sustainable Development in Africa. ISPRS International Journal of Geo-Information. 2019;8(9):399; https://doi.org/10.3390/ijgi8090399

Müller J. Eight Million Neolithic Europeans: Social Demography and Social Archaeology on the Scope of Change — from the Near East to Scandinavia. In: Kristiansen, K., Smedja, L., Turek, J. (eds.). Paradigm Found. Festschrift on Occasion of Evzen Neustupny's 80th Birthday. Oxford : Oxbow Books, 2015. Pp. 200–214.

Müller J. Inheritance, Population and Social Indentities. Southeast Europe 5200–4300 BCE. In: M. Gori/M. Ivanova (Hrsg.), Balkan Dialogues. Negotiating Identity between Prehistory and the Present. London : Routledge, 2017. Pp. 156–168.

Palmisano A., Bevan A., Shennan S. Comparing Archaeological Proxies for Long-Term Population Patterns: an Example from Central Italy. Archaeol. Sci. 2017;87:59–72. https://doi.org/10.1016/j.jas.2017.10.001

Renfrew C., and Bahn P. (ed.) Archaeology: The Key Concepts. 2005. 233 p.

Ronzino P., Acconcia V., & Falcone A. Towards the Integration of Spatial Data through the Italian Geoportal for Archaeological Resources. 2018 3rd Digital Heritage International Congress (DigitalHERITAGE) Held Jointly with 2018 24th International Conference on Virtual Systems & Multimedia (VSMM 2018). 2018. https://doi.org/10.1109/digitalheritage.2018.8810132

Rosch M., Kleinmann A., Lechterbeck J., Wick L. Botanical Off-Site and On-Site Data as Indicators of Different Land Use Systems: A Discussion with Examples from Southwest Germany. Veget Hist Archaeobot. 2014;23:647–648. https://doi.org/10.1007/s00334-014-0477-8

Ryabogina N. E., Afonin A.S., Ivanov S. N., Li H.-C., Kalinin P. A., Udaltsov S. N., Nikolaenko S. A. Holocene Paleoenvironmental Changes Reflected in Peat and Lake Sediment Records of Western Siberia: Geochemical and Plant Macrofossil Proxies. Quaternary International. 2019;528:73–87 https://doi.org/10.1016/j.quaint.2019.04.006

Schwarz A. S., Oeggl K. Vegetation Change during the Bronze Age Studied in a Multi-Proxy Approach: Use of Wood Linked to Charcoal Analysis. Veget Hist Archaeobot. 2013;22:493–507. https://doi.org/10.1007/s00334-013-0402-6

Smith M. E., Feinman G. M., Drennan R. D., Earle T., and Morris I. Archaeology as a Social Science. Proceedings of the National Academy of Sciences. 2012;109(20):7617–7621.

Spanu V., Lorrai E., Muscas L., Demontis R. Nurnet — Geoportal. Archeomatica. 2017;VIII:26–29. https://doi.org/10.48258/arc.v8i5.1669

Vita-Finzi C., Higgs E. S. Prehistoric Economy in the Mount Carmel Area of Palestine: Site Catchment Analysis. Proceedings of the Prehistoric Society. 1970;36:1–37.

Yamashkin S. A., Radovanović M. M., Yamashkin A. A., Barmin N. N., Zanozin V. V., Petrović M. D. Problems of Designing Geoportal Interfaces. GeoJournal of Tourism and Geosites. 2019;24(1):88–101. https://doi.org/10.30892/gtg.24108-345

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